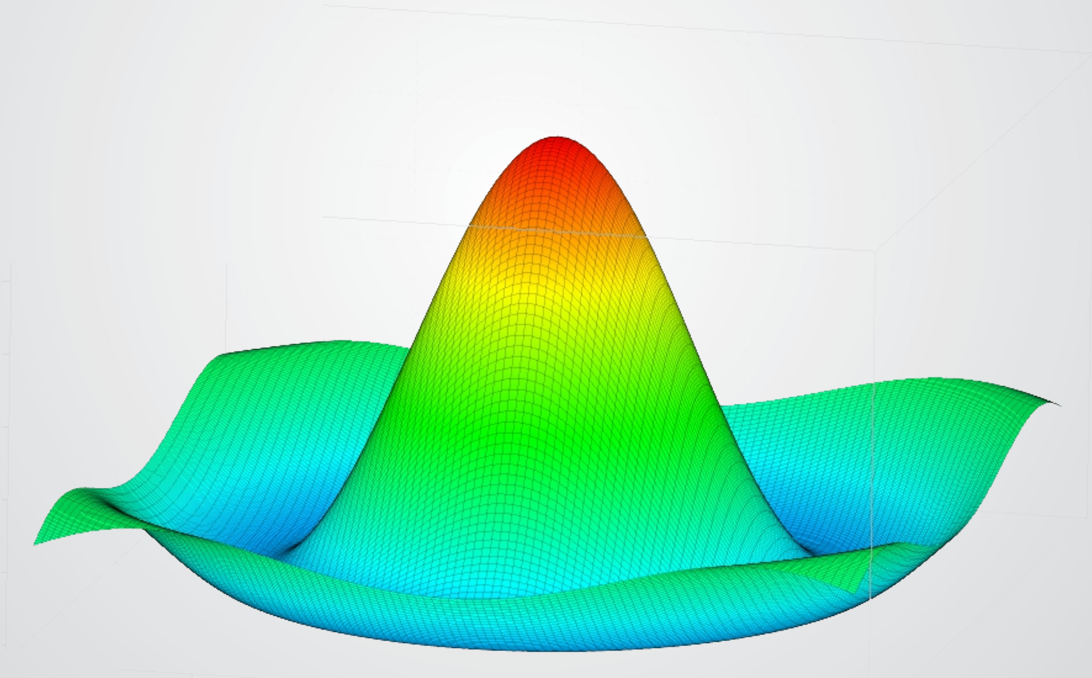
Journal of
Food and Packaging
Science, Technique and Technologies

Proceeding of conference
“Development of the Science, Technologies and Techniques for the Manufacture, Packaging, Storage and Distribution of Foods”



Volume 2

4

ISSN 1314-7773

RESEARCH OF THE PROFILE'S GEOMETRY OF SCREW CONVEYORS, WHICH ARE FORMING PART OF TRANSPORT SYSTEMS FOR MOVING CARTON PACKAGES

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Abstract: *Transport system with two timing screw are can used in the packaging equipment for the detaching single parallelepipedic form and moving with the specified steps. When designing the timing screw is necessary to find such a surface of screw's blade which moves and ensures safety of carton package damage. To do this, necessary mathematically describe the trajectory of the contact points of the angles of the package with surface of screw's blade. This trajectory is a line, that is forms the profile of the screw.*

Key words: carton box, timing screw conveyors, gift shop packs, conveyor.

I. Introduction

Screw conveyors, that are the forming part of transport systems of packaging equipment, are increasingly used for moving packages at the various stages of their formation and treatment.

The advantages of such transport systems includes the ability to move different shape rigid and semi-rigid packages: glass bottles and jars, plastic bottles and jars, carton packages, etc. In spite of constant changes in the geometry of such a package shape, the overall design of the timing screw transport system is not changing. The screw's profile changes only.

