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NUMERICAL STUDIES ON SIMULATION OF BENDING VIBRATIONS OF UPGRADED PNEUMATIC SPRINGS FOR HIGH-SPEED ELECTRIC TRAINS

Khromova Galina Alekseevna[1]
Makhamadalieva Malika Alievna[2] ,
Imomnazarov Sardor Zafar ugli[3]
[1]doctor tech. sciences, professor
[2]senior lecture (PhD),
[3]master's student of the Department of "Electric rolling stock",
State Transport University, Uzbekistan, Tashkent
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ABSTRACT

The article presents the results of numerical studies on the simulation of bending vibrations of modernized pneumatic springs for high-speed electric trains under the action of pulsating pressure, an algorithm and a program for the MATHCAD 15 programming environment have been developed. The design of the modernized air spring is protected by the patent of the Republic of Uzbekistan for the invention No. IAP 04632 [1].

Analysis of studies on the calculation of pneumatic springs of high-speed and high-speed electric rolling stock with rubber cord reinforcement showed that almost all spring suspension designs of modern electric locomotives and electric trains use pneumatic spring elements of various types (for example, in France, Germany, Switzerland, Spain, Japan, Russia, China and Uzbekistan) [2,3].

We propose a new design of pneumatic springs of increased reliability for a railway vehicle, the novelty of the technical solution of which is protected by the Patent of the Republic of Uzbekistan No. IAP 04632 [1].

The objective of our invention is to increase the efficiency of the pneumatic spring by improving its damping characteristics, the possibility of damping both low-frequency and high-frequency dynamic loads, increasing the smoothness of the crew, increasing the reliability and durability of the entire locomotive and rolling stock. Based on the review of the scientific, technical and patent literature, we have developed a numerical and analytical model for the dynamic calculation of the element of the elastic shell of the pneumatic compressor clamped by stiffening ribs, which is a logical continuation of the models and calculation methods presented in the works [5÷8].

The set task is solved by the fact that inside the elastically deformable element of toroidal shape there is a hollow annular elastic element installed, in the cavity of which there is a spiral spring of tubular section, at the same time inside the tubular section of which there is an elastic element; for example, raw rubber or rubber filler, and plugs are installed on both sides of the spiral spring, Note here that one plug is located at helical spring center while another one is arranged at its end and rigidly fixed to hollow annular resilient element inner wall.

This article presents an algorithm for numerical modeling of bending vibrations of modernized pneumatic springs for high-speed electric trains under the action of pulsating pressure. The proposed mathematical model is based on the works [4,5], and is also a logical continuation of the models and calculation methods proposed in the works [6 ÷ 8].

To justify the design model, we introduce a number of assumptions that are possible for the engineering calculation:

1) Almost all types of pneumatic springs have a «rigid» shell in the form of a metal frame of various types. In this regard, it will be assumed that closed convex rubber-cord surfaces in a metal frame formed as a result of extrusion of elastic shell elements do not allow local deformations of folding in certain areas, for example, curvilinear ends.

2) The metal frame in the form of stiffeners will be considered absolutely rigid.

3) The rubber cord shell is considered extensible. Its elements are clamped between stiffening ribs of metal frame [1,2,3,4]. We present a design diagram in the form of 2 elements of an elastic shell clamped between two stiffening ribs and an element of a metal frame in the junction of compartments *i* and *(i +1)*. Note here that every element of elastic shell 1, 3 has its initial bending radius R_{01} and R_{03}. The metal frame element 2 also has an initial bending radius R_{02} produced by the initial internal air pressure in the P_{0V} system. Elements of elastic shell 1 and 3 have masses m_1 and m_3, respectively, and element of metal frame clamped between them - m_2.

The whole system bends at the initial moment under the action of the initial internal air pressure of the P_{0V}. Next, we examine the process of vibrations in the system under the action of lateral rolling that occurs during the movement of the vehicle.

4) The whole system moves in the plane due to joint oscillations of the pneumatic spring and, for example, the electric locomotive when it moves along the rail track with periodic mating irregularities.

