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MULTI-OBJECTIVE OPTIMIZATION OF CYCLOGRAM MECHANISMS MACHINE-AUTOMATON

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Cyclogram mechanisms machine-automaton can be represented as vector polygons, while maintaining the visibility of existing linear cyclogram and the possibility of using computers to optimize cyclogram mechanisms of machines, taking into account the accuracy of their production and work, as well as the mechanisms of interaction with each other. As a result of multi-objective optimization decision problem, we obtain the optimum point, whose coordinates are the phase angles of triggering mechanisms, ie, we obtain the optimum cyclogram mechanisms of machine-automaton.

Theory of cyclogram, including the synthesis and analysis of cyclic diagrams of machines and automatic lines, is one of the main parts of the theory of design of automatic machines [1]. Cyclogram machine-automaton is a sequence of operations performed by mechanisms depending on the angular displacement of the main shaft. Cyclogram makes it possible to determine the state of dwell or motion of each mechanisms for any position of the main shaft.

The most modern methods of modeling cyclogram are two methods: the network [2] and the presentation cyclogram in the form of associated directed graph [3].

Cyclogram mechanisms machine-automaton can be represented as vector polygons [4], while maintaining the visibility of existing linear cyclogram and the possibility of using computers to optimize cyclogram mechanisms of machines, taking into account the accuracy of their production and work, as well as the mechanisms of interaction with each other. To obtain a mathematical model of the interaction mechanisms of machine-automaton with each other instead of segments, we introduce cyclogram of the vector (fig. 1) which are connected to each other, with the vector directed sequentially from one position to another - is denoted by the letter of the vector $\vec{\ell}_{ij}$, n – number of mechanisms, i – number of mechanisms, j – number of position i – mechanism, m_j – number of position i – mechanism.

Moreover, the projection of the vectors $\vec{\ell}_{ij}$ on the X axis describes α_{ij} – phase angle triggering mechanisms, and the projection on the Y-axis indicates the value of movement δ_{ij} j – position of i – mechanism, introduced as a dimensionless quantity

$$\delta_{ij} = \frac{S_{ij}}{S_{\max}}, \quad S_{\max} = \max S_{ij}, \quad i = 1,...,n; j = 1,...,m_i,$$

where S_{ij} – movement of j – position of i – mechanism (dimensional quantity).

Introduce vector $\vec{P}$ connecting point of beginning and end of the cycle. Projection vector $\vec{P}$ on the X axis is equal 2π, on the Y axis is zero. In research cyclogram machine-automaton must take into account technological and structural constraints, ie precision manufacturing and work mechanisms, as well as connections of work mechanisms among themselves. Interaction mechanisms with each other reflected in the form of vectors of connection $\vec{c}_{ik}$, where $k = 1,...,r_i$, r_i – number of vectors connection of i – mechanism emerging from j – position. Direction vectors connection refers to the sequence of triggering mechanisms. The projection vectors connection to the X axis describes the time lag trigger mechanism, and the projection on the Y axis – the difference between the maximum displacement mechanisms.

Impose cyclogram mechanisms at each other with zero vectors $\vec{O}$ (fig. 1) connecting the boundary points of cyclogram mechanisms for Y axis.

Up a system of vector equations, describing the mechanisms of machine-automaton in accordance (fig. 1).

$$\left.\sum_{j=1}^{m_i} \vec{\ell}_{ij} = \vec{P}, i = 1,...,n, \; \vec{c}_{ik} = \sum_{i=1}^{n}\sum_{j=1}^{m_i} b_{ij} \cdot \vec{\ell}_{ij} \right\} \qquad (1)$$