Except moving packages (Fig. 1, d) on the timing screw conveyors, at the same time, they can be reorientate in the horizontal plane or in the space of using the loop-shaped guides (Fig. 1, b).

One of perspective development directions of the timing screw is moving carton parallelepipedic form packages in packaging machines. Unlike other transport systems, they may ensure accomplishing all transport and reorientation operations, when the carton flat-packages are made.

On stage of making carton half-finished packages, transport system with timing screws makes such operations: detachment single flat-package from magazine, forming the half-finished packages, motion half-finished packages with the specified pitch. The transport systems with timing screw conveyor and perform a variety operations about carton half-finished packages.

The main of that operations are: detaching single carton half-finished package from previously formed clump of them into one line; motion carton half-finished packages with the specified pitch to perform different technological operation, orientation carton packages relative to the working body of packaging machine for filling, close the carton package end (cover), ability to conduct stop carton package one or more times to perform different technological operation, combining and dividing lines of transporting carton packages, grouping packages.

Maintenance of performance necessary technological operations carried out by changing the profile of the load-bearing face of the timing screw.

II. Materials and methods

Transport system with two timing screw are can used in the packaging equipment for the detaching single parallelepipedic form and moving with the specified steps (Fig. 2). Sides of such packs fit tightly, and the lateral edges is not round. So screw's blade haven't can squeeze between two adjacent packages, taken and detached one package without rotation it to the movement direction.

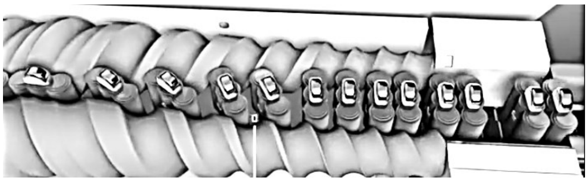
At every turn of the timing screws are performed such operations about about carton packages.

Reorientation with rotation of package on the timing screws relative to the its movement direction for the creation clearance between package and previously formed clump of packages into one line are happening in two stages:

- if the timing screw was rotated by 180 degrees, package was moved in pocket (Fig. 3, a);

- if the timing screw was rotated by angle of 180 to 360 degrees, package was rotated to the movement direction (Fig. 3, b). On this basis was created clearance between package and previously formed clump of packages into one line.

a



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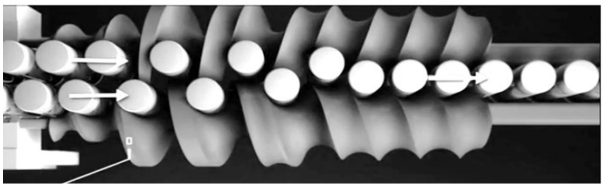

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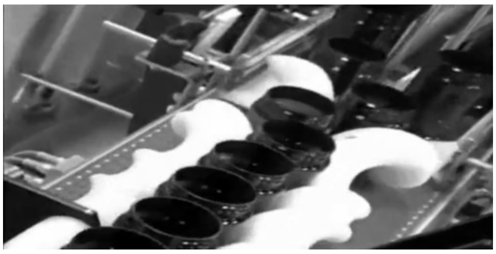

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Figure 1. *Combining technological operations for the transport system with timing screws, that move different packages: a) grouping packages – moving and picking up two or more cylindrical packages in a screw's pocket; b) moving and orienting semi-rigid packages in axial position of 90°; c) moving and orienting rigid parallelepipedic packages in axial position of 90°; d)* combining – *motion of packages, when the two output lines of transporting packages need to combine into one line; e) motion of packages, when the one output line of transporting packages need to divide into two lines; f)* dividing – *moving and orienting glass jars in the space of using the loop-shaped guides*

