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DRIVE POWER OF THE EQUIPMENT FOR THE MANUFACTURE OF CORRUGATED BOARD INVOLUTES OF DISTRIBUTION PACKAGING (JUSTIFICATION OF THE CALCULATION METHOD)

Abstract: *It has been established that the provision of modern industrial goods by the large-sized distributional packaging of corrugated board is related to the complexity of manufacture of involutes using die-cutting equipment. Large-sized involutes are obtained from several individual by gluing or binding with saddle stitching, that greatly complicates the technological process. A new technological process is proposed to eliminate the drawbacks and the unit for manufacturing large-sized involutes by means of scissor cutting with moving disk tools is developed, driven by a crank-sliding mechanism. In the article has been obtained mathematical expressions for invariants of kinematic parameters, relative instantaneous power, which spent by the unit for the manufacture of the large-sized involute of corrugated board.*

Keywords**:** *corrugated board, large-sized distribution packaging, disk tool, crank-sliding mechanism, invariant, kinematic parameters, instantaneous power.*

INTRODUCTION, PROBLEM STATEMENT

Large-sized distribution packaging of corrugated board is highly demanded today and is used for transportation to warehouses, places of storage and sale of semi-processed and finished products (household and industrial appliances, other products of various industries). Typically, such packaging is made in the form of a rectangular parallelepiped from flat involute, that are obtained during board blanks die-cutting [1, 2].

Die-cutting equipment that is used during box cutting is limited by the format of the working area, which makes impossible its usage for the manufacture of large-sized packaging from one solid corrugated board blank [3]. The way out of this problem is to die-cut few different involutes that later are glued together or bound by saddle stitching, which significantly complicates the technological process, negatively affects the rigidity, accuracy and cost of the end product [4].

MAIN ARTICLE

To eliminate described a complex of shortcomings, had been proposed a new technological process and the means of large-sized involutes manufacturing by the method of scissor cutting [5] of the cardboard blank CB (Fig. 1) that locates on the fixed counter blades 1 by the moving disk tool 2 [6]. The gap size between the cutting edges of counter blades and the thickness of the disk are conformed and tight fitted. Usage of such a tool kit justifies the technological benefits over a flat forme: tool kits assembled on the carriage allow easy adjusting to a different involute size, with purpose to make different lengths and widths of grooves. The carriages with individual drives can be easily position in the work zones of corrugated board blanks, depending on their geometric size.

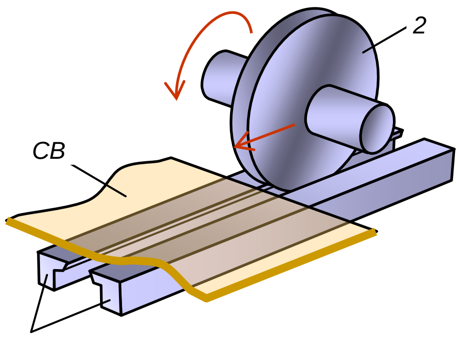

Fig. 1. *Scheme of groove making in cardboard blank by scissor method using disk cut tool, authors'*

After placing and aligning the cardboard blank CB (made of corrugated board) on the table 1 (fig. 2 a) the crank 2 transmits movement through the connecting rod 3 a slide 4 that has reciprocating motion along the guides 5. During slide motion, the gear 6 engages with the stationary rack 7 and transmits the rotation to the shaft 8 and the disk knives 9, the cutting edges of which contact with the sharp counter blades 10, and cut the grooves in the blank CB. Cutting knives 11 in contact with the front counter blades 12 cut cardboard strips in the transverse direction.

Since the crank-slide mechanism is used for the carriage drive, the kinematic parameters of the moving elements are variables that influence its inertial loads. For research of these elements, we introduce relative geometric parameters: $R_2 = 1$ – crank 2 radius; $\lambda_3 = l_3/R_2$ – relative connecting rod 3 length [7].

