ОПРЕДЕЛЯНЕ НА КИНЕМАТИЧНИТЕ ХАРАКТЕРИСТИКИ НА МЕХАНИЗМА ЗА ЗАДВИЖВАНЕ НА НОЖНИТЕ РАМКИ НА ЖАКАРДОВА МАШИНА "GROSSE EJP 4" ЧРЕЗ "МЕТОД НА МОДЕЛИТЕ"

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DETERMINATION OF THE KINEMATIC CHARACTERISTICS OF THE GROSSE EJP 4 KNIFE BOX DRIVE MECHANISM BY MEANS OF "MODEL METHODS"

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ABSTRACT

The "Model Methods" is a graphical method for determining the kinematic cha-racteristics of polyclonal mechanisms. In the present study, a comparison is made with the method of closed vector contours for determining the kinematic characteristics of the knife box drive mechanism of the "GROSSE EJP 4" jacquard machine. This mechanism is composed of a cam mechanism with a swinging roller follower and a successively connected crank mechanism.

Keywords: *kinematic analysis, model methods, knife box mechanism, jacquard machine.*

Introduction

The "Model Method" was proposed by Piperkov [1] and developed in details by Tenchev [2]. The method is geometric and limited to constructing a secondary model to determine the links velocity and tertiary model to determine their accelerations The primary model is the position of the mechanism. An advantage of the method is that complicated mathematical formulas are avoided for the transmission functions of the mechanism and the double differentiation of the positional function. Undoubted advantage is the avoidance of uncertainty of trigonometric functions at certain angular values, the division of zero in some cases and the indeterminacy of arcos functions. It is only necessary to determine the displacement functions - to draw the mechanism for the selected value of the input parameter. A major flaw in the method is the large drawing work, even with the use of computer-aided graphic software. Roussev has proposed a mathematical apparatus based on analytical geometry for analytical determination of characteristic points of the models, enabling the method to be applied for a desired number of values of the coordinate [3], [4] and [5].

Experimental part

The GROSSE EJP 4 jacquard machine knife drive mechanism is a sequentially coupled cam mechanism with swinging roller follower and crank mechanism (***Figure 1***). From the analysis [6] it was found that the cam mechanism was an eccentric mechanism and in the study it was replaced with its equivalent four-bar mechanism.

1. Analysis of mechanism through the closed vector contours.

The analysis is limited to determining the displacement functions and first two transfer functions of a polyclonal mechanism consisting of sequentially connected four-bar mechanisms. For this, the transfer functions of the compiling mechanisms must be determined first, as a function of the generalization coordinate φ_0 (rotation angle of the starting unit). The aim of the analysis is the kinematic characteristics of the executive link (the knife frame), so the equations for the rocker, not for the bascule, are presented.

The calculations were made at the following unit sizes (as far as possible to be removed from the jacquard machine): knee OA = 25 mm; rocker AB = 105 mm; cylinder BC = 100 mm; knee CD = 250 mm; rocker DN1 = 145 mm; eccentricity m = 230 mm.

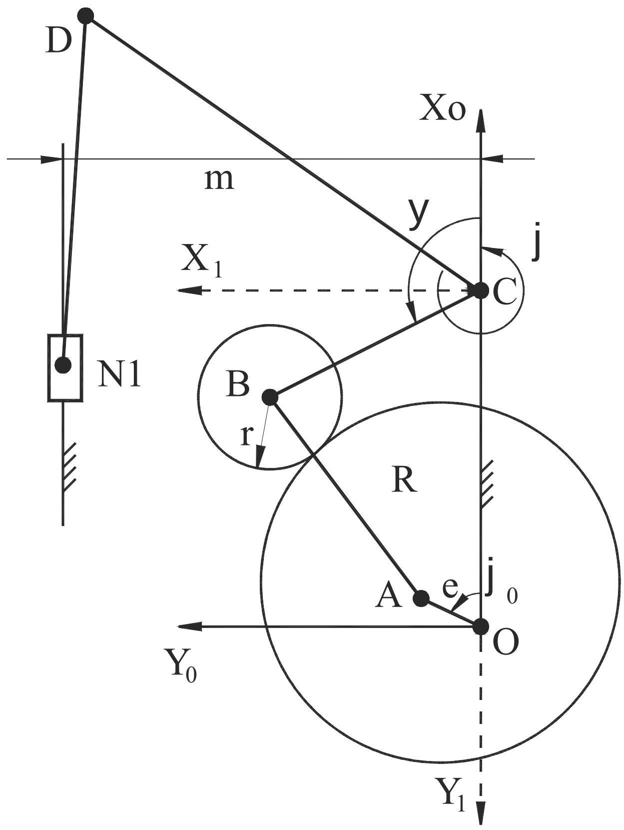

Figure 1 Used coordinate systems and mechanism links markings in closed vector contours analysis