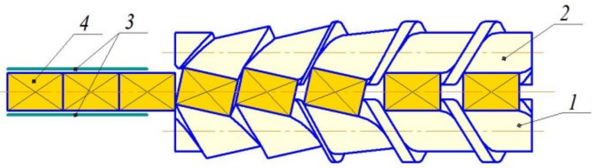
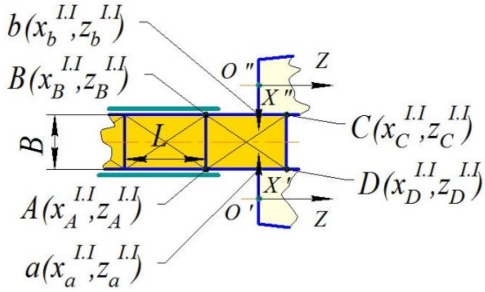


Figure 2. *Diagram of the transport system with two timing screw conveyors, that are moving carton packages: 1,2 - screw conveyors, 3 - restrictive guides for packages was grouped along line; 4 - carton packages.*



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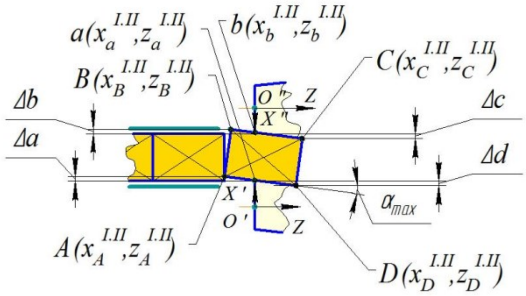


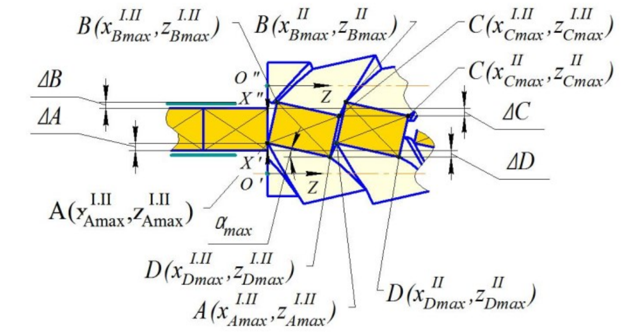
b

Figure 3. *Diagram for determining the geometrical parameters of screw's profile on stage of detaching package from previously formed clump of packages into one line during their rotation: a) by the angle of 0° to 180°; b) by the angle of 180° to 360°*

If the timing screws are rotating by angle of 360 to 720 degrees, blade of timing screw 2 is squeezing between previously formed clump of packages into one line and rotating package, taking, detaching and moving rotated package under the law uniform linear motion with zero acceleration (Fig. 4, a)

If the timing screws are rotating by angle of 720 to 1080 degrees, rotated package is moving with the increased pitch under the given law of acceleration change (Fig. 4, b).

If the timing screws are rotating by angle of 1080 to 1440 degrees, rotated package is returning to its original position (Fig. 4, c).



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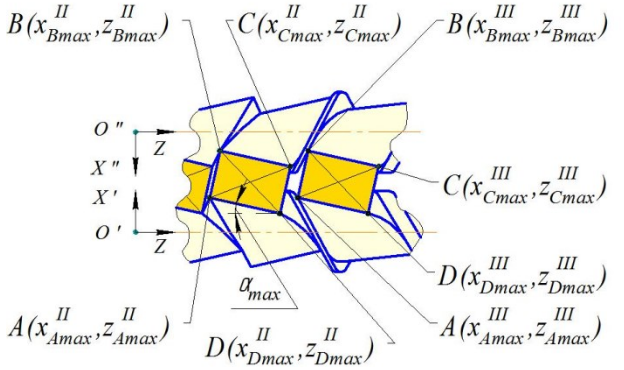

