

INVESTIGATION OF CONSTRUCTIVE GEOMETRICAL AND FILLING COEFFICIENTS OF COMBINED GRINDING SCREW CONVEYOR

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P.G. Pankiv V.R.¹⁾, Ph.D. Eng. Tokarchuk O.A.²⁾

¹⁾ Ternopil Ivan Pul'uj National Technical University, Ruska str., 56, Ternopil / Ukraine;

²⁾ Vinnitsa National Agrarian University, Sonjachna str., 5, Vinnitsa / Ukraine

E-mail: vitalijpankiv25@gmail.com

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ABSTRACT

This paper presents the structure and technological processes of combined grinding screw conveyor. The theoretical dependencies, which describe the nature of the geometric factor of screw conveyor and load factor of combined grinding screw conveyor, depending on its design parameters, are also substantiated here.

INTRODUCTION

Further development of the agricultural sector of Ukraine is possible through the use of progressive mechanization means for agricultural products production processes. Improving the technical and economic performance of processing enterprises is achieved through the development and introduction of energy saving technologies and technical facilities that are designed for preparation and processing of agricultural raw materials (Baranovsky V.M., 2014, Hevko R.B., Klendiy O.M., 2014).

Screw conveyors (augers, conveyors) have gained wide acceptance in various industries. In particular, in the agricultural sector, screw conveyors are designed for horizontal, slope and vertical continuous moving of stream at considerable distances of agricultural products, such as root crops, grains, meal mixture. In addition, screw conveyors due to their design features also can simultaneously perform related functions - mixing of materials, grinding or crushing of materials, dosage, etc. (Hevko Iv.B., 2013).

The combination of performing one or more technological operations, along with the transportation of materials, which is inherent for the combined screw conveyor, is their defining feature.

Improvement of existing designs of screw transport mechanisms can significantly increase the performance and reliability of technological operations and contributes to the further development of production. Screw conveyors are part of comprehensive mechanization and automation. According to various estimates, their share in cargo handling operations is 40-45% (Baranovsky V.M., Potapenko M.V., 2016).

Purpose of work is to improve technological process parameters of simultaneous grinding and transportation of roots through the development and justification of working bodies' parameters of combined grinding screw conveyor. Investigation of transportation process technological parameters is based on the analysis of combined grinder conveyor design features.

MATERIAL AND METHODS

Screw conveyors, as separate technical element of transport mechanisms, are widely used in layout schemes of machines for reloading or moving materials due to their simple design, of maintenance service and the ability to load and partial unload the material at any location of the processing line.

Screw transport mechanisms are widely used in the construction of agricultural machinery - grain harvesters, beet and potato harvesters, fertilizers, grinders, seed disinfectant, etc. (Voytyuk D.G., et al., 2015; Hevko R.B., Zalutskyi S.Z., et al., 2015).

Also screw conveyors are used for the mechanization of loading and unloading processes of bulk and large-size materials, such as corn and different kinds of root crops - wheat, corn, sugar and fodder beet, rape plant, chicory. For this purpose, as transportation means for the mechanization of livestock farms, bakeries use mobile assembled augers, trucks and transporters.

Combined grinding screw conveyors are widely used in agriculture production sector, processing and food branches of industry which are specified due to the wide range of technological processes of products collecting and recycling.

Therefore, during their designing should be taken into account the specific technical requirements and functional performances of machines to carry out the relevant work, and also the features of transport-technological processes, agrobiological, physical and mechanical properties of the products to be transported (Hevko Iv.B., 2008).

Investigation of transportation process technological parameters is based on the analysis of combined grinder conveyor design features.

RESULTS

Analysis of the current state of screw transport mechanisms functioning showed that there are significant preconditions for further research, aimed at the development and application of energy-saving, high technology for combined screw conveyors. They will ensure effective implementation of various functions of related operations for simultaneously transporting and grinding agricultural crop in their processing.

Based on the given analysis of technological parameters for materials transportation of agricultural production, we have offered constructive scheme of the improved combined grinding screw conveyor, fig. 1.