where $b_{ij} \in \{0, \pm 1\}$

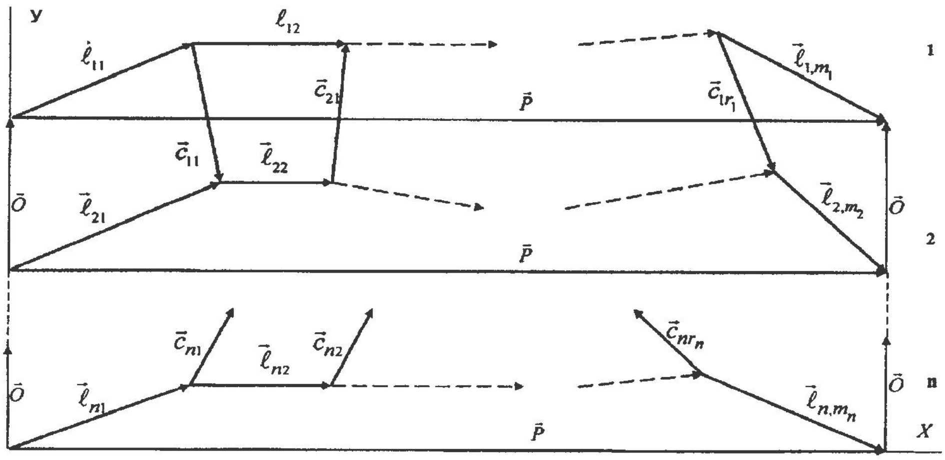

Fig. 1. Vector model cyclogram

Vector equations (1) describe the joint operation of mechanisms of machine-automaton. Project vector equations (1) on the axis X and Y.

$$\left.\sum_{j=1}^{m_i}\alpha_{ij}=2\pi,\ \sum_{j=1}^{m_i}\delta_{ij}=0,\ c_{ik}^{x}=\sum_{i=1}^{n}\sum_{j=1}^{m_i}b_{ij}\alpha_{ij},\ c_{ik}^{y}=\sum_{i=1}^{n}\sum_{j=1}^{m_i}b_{ij}\delta_{ij},\right\} \quad (2)$$

at α_{ij} – phase angle triggering mechanisms, and movement δ_{ij} – imposes constraints

$$\alpha_{ij}\ge\alpha_{ij}^{m},\quad \delta_{ij}^{\text{в}}\ge\delta_{ij}\ge\delta_{ij}^{\text{н}}, \quad (3)$$

where α_{ij}^{m} – the minimum allowable phase angles triggering mechanisms, determined from the condition of efficiency mechanisms, $\delta_{ij}^{\text{в}},\delta_{ij}^{\text{н}}$ – upper and lower limits of the designated designer.

On the projection vectors of connection imposes constraints

$$c_{ik}^{x\text{в}}\ge c_{ik}^{x}\ge c_{ik}^{x\text{н}},\quad c_{ik}^{y\text{в}}\ge c_{ik}^{y}\ge c_{ik}^{y\text{н}} \quad (4)$$

where $c_{ik}^{x\text{н}}=e_{ik}^{x}+\Delta c_{ik}^{x}$, $c_{ik}^{y\text{н}}=e_{ik}^{y}+\Delta c_{ik}^{y}$; e_{ik}^{x},e_{ik}^{y} – the minimum allowable projection vectors of connection, defined by the technological conditions, $\Delta c_{ik}^{x},\Delta c_{ik}^{y}$ – error projection vectors of connection, $c_{ik}^{x\text{в}},c_{ik}^{y\text{в}}$ – upper limit imposed by the designer.

Equations (2) and constraints (3, 4) describe the joint work mechanisms (cyclogram) machine-automaton. In steady motion machine-automaton with a centralized control system main shaft rotates at a constant speed $\omega=const$, then a transition to the times of operation mechanisms t_{ij} formula $t_{ij}=\alpha_{ij}/\omega$, and the period of the cycle $T=2\pi/\omega$.

Optimization of cyclogram mechanisms allows to solve the task of raising the actual productivity machine-automaton by increasing the reliability of its mechanisms. Here we choose the mechanisms that need to reduce the dynamic loads in order to increase their durability. The target functions assign the maximum stresses in the links of the selected mechanisms (contact, bending, twisting, etc.)

$$\Phi_{v}(A)=\max\sigma_{v}(A) \quad (5)$$

where v – number of selected mechanisms A – a point with Cartesian coordinates. The result is a multicriteria problem

$$\min_{A\in D}\Phi_{1}(A),\min_{A\in D}\Phi_{2}(A),...,\min_{A\in D}\Phi_{v}(A), \quad (6)$$

where D – the feasible region, which is determined by constraints (2-4).

To solve the multi – objective task (6) using the methodology proposed by in [5], and finally obtain the optimum point A_{opt}, whose coordinates are the phase angles of triggering mechanisms, ie, we obtain the optimal cyclogram of the mechanisms of machine-automaton. In addition to the objective functions (6) can be used, and others.

Example. For, when optimizing cyclogram mechanisms involved in paving weft yarn loom STB1-330PN to increase its actual productivity were taken two criteria: the reliability of transmission of weft thread microshuttles and switch time change color weft thread. In the process of paving the weft thread comprises three mechanisms: mechanism of compensator weft, mechanism of lift microshuttles, mechanism of opening spring microshuttles. Vector model cyclogram mechanisms is shown in fig. 2.

