UDC 621.891

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Mechanics of long-length space steel ropes taking into account a friction between coils

Investigated the spatial deformation of the steel rope with the account of friction between the turns. Application of the method described allows to investigate the spatial deformation of the steel rope with consideration of friction, as a functionally specified loading with an arbitrary vector of magnitude and direction for every coil of wire rope. Presented numerical results showing the capabilities of the method.

Modern long-span space structures, developed during the 1970s and 1980s, are light and effective structures based on new technologies and light-weight high-strength materials, such as membranes and steel cables. For the premodern space structures widely used since the mid-twentieth century (such as hinshells, space trusses, lattice shells and ordinary cable structures), new space structures have been developed by the combination of different structural forms and materials. The complex shape of their axial line at an arbitrary time interval of operation is caused by various factors, in particular by functional purpose of the construction. in after time continue the idea of a space elevator. This design will work in conditions that are more complex than on the ground. The obligatory presence of cable systems in these constructions prompts to carry out calculations taking into account the friction between the turns of the spiral rods. The solution of such problems is only possible with modern methods of nonlinear analysis, the application of which encourages the selection of modification of differential equations, providing algorithms and efficiency of the approaches. So far these studies have not been developed due to the lack of reliable mathematical models, which could quite simply and effectively be implemented in the form of algorithms and programs for numerical solution of the considered problems. The proposed mathematical model is based on known approaches of Lagrange and Euler which describe the equilibrium and the deformation of the flexible element, the external and internal geometry [1]. The method of solving the task, consisting of 18 ordinary differential equations, is based on the combined use of the method of continuation on a parameter, and the method of Newton-Kantorovich. However, the most overwhelming obstacle associated with this problem consists of the necessity to simulatefriction forces accompanying DS deformation. These forces are statically indeterminate for elastic systems.The construction of the Jacobi matrices at each step of variation of the load parameter is performed by the Runge-Kutta fourth order. The number of integration steps and points of discretization along the length of the element depends on many factors: the number and nature of the loads acting along the length, the nonlinearity of the process etc. Practical implementation of the method is carried out in the form of programs calculations on a computer. The time of calculations, depending on the complexity of the task, does not exceed 5-10 minutes for PC RAM 8000 MBt and processor frequency 2100 MHz. Consider theoretic aspects of the problem of computer simulation.

A mathematical model is based on well-known approaches of Lagrange and Euler, that describe an equilibrium and deformation of flexible element, his external and internal geometry [1]. We will describe a research method briefly.

We will enter $\bar{n}$, $\bar{b}$, $\bar{\tau}$ - a natural trihedron with single by axes of main normal and tangent; u, v, w - axes of movable trihedron; $\bar{F}$, $\bar{M}$ are vectors of internal efforts and moments; p, q, r - curvatures relatively thirl of movable trihedron; x, y, z - are coordinates of independent variable of s (Fig.1).

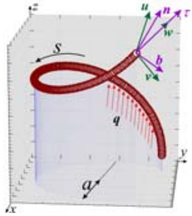


Fig. 1. Location of axes on a curve

We will present the system of resolvent equalizations that describe deformation of flexible element, in a kind

$$\mathbf{x}' = \mathbf{f}(\mathbf{x}, s, \lambda), \tag{1}$$

here x(s) - vector of the state ($m=18$), f - function of right parts of the system of equalizations; λ - parameter of intensity of indignation (ladenings), a derivative marks a stroke on s. A parameter λ can be both actual and formal, that represents quantitative descriptions of task. Shown thus in area of change of independent variable the s system of resolvent equalizations (1) has the general eighteenth order. Methodology of decision the set problem is based on sharing of method of continuation on a parameter and method of Newton-Kantorovits. On verge of $s = 0$ interval of change $0 \le s \le S$ of variable of s six independent regional conditions φ $\left[\bar{x}(0)\right] = 0$ and six following from the first integrals equalizations of connection are set $\bar{\theta}\left[\bar{x}(0)\right] = 0$. For shorting of the system of equalizations it is enough on verge of $s = S$ to set six independent regional conditions $\bar{\psi}\left[\bar{x}(s)\right] = 0$. In the set forth regional equalizations $\bar{\varphi}, \bar{\theta}, \bar{\psi}$ designate vectors-functions.

