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Optimization of Geometric Dimensions of Links Mechanism of Cross-Planer Machine

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Abstract:

This paper presents a comprehensive kinematic analysis of the mechanism of a cross-planing machine, widely used in the mechanical engineering industry in Uzbekistan. The analysis focuses on optimizing the geometric dimensions of the machine's key components, particularly the crank and connecting rods, to improve performance. A mathematical model was developed using MathCAD to evaluate the relationship between the length of the crank and the gear ratio during operation. The study identified optimal crank dimensions within the range of 250-300 millimeters, where the maximum gear ratio is achieved. These findings contribute to the development of more efficient machines, improving their overall functionality and proposing advancements for future designs.

Keywords: Cross-planing machine, kinematic analysis, geometric optimization, crank mechanism, MathCAD modeling, mechanical engineering, Uzbekistan.

Among the many priority areas for the development of Uzbekistan, adopted by presidential decree for 2022-2026, the key goal is to increase efficiency per capita by 1.6 times, due to high economic growth rates, including mining, agriculture, and most importantly, mechanical engineering. In the implementation of this task, a special place is played by the creation of modern technological equipment. A large group of this equipment consists of slotting and planing machines, which are used in mechanical shops in all large factories of Uzbekistan, including the mining and metallurgical plant in the city of Almalyk, the mining and metallurgical plant in the city of Navoi, the aggregate plant of agricultural machinery and the mechanical plant in the city of Tashkent, as well as in small-scale production.

Figure 1 shows the kinematic diagram of a cross-planing machine with a rocker drive mechanism. The mechanism consists of struts 0, crank 1, connecting rods 4,6, rocker arms 2, and slides 3, 5. The machine is powered by an electric motor, which transmits the rotation of a six-speed gearbox to a shaft equipped with a sliding splint. The shank holds a triple block of gears, which guarantees the shaft a three-speed mode. Consequently, during the movement of the block along the shaft axis, the gears are alternately captured with the gears secured to a key on the shaft [1].

The operation of the cross-planing machine (Fig. 1.) occurs as follows. The cutter makes a horizontal reciprocating movement at speeds Vp.x (working stroke) and Vx.x (idling speed). This movement is characterized by the number of double strokes per minute of the slider. One double stroke consists of a working stroke, during which the cutter cuts off a layer of metal with a cross-section f = ts = ab mm 2, and an idle stroke, during which the cutter returns to its original position. [1]

Slotting and planing machines are designed for processing horizontal, inclined.

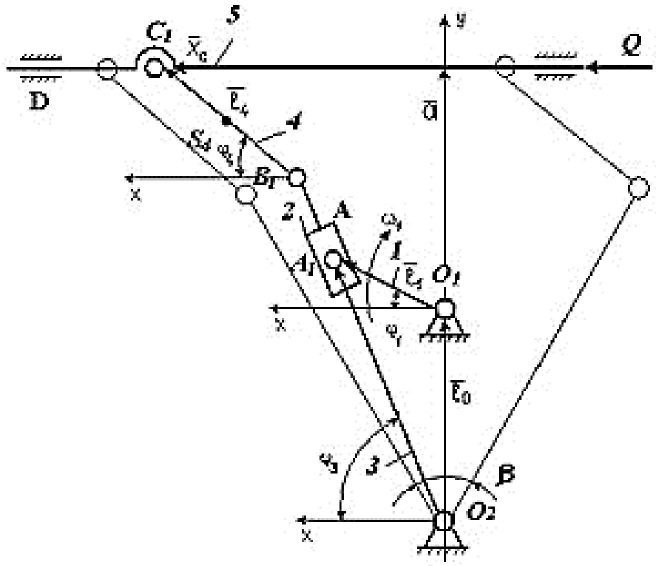

Fig.1. Mechanism of cross-planing machine

To compile analytical dependencies, we will use the condition of closedness of the contours of their kinematic chains, since it is more convenient for flat mechanisms. By drawing up equations for the projection of links onto the corresponding coordinate axes, a functional connection is established between the kinematic parameters that characterize the movement of the input and output links of the mechanisms.