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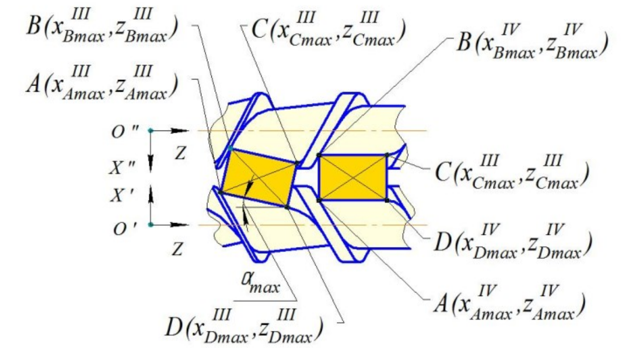


c

Figure 4. *Diagram for determining the geometrical parameters of screw's profile, on stage of motion of packages in transport system, during their rotation:*
a) by the angle of 360° to 720°;
b) by the angle of 720° to 1080°
b) by the angle of 1080° to 1440°

At the subsequent rotation of the timing screw packages move with the increased pitch under the given law of acceleration change to perform next technological operations.

When designing the timing screw is necessary to find such a surface of screw's blade which moves and ensures safety of carton package damage.

To do this, necessary mathematically describe the trajectory of the contact points of the angles of the package with surface of screw's blade. This trajectory is a line, that is forms the profile of the screw.

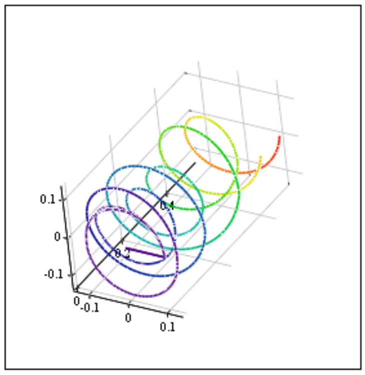
In describing the screw geometry were the following assumptions:
- geometric center package moves in a straight line;
- if the timing screws rotate by 180 degrees, package moves to the side of its smaller face in screw's pocket for the distance equal to half the length of package.

III. Results and discussion

Results of mathematically describe the trajectory of the contact points of the angles of the package with surface of screw's blade are presented in Table.

Distance between the corner of rotated package and lateral side of previously formed clump of packages into one line is varied within the range $\Delta a = \Delta c = [0; \Delta A]$; $\Delta b = \Delta d = [0; \Delta D]$ and is defined for the following formulas:

$$\begin{cases} \Delta a = 0{,}5 \cdot [B - L \cdot \sin(\gamma - \alpha) / \cos(\gamma)]; \\ \Delta d = 0{,}5 \cdot [L \cdot \sin(\gamma + \alpha) / \cos(\gamma) - B]; \\ \Delta A = 0{,}5 \cdot [B - L \cdot \sin(\gamma - \alpha_{max}) / \cos(\gamma)]; \\ \Delta D = 0{,}5 \cdot [L \cdot \sin(\gamma + \alpha_{max}) / \cos(\gamma) - B]. \end{cases}$$



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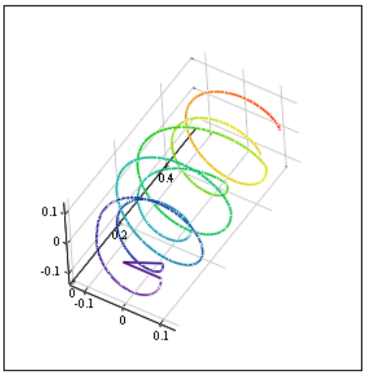

b

Figure 5. *The trajectory of the contact points of the angles of the package with surface of screw's blade for:*
a) timing screw 1 and points A, D;
b) timing screw 2 and points B, C