Combined grinding screw conveyor (combined SGC) consists of a loading bunker 1 and 2 and the guide tube. In the guide tube 2 is installed the screw conveyor, which is designed as a drive shaft 3 on which is installed the drum 4. On the drum of drive shaft, along separate helical lines, fixed spiral turns 5 and plate knife-grinders 6 are installed on the drum between the spiral turns and at an angle to the cross-section of the drum. Screw lines of spiral turns and grinder blades are made with variable step, concurrently step of spiral turns and step of plate grinder blades with a constant lifting angle of spiral line towards the unloading part of the guide tube.

The material, for example root crops, fed into the loading bunker 1, which later moved to the guide tube 2 to the screw conveyor, or to the plate grinder knives 6. During the rotation of the drive shaft 3 and, accordingly, the drum 4 and the plate grinder knife occurs simultaneous grinding of root crops and transportation (movement) of root crops milled particles by the related installation of plate grinder knives at an angle to the cross-section of the drum and its attachment to the drum along the spiral line. In addition, simultaneously with the movement of root crops milled particles by plate grinder knives also occurs their transportation as spiral turns towards unloading part of the guide tube.

By increasing the speed of the axial movement of root crops milled particles, increased performance of combined SGC was generated.

The main criteria that characterize the technological and economic efficiency of any transport vehicles or mechanisms, which move or deliver materials to a given point, is the productivity of their performance, consumption of power inputs during materials transportation process, reliability and stability, performance of the process, work resource and others (Rogatinsky R., 2012).

Combined SGC (fig. 1) has its own specific technological and structural elements and processes that significantly distinguish it from the traditional basic screw mechanisms. Simultaneous presence of technological operations, grinding and transporting of the material (root crops), or the presence of grinder blades 6, which are installed in interterm space of screw conveyor along helical lines, make significant adjustments to existing techniques and calculating methods for the screw mechanisms.

In this respect, one of the priorities and the special factors, which will regulate the calculated productivity of combined SGC, is an index that characterizes volumetric filling factor of screw conveyor working space (Hevko R.B., Dzyura V.O., Romanovsky R.M., 2014). In turn, filling factor of screw conveyor working space depends not only on the amount of material that goes into it, but also on the design of the screw conveyor main transporting element (Hevko R.B., Zalutskyi S.Z., Tkachenko I.G., et al., 2015).