The six-link mechanism shown in Figure 1 consists of a crank 1, a rocker stone 2, a swinging rocker 3, a connecting rod 4 and a slider 5, which performs a reciprocating movement relative to the rack 6. The initial link is the crank, which performs a rotational movement with an angular velocity ω_1.

The crank is also a leading link, since it has a generalized coordinate - angle ϕ_1.

We select a rectangular coordinate system XOY, the beginning of which coincides with the center of the hinge O1, the X axis passes through points O2 and B, and the Y axis is parallel to the movement of the slider 5. Angles ϕ_1, ϕ_3 and ϕ_4 are measured from the positive direction of the X axis in the direction of rotation of crank 1. We write the condition for the closure of the circuit composed of vectors l_{AB}, l_{AC} and l_{CB} of links 1, 6 and 3 in the form of a vector equation:

$l_{AB} = l_{AC} + l_{CB}$

$E_B sin\varphi_3 = l_1 sin\varphi_1 + l_0$; $E_B cos\varphi_3 = l_1 cos\varphi_1 + l_1$; $l_0 + \varphi = l_4 sin\varphi_4 + l_3 sin\varphi_3$; $x_D = l_4 cos\varphi_4 + l_3 cos\varphi_3$; $l_3 cos\varphi_4 = l_1 cos\varphi_1 + (l_3 - EB) cos\varphi_3$; $cos\varphi_4 = \frac{l_1 cos\varphi_1}{EB} - EB^2 = l_o^2 + l_1^2 -$

$2l_1l_0cos(90+\varphi_1) = l_o^2 + l_1^2 + 2l_1l_0sin\varphi_1;$ $EB = \sqrt{l_o^2 + l_1^2 + 2l_1l_0sin\varphi_1},$ $cos\varphi_3 = \frac{l_1cos\varphi_1}{\sqrt{l_o^2+l_1^2+2l_1l_0sin\varphi_1}}$, $X_D = l_4cos\varphi_4 + \frac{l_3l_1cos\varphi_1}{\sqrt{l_o^2+l_1^2+2l_1l_0sin\varphi_1}}$; $sin\varphi_3 = \sqrt{1 - \frac{l_1^2cos\varphi_1}{l_o^2+l_1^2+2l_1l_0sin\varphi_1}}$

The differential of the equation with respect to φ_1 we obtain

$$0 = l_4cos\varphi_4 \cdot d\varphi_4 + l_3cos\varphi_3d\varphi_4$$

$$dx_D = -l_4 \cdot sin\varphi_4d\varphi_4 - l_3sin\varphi_4 \cdot d\varphi_4$$

$$0 = U_{43}l_4cos\varphi_4 + l_3cos\varphi_3$$

$$\frac{dx_D}{d\varphi_3} = -l_4 \cdot U_{43}l_4sin\varphi_4 - l_3sin\varphi_4 = U_{53}$$

The given trigonometric equations are the basis for the analytical method of kinematic analysis of the mechanism of a cross-planing machine. Having compiled an algorithm and calculation program in the Mathcad computer environment [2], the authors of the article obtained a mathematical model of the dependence of changes in intermediate gear ratios depending on the lengths of the mechanism links.

Having analyzed the graph of the change in the crank-crank gear ratio U31 on the length of the crank (Figure 2), the authors of the article concluded that the optimal crank values are in the range from 250 to 300 millimeters, since this is where the maximum values of the U31 gear ratio occur. Calculations are made for one revolution of the crank.

As a result of the study, a mathematical model of operation and an analytical study of the kinematic analysis of the mechanism of the cross-planing machine was developed. In this work, mathematical expressions are obtained that describe the movement of the output - working link, in the form of functions of the angles of rotation of the input and intermediate links.