Varying the sizes of a, h and also by initial conditions, it is possible to describe necessary spatial position (geometry) of curvilinear element as a spiral.

For establishment of zone of contact of coils of spiral we will suppose the following. On Fig.2 .the spiral axes of s_1 and s_2 of two arcwise contacting wires are shown with the parameters r_1 , α_1 and r_2 , α_2 of winding accordingly (2). The diameters of wires we will designate through δ_1 and δ_2. Distance δ_{12} between the points of a and b located on a general normal to the spiral lines, equal to the semisum of diameters of wires :

$$\delta_{12} = ab = \frac{\delta_1 + \delta_2}{2} . \qquad (2)$$

In addition, the segment of ab must be perpendicular to the tangents t_1 and t_2 to the examined spiral lines.

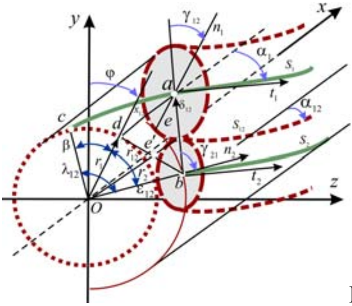


Fig. 2. Zones of contact of coils of spiral

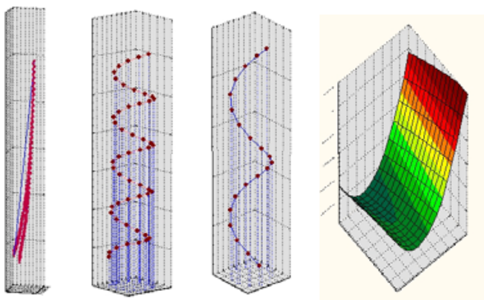
Basic equalization of contact

$$\delta_{ik}^2 = \left(\frac{\delta_i + \delta_k}{2} \right) = \Phi_{ik} \text{, where}$$

$$\Phi_{ik} = x_{ik}^2 + r_i^2 + r_k^2 - 2 r_i r_k \cos \varepsilon_{ik} ; \qquad (3)$$

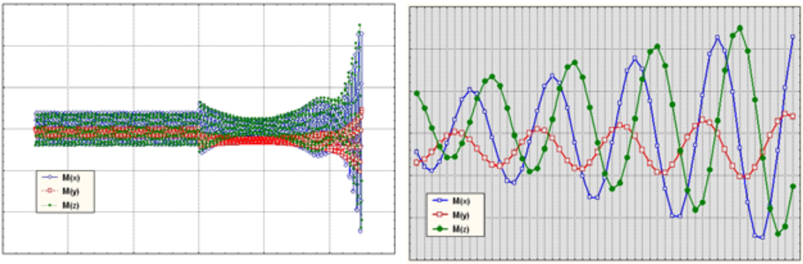
$$x_{ik} = r_i tg \alpha_k \sin \varepsilon_{ik} = r_k tg \alpha_i \sin \varepsilon_{ik} .$$

For illustration of possibilities of method on Fig.3-5 some results of numeral calculation of deformation of rope of space elevator are shown.



a) b) c) d)

Fig. 3. Original appearance of longitudinal axis of rope (a,b,c) and epure of tensions arising up at deformation (d)



a) b)

Fig. 4. Internal power factors in the aggregate state of construction (a) and in a few coils (b)

Possibilities of the offered method allow to decide tasks at any static or dynamic ladening, to carry out a алгоритмичный transition at any change of terms from one task to other without considerable alteration of calculable operations. A calculation can produced in the real mode of time with the reflection of results on the screen of monitor

References

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