

Design and dynamic problems of traction drive of electric locomotive 2ES10 and proposals on its modernization

D Ya Antipin, V I Vorobiev

Bryansk State Technical University, 7, 50 let Oktyabrya Blvd., Bryansk, 241035, Russia

E-mail: adya2435@gmail.com

Abstract. The analysis of design and dynamic features of the traction drive of the freight electric locomotive 2ES10 is carried out. The study found that the main disadvantages of the drive are the complexity of manufacturing and the lack of elastic links, damping perturbations from the path. A new drive scheme with dynamic load damping is proposed and patented.

1. Introduction

The mechanical part of the traction drive of the electric locomotive 2ES10 (Figure 1) is a modification of the integrated traction drive with an unilateral gear used by the firm Siemens. The traction gear reducer is structurally combined with the traction motor (TM), while the drive gear is located on two symmetrical supports in the gearbox housing [1,2]. The shaft of the TM is supported by one end on the bearing in the TM housing, and by the other – on the disk coupling placed on the shaft of the gearbox. One of the axial bearings is located in the gearbox housing, the other one is on the TM stator. To transfer the torque from the shaft of the traction motor to the wheel sets, a gear drive with module 9 is used. The gear is composite and consists of a hub and a gear crown, which is bolted. The angle of inclination of the tooth line of the wheel and the gear is 4° . The number of teeth of the wheel is 107 and the number of teeth of the gear is 17.

The advantage of the drive is the possibility to minimize the weight and dimensions of TM by increasing its speed when the diameter of the driving gear and the landing diameter of the shaft under the rotary bearings are reduced. It allows you not only to reduce the unsprung weight, but also to simplify the drive arrangement for different track width, dimensional limitations and wheel diameters [3–5].

The main disadvantage of the drive is an abrupt complication of the manufacturing technology and installation of the traction drive due to the complexity of the parts location, the increased number of size chains links and, accordingly, toughening the tolerances for their manufacture. In this case, the TM cannot be assembled and balanced separately from the reducer, and the membrane coupling further complicates the balancing as a result of the increased number of links in the dimensional chains of the parts that provide the basing of the TM rotor. The conventional conguration of the motor-axial bearings leads to misalignment of the gear teeth of the traction transmission due to bending of the wheel axle. Besides, the seating surfaces of both bearings on the axis cannot be processed in a single clamping position, which increases the error [6–8].



