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Analysis of Failures of Traction Electric Motors in Wheel-Motor Units of Locomotives

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Annotation: *The issues of forecasting the residual resource and extending the service life of traction electric motors of UzTE116M series locomotives are outlined. The main causes of failures of traction electric motors and statistical data on the causes of malfunctions of locomotive components after major repairs, as well as the causes of damage to traction electric motors ED-118B(A), taking into account real operating conditions, are considered.*

Keywords: *wheel, motor, locomotive, load, failure, main pole, mass, stiffness, bearing*

Introduction

On locomotives, the number of failures of traction motors is very significant. Statistics show that about 60% of all wheel-motor unit changes are made due to the failure of the traction motor.

The largest number of damage to locomotives is caused by damage to the armature, intercoil connections, output cables, jumpers and anchor bearings. Analysis data for the previous six years (2015

- 2020) show that damage to locomotives due to failure of ED-118B(A) electric traction motors has increased (Table 1).

The number of damage to locomotives as a result of failure of traction motors does not provide a complete picture of the condition, level of reliability and trends in damage. A more objective judgment can be obtained by analyzing cases of unscheduled repairs of locomotives on the network's railways over a certain period, as well as unscheduled replacement of equipment.

Table 1.
Damage to traction electric motors ED-118B(A)

Damage to traction motors ED-118B(A)	**2015 y.**	**2016 y.**	**2017 y.**	**2018 y.**	**2019 y.**	**2020 y.**
Failures of traction motors as a percentage of the number in operation	8,6	9,7	10,8	10,1	11,5	10,0
Including due to damage to: anchor bearings	1,7	2,1	2,1	2,2	1,4	2,6
Intercoil connections, jumpers, cables	1,2	1,9	2,3	2,4	1,5	2,2
Pole coils (breakdown, low insulation)	1,8	1,4	1,6	1,3	1,25	1,4
Anchors (interturn short circuit, breakdown)	0,75	1,1	1,2	1,1	1,2	1,3
Compensation windings	0,6	0,5	0,7	0,5	0,7	0,6

The distribution of failures among components is not the same for different types of engines and is determined by many factors: the design of components, operating conditions, quality of repairs and maintenance, their frequency, degree of load, frequency of slipping, etc.

Motor-axle bearings (MABs) of traction electric motors have a lot of damage or failure due to premature wear of the liners and, as a result, violation of the radial clearance between the liner and the axle of the wheelset. However, wear and damage to the MOP liners of the ED-118B(A) traction electric motor of UzTE16M diesel locomotives should be explained mainly by their unsatisfactory maintenance, untimely inspection and washing of the chambers and padding, as well as the lack of lubrication in the bearings and its non-compliance with the established grade.

Summarizing the analysis of failures on traction motor units, it is possible to identify the weakest structural elements. For the ED-118B(A) traction electric motor, such elements are the main and additional poles, as well as the terminals for connecting the pole coils. This engine is the worst in terms of reliability of the specified structural elements. In addition, the armature bearings and compensation winding are also damaged.

The distribution of failures among traction motor units and their quantitative assessment make it possible to identify weak points and focus on developing measures that increase the reliability of units, such as light engines, as well as an entire group of machines, and to search for design and technological solutions that improve the performance of locomotive traction motors .

The consequences of typical causes of failure of traction motors include the following:

- insufficient moisture resistance of winding insulation due to the imperfection of insulating materials and mainly the technology used in the manufacture and repair of winding coils;
- during routine and factory repairs, the requirements of the Repair Rules and drawings for the manufacture of windings with partially obligatory coating with moisture-resistant insulating enamels EP-91 and GF-92-GS are not always observed;

- imperfection and violation of the technology for installing inter-coil connections, which leads to breakage, burning and weakening of the fastening of the terminals of the coils of the main and additional poles and the coils of the compensation windings;
- weakening of the pole coils on the cores and compensation windings in the slots, which leads to mechanical abrasion of the cover and main insulation and breakdown to the housing;
- violations during the installation of anchor bearings, non-compliance mainly with radial clearances, excess and insufficient tension of the internal bushings,
- violation of the timing of adding and replacing bearing grease. All this causes breakage and destruction of bushings and rollers, chipping of treadmills, breakage of collars, weakening of the inner bushing and very often jamming;
- damage to the commutator-brush assembly, which most often occurs as a result of violation of deadlines and poor quality of maintenance and routine repairs of locomotives. Incorrect locomotive control mode and systematic stalling are also the cause of circular lights and the transfer of an electric arc from the collector to grounded parts with serious consequences.

Failure to comply with a number of preventive measures and malfunctions in the operation of systems protecting traction motors from overload, overvoltage and short-circuit currents are often the causes of severe damage and failures of traction motors, for example, untimely installation of contact filters on blinds leads to snow getting into the motor; poorly adjusted protection devices (BV, VOV-15, overload relays, etc.) do not protect against unacceptable load conditions or voltage values at the motor terminals.