Table 1. *Geometric parameters of the profile of the timing screws*

Value of rotation timing screw	Screw's rotation angle	Dimensionless coefficients, that characterize the change of kinematic parameters of package's movement	Coordinates of line, that is forms the profile of the timing screws	
			timing screw 1 (coordinate system X′O′Z)	*timing screw 2* (coordinate system X″O″Z)
1	**2**	**3**	**4**	**5**
I	*0°...180°*	$K_{tp}^{\mathrm{I.I}} \in [0; k_{tp}]$ $K_t^{\mathrm{I.I}} \in [0; 0,5]$ $K_{zp}^{\mathrm{I.I}} \in [0; 0,5]$	$z_a^{\mathrm{I.I}} = 0$ $z_D^{\mathrm{I.I}} = L_n \cdot K_{zp}^{\mathrm{I.I}}$ $x_a^{\mathrm{I.I}} = x_D^{\mathrm{I.I}} = 0,5 \cdot D \cdot \sin(2\pi \cdot K_t^{\mathrm{I.I}})$ $y_a^{\mathrm{I.I}} = y_D^{\mathrm{I.I}} = 0,5 \cdot D \cdot \cos(2\pi \cdot K_t^{\mathrm{I.I}})$	$z_b^{\mathrm{I.I}} = 0$ $z_C^{\mathrm{I.I}} = z_D^{\mathrm{I.I}}$ $x_b^{\mathrm{I.I}} = x_C^{\mathrm{I.I}} = 0,5 \cdot D \times ...$ $... \times \sin(-2\pi \cdot K_t^{\mathrm{I.I}})$ $y_b^{\mathrm{I.I}} = y_C^{\mathrm{I.I}} = y_a^{\mathrm{I.I}} = y_D^{\mathrm{I.I}}$
	180°...360°	$K_{tp}^{\mathrm{I.II}} \in [k_{tp}; 0]$ $K_t^{\mathrm{I.II}} \in [0,5; 1]$ $K_{zp}^{\mathrm{I.II}} \in [0,5; 1]$ $K_{t\alpha}^{\mathrm{I.II}} \in [0; 1]$ $K_{\alpha}^{\mathrm{I.II}} \in [0; 1]$	$z_a^{\mathrm{I.II}} = 0$ $z_D^{\mathrm{I.II}} = L \cdot [K_{zp}^{\mathrm{I.I}} - 1 + \cos(\alpha_{max} \cdot K_{\alpha}^{\mathrm{I.II}})]$ $x_a^{\mathrm{I.II}} = (0,5 \cdot D + \Delta a) \cdot \sin(2\pi \cdot K_t^{\mathrm{I.II}})$ $x_D^{\mathrm{I.II}} = (0,5 \cdot D - \Delta D) \cdot \sin(2\pi \cdot K_t^{\mathrm{I.II}})$ $y_a^{\mathrm{I.II}} = (0,5 \cdot D + \Delta a) \cdot \cos(2\pi \cdot K_t^{\mathrm{I.II}})$ $y_D^{\mathrm{I.II}} = (0,5 \cdot D - \Delta D) \cdot \cos(2\pi \cdot K_t^{\mathrm{I.II}})$	$z_b^{\mathrm{I.II}} = 0$ $z_C^{\mathrm{I.II}} = z_D^{\mathrm{I.II}} + B \times ...$ $... \times \sin(\alpha_{max} \cdot K_{\alpha}^{\mathrm{I.II}})$ $x_C^{\mathrm{I.II}} = (0,5 \cdot D + \Delta a) \times ...$ $... \times \sin(-2\pi \cdot K_t^{\mathrm{I.II}})$ $x_b^{\mathrm{I.II}} = (0,5 \cdot D - \Delta D) \times ...$ $... \times \sin(-2\pi \cdot K_t^{\mathrm{I.II}})$ $y_C^{\mathrm{I.II}} = y_a^{\mathrm{I.II}}$ $y_b^{\mathrm{I.II}} = y_D^{\mathrm{I.II}}$
II	*360°...720°*	$K_t^{\mathrm{II}} \in [0; 1]$ $K_z^{\mathrm{II}} \in [0; 1]$	$z_A^{\mathrm{II}} = z_{a\,max}^{\mathrm{I.II}} + [L \cdot \cos(\alpha_{max}) + h_{min}] \times ...$ $... \times K_z^{\mathrm{II}}$ $z_D^{\mathrm{II}} = z_A^{\mathrm{II}} + L_n \cdot \cos(\alpha_{max})$ $x_A^{\mathrm{II}} = (0,5 \cdot D + \Delta A) \cdot \sin(2\pi \cdot K_t^{\mathrm{II}})$ $x_D^{\mathrm{II}} = (0,5 \cdot D - \Delta D) \cdot \sin(2\pi \cdot K_t^{\mathrm{II}})$ $y_A^{\mathrm{II}} = (0,5 \cdot D + \Delta A) \cdot \cos(2\pi \cdot K_t^{\mathrm{II}})$ $y_D^{\mathrm{II}} = (0,5 \cdot D - \Delta D) \cdot \cos(2\pi \cdot K_t^{\mathrm{II}})$	$z_B^{\mathrm{II}} = z_A^{\mathrm{II}} + B \cdot \sin(\alpha_{max})$ $z_C^{\mathrm{II}} = z_D^{\mathrm{II}} + B \cdot \sin(\alpha_{max})$ $x_C^{\mathrm{II}} = (0,5 \cdot D + \Delta A) \times ...$ $... \times \sin(-2\pi \cdot K_t^{\mathrm{II}})$ $x_B^{\mathrm{II}} = (0,5 \cdot D - \Delta D) \times ...$ $... \times \sin(-2\pi \cdot K_t^{\mathrm{II}})$ $y_C^{\mathrm{II}} = y_A^{\mathrm{II}}$ $y_B^{\mathrm{II}} = y_D^{\mathrm{II}}$