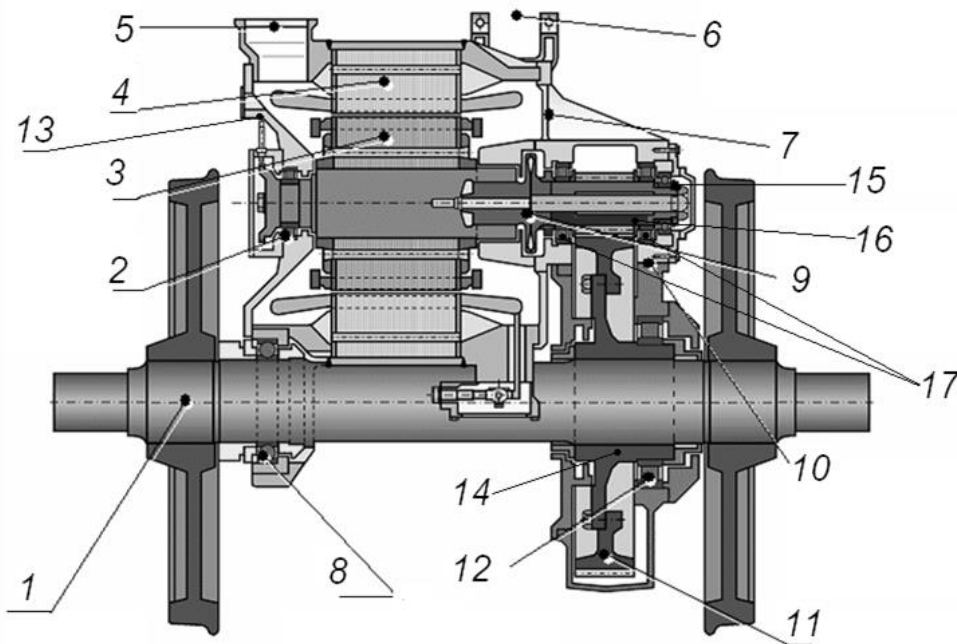


Figure 1. Electric locomotive traction drive 2ES10: 1 – wheel axle; 2 – motor bearing; 3 – motor rotor; 4 – stator; 5 – cooling air intake branch pipe; 6 – motor suspension bracket; 7 – air outlet channels; 8 – motor-axial bearing; 9 – diaphragm coupling; 10 – reducer coupling; 11 – gear crown; 12 - motor – axial bearing (gear side); 13 – rear bearing plate; 14 – gear hub; 15 – 4-point bearing; 16 - pinion; 17 – cylindrical bearing.

The drive has no elastic links, which reduce the loads when exposed to disturbances from the path. The disadvantages were the basis for the analysis of the structural and dynamic properties of the drive.

2. Results and Discussion

The results of mathematical modeling [9–13] showed the following frequencies of natural oscillations of the electric locomotive 2ES10 wheel pair: torsional vibrations of the wheel pair axis – 72 Hz; transverse vibrations of the wheel pair in the four-node form – 270 Hz; transverse vibrations of the large gear in the four-node form – 390 Hz. It is known [14–16] that in the frequency range of 125–1000 Hz the elements of the traction drive of electric locomotives and diesel locomotives with an axle support drive are under quasiperiodic dynamic loading caused by the traction transmission teeth changeover. Especially intense loads acted in the traction drive of various series of locomotives 2TE10 are caused by steaming of a traction transfer and working of a new small cogwheel in gearing with the worn-out cogwheel (the dynamic component of the moment from teeth changeover was commensurate with a static component in the mode of long draught). However, there was no evidence of cracks in the wheel centers and bands. Due to the best manufacturing technology of the gear transmission and the use of inclined teeth in the drive there is no significant reason to assume the presence of a higher dynamic component in the drive 2ES10 although this assumption requires verification, in case of factors not found in the previous studies. The determination of bending moments in the wheels under the action of the moment that occurs due to the teeth changeover using the modeling methods is difficult owing to the fact that the factors of the transverse vibration energy diffusion when rolling the wheel along the rail are understudied. Previously some Japanese railway companies studied the dynamics of such oscillations for the Sinkansen line trains, as well as the methods of vibration damping by applying a damping coating to the surface of the wheel disc and applying an elastic wheel center [17].

The dynamic moments from the non-sinusoidal supply voltage is only 0.75 kNm, with a static

moment on the TM shaft in the nominal mode of 6.8 kNm. In the case of a short circuit, the dynamic torque produced by the wheelset axis is 120 kNm, or 19 kNm on the TM shaft. These values do not exceed the dynamic moments measured in other locomotive drives with a wheel diameter of 1250 mm. Thus, in the drive 2TE121 the dynamic moments on the TM shaft when passing rough paths reached 8,0-8,5 kNm, and when boxing – up to 36 kNm.

The wheel-motor unit accelerations above the axis of the wheelset in the track section Sverdlovsk-Balezino was 28g, but the speed at what the measurements were made is not mentioned. The example also says nothing about how representative the sample was and what character the rough paths had. Then the table shows data of 21.5g for speeds below 140 km/h (assumed to be 100 km/h).

Let us try to estimate the loading of the traction drive of the electric locomotive 2ES10 by analogues. The mass of the motor-gear unit without wheelsets is 3980 kg, which allows to consider the value of the mass of the electric locomotive 2ES10 without springs as a first approximation close to the value of the mass of the electric locomotive 2TE121 with an axial gear (given that only a part of the TM mass rests on the axle).

