Possibilities of modernization of wheel motor blocks of locomotives

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Abstract. The task of modernizing the wheel-motor blocks of locomotives with a wheel diameter of 1050 mm with asynchronous and collector traction motors is considered. As a result of the analysis, it was found that the design of the traverse suspension of the collector engines is outdated and contains wearing surfaces that are difficult to protect from contamination, while due to the limited dimensions the attempt to use a hinged suspension of the “Earring” type, the silent blocks on the axes were stuck. For drives with asynchronous motors, an increase in the rotational speed is limited by the cantilever location of the gear, at which the gear rotates and the end of the motor shaft can be turned. An engine suspension design with three spherical silent blocks, a liquid with ferromagnetic nanoparticles and a permanent magnet is proposed. It eliminates jamming of the silent blocks on the axes during transverse movements of the engine and ensures interchangeability of the wheel-motor blocks for upgraded and non-upgraded trolleys. To improve the reliability of traction transmission, it is proposed to position the gear between the rotary bearings. To reduce the wear of traction gear teeth, the design of an elastic gear wheel with chevron teeth was proposed. A patent for an invention and a patent for a utility model have been obtained for the proposed technical solutions.

1. Introduction

Wheel-motor blocks (WMB) with a wheel diameter of 1050 mm are currently used on freight and shunting diesel locomotives with electricity transmission of domestic railways [1-3]. Objective prerequisites for the use of wheels with a diameter of 1050 mm in freight diesel locomotives are [4-6]:

− lower power of traction electric motor (TEM) in comparison with electric locomotives;
− the ability to reduce the length and weight of the trolley, in most cases, three-axis (due to the complexity of the layout of the three biaxial trolleys because of the fuel tank);
− less vertical displacement of the coupling axis from the longitudinal axis of the main frame, which reduces the bending moments in the frame when exposed to longitudinal loads.

The WMB of the diesel locomotive 2TE25A with asynchronous TEM (Fig. 1) is currently among the most advanced designs of domestic WMB for diesel locomotives with a wheel diameter of 1050 mm.

In WMB 2TE25A, an elastic self-aligning cogwheel (ESACW), rolling motor-axial bearings (MAB) and “Earring” type suspension, not containing wear parts, are used. This solution was made possible by the use of a new trolley with a radial installation of wheelsets in the diesel locomotive 2TE25A.
However, such a trolley was not widely used due to its higher cost. The majority of locomotives produced for domestic railways use a modernized jawless truck with a TEM collector, which still has a spring suspension (Fig. 1). The disadvantage of this suspension is the presence of wearable surfaces that are difficult to protect from contamination. The choice between MAB of rolling and sliding at delivery is made at the customer request. Thus, since the task of converting a locomotive fleet to MAB of rolling can be solved by rolling up new WMBs, the main unsolved technical task of modernizing WMB today is the search for solutions to replace the spring suspension. In addition, the current trend towards the use of asynchronous TEMs with increased rotational frequency (to reduce the TEM mass and the non-sprung mass as a whole) creates a problem of reliable attachment of the small gear wheel to the TEM shaft and strength of the TEM tail shaft due to the cantilever arrangement of the small gear wheel [7].

2. Modernization of diesel locomotives with a TEM collector
On domestic electric locomotives, the replacement of a spring suspension with a pendulum one began after switching to a six-pole TEM with a round framework, which simplified the deployment of rubber shock absorbers. Attempts to replace locomotive suspension began later, which is connected with the continued use of four-pole TEM, as well as the fact that until the end of the 70s, most of the fleet of locomotives in use were machines with axial power of about 200 kW and less [8-11].

In the early 80s the Russian Research and Design Technological Institute of rolling stock (RRDTIRS) proposed to replace spring suspension with a rubber-metal traverse (1, 2) and an “Earring” type suspension (3). During the tests, it was established that both types of suspension provide acceptable dynamic properties of the drive. However, during testing of the “Earring” suspension of the 2TE10M diesel locomotive at the Sary-Shagan depot, rubber was squeezed out of the suspension hinges. There was no failure of the rubber-metal traverse, but it was not also introduced into production. The termination of suspension modernization work, in particular, was affected by the fact that at this time the mounting-axial drive was considered unpromising.