Up a system of vector equations, describing the work of mechanisms loom STB1-330PN (fig. 2.)

$$\left.\begin{array}{l}\vec{\ell}_{11}+\vec{\ell}_{12}+\vec{\ell}_{13}+\vec{\ell}_{14}+\vec{\ell}_{15}+\vec{\ell}_{16}=\vec{P},\ \vec{\ell}_{21}+\vec{\ell}_{22}+\vec{\ell}_{23}+\vec{\ell}_{24}+\vec{\ell}_{25}=\vec{P},\ \vec{\ell}_{31}+\vec{\ell}_{32}+\vec{\ell}_{33}+\vec{\ell}_{34}=\vec{P},\\ \vec{c}_{11}=\vec{\ell}_{21}+\vec{\ell}_{22}-\vec{\ell}_{11}-\vec{\ell}_{12}-\vec{O},\ \vec{c}_{31}=\vec{\ell}_{21}+\vec{\ell}_{22}-\vec{\ell}_{31}+\vec{O},\ \vec{c}_{32}=\vec{\ell}_{33}+\vec{\ell}_{34}-\vec{\ell}_{14}-\vec{\ell}_{15}-\vec{\ell}_{16}-\vec{O}\end{array}\right\} \quad (7)$$

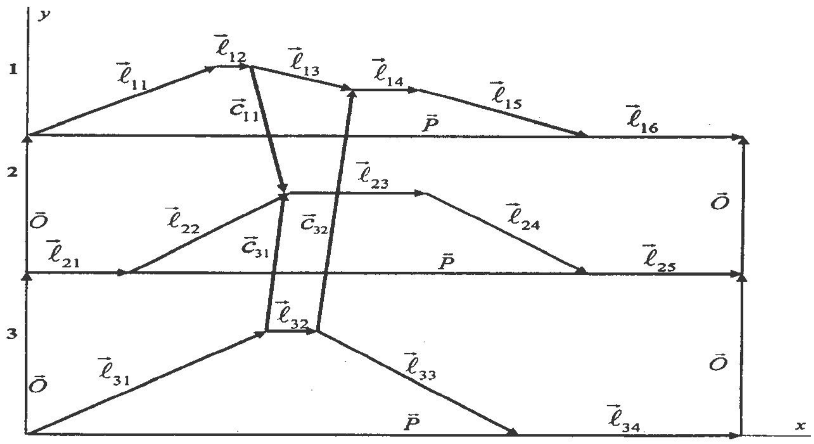

Fig. 2. Vector model cyclogram mechanisms involved in paving weft yarn loom STB1-330PN

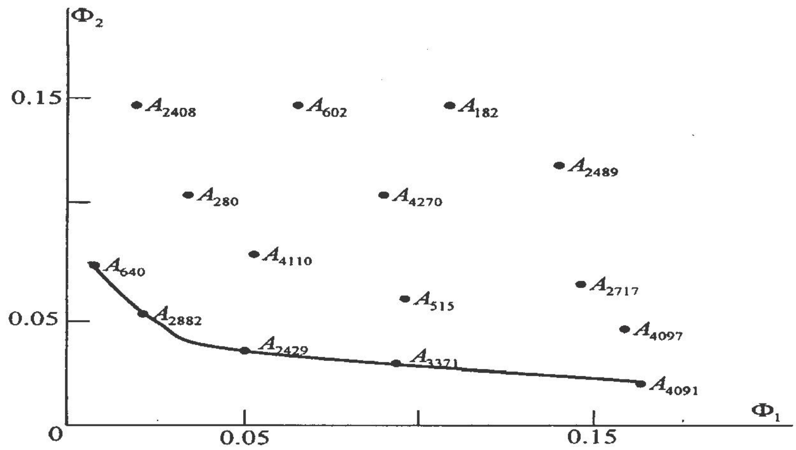

Fig. 3. Approximate compromise curve

We project the vector equation (7) on the axis x

$$\left.\begin{array}{l}\alpha_{11}+\alpha_{12}+\alpha_{13}+\alpha_{14}+\alpha_{15}+\alpha_{16}=2\pi,\ \alpha_{21}+\alpha_{22}+\alpha_{23}+\alpha_{24}+\alpha_{25}=2\pi,\ \alpha_{31}+\alpha_{32}+\alpha_{33}+\alpha_{34}=2\pi \\ c_{11}^{x}=\alpha_{21}+\alpha_{22}-\alpha_{11}-\alpha_{12},\ c_{31}^{x}=\alpha_{21}+\alpha_{22}-\alpha_{11}-\alpha_{12},\ c_{32}^{x}=\alpha_{33}+\alpha_{34}-\alpha_{14}-\alpha_{15}-\alpha_{16}\end{array}\right\} \quad (8)$$