Relative linear slide 4 displacement (fig. 2 b) found of the outline projection on the horizontal axis [8]:

$$s_{i4} = L_i - \cos\phi_2 - \lambda_3 \cos\vartheta_3, \qquad \textbf{(1)}$$

where $L_i = \lambda_3 + 1$ – relative distance from the rotation axis of the crank 2 to the extreme left slider 4 position; φ_2 – current angle of crank 2 rotation; ϑ_3 – the slope of the connecting rod 3 to horizontal axis.

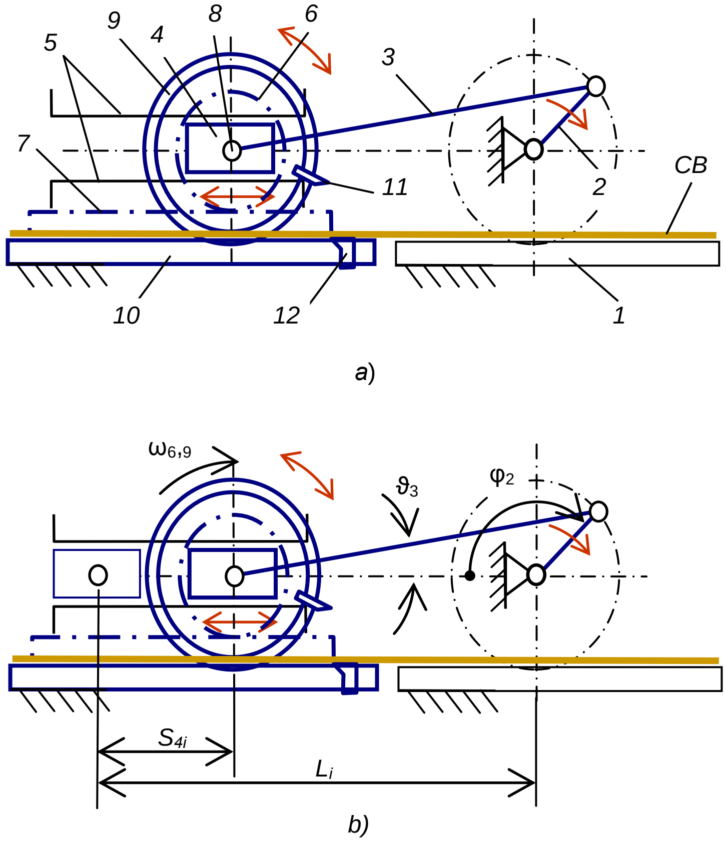

Fig. 2. *Cutting unit of grooves in cardboard blank made from corrugated board: kinematic (a) and computational (b) schemes, authors'*

By projecting the crank-slide contour on the vertical axis, we obtain the slope of the connecting rod 3:

$$\vartheta_3 = arcsin\left(\frac{sin\phi_2}{\lambda_3}\right) \qquad \textbf{(2)}$$

To obtain the velocity invariant of the slider, we differentiate the formula (1):

$$V_{i4} = \frac{ds_{4i}}{d\phi_2} = sin\phi_2 + \lambda_3 \, sin\vartheta_3 \frac{d\vartheta_3}{d\phi_2}. \qquad \textbf{(3)}$$

With allowance (2) formula (3) takes form:

$$V_{i4} = sin\phi_2 + tg\vartheta_3 \cdot cos\phi_2. \qquad \textbf{(4)}$$

The linear acceleration invariant of the slider 4 is obtained by differentiating the formula of its velocity invariant:

$$W_{i4} = \frac{dV_{4i}}{d\phi_2} = cos\,\phi_2 + \lambda_3 \left[cos\,\vartheta_3 \left(\frac{d\vartheta_3}{d\phi_2} \right)^2 + sin\,\vartheta_3 \frac{d_2\vartheta_3}{d\phi_2^2} \right]. \quad \textbf{(5)}$$

where $\frac{d_2\upsilon_3}{d\phi_2^2} = \frac{cos^2\phi_2 \cdot sin\,\upsilon_3}{\lambda_3^2 \cdot cos^3\vartheta_3} - \frac{sin\,\phi_2}{\lambda_3 \cdot cos\,\vartheta_3}$ – angular acceleration of connecting rod 3.

