



MODERNIZATION OF THE DESIGN OF THE COIL SPRING OF THE AXLE SUSPENSION OF HIGH-SPEED ELECTRIC TRAINS

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ABSTRACT

The article presents a mathematical model and a developed algorithm for numerical studies on the selection of rational parameters of a modernized coil spring for axle box spring suspension of high-speed electric trains, the design of which is protected by patent of the Republic of Uzbekistan for invention No. IAP 05219 [1].

МОДЕРНИЗАЦИЯ КОНСТРУКЦИИ ВИНТОВОЙ ПРУЖИНЫ БУКСОВОГО ПОДВЕШИВАНИЯ ВЫСОКОСКОРОСТНЫХ ЭЛЕКТРОПОЕЗДОВ

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ABSTRACT

В статье представлены математическая модель и разработанный алгоритм численных исследований по выбору рациональных параметров модернизированной винтовой пружины для буксового рессорного подвешивания высокоскоростных электропоездов, конструкция которой защищена патентом Республики Узбекистан на изобретение No IAP 05219 [1].



вибрации, напряженно-деформированное состояние, метод расчета динамической прочности винтовых пружин, алгоритм, программа, MATHCAD 15.

The spring suspension system of electric rolling stock is one of the critical components of mechanical equipment, since its design and characteristics directly determine the safety of movement, smoothness of the ride and reliability of other components of the sprung part. The main tasks in creating new designs of spring suspension of electric trains, as well as modernization of existing ones, are expansion of functional capabilities, increase in reliability, strength and durability [2,3,4].

Research has been conducted and is being conducted on this topic by leading scientists worldwide such as S.A. Brebbia (Wessex Institute of Technology, UK), G.M. Carlomagno (University of Naples di Napoli, Italy), A. Varvani-Farahani (Ryerson University, Canada), S.K. Chakrabarti (USA), S. Hernandez (University of La Coruna, Spain), S.-H. Nishida (Saga University, Japan). Authoritative scientific schools and prominent scientists in the CIS countries from MIIT, PGUPS, MAI, VNIIZhT, JSC VNIKTI, JSC Russian Railways, etc. worked on these issues. A significant contribution to solving many complex problems and checking theoretical conclusions related to the study of the processes of oscillations of the spring suspension of the rolling stock was made by the Russian Research Institute of Railway Transport (CNII MPS) and the Russian Research Institute of Railcar Building (NIIV), where along with theoretical studies, a large number of experimental studies (bench and full-scale ones) were conducted [2,3,4]. In Uzbekistan, the academician of the Academy of Sciences of the Republic of Uzbekistan, professor, doctor of technical sciences Glushchenko A.D., professors Fayzibaev Sh.S., Khromova G.A., Shermukhamedov A.A., Adylova Z.G., Rakhimov R. V., Ruzmetov Ya. O., Khamidov O. R., Radjibaev D. O. and their students studied the problems of optimizing the systems of spring suspension of rolling stock [5÷8].

However, in the existing calculation methods, the curvilinearity of surfaces, impulse contact processes that occur during the operation of the spring suspension of ground vehicles, the complexity of the dynamic loading pattern, and the volumetric configuration of systems have not been taken into account so far.

To derive the equations of spatial oscillations of a cylindrical elastic rod bent along a helix with a variable radius of curvature of the coils, we used the results obtained in [5÷8] and the following assumptions.

1. The boundary element is taken as a single coil of a cylindrical elastic rod bent along a helix with a fixed radius of curvature (Fig. 1). N is the number of boundary elements (depending on the spatial configuration of the spring element); it is connected into a single dynamic system using boundary conditions.

We used the calculation scheme shown in Fig. 2 (for axle box spring suspension of high-speed electric trains) [by patent of the Republic of Uzbekistan for invention No. IAP 05219 [1].

2. One coil is described by a curvilinear coordinate system (Fig. 1), characterized by distance ℓ to fix the location of a particular section, measured along the length of a helical line bent along the radius R_s in plane $Y \ell$, passing through the centers of gravity of these sections.

The parameters of the sections of the spring coil (Fig. 1) are taken into account according to

- cross-sectional area $F_s = \frac{\pi d_s^4}{4}$;

- mass intensity $M_1 = \frac{\pi d_s^2 \cdot \rho}{4}$ and i_1 mass moment of inertia, where ρ is the density of the spring coil material;

- equatorial $I_x = I_y = \frac{\pi d_s^4}{64}$ and polar $I_0 = I_x + I_y = \frac{\pi d_s^4}{32}$ moments of inertia of the cross-sectional area of the spring coil,

- modulus of elasticity of the first E and the second G kinds of the coil material.