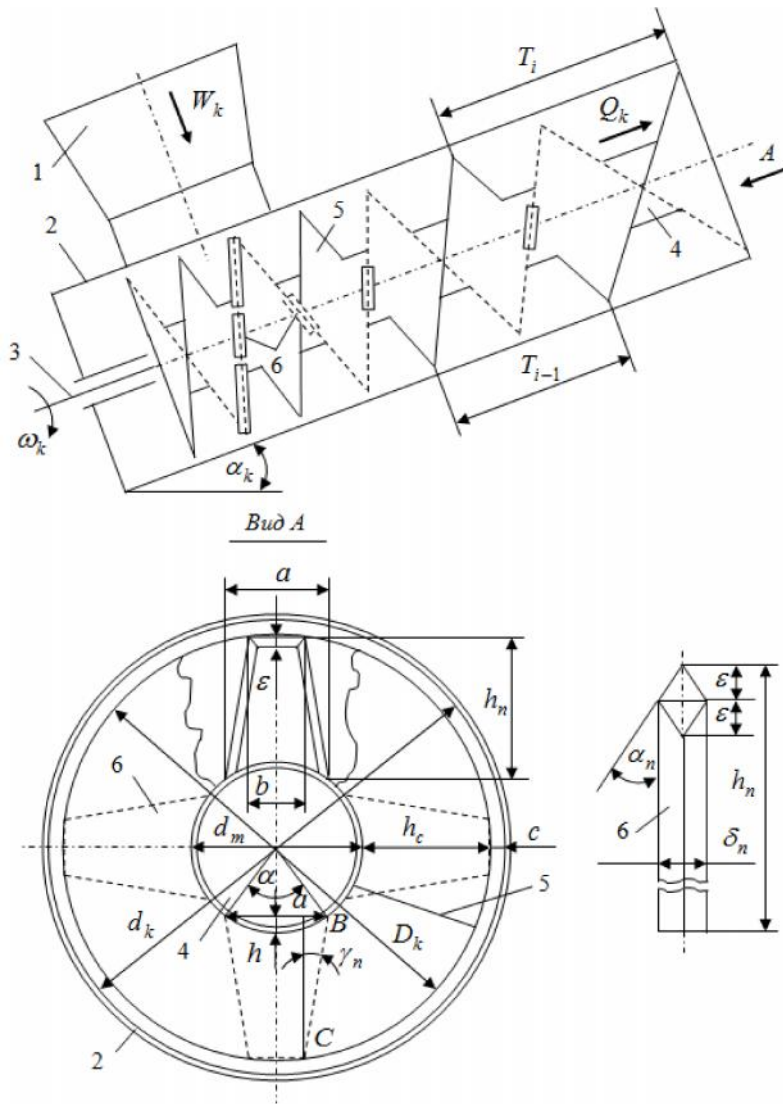


Fig. 1 - Construction scheme of combined grinding screw conveyor
 1 – loading bunker; 2 – guide tube; 3 – drive shaft; 4 – drum; 5 – spiral turn;
 6 – grinder knife

In the general context, filling factor of screw conveyor working space shows, which is the part of useful volume filled with material that moves along the turns of the screw.

Then, taking into account known provisions (Hevko R.B., Zalutskyi S.Z., Tkachenko I.G., et al., 2015) we represented the filling factor of combined SGC (hereinafter - filling factor k_z) as the ratio of the interterm space volume of screw conveyor, which is filled with grinded root crops, and the total volume of combined SGC, as follows:

$$k_z = V_{zk} / V_z \tag{1}$$

where

V_{zk} – filled volume of screw conveyor space, m^3 ;

V_z – total amount of combined SGC, space, m^3 .

To determine the set volume V_{zk} , V_z and ultimately filling factor k_z and calculate performance let's consider the composite structural and design scheme to determine the technological indicators of combined SGC, which is shown in fig. 1.

We initiate indication of the first helical turn step by alphabetic expression T_1 , second helical turn – T_2 , and last i - helical coil - T_i .

According to fig. 1, total volume V_z of combined SGC space consists of internal volume of the guide tube 2, or the volume of straight hollow cylinder:

$$V_z = 0,25fd_k^2L_k = 0,25f(D_k + 2c)^2(T_1n_1 + T_2n_2 + \dots + T_in_j), [\text{m}^3] \quad (2)$$

where

d_k – inner diameter of the covering, m;

L_k – working height of the guide tube, or the length of screw conveyor, m;

D_k – outside diameter of screw conveyor, m;

c – the gap between the external edge of the spiral turn and the inner diameter of the guide tube, m;

T_1, T_2, \dots, T_i – the step of first, second, i -th spiral coil, m;

n_1, n_2, \dots, n_j – the total number of spiral turns per one step, m.

Filled volume of screw conveyor space V_{zk} by the grinded root crops will be determined according to the following considerations. V_{zk} , essentially, is a useful volume where root crops are placed loaded and grinded during the transportation.

The useful volume of screw conveyor V_{zk} consists of volume difference of screw conveyor total volume V_k and the total volume, occupied by the working elements of screw conveyor V_e , or the amount of drum volume V_{dm} , the volume of spiral turns V_c and the volume V_n knives-grinders, as follows:

$$V_{zk} = V_k - V_e; \quad V_e = V_{dm} + V_c + V_n; \quad V_{zk} = V_k - V_{dm} - V_c - V_n, [\text{m}^3] \quad (3)$$

where

V_{dm} – total volume of the screw conveyor, m^3 ;

V_{dm} – the volume of the tube drum of the screw conveyor, m^3 ;

V_e – total volume, occupied by the working elements of the screw conveyor, m^3 ;

V_c – volume occupied by the spiral turns, m^3 ;

V_n – volume occupied by knife-grinders, m^3 .

