Proceedings of the World Congress on Engineering 2011 Vol III
WCE 2011, July 6 - 8, 2011, London, U.K.

Multi-Objective Optimization Of Cyclogram Mechanisms Machine-Automaton

A. A. Assylbek Jomartov, *Member, IAENG*

Abstract - **Cyclogram mechanisms machine-automaton can be represented as vector polygons, while maintaining the visibility of existing linear cyclogram and the possibility of using multi-objective 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.**

Index Terms— **machine-automaton, cyclogram, vector polygons, multi-objective optimization**

I. INTRODUCTION

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 mechanism for any position of the main shaft. The correct synthesis cyclogram depends on productivity and reliability of machine-automaton [2]. Therefore, issues of design cyclogram the subject of many scientific papers. A detailed analysis of the works on the theory cyclogram performed before 1965, is given in [1]. Theory of cyclogram modern machine-automaton [1] requires consideration of the physical properties of the materials, temperature conditions, the elastic parts, precision manufacturing and assembly of parts. There are following kinds of cyclogram: circular cyclogram (Fig.1), rectangular cyclogram (Fig.2), linear cyclogram (Fig. 3, 4).

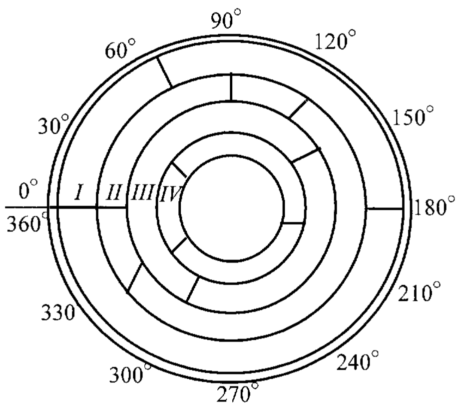

Fig. 1. Circular cyclogram

A. A. Jomartov is with the Institute of Mechanics & Mechanical Engineering, Almaty, 050010 Kazakhstan (corresponding author to provide phone: 727-272-3426; fax: 727-272-3426; e-mail: legsert@ mail.ru).