A. Positioning and transfer functions of the cylindrical four-bar mechanism OABC

► displacement function (positional)

(1) $\psi = \alpha + \gamma$ - for the bascule BC, (this is the angle it concludes with the axle OX_0)

where:

$$\alpha = \arccos\left(\frac{AB^2 - BC^2 - d^2}{2.BC.d}\right)$$

$$\gamma = 2.\pi + arctg\left(\frac{-AB.\sin\varphi_0}{OC - OA.\cos\varphi_0}\right)$$

$$d = \sqrt{OC^2 + OA^2 - 2.OC.OA.\cos\varphi_0}$$

► The first transfer function is the first derivative of the displacement function relative to the generalization coordinate φ_0:

(2) for the bascule BC -

$$\psi' = \frac{OA.\sin(\varphi_0 - \xi)}{BC.\sin(\psi - \xi)}$$

► The second transfer function is the second derivative of the displacement function relative to the generalization coordinate φ_0:

(3) For the bascule BC -

$$\psi'' = \frac{OA.\cos(\varphi_0 - \xi) + \xi'^2.AB - \psi'^2.BC.\cos(\psi - \xi)}{BC.\sin(\psi - \xi)}$$

B. Displacement (positional) and transfer functions of the crank mechanism CDN1

► displacement function (positional)

(4) $$SN1 = CD.\sin\alpha + \sqrt{DN1^2 - (m - CD.\cos\alpha)^2}$$

► The first transfer function is the first derivative of the displacement function:

(5) $$SN1' = CD.\cos\alpha + \frac{CD.\sin\alpha.(CD.\cos\alpha - m)}{\sqrt{DN1^2 - (CD.\cos\alpha - m)^2}}$$

► The second transfer function is the second derivative of the displacement function:

(6) $$SN1'' = -CD.\sin\alpha + \frac{A'B + A.B'}{B^2}$$

where:

$$A = CD.\sin\alpha.(CD.\cos\alpha - m)$$

$$B = \sqrt{DN1^2 - (CD.\cos\alpha - m)_2}$$

$$A' = CD^2.\cos(2.\alpha - CD.m.\cos\alpha)$$

$$B' = \frac{-(CD.\cos\alpha - m).CD.\sin\alpha}{\sqrt{DN1^2 - (CD.\cos\alpha - m)^2}}$$

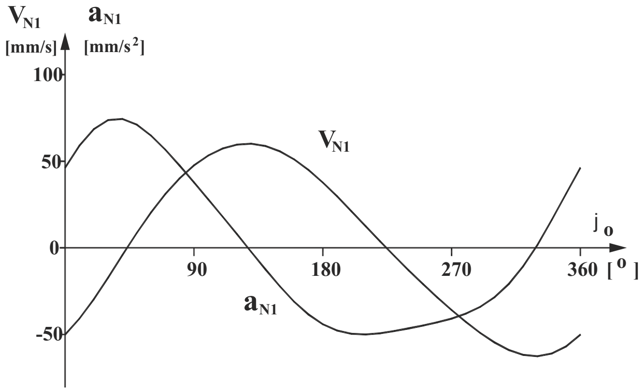

Figure 2 Velosity and acceleration of the executive link - the knife frame N1

C. velosity and acceleration of the knife box N1

Calculate the formulas:

(7) velosity of the knife box frames:

$$V_{N1} = SN1'.\omega_{CB}$$

and acceleration

$$a_{N1} = \varepsilon_{CB}.SN1' + \omega_{CB}^2.SN1''$$

The results are shown in ***Figure 2***.