III	*720°...1080°*	$K_t^{\mathrm{III}} \in [0; 1]$ $K_z^{\mathrm{III}} \in [0; 1]$	$z_A^{\mathrm{III}} = z_{A\,max}^{\mathrm{II}} + [L \cdot \cos(\alpha_{max}) + h_{min}] \times ...$ $... \times K_z^{\mathrm{III}}$ $z_D^{\mathrm{III}} = z_A^{\mathrm{III}} + L \cdot \cos(\alpha_{max})$ $x_A^{\mathrm{III}} = (0,5 \cdot D + \Delta A) \cdot \sin(2\pi \cdot K_t^{\mathrm{III}})$ $x_D^{\mathrm{III}} = (0,5 \cdot D - \Delta D) \cdot \sin(2\pi \cdot K_t^{\mathrm{III}})$ $y_A^{\mathrm{III}} = (0,5 \cdot D + \Delta A) \cdot \cos(2\pi \cdot K_t^{\mathrm{III}})$ $y_D^{\mathrm{III}} = (0,5 \cdot D - \Delta D) \cdot \cos(2\pi \cdot K_t^{\mathrm{III}})$	$z_B^{\mathrm{III}} = z_A^{\mathrm{III}} + B \cdot \sin(\alpha_{max})$ $z_C^{\mathrm{III}} = z_D^{\mathrm{III}} + B \cdot \sin(\alpha_{max})$ $x_C^{\mathrm{III}} = (0,5 \cdot D + \Delta A) \times ...$ $... \times \sin(-2\pi \cdot K_t^{\mathrm{III}})$ $x_B^{\mathrm{III}} = (0,5 \cdot D - \Delta D) \times ...$ $... \times \sin(-2\pi \cdot K_t^{\mathrm{III}})$ $y_C^{\mathrm{III}} = y_A^{\mathrm{III}}$ $y_B^{\mathrm{III}} = y_D^{\mathrm{III}}$
IV	*1080°...1440°*	$K_t^{\mathrm{IV}} \in [0; 1]$ $K_z^{\mathrm{IV}} \in [0; 1]$	$z_A^{\mathrm{IV}} = z_{A\,max}^{\mathrm{III}} + L\ \ [0,5\ \ \cos(\gamma - ...$ $...- \alpha_{max} \cdot K_{\alpha}^{\mathrm{IV}}) / \cos(\gamma) + h_{min} + ...$ $...+ 0,5] \cdot K_z^{\mathrm{IV}}$ $z_D^{\mathrm{IV}} = z_{D\,max}^{\mathrm{III}} + L \cdot [0,5 \cdot \cos(\gamma - ...$ $...- \alpha_{max} \cdot K_{\alpha}^{\mathrm{IV}}) / \cos(\gamma) + h_{min} + ...$ $...+0,5] \cdot K_z^{\mathrm{IV}}$ $x_A^{\mathrm{IV}} = (0,5 \cdot D + \Delta A - \Delta a) \times ...$ $... \times \sin(2\pi \cdot K_t^{\mathrm{IV}})$ $x_D^{\mathrm{IV}} = (0,5 \cdot D - \Delta D + \Delta d) \times ...$ $... \times \sin(2\pi \cdot K_t^{\mathrm{IV}})$ $y_A^{\mathrm{IV}} = (0,5 \cdot D + \Delta A - \Delta a) \times ...$ $... \times \cos(2\pi \cdot K_t^{\mathrm{IV}})$ $y_D^{\mathrm{IV}} = (0,5 \cdot D - \Delta D + \Delta d) \times ...$ $... \times \cos(2\pi \cdot K_t^{\mathrm{IV}})$	$z_B^{\mathrm{IV}} = z_A^{\mathrm{IV}} + B \times ...$ $... \times \sin[\alpha_{max}(1 - K_{\alpha}^{\mathrm{IV}})]$ $z_C^{\mathrm{IV}} = z_D^{\mathrm{IV}} + B \times ...$ $... \times \sin[\alpha_{max}(1 - K_{\alpha}^{\mathrm{IV}})]$ $x_C^{\mathrm{IV}} = (0,5 \cdot D + ...$ $...+ \Delta A - \Delta a) \cdot \sin(-2\pi \cdot K_t^{\mathrm{IV}})$ $x_B^{\mathrm{IV}} = (0,5 \cdot D - \Delta D + \Delta d) \times ...$ $... \times \sin(-2\pi \cdot K_t^{\mathrm{IV}})$ $y_C^{\mathrm{IV}} = y_A^{\mathrm{IV}}$ $y_B^{\mathrm{IV}} = y_D^{\mathrm{IV}}$