After substituting (2) and (3) in (1), we obtain:

$$k_z = \frac{1 - \frac{V_e}{V_k}}{0,25f(D_k + 2c)^2(T_1n_1 + T_2n_2 + \dots + T_in_j)} \quad (4)$$

Let's designate in (4) the ratio $V_e/V_k = k_n$, where the symbol k_n is the definition of constructive geometric factor of combined SGC (hereinafter – constructive geometric factor k_n), only during one configured constructive cycle of combined SGC technological process.

Then, the relation (4) will have the following form:

$$k_z = \frac{(1 - k_n)V_k}{0,25f(D_k + 2c)^2(T_1n_1 + T_2n_2 + \dots + T_in_j)} \quad (5)$$

To set the limits of structural changes of geometric factor k_n determine the total volume of screw conveyor V_k , total volume occupied by the working elements of the screw conveyor V_e which consists of the volume of the screw conveyor tube drum V_{dm} , the volume occupied by the spiral turns V_c , the volume

occupied by knife-grinders V_n . However, according to fig. 1 and (Berd J., 2008) we have:

$$V_k = 0,25fD_k^2L_k, [m^3]; \quad V_{d_m} = 0,25fd_m^2L_k, [m^3]; \quad V_c = F_n l_c z, [m^3]; \quad V_n = V_{1n} n_n, [m^3] \quad (6)$$

where

d_m – diameter of the screw conveyor tube drum, m;

F_n – cross sectional area of screw conveyor card bales turn $F_n = u_c h_c, m^2$;

u_c – thickness of the spiral turn card bales, m;

h_c – height of the spiral turn card bales $h_c = 0,5(D_k - d_m), m$;

l_c – total length of the spiral line by the average diameter of the screw conveyor, m;

z – number of the screw conveyor activities, units;

V_{1n} – volume of one knife-grinder, m^3 ;

n_n – the amount of knife-grinders, units.

Or:

$$V_k = 0,25fD_k^2(T_1n_1 + T_2n_2 + \dots + T_in_j), [m^3] \quad (7)$$

$$V_{d_m} = 0,25fd_m^2(T_1n_1 + T_2n_2 + \dots + T_in_j), [m^3] \quad (8)$$

$$V_c = 0,5u_c z (D_k - d_m) \left(n_1 \sqrt{T_1^2 + 0,25(D_k + d_m)^2} + n_2 \sqrt{T_2^2 + 0,25(D_k + d_m)^2} + \dots \right. \\ \left. \dots + n_j \sqrt{T_j^2 + 0,25(D_k + d_m)^2} \right), [m^3] \quad (9)$$

The volume V_n , occupied by knife-grinders 6 can be determined according to the following considerations. Each knife-grinder made in straight prism form, which is based on equilateral trapezium, with this three working side edges of the prism from two sides sharpen with the grinding angle Γ_n , and side edge, which relies on a large basis b of the trapezium has the shape of a segment whose radius is the radius of the tube drum r_m of the screw conveyor.

Then the volume V_n , occupied by knife-grinder will be equal:

$$V_n = (V_{np} - V_z - V_{cn}) n_n, [m^3] \quad (10)$$

where

V_{np} – volume of direct prism, m^3 ;

V_z – total volume of direct prisms that are cut during the sharpening of side edges with basis BC , m^3 ;

V_{cn} – volume of straight prism, which is cut out of side edge with basis b , m^3 .