At phase angles triggering α_{ij} of mechanisms imposes restrictions

$$\left.\begin{array}{l}\alpha_{11}\geq 50^{\circ},\alpha_{12}\geq 0^{\circ},\alpha_{13}\geq 15^{\circ},\alpha_{14}\geq 5^{\circ},\alpha_{15}\geq 100^{\circ},\alpha_{16}\geq 80^{\circ},\alpha_{21}\geq 20^{\circ},\alpha_{22}\geq 60^{\circ}, \\ \alpha_{23}\geq 0^{\circ},\alpha_{24}\geq 70^{\circ},\alpha_{25}\geq 120^{\circ},\alpha_{31}\geq 70^{\circ},\alpha_{32}\geq 0^{\circ},\alpha_{33}\geq 70^{\circ},\alpha_{34}\geq 100^{\circ},\end{array}\right\} \quad (9)$$

On the projection vectors of connection imposes constraints

$$1^{\circ}\leq c_{11}^{x}\leq 7^{\circ},\ 1^{\circ}\leq c_{31}^{x}\leq 8^{\circ},\ 1^{\circ}\leq c_{32}^{x}\leq 6^{\circ}, \quad (10)$$

From the experiment found that for more reliable feeding and capture threads of tracer should increase the time of issue threads, ie, the need to increase the phase angle α_{12} corresponding section of issue threads. To improve the reliability of the switching mechanism of color change must be expanded phase angles α_{13}.

As a result, we have the following optimization problem: subject to constraints (8) - (10):

$$\Phi_1 = 1/\alpha_{12} \to \min,\quad \Phi_2 = 1/\alpha_{13} \to \min, \quad (11)$$

A solution of problem (11) is an approximate compromise curve (fig. 3). From the analysis of this curve, we find that the most plausible point A_{2429}.

This point corresponds to the following values of the phase angle triggering mechanisms:

$$\alpha_{11}=76^{\circ},\alpha_{12}=15^{\circ},\alpha_{13}=16^{\circ},\alpha_{14}=18^{\circ},\alpha_{15}=150^{\circ},$$
$$\alpha_{16}=87^{\circ},\alpha_{21}=23^{\circ},\alpha_{22}=63^{\circ},$$

$$\alpha_{23}=38^{\circ},\alpha_{24}=80^{\circ},\alpha_{25}=146^{\circ},\alpha_{31}=86^{\circ},\alpha_{32}=16^{\circ},$$
$$\alpha_{33}=75^{\circ},\alpha_{34}=181^{\circ}.$$

Conclusion.

Optimization cyclogram mechanisms can solve the problem of elevated actual productivity of machine-automaton due to an increase reliability discounts its mechanisms. In this case we are selected mechanisms, which is necessary to reduce dynamic loads in order to increase their durability. The objective functions set a maximum stress in the links of the selected mechanisms (contact, bending, torsion, etc.)

As a result of multi-objective optimization decision problem, we obtain the optimum point, whose coordinates are the phase angles of triggering mechanisms, ie, we obtain the optimum cyclogram mechanisms of machine-automaton.

Compared with other methods of optimizing cyclogram mechanisms [2, 3], this method takes into account the accuracy of manufacturing and operation mechanisms, to carry out optimization on several criteria.

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Резюме

Сызықтық циклограмманы сақтай отырып және оларды дайындау мен іске қосылу дәлдігін, сонымен қатар механизмдердің бір-бірімен әсерлесуін ескере отырып, ЭЕМ мүмкіншілігін қолданып механизм циклограммасын оңтайландыру үшін машина-автомат механизмінің циклограммасы векторлы көп бұрыш түрінде келтірілді. Көп критерийлі есептерді шешу кезінде механизмнің іске қосылу фазалары координата болып табылатын нүктесін, яғни машина-автомат механизмінің оңтайлы циклограммасын аламыз.

Резюме

Циклограмма механизмов машины-автомата представлена в виде векторных многоугольников, сохраняя при этом наглядность существующих линейных циклограмм и возможность использования ЭВМ для оптимизации циклограммы механизмов с учетом точности их изготовления и работы, а также взаимодействия механизмов друг с другом. В результате решения многокритериальной задачи, получаем оптимальную точку, координатами которой являются фазовые углы срабатывания механизмов, т. е. получаем оптимальную циклограмму механизмов машины-автомата.