Evaluation of indeterminacy of initial data for cad system of electric engine suspension

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Abstract. The research of the variants of the suspension of the traction electric motor of diesel locomotives was performed. It was found that the method of designing the suspension does not take into consideration the possible changes of the characteristics of the parts in operation conditions. Variants of the suspension design were proposed and patented, which provide the work reliability despite the operating conditions.

1. Introduction

On the majority of cargo locomotives used by RZhd (Russian railroads), there are collector traction motors (CTM) with a spring traverse suspension (Figure1).

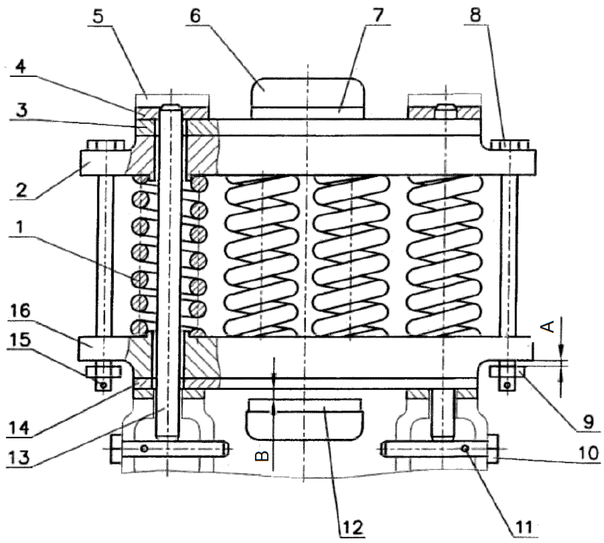
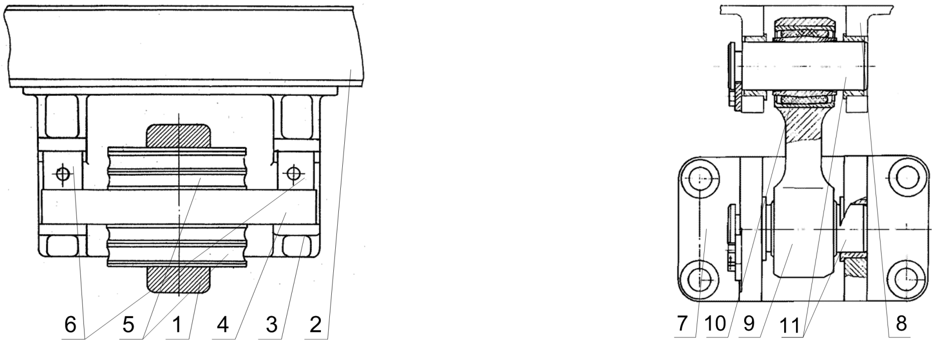


Figure 1. Spring suspension CTM of the 2TE25K locomotive. 1 - spring; 2, 16 – holders, 3, 4, 7, 12, 14 – cover plates; 5 – suspension bracket on the frame of the car truck; 6 – the tip of the upper CTM; 8 - bolt; 11, 15 - splint 9 - nut; 10 - roller; 13 - pin; A – clearance between the holder and the nut; B – clearance between the cover plates of the lower frame and the lower tip.

The main problem of the structure is a significant wear of the cover plates. It is impossible to protect flat interacting surfaces from moisture and dust, the appearance of rust; it is impossible to cover them with a casing or a cover to retain the lubrication.

2. Results and Discussion

The use of an elastic gear wheel in the traction transmission of cargo locomotives made the dynamic system of the wheel motor unit unperceptive to the hardness of the CTM suspension, which made its modernization possible. As the ways of modernizing the suspension, the authors proposed the rubber metal cross beam (RMCB) designed by Open JSC VNIKTI by the standard of the USSR, No. 925718, shown in figure 2 a, and for the second one – the “Serga” suspension (figure 2 b).



a b

Figure 2. Researched variants of suspension CTM: a – RMCB; b – “Serga”; 1 – CTM; 2 – bogie frame; 3, 8 – brackets on the frame; 4 – cross beam; 5 – elastic elements, 6 – clampings; 7 – bracket on CTM; 9 – link; 10 – joint; 11 – rollers.