In such case (Shipachev V.S., 2003):

$$V_{np} = F_{mp} u_n = \frac{a+b}{2} h_n u_n, [m^3]; \quad V_z = 2V_{1z} + 4V_{2z}, [m^3]; \quad V_{cn} = F_c L_k, [m^3] \quad (11)$$

$$V_{1z} = 0,125u_n^2 b t g \Gamma_n, [m^3]; \quad V_{2z} = 0,125u_n^2 h_n / \cos \chi_n, [m^3] \quad (12)$$

$$V_z = 0,25u_n^2 b t g \Gamma_n + \frac{0,5u_n^2 h_n}{\cos \chi_n}, [m^3] \quad (13)$$

$$F_c = r_m^2 [(f r / 180) - \sin \Gamma] / 2, [m^2] \quad (14)$$

where

F_{mp} – area of main prism (trapezoid area) m^2 ;

a, b – base of trapezoid, m;

V_{1z} – volume which is cut out from one side of side edge with the base b , $V_{1z} = 0,5u_n \sqrt{b} / 2, m^3$;

V – triangle height $v = 0,5u_n \operatorname{tg} \Gamma_n$, m;

Γ_n – skew angle of side edge, grade;

V_{2z} – volume which is cut out from one side of side edge with the base BC , $V_{2z} = 0,5u_n v_{BC}$, m^3 ;

$BC = h_n / \cos \chi_n$ – length of the side edge $BC = h_n / \cos \chi_n$, m;

χ_n – the angle between the knife height and trapeze edge, grad;

F_c – segment area with height h , tighten by chord a and a central angle Γ , m^2 ;

r_m – the radius of the screw conveyor drum tube (m), with this $a = 2r_m \sin(\Gamma / 2)$, from where $\sin(\Gamma / 2) = a / 2r_m$, $\Gamma / 2 = \arcsin(a / 2r_m)$.

Then according to (11), (14) we will have:

$$V_{cn} = 0,25d_m^2 \left[\left(f \arcsin \frac{a}{d_m} \right) / 180 - \frac{a}{d_m} \cos \arcsin \frac{a}{d_m} \right] (T_1 n_1 + T_2 n_2 + \dots + T_i n_j), \quad [\text{m}^3] \quad (15)$$

Substituting the values of the components from (11) (13) (15) in equation (10) we obtained a formula for determining the volume V_n , which is occupied by knives-grinders:

$$V_n = \left[\left((a+b)h_n u_n - 0,5u_n^2 \left(\operatorname{btg} \Gamma_n + \frac{h_n}{\cos \chi_n} \right) - 0,5d_m^2 \times \right. \right. \\ \left. \left. \times \left[\left[\left(f \arcsin \frac{a}{d_m} / 180 \right) + \frac{a}{d_m} \cos \arcsin \frac{a}{d_m} \right] (T_1 n_1 - T_2 n_2 - \dots - T_i n_j) \right] \right) \right] \frac{n_n}{2}, \quad [\text{m}^3] \quad (16)$$

Then, the total volume V_e of the screw conveyor, according to (3), (8), (9) and (16), is defined by the formula:

$$V_e = 0,25\pi d_m^2 (T_1 n_1 + T_2 n_2 + \dots + T_i n_j) + 0,5\delta_n z (D_k - d_m) \times \\ \times \left(n_1 \sqrt{T_1^2 + 0,25(D_k + d_m)^2} + n_2 \sqrt{T_2^2 + 0,25(D_k + d_m)^2} + \dots + n_j \sqrt{T_j^2 + 0,25(D_k + d_m)^2} \right) + \\ + 0,5\theta_n \left[\left((a+b)h_n \delta_n - 0,5\delta_n^2 \left(\operatorname{btg} \alpha_n + \frac{h_n}{\cos \gamma_n} \right) - 0,5d_m^2 \times \right. \right. \\ \left. \left. \times \left[\left[\left(\pi \arcsin \frac{a}{d_m} / 180 \right) + \frac{a}{d_m} \cos \arcsin \frac{a}{d_m} \right] (T_1 n_1 - T_2 n_2 - \dots - T_i n_j) \right] \right) \right] \quad [\text{m}^3] \quad (17)$$