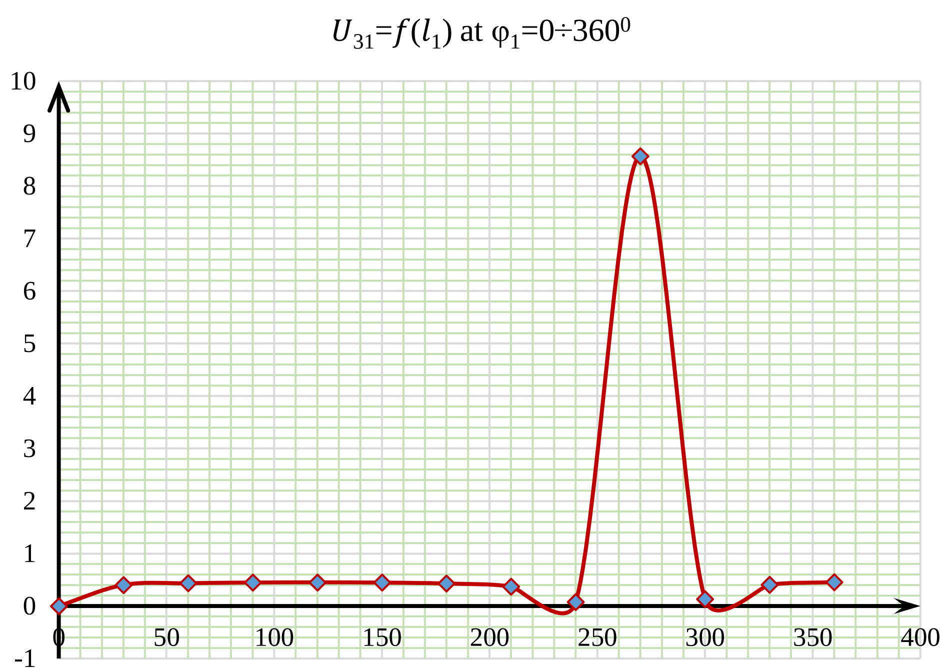

Fig. 2. Graph of the change in gear ratio U31 from the length of the crank, per revolution.

Calculations were carried out for the optimal dimensions of the crank, link and connecting rod, and the mechanism of the cross-planing machine, at a given value of the distance between the line of movement of the cutter and the place where the crank is attached to the stand, using the MathCAD application program.

The prospect of improving existing machines, which include rocker mechanisms similar to a cross-planing machine, and inventing new ones is proposed.

References

1. Khalilov I.A., Kerimov S.Kh., Rzaeva G.M. A method for synthesizing a lever mechanism that ensures a given law of motion // Bulletin of Mechanical Engineering, 2017. No. 3. P. 3-5.
2. Matsyuk I.N. Kinematic analysis of high-class flat lever mechanisms in the MathCAD program // Theory of mechanisms and machines, 2012. No. 1, vol. 10. pp. 65-70.
3. Mamayev, S., Avdeeva, A., Ablyalimov, O., & Nigmatova, D. (2023). Optimization of the operation of the mechanism of the cross planer. In E3S Web of Conferences (Vol. 401, p. 05026). EDP Sciences.
4. Ablyalimov O. S., Avdeyeva A. N., Khamidov O. R., Kasimov O. T. Analysis of mechanical structures of complex technical systems // Annals of Forest Research, 2022. №65, Vol 1. P. 10413 – 10427.
5. Kasimov, Obidjon T., Akhat T. Djanikulov, and Sherali I. Mamayev. "Modeling the bending of the tire surface by pads during braking." AIP Conference Proceedings. Vol. 2402. No. 1. AIP Publishing LLC, 2021.
6. Djanikulov, Akhat T., Sherali I. Mamayev, and Obidjon T. Kasimov. "Modeling of rotational oscillations in a diesel locomotive wheel-motor block." Journal of Physics: Conference Series. Vol. 1889. No. 2. IOP Publishing, 2021.