



DETERMINATION OF DYNAMIC LOADS ARISING IN THE TRACTION TRANSMISSION OF AN ELECTRIC LOCOMOTIVE

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When calculating the dynamic force factors acting on the elements of the traction transmission of an electric locomotive, all the necessary parameters are set, except for the stiffness of the shock absorber of the traction motor suspension. In the design scheme accepted (Figure 1), the shock absorber of the suspension is the only elastic element, and its parameters largely determine the course of the oscillatory process. Rigidity and inelastic resistance β of rubber elements depend on the brand of rubber, ambient temperature, and shock absorber design. The parameter β is given, while the stiffness of the shock absorber must be determined by calculating it from the initial data.

ABSTRACT

The article presents dynamic calculation of the traction transmission of an electric locomotive, taking into account its motion along the irregularities of the railway track.

To solve the problem of determining the dynamic loads that occur in the traction transmission of an electric locomotive, we introduce the following assumptions:

1. The track profile is a continuous series of periodically repeating harmonic irregularities with amplitude Z_H . The current value of the deviation of the rail level from the center line [1, 2, 3] is:

$$Z_p = Z_H \cdot \cos \omega_H t \quad (1)$$

where Z_H is the depth of the rail track irregularities, m;

t is the time of the electric locomotive motion, s;

ω_H is the cyclic frequency of kinematic disturbances caused by the electric



locomotive passing the track irregularities; it is calculated by the following formula

$$\omega_H = \frac{2\pi V}{\ell_H}, \quad (2)$$

where V is the speed of the electric locomotive along the track with periodic irregularities, m/s;

ℓ_H is the length of irregularities of the rail track, m.

2. Both wheels of the wheelset simultaneously pass identical sections of the rails. We assume that the railway track and the wheelset are absolutely rigid, as a result of which the trajectory of the Z_0 axis of the wheelset repeats the longitudinal profile of the rail Z_p , i.e. [1,3]

$$Z_0 = Z_p = Z_H \cdot \cos \omega_H t, \quad (3)$$

In fact, due to the elasticity of the railway track, oscillations of the wheelset differ in amplitude and in phase from the rail irregularities passed by the wheel. With an increase in the speed of motion, the amplitude of oscillations of the Z_0 axis decreases.

3. There is no clearance in the gearing of the traction drive, and the parts of the traction electric motor and gearbox are rigid.

4. In the design of the traction drive, there is only one elastic element with the energy dissipation - a rubber-metal shock absorber for the suspension of the traction electric motor housing. The stiffness of the set of rubber washers is determined by

considering the pre-tightening action, the motor mass, and the traction torque response. Rigidity is assumed to be constant.

5. The oscillatory system is assumed linear (i.e., the frequency of oscillations does not depend on the amplitude), and the angular displacements are small so that the angle of rotation of the motor housing can approximately be calculated by the following formula

$$\varphi \approx \sin \varphi \approx \tan \varphi. \quad (4)$$

6. Oscillations of the masses of the system in the vertical direction and, accordingly, the equation of the balance of forces in the projection onto the Z axis are not considered since the responses associated with the vertical displacement of masses are an order of magnitude smaller than the forces caused by rotational oscillations.

It is assumed that the frame of the electric locomotive bogie does not participate in the process of oscillations of the traction drive, keeping its position unchanged relative to the average rail level.

With these limitations, the design scheme of the system "railway track - wheelset - traction drive - traction electric motor (TEM) - supports - transverse (pivot) beam of the bogie frame" with the support-axial suspension of the NB-418K TEM for the VL-80s electric locomotive takes the form shown in Figure 1 [4, 5].