The main difficulty in using the “Earring” suspension type for TEM suspension of a locomotive with
a wheel diameter of 1050 mm is the limitation of the length dimensions, due to the location of the TEM close to the transverse beams of the trolley frame. For this reason, the distance between the axles of the suspension hinges had to be reduced to 270 mm. As a result, the compensation of the TEM transverse movements relative to the trolley frame only due to the skewing of rubber-metal hinges was impossible due to excessive rubber deformation, and it had to be ensured by movements of the inner sleeves of the hinges along the axes. In operation, drying and contamination of the axle lubricants occurred, as a result the hinges on the axles were seized and rubber was squeezed out of the hinges. Another disadvantage of the “Earring” suspension is the impossibility of the rolling up of the modernized WMB for ordinary trolleys, since to install the “Earring” type suspension it is necessary to remove TEM spouts.

Thus, from among the already created, brought to the prototype and tested structures, only rubber-metal traverse RRDTIRS structure can be used, in the variant of placing rubber-metal elements between TEM spouts (Fig. 2).

![Figure 2](image)

**Figure 2. Rubber-metal traverse RRDTIRS:**
1 – TEM; 2 – spouts; 3 – rubber-metal elements; 4 – traverse; 5 – bracket; 6 – trolley frame; 7 – wedges; 8 – bolt.

When placing the rubber-metal elements between the TEM spouts, the compression deformation of the rubber-metal elements decreases when the trolley rolls sideways. The design of the traverse is simple, technological and does not contain friction pairs. The disadvantages of rubber-metal traverse include the need for making indentations in the lining on the spouts to fix rubber-metal elements relative to the TEM and the possibility of insufficient tightening of the bolt joint made under the locomotive in the pit track.

The operating experience of the main electric locomotives of the VL80 series with various indices shows that the presence of a friction pair “bushing-axis” in the TEM pendulum suspension, even with an open friction pair, does not create significant operational problems, due to the cheapness of wearing parts (axes) and its simplicity of replacement. In connection with this the authors proposed an improved version of the “Earring” suspension (Fig. 3). The suspension has three spherical hinges, and one of them, the upper one, has the possibility of transverse movement along the axis, corresponding to the calculated transverse displacements of the TEM relative to the trolley frame in straight and curved track sections.

In the proposed version, the same axial spacing between the suspension hinges was adopted; however, instead of one lower hinge, two spherical ones were used, located on opposite sides of the lower spout on the TEM frame. This allows, if necessary, to drive WMB under the locomotives that have not been upgraded, and using a spring suspension. The use of two lower hinges instead of one completely eliminates the suspension torsion with TEM transverse movement, and using a spherical hinge as the top reduces to a minimum the unevenness of the load of the spherical hinge sleeve on the axis, and accordingly, excludes its clearing on the axis. The low coefficient of friction between the upper hinge sleeve and the axis is ensured by the fact that the space between the hinge and the axis is filled.
with lubricant with ferromagnetic nanoparticles, and a permanent magnet is installed in the bore of the internal hinge sleeve. To protect friction pairs from ingress of dust and moisture, the surface of the axis of the upper hinge is closed by a corrugated rubber sheath (not shown in Fig. 3).

The suspension design provides ease of disassembly, as to separate the TEM and the suspension, it is necessary just to unscrew the two bolts securing the locking bar and knock the axle out of the hinge and bracket. A patent for a useful model was obtained for the proposed suspension variant [12].

![Diagram](image)

**Figure 3.** Option of a TEM suspension, ensuring the compatibility of the latter with a spring suspension (covers not shown):

- a – general view, b – suspension type, c – lower hinge device.
- 1 – bearing supports; 2 – a carries; 3,4 – silent blocks; 5,6 – axis; 7 – bracket; 8 – TEM housing; 9 – trolley frame; 10 – lubricating fluid; 11 – permanent magnets; 12, 13 – upper and lower spouts of TEM.

### 3. Modernization of diesel locomotives with asynchronous TEM

One of the weak points of WMB locomotives with asynchronous TED is the console position of the pinion gear. Reducing the diameter of the gear leads to a weakening of its mounting on the TEM shaft, as well as to a decrease in the shaft strength due to the increase of circumferential forces in the transmission [13-17]. As a result, the maximum rotation frequency of the TEM DAT 350-6 UHL1 used in the 2TE25A diesel locomotive is only 2300 rpm, while on electric locomotives with ATEM, the maximum rotational speed is brought to 3500 rpm, which allows reducing the WMB weight and the effect a path in straight lines and curves. An important requirement for the design of WMB of a freight diesel locomotive is the utmost simplicity of manufacturing, which practically excludes the structures using compensating mechanisms.
Based on this condition, the authors propose to use the drive in cargo AEM, in which the pinion gear is located on the shaft between the bearing and the rotor (Fig. 4). In this case, it becomes possible to increase the length of the gear hub and, accordingly, the strength of the gear seat on the shaft, and, due to the location of the gear between the supports, the shaft bending stresses decrease. This arrangement is used in the domestic electric locomotive 2ES5.

