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DYNAMICS OF MECHANISMS WITH ESSENTIALLY ELASTIC LINKS

In this report it is presented some principles of construction of mathematical models of transfer mechanisms with essentially elastic links. In different driving phases the elastic links are presented both as connections and as driving source, i.e. driving is realized at the expense of potential energies of elastic links. It was examined definition problems of elastic forces longitudinally to the deformable connecting rod of the mechanism with four links, and the problem of equation setting up of double-lever mechanism driving taking into account a mass of the elastic connecting rod.

1. Introduction. The mathematical modeling of complex mechanical systems, especially of multi-mass torsional oscillatory systems with concentrated and distributed masses, in which we have many settlement circuits of technological machines and automatic transfer lines, is connected with constructions of general dynamic models and local models of the executive or transfer cam-lever mechanisms with nonlinear state functions.

Constructing mathematical models of multi-mass mechanical systems with concentrated parameters we usually start from the proposals, that the inertial properties of system are displayed in masses m_{ij} or moments of inertia J_{ij}, concentrated in sections, which are connected with non-inertial elastic dispersion c_{ij} connections. The movement of such multi-mass torsional system is described by system of the equations in this way [1],

$$\|a_{ij}\|\{\ddot{q}_j\}+\|b_{ij}\|\{\dot{q}_j\}+\|c_{ij}\|\{q_{ij}\}=\{Q_j\} \qquad (1)$$

where $\|a_{ij}\|$, $\|c_{ij}\|$ – are matrices of inertial and quasielastic coefficients, q_j are generalized coordinates.

At drawing up the equations of movement of such systems there is a necessity connected with experimental calculated settlement of the given inertial parameters of many transfer and executive mechanisms. In the given work some principles of drawing up of mathematical models of transfer and executive mechanisms of independent movement with elastic parts are resulted. In mechanisms with considerable elastic parts the complete cycle of their movement is supposed to be considered as separate periods. In the various periods of movement the elastic parts are represented both as communication, and as source of movement, i.e. movement is carried out at the expense of the potential energies of elastic parts [2].

The questions of drawing up of mathematical models of resulted executive mechanisms of independent movement and definition of inertial parameters of separate mechanisms of variable structure with elastic connections are considered.

2. Analytical method of definition inertial parameters. The movement of a link of reduction of the executive and transfer mechanism can be described by elastic parts with one degree of freedom by such an equation [2]:

$$J_n(\varphi)\ddot{\varphi}(t)+0,5J_n'(\varphi)\dot{\varphi}^2(t)\equiv M_{\Pi}(\varphi) \qquad (2)$$

In the period of accumulating, i.e. in process of compression of springs or rotating of the elastic shaft the given moment of forces is represented as the sum of driving M_q and moment of resistance to elastic deformation M_c. The latters depend on the statement of a link of reduction. Inertial parameters - the given moment of inertia of the mechanism . $J_n(\varphi)$ is always a positive function.

The return task of dynamics of mechanisms with considerable elastic parts is formulated. The law of movement of the executive mechanism in the period of accumulation is determined by the speed of rotation of the main shaft, which is possibly approximately to consider as constant . In such case the equation (2) can be written down concerning the given moment of inertia, as the linear differential equation of the first order.

$$\dot{\varphi}^2(t)J_n'(\varphi)+2\ddot{\varphi}(t)J_n(\varphi)=K\varphi(t), \qquad (3)$$

Where $\dot{\varphi}(t),\ddot{\varphi}(t)$ - are angular speeds and acceleration of entrance link of the executive mechanism. These transfer functions can be determined through functions of the situation between the main shaft of machines – of automatic devices

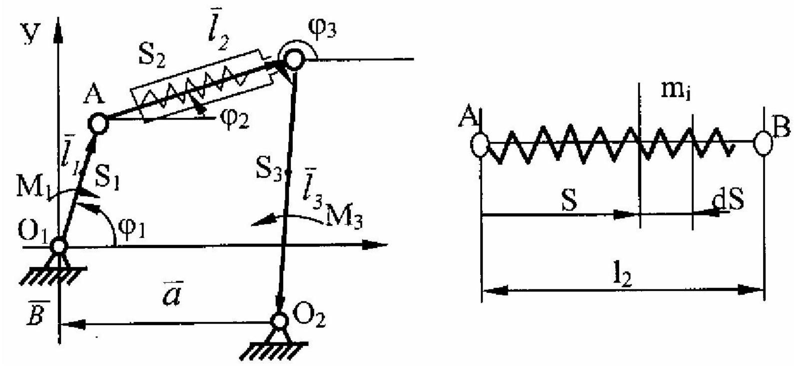

Fig. 1. The mechanism of 4-part machine with elastic connecting-rod

and entrance part of the executive mechanism. From the equation (3) at $\dot{\varphi}(t) \neq 0, J_{n0} = J_n(\varphi_0)$ the analytical expression of the given moment of inertia is defined $J_n = A(\varphi, \dot{\varphi})$

The decisions of a return task allows to construct mathematical model of the executive mechanism, and by the decision of the equation (2) the law of movement of the mechanism with elastic parts in process of re -accumulating is defined, i.e. in the period of re-twisting of the elastic shaft or release of springs.

The usage of the equation of movement of the executive mechanisms is convenient for definition of the given moment of inertia at construction of general dynamic model of complex mechanical system at study of movement of so-called mechanisms of independent movement [3]. Such mechanisms, at which the basic movement is carried out at the expense of the moments of elastic forces of the twirled shaft or compressed springs are frequently met in high-speed machines.