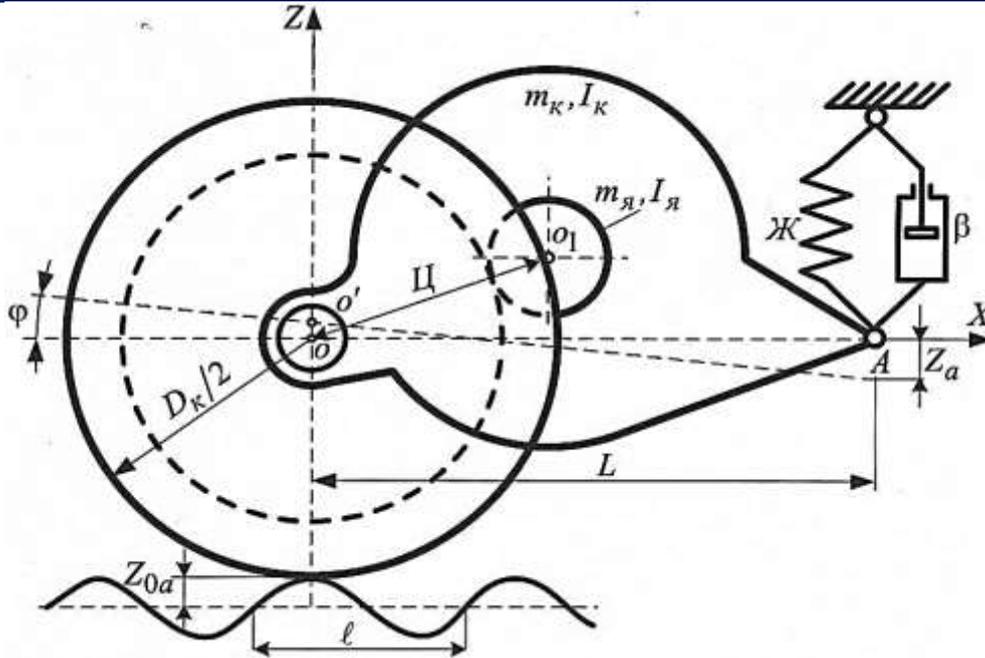


Figure 1. Design scheme of the system “railway track – wheelset – traction transmission – traction electric motor – supports – cross (pivot) beam of the trolley frame” with axial suspension

If there are rail irregularities and the Z_0 coordinate changes by OO' , the motor housing, together with the gearbox, rotates at some angle φ . Assuming angle φ to be positive when turning the TEM housing counterclockwise, we determine coordinate Z_a of the suspension point

$$Z_a = Z_0 + L \varphi. \quad (5)$$

We must not forget that the angle of rotation of the TEM housing φ depends not only on the lift height of the wheelset, but also on the change in the length L of the suspension when the washers of the rubber-metal shock absorber of the TEM are compressed and stretched under the action of the force applied at the moment. The rotation of the gear and the armature of the traction electric motor connected to it becomes irregular as the body rotates (wabbles) about its transverse axis.

Due to rotation irregularities of the armature through the gear teeth, in addition to the useful traction moment M , the dynamic inertial moment M_D , depending on the angular acceleration of the armature $\frac{d\omega_{я}}{dt}$, is transmitted; it can be calculated by the following formula [4]

$$M_D = I_{я} \frac{d\omega_{я}}{dt}, \quad (6),$$

where $\frac{d\omega_{я}}{dt}$ is the angular acceleration of the TEM armature; $I_{я}$ is the moment of inertia of the TEM armature.

In this case, the total moment transmitted by the gear consists of constant traction moment M_T and cyclically changing inertial moment M_D , i.e.

$$M = M_T + M_D. \quad (7)$$

Since only rotational movements are considered in the calculation model, we represent the entire transmission as a planetary gearbox, in which a large gear wheel with radius R serves as a fixed sun gear; the housing connecting the centers of



the gears O and O_1 is the carrier, and the gear with radius r is the satellite.

Rotation of the TEM housing by an angle φ is accompanied by additional rolling of the gear along the wheel along an arc of length $R\varphi$. The corresponding arc of displacement of the point of contact along the gear has the same length.