Figure 4. Proposed option of WMB with AEM:
1 – wheel pair, 2 – TEM, 3 – ESAC, 4 – axial bearing, 5 – drive gear; 6 – rotary bearing

Figure 5. Elastic self-aligning wheel:
1 – hub; 2 – crown; 3 – elastic elements; 4 – slots; 5 – bushings; 6 – locking screws; 7 – internal protrusions; 8 – outer protrusions

A feature of this design as compared to the integrated drive of “Siemens” is that the rotary bearing on the gearing side is located in the protrusion of the bearing shield, which also serves as a protective
cover. The axial gear case is divided longitudinally into two halves, which are put on the seats, formed by the projection of the bearing shield and the case of the MAB unit. This reduces the requirements for precision machining of the gearbox housing, which, to reduce weight, can be made as a non-bearing casing. The purpose of using a thick-walled cast or welded body in this case is the possibility to increase the lubricant supply in the body, reduce the leakage of grease through the seals and prevent damage to the body from frost at crossings.

Unlike the prototype, the authors propose to speed up the introduction of the drive of such a scheme in the first stage to use a spur gear and a ESAC design similar to that in the 2TE25A diesel locomotive. Subsequently, in order to ensure a further increase in the locomotive axial power, it is proposed to use a chevron gear, for which the authors have developed and proposed a ESAC with two gear rims (Fig. 5). In the proposed ESAC cylindrical elastic elements are installed without a gap in the slots, made evenly around the circumference of the wheel, in pairs and coaxially on one sleeve, i.e. one at each end of the elastic gear wheel, and secured with locking screws. In the disk of the crown there are internal protrusions, which alternate with the external ones on the hub with the regulated clearances.

The slots are non-through and are located at the junction of the protrusions from both ends of the wheel. One half of each slot is made on the inner protrusion of the hub, and the other on the outer. The ends of the outer projections have spherical surfaces at the ends that are in contact with the slots between the inner projections in the crown disk. The crown is made detachable from two parts connected by bolts. The peculiarity of this wheel is that the spherical surfaces, on which the gear crown is supported on the hub, are made on a larger diameter than the elastic wheel used at present, as a result the area rubbing surfaces increases and the contact pressure decreases which leads to wear reduction.

4. Conclusions and recommendations

It has been established that for existing WMB of diesel locomotives with wheels having a diameter of 1050 mm, the problem of upgrading the following components has not been solved: for WMB with collector TEM - a spring suspension with wear nodes, and for WMB with asynchronous TEM - a small gear assembly located on the shaft of the TEM , which limits the possibility of reducing the diameter of the small gear to increase traction due to a decrease in the strength of the pinion gear on the shaft and the growing danger of breaking the TEM shaft.

It is proposed to apply the layout of the traction drive with the gear between the hubs to eliminate the console arrangement of the small gear on the shaft of the asynchronous TEM. The proposed new design of TEM suspension and ESAC with chevron teeth, obtained a RF patent for the invention and a RF patent for a utility model [18].

The task of creating a method for constructing components and parts of a locomotive drive allowing not only to simulate the physical properties of the latter but also to form and automate the recognition of technical solutions, is considered. A model of a traction drive, which is a system of sets of descriptions of real objects of the set which makes it possible to create mathematical models of the structure in the form of a set of related elements included in the libraries of well-known solutions is proposed. In contrast to previously known methods based on the procedure of creating new solutions under which a prototype of the structure is made and then improved on the basis of an empirical analysis of its development (while the design task is to create new structures). In the proposed method, the basis for the construction of the technical system objective model is the classification of technical systems. The proposed generalized objective model of a traction consists of two parts- a hierarchy of sets of a traction drive descriptions with different degrees of their schematization and a library, containing the descriptions of provided typical objects in the form of a hierarchical structure of the functional interaction between the elements (I–graph).

At the same time at the level of the drive functional elements similar objectives are searched for in the library using similarity matrix. As an example the design of a suspension of the traction motor with a support-axial drive is considered. Solutions to eliminate jamming of the sleeves of the axes with the transverse movement of the engine are proposed. A patent for the invention and two patents for the utility models are obtained.
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