To find the current values of the angular velocity invariant and angular acceleration invariant of the gear 6, shaft 8 and disk knives 9, we use the formula:

$$\omega_{i6,8,9} = \frac{sin\,\phi_2 + \lambda_3\, sin\,\vartheta_3 \frac{d\vartheta_3}{d\phi_2}}{\lambda_4}, \quad \textbf{(6)}$$

$$\varepsilon_{i6,8,9} = \frac{cos\,\phi_2 + \lambda_3 \left[cos\,\vartheta_3 \left(\frac{d\vartheta_3}{d\phi_2} \right)^2 + sin\,\vartheta_3 \frac{d_2\vartheta_3}{d\phi_2^2} \right]}{\lambda_4}. \quad \textbf{(7)}$$

where λ4 = R6/R2 – relative gear 6 radius.

The total relative instantaneous power of the cutting unit drive includes the components (without friction in the guides) [8]:

$$N_{i\Sigma} = N_{i1} \pm N_{i2} \pm N_{i3}, \quad \textbf{(8)}$$

where N_{i1} – relative instantaneous power spent on overcoming of technological resistance due to grooves cutting in corrugated board; N_{i2} – the relative instantaneous power spent on overcoming inertial loads caused by elements of the cutting unit mass with translational motion; N_{i3} – the relative instantaneous power spent on overcoming inertial loads caused by the elements of the cutting unit mass with rotational motion. The sign of the relative power components depends on the sign of the acceleration of the cutting unit elements.

Relative instantaneous power spent on the overcoming of technological resistance:

$$N_{i1} = n_9 \cdot M_{mo} \cdot \omega_{i9}, \quad \textbf{(9)}$$

where n_9 – number of disk knives 9, M_{mo} – torque of the technological resistance to corrugated board cutting, ω_{i9} – relative angular velocity of disk knives 9.

Relative instantaneous power spent on overcoming of inertial loads caused by elements of the cutting unit mass with translational motion:

$$N_{i2} = \pm\sum(n_k \cdot m_k)W_{i4} \cdot V_{i4} = \pm(m_4 + m_6 + m_8 + n_9 \cdot m_9)W_{i4} \cdot V_{i4}, \quad \textbf{(10)}$$

where m_4, m_6, m_8, m_9 – the mass, correspondingly, of the slider 4, the gear 6, the shaft 8 and the disk knife 9; W_{i4} і V_{i4} – invariants of linear velocity and acceleration of slider 4.

Relative instantaneous power spent on overcoming the inertial loads caused by elements of the cutting unit mass with rotational motion:

$$N_{i3} = \pm \sum (n_k \cdot J_k) \varepsilon_{i6} \cdot \omega_{i6} = \pm (J_6 + J_8 + n_9 \cdot J_9) \varepsilon_{i6} \cdot \omega_{i6}, \qquad \mathbf{(11)}$$

where J_6 = 0,5$m_6 \cdot r_6^2$, J_8 = 0,5$m_8 \cdot r_8^2$ та J_9 = 0,5$m_9 \cdot r_9^2$ [10] – moments of inertia, correspondingly, of the gear 6, shaft 8 and disk knife 9; ε_{i6} і ω_{i6} – invariants of angular velocity and acceleration of gear 6.

Thus, the given dependences form the method of calculating the values of the relative power consumption, which spent by the cutting unit for cutting grooves in the corrugated board blanks depending on its geometric parameters and operational mode. The obtained values are important for the engineering design of the cardboard cutting unit and acquisition with rational power drive.

CONCLUSIONS

The need to provide modern industrial goods with large-sized distribution packaging is associated with the complexity of its involutes making using die-cutting equipment, which is limited by the format of the working area. Therefore, the large-sized involute forming from several separate by ways of gluing or binding with saddle stitching, that greatly complicates the technological process. With purpose of drawbacks elimination, new technological process was proposed. Was developed the unit for the manufacture of large-sized involutes by means of scissor cutting of cardboard blanks by moving disk instruments, which are driven by a crank-sliding mechanism. Mathematical formulas for finding the invariants of its kinematic parameters and the relative instantaneous power spent by the unit for manufacture of the involute components made of corrugated board are derived.

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