In this case, the angle of rotation of the gear $\varphi_{\text{Я}}$ or the angle of rotation of the radius drawn to the point of contact from the point O_1 is the sum of two angles

$$\varphi_{\text{Я}} = \varphi_{\text{Я}}^1 + \varphi \quad (8)$$

where $\varphi_{\text{Я}}^1 = \frac{R\varphi}{r}$ is the angle of rotation of the gear due to the contact with the wheel; φ is the angle of gear rotation together with the TEM housing.

The gear ratio from the housing to the gear and armature, i.e., the ratio of the rotation angles is

$$q = \frac{\varphi_{\text{Я}}}{\varphi} = \left(\frac{R\varphi}{r} + \varphi \right) = u + 1 \quad (9)$$

Next, a numerical calculation was performed on a computer using the *Mathcad 15 programming environment* according to the technique developed in the article using the iteration method [6].

As a result of the numerical studies conducted according to a mathematical model, developed to improve the methods for calculating the rational dimensions of the parts of the upgraded support of the NB-418K6 traction electric motors for the bogie frame of the VL-80s electric locomotive, the following generalizing conclusions can be drawn:

1. From Figure 2, it is obvious that at an increase in the height of the rail irregularities Z_H of the railway track the amplitude of vertical oscillations of the axis of the electric locomotive wheelset $Z_{0i}(t)$ increases, at the variation in $i = 0, \dots, 4$ and the change in the height of the rail irregularities $Z_H = 1, \dots, 5$ mm. At an increase in the speed of the electric locomotive $V_3 = 50, \dots, 110$ km/h, the amplitude of oscillations of the axis of the wheelset $Z_0(V_3)$ decreases.
2. The cross-sectional dimensions of the rubber washer of the rubber-metal shock absorber of the TEM support suspension are determined from the strength condition, i.e., the acting stress should not exceed the permissible one, which is $[\sigma] = (3 \dots 5) 10^3$ kPa.

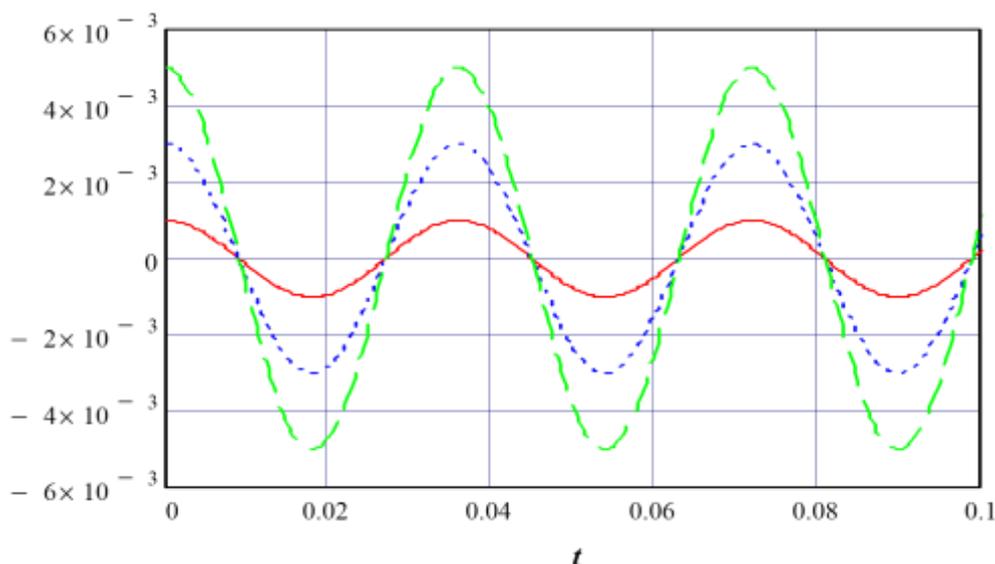




Figure 2. Vertical vibrations of the electric locomotive wheelset during the passage of a railway track with rail irregularities $Z_{0i}(t)$ at the variation of $i = 0, \dots, 4$ and

the change in the height of the rail irregularities $Z_H = 1, \dots, 5$ mm.

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