The trials of the both suspension variants [1-5] have shown that they provide satisfactory dynamic characteristics of the wheel motor unit. As the main variant, the producing plant accepted the “Serga” suspension providing a smaller labour input for the suspension mounting and for the dismantling during the rolling out of the wheel-motor unit while repairing it. Because of the restriction of the dimensions of the suspension by the height determined by the design of the bogie, it was impossible to provide the compensation of the transverse movements using only rubber metallic joints including spherical joints and it was necessary to compensate those movements partially on account of the sliding of the joints on the rollers. During the operation of the experimental locomotive, the jamming of the joints on the rollers and pressing out of the rubber from the joints took place. This phenomenon takes place in case if the resistance force to the movement of the upper joint created by the friction is more than the force of the angular deformation of the joint during the suspension skewing:

$$F_{fr} \geq F_{\partial}; \quad F_{fr} = F \cdot f; \quad F_{ä} = \frac{M_{ä}}{L} = \frac{G_{\varphi} \cdot \varphi}{L} = \frac{G_{\varphi}}{L} \cdot \arcsin\left(\frac{\Delta}{L}\right), \tag{1}$$

where f – the coefficient of sliding friction of the suspension; F is the summary effort in the suspension from the weight of the traction electric motor and the reactive effort of the traction force realization; kN, G_{φ} – angular rigidity of the shock absorber in case of skewing; kN/rad, L – inter-center distance along the shock absorbers of the suspension, mm; and Δ is the amplitude of the traverse motion of the wheel pair with an electric motor with respect to the bogie frame, mm.

In connection with it, Open JSC VNKTI proposed a modernized variant of the suspension, in which the parameters of the silent blocks were interrelated with the ratio:

$$f \leq \frac{1}{\left[\frac{F\left(2 \cdot l^2 \cdot G_r + 6 \cdot L^2 \cdot G_0\right)}{G_0 \cdot l^2 \cdot G_r \cdot \Delta} + \frac{L}{t}\right]} \tag{2}$$

where t is the length of the internal bushing of the shock absorber, mm; G_r – the radial rigidity of the shock absorber, kN/mm; G_o – the axial stiffness of the shock absorber, kN/mm.

But because of the contamination and the corrosion of the surfaces of the rollers, the friction ratio

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can change significantly, which makes the operation of the suspension unreliable. If during nonautomatic designing, such problems could have been found purely empirically, during the accumulation and generalization of different structures, while using classical CADS, the situation can take place when the modeling of the design can give a formally positive result, which will be erroneous because of the unpredictable changes of the real properties of the unit during operation [6-8]. For the purpose of avoiding it in the intelligent CAD of the traction drive, it is necessary to provide the choice of such design schemes, in which parameters can be changed within broad limits, can be excluded completely or they do not change the working ability of the unit.

Let us consider the kinematical schemes of the suspension (Figure 3 a-c).

In the initial scheme (Figure 3a), silent blocks can be considered as spherical joints with the possibility of the traverse motion along the rollers. To bring that scheme to a statistically defined one without superfluous degrees of freedom, it is necessary to change one of the joints for as cylindrical one (Figure3 b). At that the rotation of CTM is provided using the second joint having a spherical pair and a cylindrical guide. To be able to consider the rubber metallic joint as a cylindrical one (i.e. to consider the skewing of link 2 as negligibly small with respect to joint 4), on the basis of the practice of designing axlebox links of “jawless” bogies, the ratio of bushing length t of the cylindrical rubber-metal joint to the distance between the axles of joints L is considered as equal:

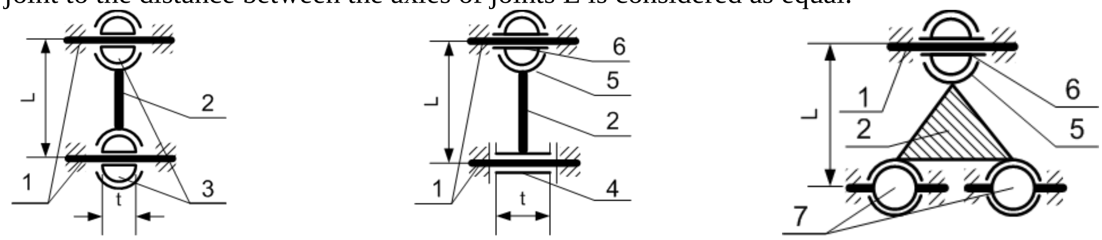

Figure 3. Kinematical schemes of CTM suspension: a - initial; b – with a cylindrical joint; c – three-joint; 1 – rollers; 2 – link; 3 – moving spherical joints; 4 – cylindrical joint; 5 – spherical pair; 6 – cylindrical guideway; 7 – nonmovable spherical joints.

$$\frac{t}{L} \geq \frac{2}{3}. \quad (3)$$

For the purpose of neglecting the friction value of the cylindrical guide of the spherical joint along the roller, magnets are placed in the boring of the bushing of the cylindrical joint keeping the lubrication liquid with ferromagnetic nanoparticles (figure 4a). An invention patent was obtained for the proposed design [3].

Another variant of bringing the suspension scheme to the statistically defined one without redundant degrees of freedom is the change of one of the joints for two spherical ones without any possibility of the traverse movement (figure 3c). At first glance, it is seen that the use of one more joint makes the suspension unit more complicated (figure 4b).

But it gives the opportunity during the modernization of the locomotive not to cut the tips of CTM and to place the upper joint between the two tips of CTM while the two lower joints together with the brackets on the basis of CTM positioned on different sides of the lower tip of CTM. In the movable joint, it is possible to protect the surface of the roller with a rubber cover and to provide its protection from moisture, contamination drying and the loss of lubrication, which increases the service life of the unit [9].

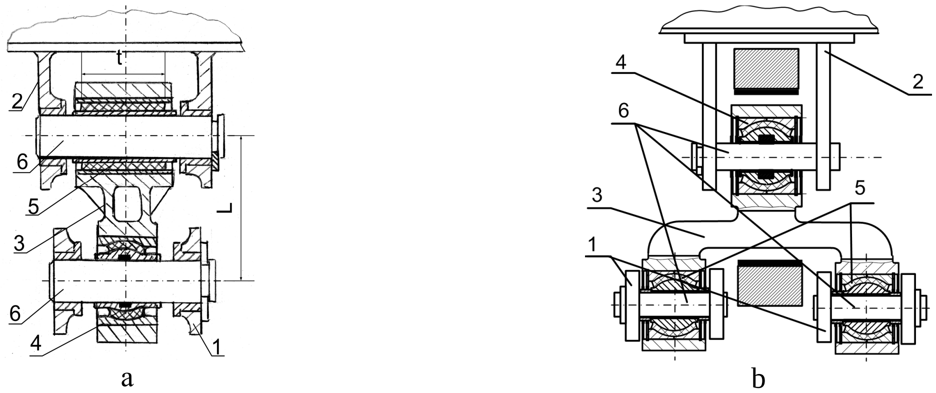

Figure 4. The proposed variants of CTM: a – by patent of RF No.2549427; b – providing compatibility with CTM; 1 – brackets on CTM; 2 – bracket on the frame; 3 – link; 4 – movable joint; 5 – nonmovable joints; 6 – rollers.

The use of three-joint suspension CTM gives an opportunity to reduce significantly the expenditures on modernizing locomotives because the modernized CTM can be installed without further expenditures on the bogie having a spring suspension, which prevents the necessity to have a store of different CTM for different suspension variants [10-11].

3. Conclusions and proposals

1. While designing the CTM suspension using the CAD instruments for the purpose of excluding the spread of values of friction forces in the operating conditions, it is necessary to choose the variants, which provide statistical determinability of the design without redundant degrees of freedom.

2. Two new variants of the CTM suspension were proposed providing a reliable operation of the suspension at small distances of the hinge pins. A patent was obtained for the invention [12].

3. To modernize diesel locomotives with a spring CTM suspension, it is proposed to use the suspension variant with three joints, using which the same CTM can be provided with a joint suspension or with a spring one. This suspension type gives an opportunity to modernize the existing locomotive park with the lowest expenditures.

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