In the table taken such symbols: L , B – length and width of the carton packages; $\alpha = [0, \alpha_{max}]$ – package's rotation angle on timing screws to the movement direction of packages; (x, y, z) – coordinates of the line which is the screw's profile; D – outside diameter of the timing screws; K_{tp} , K_t – dimensionless coefficients, that characterize the time change of package movement assisted pusher and screws relative to moving direction; $K_{t\alpha}$ – dimensionless coefficients, that characterize the time change of package movement when it rotate in horyzontal plane to the moving direction assisted the timing screws; k_{tp} – dimensionless coefficients that characterize the time change of package movement assisted pusher at $z_{Cmax}^{I.I}$ distance, where distance is $z_{Cmax}^{I.I} = z_{Dmax}^{I.I} = 0{,}5L$; $K_{zp} = f(K_{tp})$ – dimensionless coefficient, that describes the change of package's movement assisted pusher relative to moving direction; $K_z = f(K_t)$ – dimensionless coefficient, that describes the change of package movement assisted timing screw relative to moving direction; $K_\alpha = f(K_{t\alpha})$ – dimensionless coefficient, that describes the change of package's rotation angle assisted timing screw relative to moving direction; h_{min} – the minimal possible the thickness of screw's blade.

IV. Conclusions

Under the conducted research of movement carton packages on timing screw was defined: the optimum geometrical profile of the timing screws, that allows to provide a highly productive work, uninterrupted process of filling and packaging in automatic packing machine.

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