However, according to (4), the constructive geometric factor k_n of the screw conveyor will be determined by applying the formula:

$$k_n = \frac{0,5f d_m^2 (T_1 n_1 + T_2 n_2 + \dots + T_i n_j) + u_c z (D_k - d_m) \times \\ \times \left(n_1 \sqrt{T_1^2 + 0,25(D_k + d_m)^2} + n_2 \sqrt{T_2^2 + 0,25(D_k + d_m)^2} + \dots + n_j \sqrt{T_j^2 + 0,25(D_k + d_m)^2} \right) + \\ + n_n \left[\left((a+b)h_n u_n - 0,5u_n^2 \left(\operatorname{btg} \Gamma_n + \frac{h_n}{\cos \chi_n} \right) - 0,5d_m^2 \times \right. \right. \\ \left. \left. \times \left[\left[\left(f \arcsin \frac{a}{d_m} / 180 \right) + \frac{a}{d_m} \cos \arcsin \frac{a}{d_m} \right] (T_1 n_1 - T_2 n_2 - \dots - T_i n_j) \right] \right) \right]}{f D_k^2 (T_1 n_1 + T_2 n_2 + \dots + T_i n_j)} \quad (18)$$

Thus, according to (5), the filling factor k_z is determined by dependence:

$$k_z = \frac{D_k^2}{(D_k + 2c)^2} - \frac{0,5fd_m^2(T_1n_1 + T_2n_2 + \dots + T_in_j) + u_c z(D_k - d_m) \times \left[\sqrt{T_1^2 + 0,25(D_k + d_m)^2} + n_2 \sqrt{T_2^2 + 0,25(D_k + d_m)^2} + \dots \right] + \dots}{f(D_k + 2c)^2(T_1n_1 + T_2n_2 + \dots + T_in_j)} + \frac{\left[(a+b)h_n u_n - 0,5u_n^2 \left(b \operatorname{tg} \gamma_n + \frac{h_n}{\cos \alpha_n} \right) - 0,5d_m^2 \times \left[\left(f \arcsin \frac{a}{d_m} / 180 \right) + \frac{a}{d_m} \operatorname{cos} \arcsin \frac{a}{d_m} \right] \times (T_1n_1 - T_2n_2 - \dots - T_in_j) \right]}{f(D_k + 2c)^2(T_1n_1 + T_2n_2 + \dots + T_in_j)} \quad (19)$$

For practical application of obtained dependences (18) and (19) let's simplify them through the formalization of constructive execution of combined screw conveyor SGC.

For this, let's accept the assumption that:

– the number of turns n_1, n_2, \dots, n_j of each n -th T_i step is the same, which means

$$n_1 = n_2 = \dots = n_j = n_z;$$

– each next step of turns starts with the first increases in constant value UT , thus:

$$T_2 = T_1 + UT; \dots; T_i = T_{i-1} + UT;$$

– the number of knife-grinders that are installed on the screw conveyor tube drum between one pair of two adjacent spiral turns is the same and equal n_1 .

In this case:

– the sum of $T_1n_1 + T_2n_2 + \dots + T_in_j$ n -th steps of spiral turns, which is equal to the screw conveyor length L_k , can be represented as dependence:

$$T_1n_1 + T_2n_2 + \dots + T_in_j = \frac{n_z n}{2} [T_1 + UT(n-1)], \text{ [m]} \quad (20)$$

where

n_z – number of turns of each T_i -th step;

n – number of T_i -th steps;

– total number of knives n_n , that are installed on the screw conveyor tube drum will be equal:

$$n_n = n_1(n_z n - 1), \text{ [units]} \quad (21)$$

In addition, also accept the assumption that each knife-grinder designed as straight prisms whose height is equal to u_n and the basis of the prism is an equilateral trapezium, whose height is equal to h_n , we can notice that the height of the trapezoid will be approximately equal to the height of the spiral coil, or $h_n \cong h_c \cong 0,5(D_k - d_m)$, three working side edges of the prism on both sides will have sharpening angle γ_n .