As the results of the research of the locomotive 2TE121 show (Figure 2) the impulsive disturbance on the mass without springs passing, the rough paths essentially depend on the character of the roughness (mainly on the angle of the fracture in the joint) and the speed of movement. Higher values of the accelerations obtained for the electric locomotive 2ES10 indicate a higher stiffness of the rail base (for locomotive 2TE121 the data of acceleration was obtained in summer conditions). Thus, it is expected that the level of dynamic moments in the traction drive shaft of the electric locomotive 2ES10 can reach values exceeding the traction moment of diesel locomotives with a rigid gear transmission built in the 50-60-ies. We conclude that there are additional opportunities for the traction drive of the electric locomotive 2ES10 to improve its reliability and durability due to the choice of the constructive scheme of a drive with an elastic link in the shafting. In view of this, it is necessary to eliminate such shortcomings of the drive as low processability in production and repair, high weight attached to the small gear, which increases the dynamic loading during the teeth changeover and the misalignment of the teeth due to the wheel pair axle bending.

Based on the analysis, the authors proposed a new aggregate scheme of the traction drive (Figure 3). In this drive the TM and the axial gearbox are made in the form of two separate assembly units, each of which independently rests on the axis through its bearings. In this case the axial gearbox housing is connected to the TM housing with a swivel joint. Thus, when moving the wheel pair relative to the bogie frame, the axial position of the gear shaft relative to the TM shaft of alternating current does not change. Radial and angular misalignment of the shafts is determined by manufacturing errors in the body parts and gaps in the bearings and in the TM hinge joint with the reducer, which is at least by a factor of ten lower than the centerings in the support frame suspension. This allows to use a single elastic couple which does not limit the maximum number of revolutions of the asynchronous TM, instead of a cardan shaft or a double clutch. Unlike the drives of the electric locomotives EP10 or DS3.

The dynamic loads in the traction drive when it passes rough paths are damped due to the elastic coupling, which elements are available for inspection. The mass attached to the small gear (a flange instead of the TM rotor) is reduced, which leads to a decrease in disturbances during the transmission teeth changeover [17–19].

A swivel joint allows TM balancing without a reducer, which simplifies the TM production and diagnosis. The design of the axle gear is more simple and feasible than of the existing drive. The link number of the size chains defining parallelism of the toothed gears is less, which simplifies the gear manufacturing and assembly. The small gear is located symmetrically relative to the bearing supports, and the location of the axial bearings virtually eliminates the effect of bending of the axle of the wheel pair on the misalignment of the gears. In contrast to the bearing housing the gear housing can have a welded-in pocket to increase the supply of lubricant, as it is done in the locomotive 2TЭ121 and the electric locomotive DS3. The axial gearbox can use roller bearings with cylindrical rollers for the perception of radial loadings and ball bearings for the perception of axial forces.