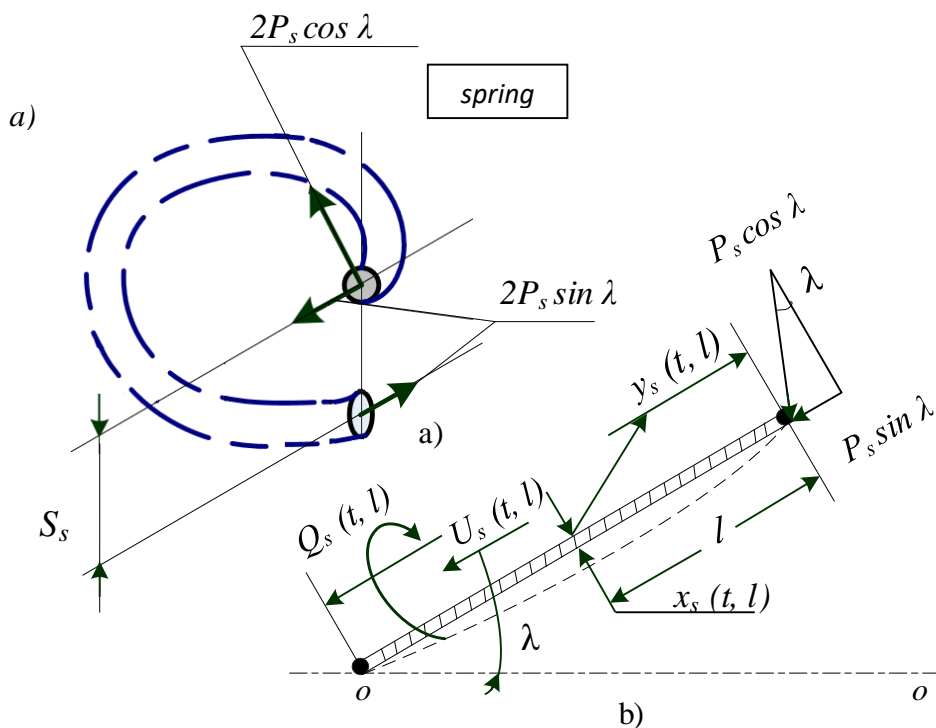


Fig. 1. Boundary element in the form of a single coil of a cylindrical elastic rod bent along a helix with a fixed radius of curvature: a). one model coil; b). developed view.

3. We introduce generalized coordinates that take into account:

- elastic bending deformations $x_s(t, \ell)$, $y_s(t, \ell)$ in two planes - tangent to the helix and parallel to the axis of the cylinder of radius R_s of the winding of the coil, and perpendicular to the first plane;

- elastic deformations under torsion $Q_s(t, \ell)$ and compression $U_s(t, \ell)$ relative to the longitudinal axis of the helix of the spring.

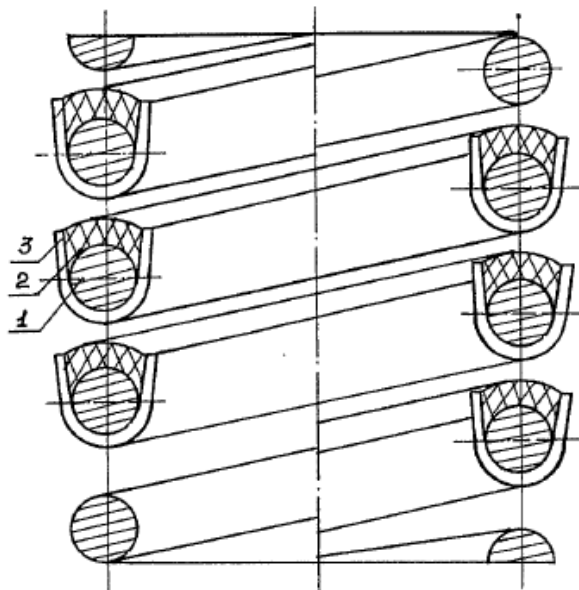


Fig. 2. Calculation scheme for simulation of vibrations of cylindrical elastic rod bent along a helix (for axle box spring suspension of high-speed electric trains).

3. With the introduced assumptions, using the Ostrogradsky-Hamilton method [4], we compose the equations of oscillations for one coil of the spring along each generalized coordinate of elastic deformations. Then, using the Euler equation for elastic systems, we obtain, as a result, a system for describing the bending (in two planes), longitudinal and torsional vibrations of a cylindrical rod bent along a helix, which generally characterizes the spatial vibrations of a coil of a helical spring

$$\frac{\partial^4 y_s}{\partial \ell^4} + \frac{\partial^2 y_s}{\partial \ell^2} \cdot \frac{1}{E I_y} \left(\frac{2}{R_s^2} + P_s \sin \lambda \right) + \frac{y_s}{R_s^4} + \frac{1}{E I_y} \left(M_1 \frac{\partial^2 y_s}{\partial t^2} - i_1 \frac{\partial^4 y_s}{\partial t^2 \partial \ell^2} \right) + \frac{1}{R_s} \cdot \left(\frac{1}{R_s^2} \frac{\partial U_s}{\partial \ell} + \frac{\partial^3 U_s}{\partial \ell^3} \right) = \frac{2\pi \sin \lambda}{\ell_s E I_y} \cdot P_s(t) \cos \left(\frac{\ell}{R_s} \right), \quad (1)$$