In this case, the volume V'_n which is occupied by knives-grinders will be equal:

$$V'_n = (V_{np} - V_z) n_1 (n_z n - 1) = \frac{n_1 (n_z n - 1) \left[(a+b)(D_k - d_m) u_n \cos \alpha_n - u_n^2 (b \operatorname{tg} \gamma_n + 0,5(D_k - d_m)) \right]}{\cos \alpha_n}, \text{ [m}^3 \text{]} \quad (22)$$

Then, equations (18) and (19) will have a final form:

$$k_n = \frac{d_m^2}{2D_k^2} \left[1 + \frac{4hu_c z(D_k - d_m)}{fnD_k^2[2T_1 + UT(n-1)]} + \frac{{}_{n_1}(n_z n - 1)u_n}{f} \times \left(\frac{2(a+b)(D_k - d_m)\cos x_n - u_n[btgr_n \cos x_n + 0,5(D_k - d_m)]}{nd_m^2[2T_1 + UT(n-1)]\cos x_n} \right) \right] \quad (23)$$

$$k_z = \frac{D_k^2 - \frac{d_m^2}{2} \left[1 + \frac{4hu_c z(D_k - d_m)}{fnD_k^2[2T_1 + UT(n-1)]} + \frac{{}_{n_1}(n_z n - 1)u_n}{f} \times \left(\frac{2(a+b)(D_k - d_m)\cos x_n - u_n[btgr_n \cos x_n + 0,5(D_k - d_m)]}{nd_m^2[2T_1 + UT(n-1)]\cos x_n} \right) \right]}{(D_k + 2c)^2} \quad (24)$$

where $h = \sqrt{T_1^2 + 0,25(D_k + d_m)^2} + \sqrt{T_2^2 + 0,25(D_k + d_m)^2} + \dots + \sqrt{T_i^2 + 0,25(D_k + d_m)^2} = \sqrt{T_1^2 + 0,25(D_k + d_m)^2} + \sqrt{(T_1 + UT)^2 + 0,25(D_k + d_m)^2} + \dots + \sqrt{[T_i + UT(n-1)]^2 + 0,25(D_k + d_m)^2}$; $b = \left[\left(f \arcsin \frac{a}{d_m} / 180 \right) + \frac{a}{d_m} \cos \arcsin \frac{a}{d_m} \right]$.

According to initial conditions $d_m = 0.04$ m; $UT = 0.01$ m; $u_n = 0.002$; $n_z = 2$; $n = 3$; $\Gamma_n = f / 6$ grad.; $a = 0.03$ m; $b = 0.02$ m; $c = 0.002$ m, according to equation (23) results the built dependence of constructive geometric factor k_n , and according to (24) – the filling factor k_z .

Analysis of the dependence (fig. 2) showed that constructive geometric factor k_n depends on the diameter changes D_k and step T of the screw conveyor is in the range 0.025...0.07 on a number of variables T_i -th steps that are equal to $n = 3$, number of spiral turns of the same T_i -th step – $n_z = 2$ and the number of knife-grinders, installed between one pair of two adjacent spiral turns ${}_{n_1} = 4$ units.