2. Analysis of mechanism by means of "model methods"

The modeling method consists in the geometric construction of a primary (position of the different values of generalization coordinate φ_0), secondary (for determining the velocities of the links) and tertiary (to determine their accelerations) model. This requires a lot of drawing work, even when using a computer-aided graphic software.

Roussev has proposed a mathematical model for determining the characteristic points of the models for the most common four-way mechanisms [3], [4], [5]. For a crank mechanism, the constructions are shown in ***Figure 3*** and are explained below.

The approach is as follows:

The "primary model" defines the displacement functions: $x_B = x_B(\varphi)$ and $\sigma = \sigma(\varphi)$

The coordinates of the characteristic points of the mechanism are: p. A: $x_A = OA.\cos\varphi$ and $y_A = OA.\sin\varphi$; p. B: $x_B = OA.\cos\varphi + AB.\cos\sigma$ and $y_B = e$; p. C: $x_C = OA.\cos\varphi + AC.\cos(\alpha + \sigma)$ and $y_C = OA.\sin\varphi + AC.\sin(\alpha + \sigma)$.

A. Sequence

In ***Figure 3*** for illustration are constructions for any mechanism.

a. Primary Model: Draw the mechanism for its desired position on a scale of 1: 1. The axis Ox of the coordinate system is selected parallel to the sliding direction n-n.

b. Secondary model: Through p. O, the line m ⊥ Ox is done; continue section AB until it is intersected with m; the intersection point is B ', through B" the right p || BC is constructed,; and through point A the line q (continuation of segment AC); the intersection of q and p is C '.

c. Tertiary model: the section $AA'' \perp OA$ is line; through point A", the line k || AB is constructed; and the section A" N1 is marked; at point N1 the h ⊥ AB line is passed; the intersection of h with the coordinate axis Ox is the tertiary image B" of point B; the triangle A"B"C ", which is similar to triangle ABC is drawn.

B. Determination of the characteristic points of the secondary model through the Roussev apparatus.

- coordinates of the p. A': $x_{A'} = x_A$ $y_{A'} = y_A$
- angular coefficient of straight line:

$$AB \rightarrow K_{AB} = \frac{y_B - y_A}{x_B - x_A}; \quad OA \rightarrow K_{OA} = \frac{y_A}{x_A};$$

$$AC \rightarrow K_{AC} = \frac{y_C - y_A}{x_C - x_A}; \quad BC \rightarrow K_{BC} = \frac{y_C - y_B}{x_C - x_B};$$

- coordinate of the intersection point of the coupler AB with the coordinate axis Ox:

$$x_P = x_A - \frac{y_A}{K_{AB}} \quad \text{and} \quad y_P = 0;$$

- coordinates of point B': $y_{B'} = x_P.\tan(-\sigma)$ and $x_{B'} = 0$;
- coordinates of point C':

$$x_{C'} = \frac{K_{AC}.x_{A'} - K_{BC}.x_{B'} + y_{B'} - y_{A'}}{K_{AC} - K_{BC}} \quad \text{and}$$

$$y_{C'} = y_{B'} + K_{BC}.(x_{C'} - x_{B'})$$

- sectional length OC': $OC' = \sqrt{x_{C'}^2 + y_{C'}^2}$

C. Determination of the characteristic points of the tertiary model through the Roussev apparatus.

- sectional length AA": $AA'' = \frac{\varepsilon_1}{\omega_1^2}.OA$

- Coordinates of point A":

$$x_{A''} = x_A + AA''.\cos\left(\frac{p}{2} - j\right)$$

$$y_{A''} = y_A + AA''.\sin\left(\frac{p}{2} - j\right)$$

- Length of section A'B':

$$A'B' = \sqrt{(x_{A'} - x_{B'})^2 + (y_{A'} - y_{B'})^2};$$

- length of section A"N1: $A''N1 = \frac{(A'B')^2}{AB};$

- coordinates of point N1:

$$x_{N1} = x_{A''} + A''N1.cos\, s \quad \text{and}$$

$$y_{N1} = y_{A''} + A''N1.sin\, s$$

- angular coefficient of straight line *N1B*:

$$K_{N1B''} = \frac{1}{K_{AB}}$$

- coordinates of p. *B"*: $x_{B''} = x_{N_1} + \frac{y_{N_1}}{K_{N_1B''}}$ and $y_{B''} = 0$