The build quality of the wheel-motor unit is of no small importance. Vibration caused by gear transmission when the gears are incorrectly selected for joint operation has a particularly bad effect on engine operation. We must not forget about selecting the characteristics of traction motors for the locomotive with a minimum difference in rotation frequency at given current values. This achieves better load distribution and reduces the likelihood of slipping and overload.

One could name a number of additional reasons for failures of traction electric motors, but they, as a rule, will indicate low technological discipline, insufficient quality of work, and all taken together characterize the sometimes insufficient qualifications of workers, foremen, and foremen.

More than 40% of the total number of damages to locomotive traction motors are caused by breakdowns and interturn short circuits of armature windings, pole and compensation coils.

The greatest number of these damages occurs during the winter and spring-winter seasons, and especially during blizzards, snowfalls, and changes in ambient temperature, i.e., under conditions that promote moisture insulation. It should be noted that surface moisture in the windings of “healthy” insulation is usually not dangerous.

The danger is represented by deep moisture, which becomes possible when the insulation has cracks, abrasions, porosity and other damage that is sometimes invisible to the eye, through which moisture mixed with contaminants penetrates deep into the winding. Thus, an insulation breakdown can be considered as a combination of unfavorable factors - insulation defects, moisture, and contamination. The more defects in the insulation, the faster they appear, and at the same time, the more moisture, the more dangerous the presence of even minor damage to the insulation becomes, especially for traction motors of DC locomotives, the insulation of which is designed for 3000 V.

Therefore, to increase the reliability of the insulation of traction motors, it is necessary to ensure high quality manufacturing and repair of windings, as well as proper operation of machines and their maintenance.

If the windings are monolithic, tightly laid and fixed to the cores, well impregnated and covered with a uniform layer of electrical insulating enamel, then such windings dissipate heat well, are resistant to mechanical and dynamic influences and are less susceptible to abrasion.

Deterioration of the insulation structure (“bulge”, air inclusions, poor impregnation, etc.), damage during installation of windings, lack of tightness in grooves and frontal parts, allowed in case of violations of the manufacturing and installation technology of windings, increase their heating, cause mechanical abrasion of the insulation, rapid the appearance of small cracks in the protective insulating film.

All these defects ultimately contribute to intensive aging of the winding insulation. Such windings are very sensitive to moisture and when exposed to voltage (especially during non-stationary operating modes of the machine - boxing, overvoltage in the contact network, separation of the pantograph from the contact wire, etc.) can easily be “broken.”

It should be noted that insulation aging is a natural and irreversible process, since the operating temperature of the windings inevitably causes gradual destruction of the insulation. However, this process can be significantly slowed down with proper operation of electrical machines. It is known that an increase in the operating temperature of the windings by 10°C reduces the service life of their insulation by half.

Therefore, special attention must be paid to the heating of machine windings, which is determined by the correct choice of train weight and strict adherence to its control mode, compliance with the established ventilation modes of traction engines. In addition, it is necessary to ensure that the current distribution between the traction motor on the locomotive is uniform.

As part of GOST-2583-72, the permissible temperature rise of the windings of traction electric motors in relation to the temperature of the cooling air in operation, depending on the insulation class used in them, should be no more than that indicated in Table 2.

The existing cyclicity of scheduled preventative repairs of electrical machines is developed from the conditions for ensuring the restoration of the insulating properties of the windings depending on the mileage of the machines. This system provides for a complete replacement of insulation during a major overhaul after a run of 1,320 thousand km and its restoration during an average repair after a run of 330 thousand km on average across the railway network.

Table 2.

Winding name	**Permissible temperature rise for insulation class for heat resistance, C^0**		
	B	F	H
Armature winding	120	140	160
Field winding	130	155	180

During a major overhaul, the entire insulation of the armature and compensation windings must be replaced, three or two impregnations (including one vacuum injection) of the armature in thermosetting varnish, mandatory replacement of the body insulation of the pole coils, checking their interturn and interlayer insulation, double compounding of the pole coils and coating of armature windings and poles with electrical insulating enamel.

Before impregnation, anchor bands must be removed from the frontal parts of the anchor. Evacuation of the windings and subsequent injection of varnish under pressure with the frontal parts of the winding open create conditions for deep penetration of the varnish into the insulation. The varnish, filling defective areas, improves the insulation structure, cements the winding, and protects it from environmental influences. A similar effect is achieved by compounding pole coils.

After impregnation of the armature windings, compounding of the pole coils and their drying, the windings are covered with electrical insulating enamel, which forms a strong, uniform surface film that protects the main insulation from oxidation by atmospheric oxygen, as well as from dust, moisture and oil.

Conclusion

The analysis performed shows the relevance of the problem of controlling a locomotive at the limit of wheel-rail adhesion and reducing the resulting dynamic loads. At the same time, he confirms that this problem is complex and not yet fully resolved. This is due to the complexity of the traction power transmission system with synchronous motors, which includes mechanical and electrical (power and control) subsystems in their interaction and mutual influence.

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