3. Mathematical model of the executive mechanisms with essential elastic connecting-rod of multimass systems.

. The mechanisms of making of duck thread of looms tools such as STB, such as the dashing mechanism, 4-color and 6-color mechanisms of change of duck, the mechanisms of braking construction represent cam-lever mechanisms with elastic parts and connections. And movement in these mechanisms is carried out at the expense of potential energy of twirled torso platen or compressed cylindrical springs. In connection with research of movements of such mechanisms there is a necessity to account final elastic movements of its parts. In the given work the questions of definition of elastic forces of longitudinal deformable connecting-rod of 4-part mechanism are considered, also the equation of movement of flat 2- rocker mechanism in view of weight of elastic connecting-rod is drawn up.

In flat 4-part mechanism (fig. 1) the elastic connecting-rod can be considered as well as non-stationary connection. The mathematical expression of deformation of an elastic link allows to unit in one system equations of movement of firm bodies located till both parties of an elastic link. The task in this case will be shown to search basic movements O_1B and O_2B as systems of firm bodies, and additional movement determined by the elastic characteristics of AB. We got differential equation for defining the movement of elastic connecting-rod as following [4]:

$$\frac{d\lambda}{d\varphi_1} - a_1\lambda^2 - b_1\lambda = F(\varphi_1, \dot{\varphi}_2), \tag{4}$$

where $\lambda = l_2 - l_2^0$ change of length of connecting-rod .

From the equation (7), as the special case, the well-known expression for small elastic movements will be got [4].

The system of the equations describing the movement of 2-rocker mechanism with elastic connecting-rod is received [1]:

$$\left.\begin{aligned} I_1\ddot{q}_1 + (I_3\ddot{q}_2 + I_3\ddot{q}_3)\Pi' &= M_1 - M_3\Pi' \\ I_3\ddot{q}_2 + I_3\ddot{q}_3 + c * q_2 &= -M_3 \end{aligned}\right\}, \tag{5}$$

where

$$q_1 = \varphi_1, q_2 = \Delta\varphi_3 = \left(\frac{d\Pi}{dl_2}\right)^0 \lambda, q_3 = \Pi(q_1),$$

«0» is a statement at $\Delta l_2 = \lambda = l_2 - l_2^0 = 0$, I_1, I_3 M_1, M_3 – moments of inertia and moments of forces.

In many systems there is a necessity to account weight of a deformable part. It is connected with that the elastic part has weight of the same order or even more, than rigid parts, and as the consequence, it is a source of inertial stimulating forces. For example, in mechanisms of changing of colour duck of looms tools [5] movements are carried out at the expense of deformation (compression - stretching) elastic connecting-rod, and its weight is more than weight of crank and rocker. It is shown, that kinetic energy of elastic connecting-rod is defined from the expression.

$$2T = m_2\left(l_1^2\dot{\varphi}_1^2 + \dot{\lambda}^2 + 2l_1^2\dot{\varphi}_1\dot{\lambda}\cos\beta\right) + I_2(\varphi_1)\dot{\varphi}_2^2, \quad (6)$$

where $\dot{\lambda} = V_{S_2A}$ – is a component of relative speed of a point S_2 along the connecting-rod; β – angle between vectors and I_2 – variable moment of inertia of connecting-rod.

The system of the equations describing movement of the flat 4-part mechanism in view of weight of elastic connecting-rod is received as following:

$$\left.\begin{aligned} &I_{11}\ddot{\varphi}_1 + I_{13}\ddot{\varphi}_3 + c\frac{l_1 l_2}{2l_2^2}\cos(\varphi_3 - \varphi_1)\frac{\partial\phi}{\partial\varphi_3} = M_1, \\ &I_{31}\ddot{\varphi}_1 + I_{33}\ddot{\varphi}_3 + c\frac{\varphi_3 l_3}{2l_2^2}\cdot\frac{\partial\phi}{\partial\varphi_3}(\varphi_3\frac{\partial^2\phi}{\partial\varphi_3^2} + \frac{\partial\phi}{\partial\varphi_3}) = M_3, \end{aligned}\right\} \quad (7)$$

where $\phi(\varphi_3, l_2)$ – the equation of connection.

The decision of systems of equations (5) defines the laws of movement of 2-rocker mechanism at known deformation of a center of gravity of an elastic part determined from the equation (4). The specified laws of movement for the periods of compression and re-accumulating are defined from systems of equations (7) in view of weight of elastic connecting-rod.

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Резюме

Жұмыста ауыстыратын механизмдердің математикалық модельдерінің серпімді мәнді қозғалыстарының кейбір принципті құрылымы ұсынылған. Әртүрлі дәрежедегі серпімді қозғалыстар байланыстар ретінде де және қозғалыстың қайнар көзі ретінде де қарастырылады, яғни қозғалыс серпімді байланыстардың әлеуетті энергиясы есебінен қозғалысқа түседі. Жайпақ екішнағашты механизмнің қозғалу теңдеуінің серпімді бұлғақтың (шатун) массасын есепке ала отырып төртбуынды көлденең формасы өзгерген бұлғақтың күшін анықтау мәселесі қарастырылған.

Резюме

В работе представлены некоторые принципы построения математических моделей передаточных механизмов с существенно упругими связями. В различных стадиях движения упругие связи представляются как связи, и как источник движения, то есть движение создается за счет потенциальных энергий упругих связей. Рассмотрены вопросы определения сил продольно деформируемого шатуна четырехзвенника, составления уравнения движения плоского двухкоромыслового механизма с учетом массы упругого шатуна.

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