ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 7, Issue 4 , April 2020

Kinematic Analysis of a Closed Lever-Articulated Mechanism for Moving Material of a Sewing Machine

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ABSTRACT: The article provides a kinematic analysis of a closed lever-hinged mechanism for moving material of a sewing machine. The angular and linear movements of the links, the angular velocities and accelerations of the links and the absolute speeds of the links, as well as the speeds and accelerations of the singular points of the links of the material moving mechanism are considered.

KEYWORDS: rail, material movements, trajectory, absolute speed, angular speeds and link accelerations, device, roller, elastic sleeve, polymer composition, strength, machine unit, law of motion, parameters, full-factor, stiffness, frequency, flow rate.

I.INTRODUCTION

The main directions of further development of machinery and technology for light industry is a sharp increase in the productivity of machines and mechanisms and the production of high quality products with a wide range.

The growth in the volume of sewing production and the improvement of the quality of manufactured clothes are directly dependent on further improvement and intensification of technological processes, equipping enterprises with new highly efficient equipment, improving the structure and management of production, organizing labor, rational use of material and energy resources, introducing the achievements of science and technology, improving quality of work at all levels of sewing production.

In the process of moving the material, the mechanism rail performs not only horizontal, but also vertical movement. The rail path is elliptical [1]. In the proposed scheme of the material movement mechanism (see Fig. 1), the rail 6 receives movement from the crank 1, the connecting rod 8 and the two-armed rocker 7 in the horizontal direction, and through the right crank 1, the connecting rod 2, the two-arm lever 3, the connecting rod 4 makes vertical movements.

Kinematic analysis is carried out using the closed loop method [2]. From the presented calculation scheme (see Fig. 2), the following vector outlines of triangles were distinguished: AKG, KNG, ABD, BCD, GHF, DEF.

In the kinematic analysis of the movement mechanism, the expressions of the following parameters are determined:

- angular and linear movements of links and their points;
- the angular speeds and accelerations of the links and the absolute speeds of the links, as well as the speeds and accelerations of the special points of the links of the material movement mechanism;
- transfer functions between the links of the mechanism;

-Absolute speed of the movement of the staff, etc.

The mechanism for moving the material moves in the HOW plane. For the triangular vector contours under consideration, we can write:

$$l_0 = l_1 + q_1;\ l_3 = l_2 + q_1;$$
$$l_0' + l_0 = l_1' + q_2;\ l_7 = l_8 + l_7; \qquad (1)$$
$$l_7' + q_3 = l_5; \qquad l_3 + q_4 = l_4.$$

Where, q_1, q_2, q_3, q_4 – modulo-variable vectors defining the positions of points B, K, F of the links of the material movement mechanism.