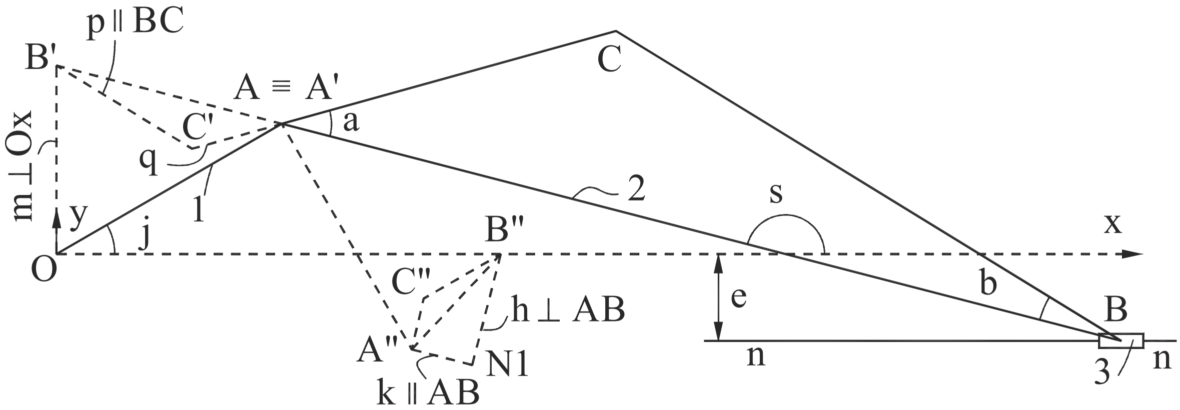

Figure 3 Drawings for the secondary and tertiary model in the coordinate system of the mechanism

angular coefficient of straight line:

$$A''B'' \rightarrow K_{A''B''} = \frac{y_{A''}}{x_{A''} - x_{B''}};$$

$$A''C'' \rightarrow K_{A''C''} = \frac{K_{A''B''} + \tan(a)}{1 - K_{A''B''}\tan(a)};$$

$$B''C'' \rightarrow K_{B''C''} = \frac{K_{A''B''} - \tan(b)}{1 + K_{A''B''}\tan(b)}$$

-coordinates of point C":

$$x_{C''} = \frac{K_{A''C''}.x_{A''} - K_{B''C''}.x_{B''} - y_{A''}}{K_{A''C''} - K_{B''C''}}$$

$$y_{C''} = K_{B''C''}(x_{C''} - x_{B''})$$

- section length OC": $OC'' = \sqrt{x_{C''}^2 + y_{C''}^2}$

The kinematic characteristics of random points and points of the mechanism are calculated with the coordinates of the points and the sizes of the segments so determined.

The velocity $V_B = \omega_0.OB'$ of point B is perpendicular to the segment OB' and has a direction corresponding to ω_0 with respect to the center O. The acceleration a_B in the tertiary model has a direction from B" to O and has the size $a_B = \omega_0^2.OB''$.

Results:

The velosity and the acceleration of one of the knife box of the "GROSSE EJP 4" jacquard machine were obtained. The other knife box moves along the same law, counter-directional. The method of models is used by his analytical interpretation proposed by Roussev. The same results for the kinematic characteristics of the output link are obtained. The analysis was done for 36 different positions of the mechanism. The computer-aided mathematical software Mathcad 15 was used to perform the analysis in both ways. For the polyclone mechanism, the constructions were made with the pole O of the composite mechanism (***Figure 1***)

Conclusion:

From the presentation of the two methods, the following conclusions can be drawn:

- Both methods give the same results.
- Roussev's analytical adaptation to the "Model Method" is easier to interpret than the vector contours method;
- in the "Model Method", it is not necessary to determine the kinematic characteristics of the previous mechanism;

- there is no uncertainty about arcos functions;
- the secondary and tertiary models are on a real existing mechanism, so there is no points uncertainty.

The "model method" can be used to determine the kinematic characteristics of the links (units) of a polyclonal mechanism. It can be used to solve the problem of "conflicting" points from the position of the mechanism and to determine the position of a given link in the uncertainty of the trigonometric functions. By this method, the directions of the velocities and the accelerations of the units are easily and unambiguously determined.

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