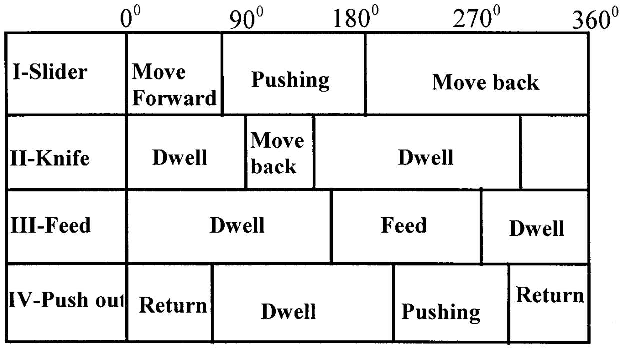

Fig. 2. Rectangular cyclogram

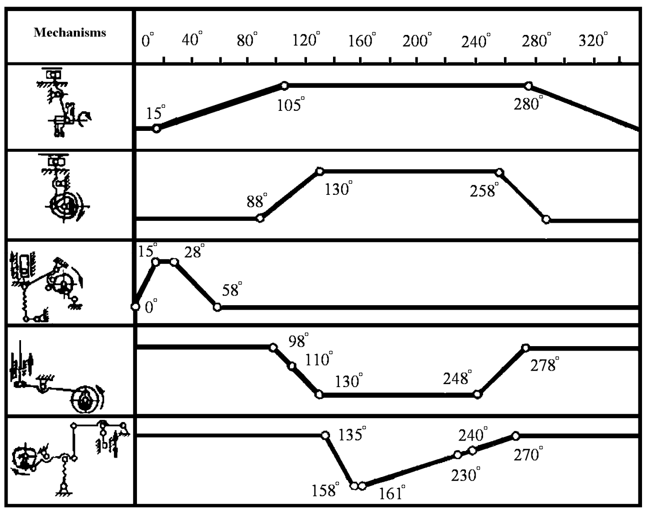

Fig. 3. Linear cyclogram

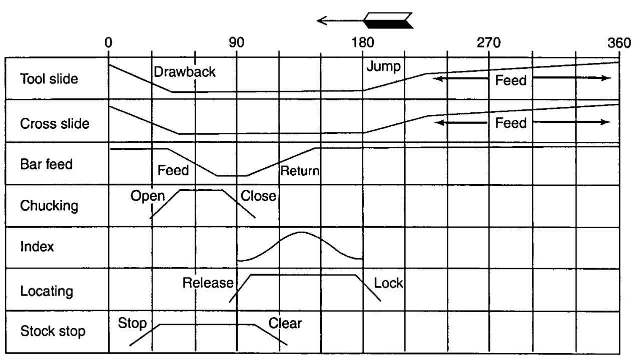

Fig. 4. Linear cyclogram. Developed cyclogram of working and auxiliary cams of a four-spindle bar automatic. (From Browne, J. W., *The Theory of Machine Tools,* Cassell and Co. Ltd., 1965, FIGURE 7.45.)

Limitations of all its graphic images cyclograms is that its do not have sufficient information necessary for reconstruction cyclogram. The above cyclograms may only be used when setting up machines, not possible to construct an algorithm adjustment cyclogram suitable for computer implementation.

The most modern methods of modeling cyclogram are two methods: the network (Fig. 5) [3] and the presentation cyclogram in the form of associated directed graph (Fig. 6) [4]

To identify the connections between the movements of the executive mechanisms of complex machine-automaton and synthesis of rational cyclogram, we are building model without scale of the machine process [4] type systems, network planning and management. The disadvantages of the network method are poor visibility, the unsuitability of the optimization algorithm based on network planning and management for cyclically operating mechanisms do not affect the necessary connections for adjustment cyclogram.

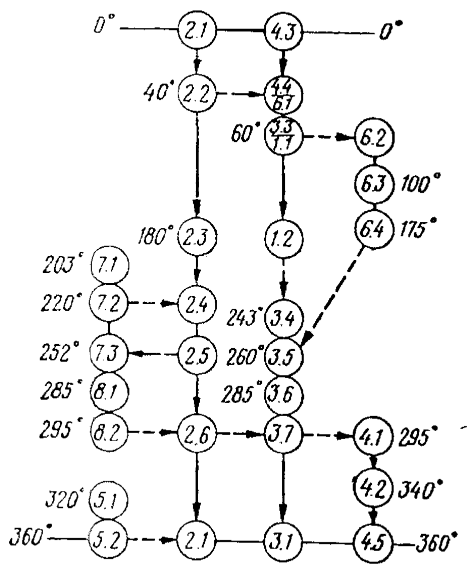

Fig. 5. The network cyclogram

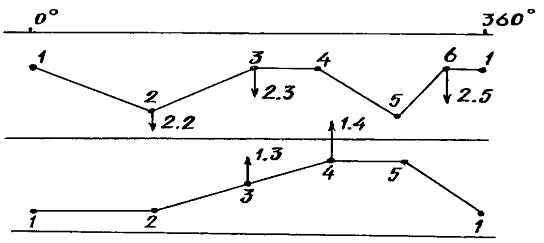

Fig.6. Cyclogram in the form of associated directed graph

These defects have been remedied in [4], where cyclogram machines are in the form of associated directed graph, while maintaining the visibility of existing linear cyclogram and the main advantage of graphs - the use of computers for processing. The disadvantages of this method are the lack of consideration of displacement connections executive mechanisms accuracy of manufacturing and accounting mechanisms in the synthesis of cyclogram.

Analysis of the methods for synthesis and analysis of cyclogram mechanisms machine-automaton showed the need for further development of methods for optimizing cyclogram of machine-automaton .

II. VECTOR MODEL CYCLOGRAM MECHANISMS MACHINE-AUTOMATON

Cyclogram mechanisms machine-automaton can be represented as vector polygons [5], 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. 7) 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.