For the model of the rectangular plate of the element of the side wall of the elastic shell, the pneumatic springs of the high-speed electric train and taking into account the introduced assumptions, we will record the differential equation of bending oscillations in the form [4]

$$\frac{\partial^4 W_p}{\partial X^4} + 2 \cdot \frac{\partial^4 W_p}{\partial X^2 \partial Y^2} + \frac{\partial^4 W_p}{\partial Y^4} = \frac{q_p(X,Y)}{D_p}. \qquad (1)$$

We use the bending functions of the middle layer of the supporting frame model along the axis *OX*, taking into account the own bending functions of the elastic rods of the metal mesh frame, which arise under the quasi-static effect of internal air pressure in the system. In this regard, taking into account the non-linearity of the impact, we assume a dynamic load in the form of harmonic decomposition into a series

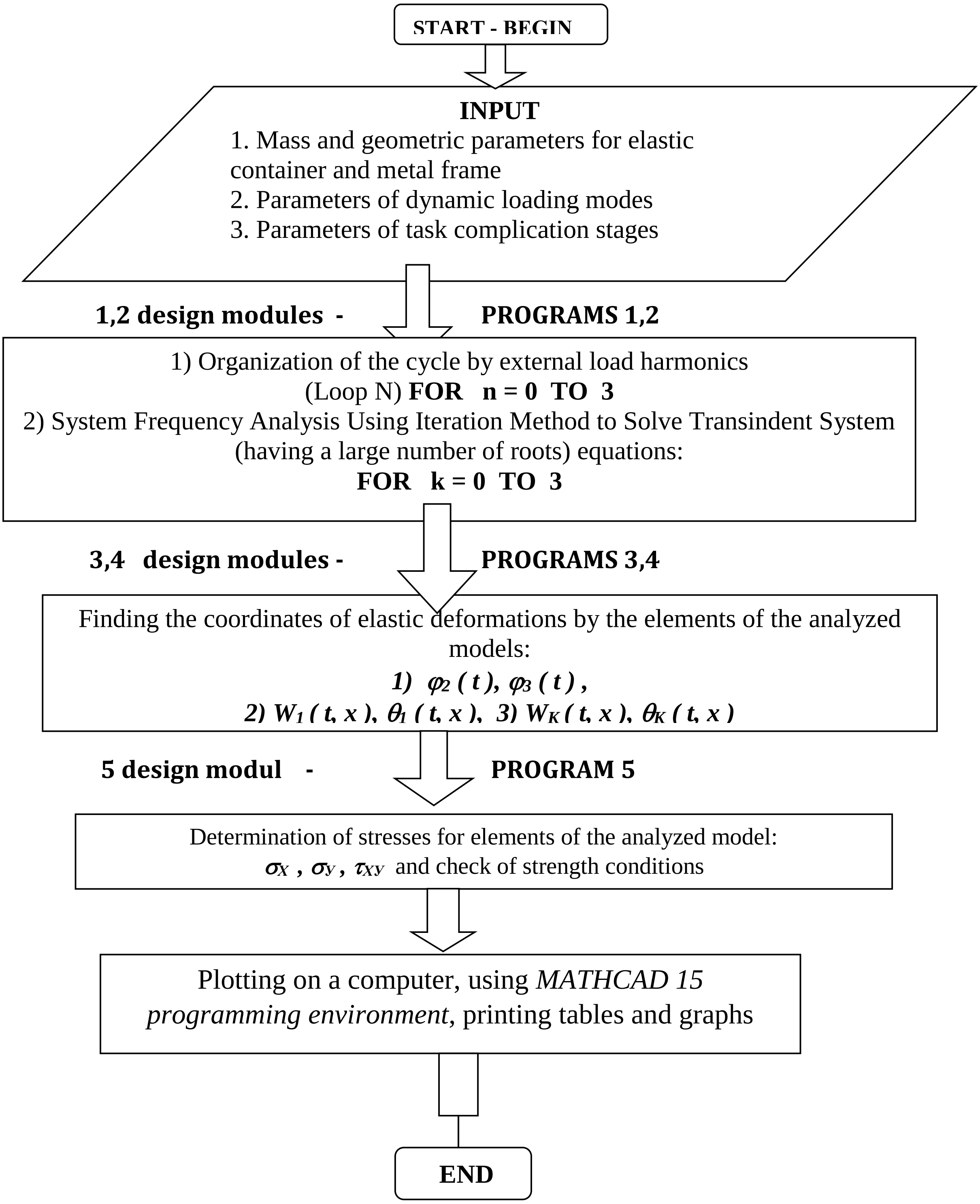

Figure 1. Block diagram for numerical studies on the model of the elastic shell of a pneumatic spring in the form of a plate with a mesh frame.