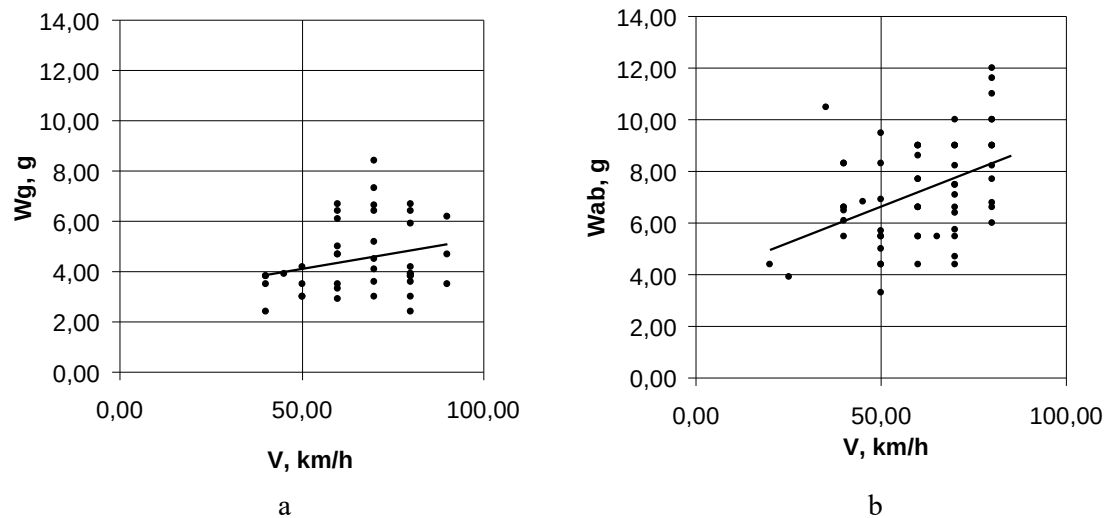


Figure 2. Diagrams of vertical accelerations of the locomotive 2TE121 mass without carriage springs in summer conditions a) vertical accelerations of the gearbox on the track Golutvin-Ryazhsk; b) vertical accelerations of axle boxes on the track section Vorkuta-Sosnogorsk.

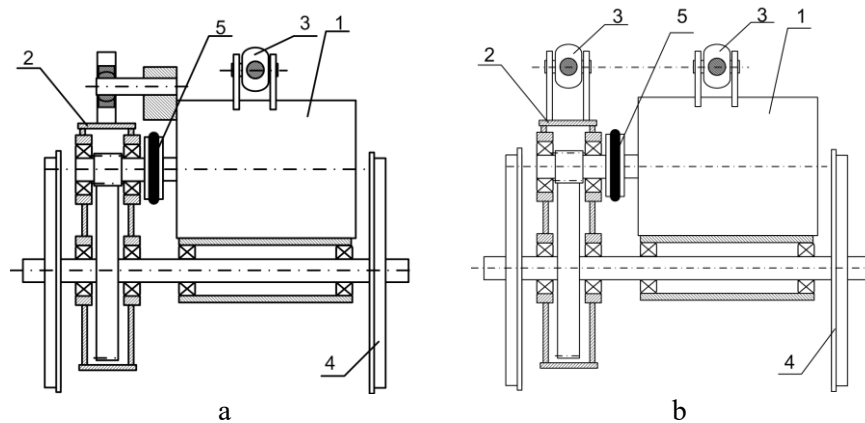


Figure 3. Schemes of the aggregate traction drive: a – with a swivel gear of the reducer and TM; b – with suspensions having hinges on the same axis. 1 – TM; 2 – axle gearbox; 3 – suspension; 4 – wheel pair; 5 – elastic coupling.

Let us consider the overall limits under the operational conditions of the locomotive only on the tracks of 1520 mm wide. It is known that for the reference axis of the drive the total length without the axial bearing assemblies (including the gaps between the parts of the drive and the bandages of the wheel pairs), shall not exceed 1370 mm. The width of the axle gear when the small gear bearings are outside the ring gear may be of about 260 mm (the electric locomotive DS3). Thus, with the length of the TM housing excluding shaft tailing of about 980-990 mm, the axial dimension for the placement of the elastic coupling is about 100 mm with the outer diameter limited to 500-600 mm. In this regard, it is necessary to develop an elastic-compensating coupling of low thickness with the possibility of the connector to ensure the TM dismantling without disassembling the axial gearbox. The proposed solutions are patented.

3. Conclusions

The integrated drive of the electric locomotive 2ES10 has an increased complexity in manufacturing and repair, high TM acceleration over the axle of the wheelset when traveling along rough paths

(about 20-30g) can lead to high forces in the traction transmission and TM suspension, and the high mass of the rotor attached to the small gear leads to an increase in loading during the teeth changeover.

The drive of the aggregate type with the engine having the maximum number of turns of 3500 min⁻¹ and constructed according to the scheme with the basic-axial engine and the axial reducer, connected with each other by a hinge connection and an elastic coupling, or with two suspensions having hinges on one axis, is offered. This drive provides reduction of dynamic loadings in case of technologically simpler decisions in comparison with the drive of the electric locomotive 2ES10.

The proposed solutions made it possible to obtain two patents for utility models.

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