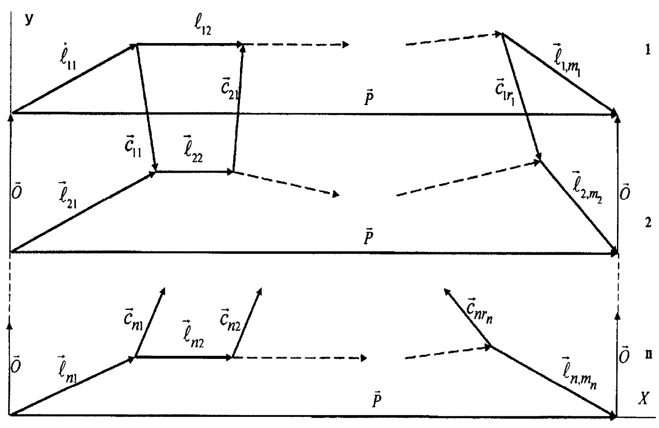

Fig. 7. Vector model cyclogram

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

ISBN: 978-988-19251-5-2
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

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. 7) 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. 7).

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

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

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

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

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

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

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

On the projection vectors of connection we impose constraints

$$c_{ik}^{xв} \geq c_{ik}^{x} \geq c_{ik}^{xн}, \quad c_{ik}^{yв} \geq c_{ik}^{y} \geq c_{ik}^{yн} \qquad (4)$$

where $c_{ik}^{xн} = e_{ik}^{x} + \Delta c_{ik}^{x}, \quad c_{ik}^{yн} = e_{ik}^{y} + \Delta c_{ik}^{y}$;

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, $c_{ik}^{xв}, c_{ik}^{yв}$ - 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.)

$$\Phi_{\nu}(A) = \max \sigma_{\nu}(A) \qquad (5)$$

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

$$\min_{A \in D} \Phi_1(A), \min_{A \in D} \Phi_2(A), ..., \min_{A \in D} \Phi_{\nu}(A), \qquad (6)$$

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

To solve the multi - objective task (6) we use the methodology proposed by in [6], 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.

III. 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 illustrated in Fig. 8.

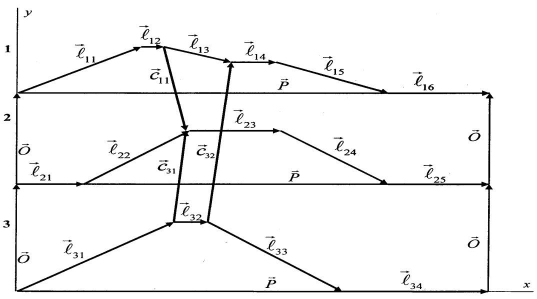

Fig. 8. Vector model cyclogram mechanisms involved in paving weft yarn loom STB1-330PN

Up a system of vector equations, describing the work of mechanisms loom STB1-330PN (Fig. 8).

$$\left.\begin{aligned}
&\vec{\ell}_{11}+\vec{\ell}_{12}+\vec{\ell}_{13}+\vec{\ell}_{14}+\vec{\ell}_{15}+\vec{\ell}_{16}=\vec{P}\\
&\vec{\ell}_{21}+\vec{\ell}_{22}+\vec{\ell}_{23}+\vec{\ell}_{24}+\vec{\ell}_{25}=\vec{P}\\
&\vec{\ell}_{31}+\vec{\ell}_{32}+\vec{\ell}_{33}+\vec{\ell}_{34}=\vec{P}\\
&\vec{c}_{11}=\vec{\ell}_{21}+\vec{\ell}_{22}-\vec{\ell}_{11}-\vec{\ell}_{12}-\vec{O}\\
&\vec{c}_{31}=\vec{\ell}_{21}+\vec{\ell}_{22}-\vec{\ell}_{31}+\vec{O}\\
&\vec{c}_{32}=\vec{\ell}_{33}+\vec{\ell}_{34}-\vec{\ell}_{14}-\vec{\ell}_{15}-\vec{\ell}_{16}-\vec{O}
\end{aligned}\right\} \tag{7}$$