$$\frac{\partial^4 x_s}{\partial \ell^4} + \frac{\partial^2 x_s}{\partial \ell^2} \cdot \frac{1}{E I_x} \left(P_s \sin \lambda - \frac{G I_0}{R_s^2} \right) + \frac{1}{E I_x} \left(M_1 \frac{\partial^2 x_s}{\partial t^2} - i_1 \frac{\partial^4 x_s}{\partial t^2 \partial \ell^2} \right) + \frac{\partial^2 Q_s}{\partial \ell^2} \cdot \frac{G I_0}{R_s E I_x} = \frac{2\pi \cos \lambda}{\ell_s E I_x} \cdot P_s(t) \cos \left(\frac{\ell}{R_s} \right), \quad (2)$$

$$\frac{\partial^3 y_s}{\partial \ell^3} + \frac{1}{R_s^2} \cdot \frac{\partial y_s}{\partial \ell} + \frac{F_s R_s^2}{I_y} \cdot \frac{\partial^2 U_s}{\partial \ell^2} - \frac{M_1 R_s}{E I_y} \cdot \frac{\partial^2 U_s}{\partial t^2} = 0, \quad (3)$$

$$\frac{1}{R_s} \cdot \frac{\partial^2 x_s}{\partial \ell^2} + \frac{\partial^2 Q_s}{\partial \ell^2} - \frac{i_1}{G I_0} \cdot \frac{\partial^2 Q_s}{\partial t^2} = -\frac{1}{G I_0} \cos \lambda \cdot \sin \left(\frac{\ell}{R_s} \right) \cdot P_s(t). \quad (4)$$

The resulting system of differential equations allows approximate solutions for the cases when $P_s \sin \lambda$ and $P_s \cos \lambda$ are constants. These solutions include functions of static $x_s(\ell), y_s(\ell), U_s(\ell), Q_s(\ell)$ and dynamic $x_a(t, \ell), y_a(t, \ell), U_a(t, \ell), Q_a(t, \ell)$ components.

For numerical calculation in the *MATHCAD 15* programming environment, we accept the following initial data and assumptions:

1. We accept a model of a cylindrical helical spring, characterized by a wire diameter d_s , an average coil diameter D_s , a pitch between turns S_s in an unloaded state, a number of turns i_s , a static load P_s , a lead angle in a loaded state λ .



2. We present the initial model as a single coil with a vertical axis of symmetry and length passing through the center of gravity of the sections of the helix ℓ_s (Fig. 1, a).

3. For the accepted model of a single coil, the upper section for $\ell = 0$ is considered cantilever (free end), loaded with concentrated static load P_s , and the lower section for $\ell = \ell_s$ - is considered clamped.

Conclusions:

1. The proposed numerical-analytical applied method and refined methods of dynamic strength calculation (using the method of boundary elements - Boundary Element Technology) for curvilinear elements of the rolling stock of railways of a complex profile (springs, vibration dampers, cradle suspension units, spring suspension) are planned to be used in the design, operation and modernization with the extension of the useful life of locomotives.

2. The proposed methods are relevant for the Republic of Uzbekistan, and for the CIS countries, as they allow us to obtain better dynamic characteristics of ground vehicles, which determine their reliability and key performance indices.

References:

1. Глущенко А.Д., Хромова Г.А., Мохаммед Исса Махмуд Ахмад. Упругий элемент. Патент Республики Узбекистан на изобретение № IAP 05219, опублик. 28.06.2002 г., Бюл. № 3.
2. Ибрагимов М.А. Совершенствование конструкции рессорного подвешивания локомотивов. Винтовые цилиндрические пружины: монография. / М.А. Ибрагимов.- МИИТ, 2010.-127 с.
3. Branislav Titurus, Jonathan du Bois, Nick Lieven, Robert Hansford. A method for the identification of hydraulic damper characteristics from steady velocity inputs. *Mechanical Systems and Signal Processing*, 2010, 24, (8), pp. 2868–2887. (2010).
4. Timoshenko S. P. *Strength of Materials: Part II – Advanced Theory and Problems*. - СПб.: Издательство «Лань», 2002. - 672 с.
5. Khromova G. A., Mukhamedova Z. G., Yutkina I. S. Optimization of dynamic characteristics of emergency recovery rail service cars. / Monograph. ISBN 978-9943-975-96-6. - Tashkent: "Fan va tekhnologiya", 2016. - 253 p.
6. Khromova G., Makhamadalieva M. and Khromov S. Generalized dynamic model of hydrodynamic vibration dampener subject to viscous damping. *E3S Web of Conferences, EDP Sciences* 264 (2021), 05029. <https://doi.org/10.1051/e3sconf/202126405029>
7. Khromova G., Kamalov I. and Makhamadalieva M. Development of a methodology for solving the equations of bending vibrations of the hydro friction damper of the electric train of disk type. *AIP Conference Proceedings*, 2656(1) (2022). <https://doi.org/10.1063/5.0108814>
8. Khromova G. A., Makhamadalieva M. A. Development of a mathematical model to justify rational parameters of the spring suspension of the high-speed electric train Afrosiab. // *Universum: технические науки : электрон. научн. журн.* 2022. 10(103). URL: <https://7universum.com/ru/tech/archive/item/14404>