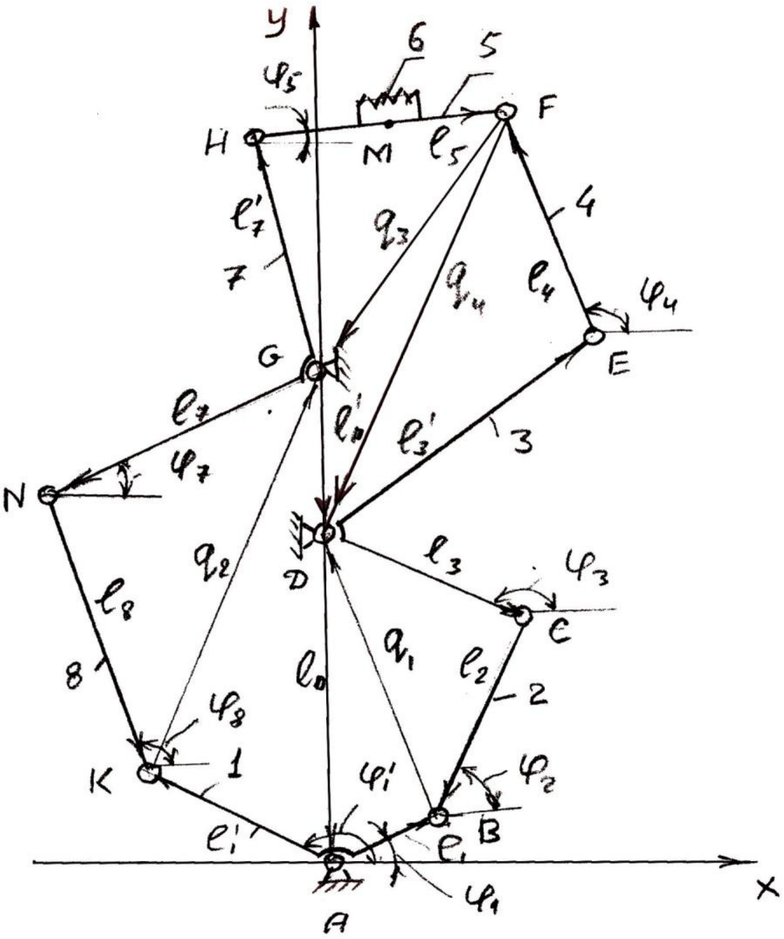

Fig. 1. Kinematic diagram of a closed mechanism for moving material of a sewing machine.

We design vector equations (1) on the axes AX and AU and, accordingly, we obtain the following expressions:

$$l_1 \cos\varphi_1 - q_1 \cos\varphi_{q1} = 0;\ \ -l_2 \cos\varphi_2 - l_3 \cos\varphi_3 - q_1 \cos\varphi_{q1} = 0;$$

$$l_1'\cos\varphi_1' = q_2\cos\varphi_{q2}; \quad -l_7\cos\varphi_7 - l_8\cos\varphi_8 + q_2\cos\varphi_{q2} = 0;$$
$$l_3'\cos\varphi_3' - l_\varphi\cos\varphi_4 - q_4\cos\varphi_{q4} = 0; \ l_5\cos\varphi_5 - l_7'\cos\varphi_7' - q_3\cos\varphi_{q3} = 0;$$
$$l_1\sin\varphi_1 + q_1\sin\varphi_{q1} - l_0 = 0; \ -l_2'\sin\varphi_2 - l_3\sin\varphi_3 + q_1\sin\varphi_{q1} = 0; \tag{2}$$
$$-l_1'\sin\varphi_1' + q_1\sin\varphi_{q2} - l_0 - l_0' = 0; \ -l_8'\sin\varphi_8' - l_7'\sin\varphi_7 + q_2\sin\varphi_{q2} = 0;$$
$$l_7'\sin\varphi_7' + l_5\sin\varphi_5 - q_3\sin\varphi_{q3} = 0; \ l_3'\sin\varphi_3' - l_4\sin\varphi_4 - q_4\sin\varphi_{q4} = 0;$$

Where, $\varphi_1,\varphi_2,\varphi_3,\varphi_4,\varphi_5,\varphi_6,\varphi_7,\varphi_8,\varphi_{q1},\varphi_{q2},\varphi_{q3},\varphi_{q4},\varphi_1',\varphi_3',\varphi_7'$ - angles between the axis AX and the corresponding vectors of the contours of the mechanism.

From the first and seventh equations in (2) we define:

$$\varphi_{q1} = arctg\frac{l_0 - l_1\sin\varphi_1}{l_1\cos\varphi_1}$$

From ΔAWD using the sine theorem we determine:

$$q_1 = l_1\frac{\sin\varphi_1}{\sin\varphi_{q1}} = \frac{l_1\sin\varphi_1}{\sin\left[\varphi_{q1} = arctg\frac{l_0 - l_1\sin\varphi_1}{l_1\cos\varphi_1}\right]} \tag{3}$$

According to the calculation scheme in Fig. 2, we have:

$$\varphi_1 = \varphi_1' - \alpha_1 \tag{4}$$

Where, α_1 - the angle between the shoulders l_1 and l_1' the lever 1. Then from ΔAHG we have:

$$\varphi_{q2} = arctg\frac{l_0 + l_0' - l_1'\sin(\varphi_1 + \alpha_1)}{l_1'\cos(\varphi_1 + \alpha_1)}; \tag{5}$$

Accordingly, in a similar way we define the expressions to determine $\varphi_{q3},\varphi_{q4}$:

$$\varphi_{q3} = arctg\frac{l_7'\sin(\varphi_7 + \alpha_7) + l_5\sin\varphi_5}{l_5\cos\varphi_5 - l_7'\sin(\varphi_7 + \alpha_7)};$$
$$\varphi_{q4} = arctg\frac{l_3'\cos(\varphi_3 + \alpha_3) - l_4\cos\varphi_4}{l_3'\sin(\varphi_3 + \alpha_3) - l_4\sin\varphi_4} \tag{6}$$