$$\frac{q_p(X,Y)}{D_p} = \sum_{i=1,3,5} A_{ip}(Y) \cdot SIN\,\frac{i\pi X}{2\cdot h_p}\ . \qquad (2)$$

For such assumptions, it is possible by Fourier to represent the solution of equation (2) in the form of the sum of a series of the form

$$W_{ip}(X,Y) = W_{ip}(Y) \cdot SIN\frac{i\pi X}{2 \cdot h_p}, \qquad (3)$$

where $i = 1, 3, 5...$

After substituting partial derivatives of (3) into equation (1) for each «*i*» vibration form, we obtain the equation

$$\frac{d^4 W_{pi}}{\partial Y^4} - \frac{\pi^2 \cdot i^2}{4 \cdot h_p^2} \cdot \frac{d^2 W_{pi}}{\partial Y^2} + \frac{\pi^4 \cdot i^4}{16 \cdot h_p^4} \cdot W_{pi} = A_{ip}(Y), \qquad (4)$$

which allows precise solutions to define the function $W_{ip}(X,Y)$.

As a result of numerical studies on the bending vibrations of the elastic plate with a mesh frame in the pneumatic compressor of a high-speed electric train in the MATHCAD 15 programming environment, we will obtain a solution on the real structural dimensions of the integral soft container of the pneumatic spring by the numerical method using the ready-made analytical solution $W_{ip}(X,Y)$ for the elastic shell element by piecemeal-linear approximation and binding by iteration by system nodes by analogy with works [5÷8].

The block diagram for numerical studies consists of 5 stages (Figure 1).

This article developed a promising complex analytical and numerical method for studying the stress-strain state of the elastic shell of a pneumatic compressor filled with air under pressure, and also developed a methodology for engineering calculation of elastic shells of pneumatic springs and a lightweight lattice frame of a rod type with the selection of their rational parameters for electric rolling stock on the basis of theoretical, experimental and experimental development [7÷8].

References:

1. Пневматическая пружина электровоза. /Авторы: Г.А. Хромова, Г.А. Уринбаева, С.А. Хромов. Патент Республики Узбекистан на изобретение No. IAP 04632 от 31.01.2013.
2. Высокоскоростной железнодорожный транспорт. Общий курс: учеб. пособие: в 2 т./ И.П. Киселёв м др.; под ред. И.П. Киселёва.-М.: ФГБОУ «Учебно-методический центр по образованию на железнодорожном транспорте», 2014. Т.2.-372 с.
3. Andrŕe M. de Roos. Modeling Population Dynamics.1098 SM Amsterdam. Netherlands 2014. - 528 p.
4. Вольмир А.С. Оболочки в потоке жидкости и газа (задачи аэроупругости). - М: Наука, 1976. – 416 с.
5. Khromova G., Makhamadalieva M. Разработка математической модели по обоснованию рациональных параметров рессорного подвешивания высокоскоростного электропоезда Afrosiab. // Universum: Technical sciences, 2022, № 10 (103), октябрь 2022, часть 2, С. 62-66. DOI: 10.32743/unitech.2022.103.10.14404. Available at: https://7universum.com/ru/tech/10(103)/10(103_2).pdf
6. Khromova G.A., Makhamadalieva M.A. Numerical studies on elastic thin-walled plate model with mesh frame for pneumatic springs of high-speed electrical train. // «Eurasian

Journal of Academic Research»: International scientific journal (ISSN: 2181-2020), Volume 3 Issue 10, October 2023, pp.310-314. https://doi.org/10.5281/zenodo.10058036

7. Khromova G.A., Makhamadalieva M.A., Imomnazarov S.Z. Новая конструкция устройства пневматического подвешивания высокоскоростных электропоездов для Узбекистана. // «Eurasian Journal of Academic Research»: International scientific journal (ISSN: 2181-2020), 2023, Volume 3, Issue 9, September 2023, pp.7-11. https://doi.org/10.5281/zenodo.8321782

8. Хромова Г.А., Махамадалиева М.А., Имомназаров С.З. Методы совершенствования двухосных тележек высокоскоростных электропоездов с помощью применения пневморессор. // Международный научно-образовательный электронный журнал «Образование и наука в XXI веке». выпуск № 42, том 2, сентябрь, 2023. С. 39-44.