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

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

Impose restrictions at phase angles triggering α_{ij} of mechanisms

$$\left.\begin{aligned}
&\alpha_{11}\ge 50^{\circ},\alpha_{12}\ge 0^{\circ},\alpha_{13}\ge 15^{\circ},\alpha_{14}\ge 5^{\circ},\\
&\alpha_{15}\ge 100^{\circ},\alpha_{16}\ge 80^{\circ},\alpha_{21}\ge 20^{\circ},\alpha_{22}\ge 60^{\circ},\\
&\alpha_{23}\ge 0^{\circ},\alpha_{24}\ge 70^{\circ},\alpha_{25}\ge 120^{\circ},\alpha_{31}\ge 70^{\circ},\\
&\alpha_{32}\ge 0^{\circ},\alpha_{33}\ge 70^{\circ},\alpha_{34}\ge 100^{\circ},
\end{aligned}\right\} \tag{9}$$

Imposes constraints on the projection vectors of connection

$$1^{\circ}\le c_{11}^{x}\le 7^{\circ},\ 1^{\circ}\le c_{31}^{x}\le 8^{\circ},\ 1^{\circ}\le c_{32}^{x}\le 6^{\circ}, \tag{10}$$

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):

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

A solution of problem (11) is an approximate compromise curve (Fig. 9). From the analysis of this curve, we find that the most plausible point A_{2429} .

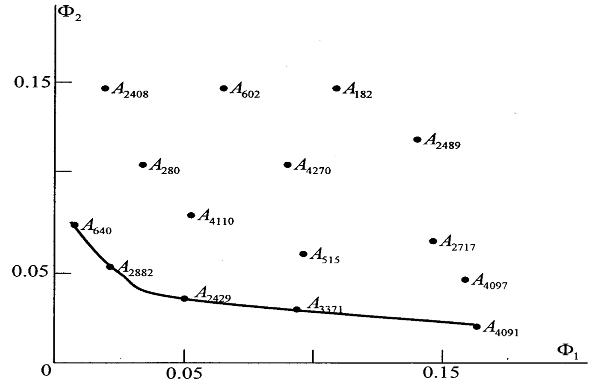

Fig. 9. Approximate compromise curve

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

$$\begin{aligned}
&\alpha_{11}=76^{\circ},\alpha_{12}=15^{\circ},\alpha_{13}=16^{\circ},\alpha_{14}=18^{\circ},\alpha_{15}=150^{\circ},\\
&\alpha_{16}=87^{\circ},\alpha_{21}=23^{\circ},\alpha_{22}=63^{\circ},\alpha_{23}=38^{\circ},\alpha_{24}=80^{\circ},\\
&\alpha_{25}=146^{\circ},\alpha_{31}=86^{\circ},\alpha_{32}=16^{\circ},\alpha_{33}=75^{\circ},\alpha_{34}=181^{\circ}.
\end{aligned} \tag{8}$$

IV. 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 select 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, i.e., we obtain the optimum cyclogram mechanisms of machine-automaton.

Compared with other methods of optimizing cyclogram mechanisms [1-4], this method takes into account the accuracy of manufacturing and operation mechanisms, to carry out optimization on several criteria.

REFERENCES

[1] L.V. Petrokas, “Reviews of cyclogram manufacturing machines and automatic production lines // Theory of automatic machines and pneumatic.” Moscow: Mashinostroenie, 1970, pp. 22-36.
[2] I. I. Artobolevsky, “Problems in the theory of machines and mechanisms in the development of methods of calculation and design of automatic machines.” Session of USSR Academy of Sciences on scientific issues in industrial automation, vol. VI, AN USSR, 1957, pp. 345-350.
[3] G.V. Zeitlin, “Cyclogram of complex technology of automatic machines.” Engineering Science. Moscow, № 3, 1975, pp. 49-53.
[4] V.A Novgorodtsev, “Cyclogram machines are represented in the form of associated directed graph.” Harkov, 1982, iss. 33, pp. 57-60.
[5] A.A.Jomartov, A.A. Ermolov, “Optimization cyclogram machine-automaton.”Engineering Science, Moscow, №6,1987, pp. 42-45.
[6] I.M. Sobol, R.V. Statnikov Selection of optimal parameters in problems with many of the criteria. M.: Hayka, 1981. p.110.