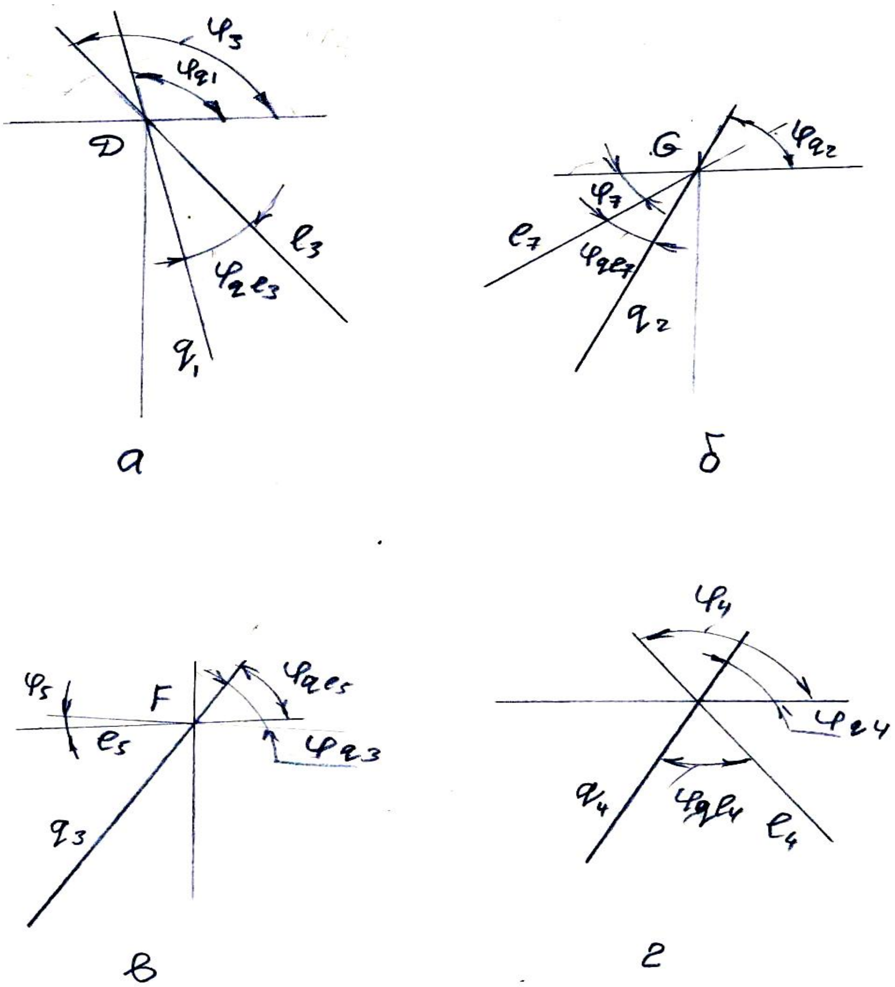

Fig. 2. Scheme for calculating angles

According to the calculation scheme (see Fig. 1) using the sine theorem in ΔAND, ΔДNF, ΔДEF we get:

$$q_1 = l_1' \frac{\sin \varphi_{q1}}{\sin \varphi_1'} = l_1' \frac{\sin \varphi_{q2}}{\sin(\varphi_1 + \alpha_1)} \;;$$

$$q_3 = l_7' \frac{\sin \varphi_{q3}}{\sin(\varphi_7 + \alpha_7)} \tag{7}$$

$$q_4 = l_3' \frac{\sin \varphi_{q4}}{\sin(\varphi_3 + \alpha_3)}$$

In fig. 2 presents diagrams for determining the angles according to which we have: $\varphi_3 = \varphi_{q1} + \varphi_{qe3}$; $\varphi_7 = \varphi_{q2} - \varphi_{qe7}$;

$$\varphi_5=\varphi_{q3}-\varphi_{qe5};\ \varphi_4=\varphi_{q4}+\varphi_{qe4}; \tag{8}$$

$$l_5^2=(l_7')^2+q_3^2-2q_3(l_7')^2\cos\varphi_{qe7};$$

$$(l_7')^2=l_5^2+q_3^2-2q_3l_5\cos\varphi_{qe5};$$

$$(l_3')^2=l_4^2+q_4^2-2l_4q_4\cos\varphi_{qe4};$$

$$l_4^2=(l_3')^2+q_4^2-2(l_3')^2q_4\cos\varphi_{qe3}.$$

From the obtained (9) expressions, we determine the corresponding angles: $\varphi_{qe3}=\arccos\frac{q_1^2+l_3^2-l_2^2}{2q_1l_3};\ \varphi_{qe2}=\arccos\frac{q_1^2+l_2^2-l_3^2}{2q_1l_2};$

$$\varphi_{qe7}=\arccos\frac{l_7^2+q_2^2-l_8^2}{2l_7q_2};\ \varphi_{qe8}=\arccos\frac{l_8^2+q_2^2-l_7^2}{2l_8q_2};$$

$$\varphi_{qe7'}=\arccos\frac{(l_7')^2+q_3^2-l_5^2}{2q_3(l_7')};\ \varphi_{qe5}=\arccos\frac{l_5^2+q_3^2-(l_7')^2}{2q_3l_5}; \tag{10}$$

$$\varphi_{qe4}=\arccos\frac{l_4^2+q_4^2-(l_3')^2}{2q_4l_4};\ \varphi_{qe3'}=\arccos\frac{(l_3')^2+q_4^2-l_4^2}{2(l_3')^2q_4};$$

From (5), (6), (7), (9) and (10) after some transformations we have: $\varphi_3=arctg\frac{l_0-l_1\sin\varphi_1}{l_1\cos\varphi_1}+\arccos\frac{C_1}{D_1};$

$$\varphi_4=arctg\frac{A_4}{B_4}+\arccos\frac{C_4}{D_4};$$

$$\varphi_5=arctg\frac{A_5}{B_5}-\arccos\frac{C_5}{D_5};$$

$$\varphi_7=arctg\frac{A_7}{B_7}-\arccos\frac{C_7}{D_7};$$

Where,

$$C_1=\left\{\frac{l_1\sin\varphi_1}{B_1}\right\}^2+l_3^2-l_2^2;\ D_1=\frac{2l_3l_1\sin\varphi_1}{B_1};\ B_1=\sin\left[arctg\frac{l_0-l_1\sin\varphi_1}{l_1\cos\varphi_1}\right];$$

$$A_4=l_3'\cos(\varphi_3+\alpha_3)-l_4\cos\varphi_4;\ B_4=l_3^i\sin(\varphi_3+\alpha_3)-l_4\sin\varphi_4;$$

$$C_4=l_4^2+q_4^2-(l_3^i)^2;\ D_4=2l_4q_4;\ A_5=l_7^i\sin(\varphi_7+\alpha_7)+l_5\sin\varphi_5;$$

$$B_5=l_5\cos\varphi_5-l_7^i\cos(\varphi_7+\alpha_7);\ C_5=l_5^2-q_3^2-(l_7^i)^2;D_5=2q_3l_5$$

$$A_7 = l_o + l_o^i - l_1^i \sin(\varphi_1 + \alpha_1);\;\; B_7 = l_1^i(\varphi_1 + \alpha_1)$$

$$C_7 = l_7^2 - l_8^2 + \left[\frac{l_1^i E_7}{\sin(\varphi_1 + \alpha_1)}\right]^2;$$

$$D_7 = \frac{2 l_7 l_1^i E_7}{\sin(\varphi_1 + \alpha_1)} \quad E_7 = \sin[\, arctg \frac{l_0 + l_0^i - l_1^i \sin(\varphi_1 + \alpha_1)}{l_1^i \cos(\varphi_1 + \alpha_1)}];$$

Numerical solutions of the kinematics problem of the material movement mechanism were performed at the following parameter values: $l_1 = 28 \cdot 10^{-3} м;\; l_1^i = 28 \cdot 10^{-3} м;$

$l_2 = 22{,}5 \cdot 10^{-3} м;\; l_8 = 22{,}5 \cdot 10^{-3} м;$

$l_3 = 30 \cdot 10^{-3} м;\; l_3^I = 30 \cdot 10^{-3} м;$

$l_7 = 28 \cdot 10^{-3} м;$

$l_7^I = 28 \cdot 10^{-3} м;$

$l_5 = 12{,}0 \cdot 10^{-3} м;$

$l_4 = 25 \cdot 10^{-3} м,$

$\alpha_1 = 116^\circ;\;\; \alpha_7 = 11^\circ;\; \alpha_3 = 10^\circ;\; \omega_1 = 303{,}5 c^{-1}.$

II. CONCLUSION

The kinematic characteristics of a closed eight-link lever-hinged flat mechanism for moving the material of the sewing machine are determined. Formulas are obtained for determining the angular displacements of cranks, connecting rods, rocker arm and lever with rail. Based on the numerical solution of the problem, regularities of the angular displacement of the lever with the rail with varying the length of the links of the mechanism are obtained.

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