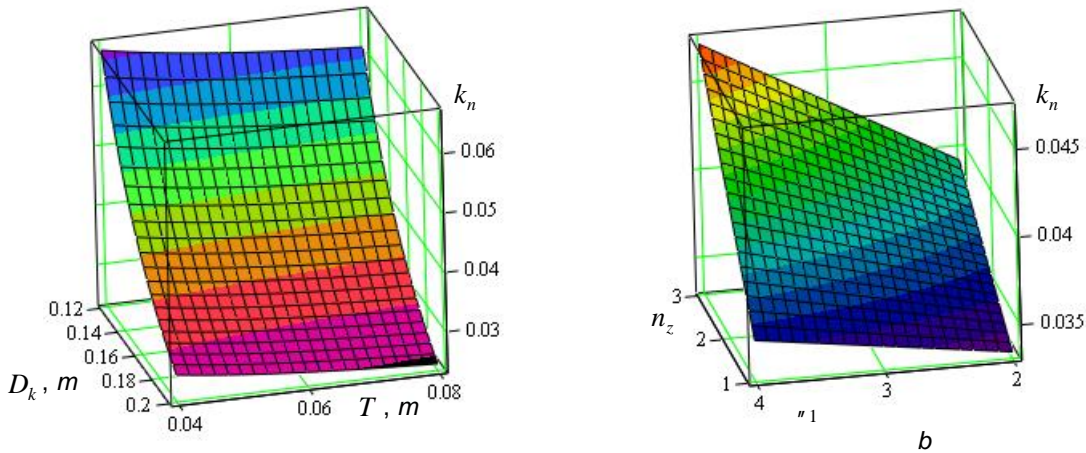


Fig. 2 - Dependence on change of constructive geometric factor k_n as functionality

– $k_n = f_n(D_k; T)$ with ${}_{n_1} = 3$ units; $b - k_n = f_n(n_z; {}_{n_1})$ with $D_k = 0.16$ m; $T = 0.05$ m

With this change, k_n , which is defined as a functional dependence $k_n = f_n(D_k; T)$ is reversible - with increasing of the diameter D_k and step T of the screw conveyor constructive geometric factor k_n decreases by parabolic function. We established that with increasing the number of knife-grinders ${}_{n_1}$, which are installed between a pair of two adjacent spiral turns and the number of spiral turns n_z of one T_i -th step,

the constructive geometric factor k_n increases in direct proportion to the n_1 n_z , thus, the average growth value of k_n is in the range 0.002...0.0025 and 0.003...0.005.

In this regard, we can say that structural change in the number of blade-grinders n_1 and the number of spiral turns n_z of one T_i -th step do not significantly affect the structural change of the factor k_n .

Three-dimensional graphical interpretation of filling factor changes depending on k_z as functional $k_z = f_z(D_k; T)$ and $k_z = f_z(D_k; UT)$ given, respectively, on fig. 3 and fig. 4.

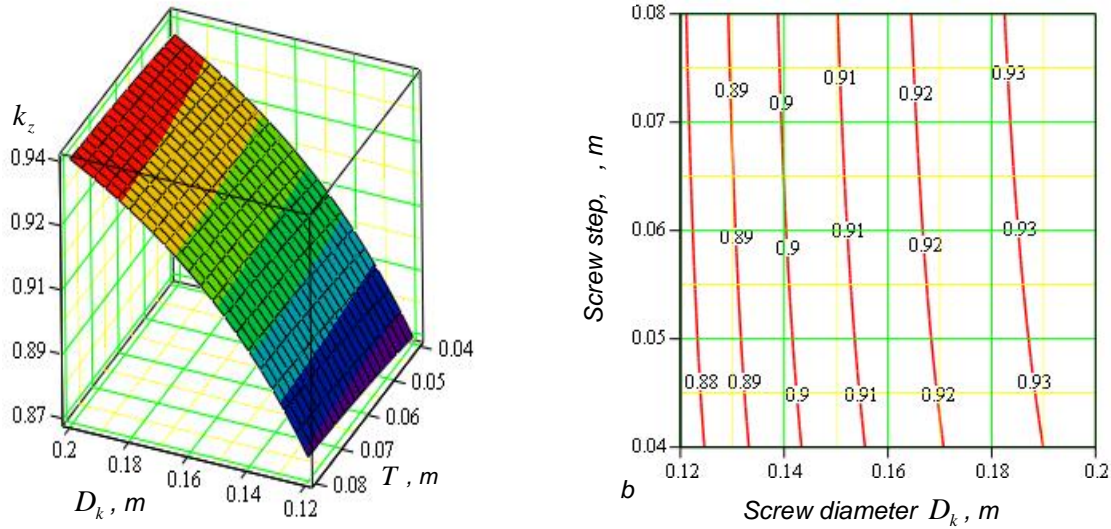


Fig. 3 - Dependence of change of filling coefficient k_z as functional $k_n = f_n(D_k; T)$ on $n_1 = 3$
 – three-dimensional surface; b – two dimensional surface cross section

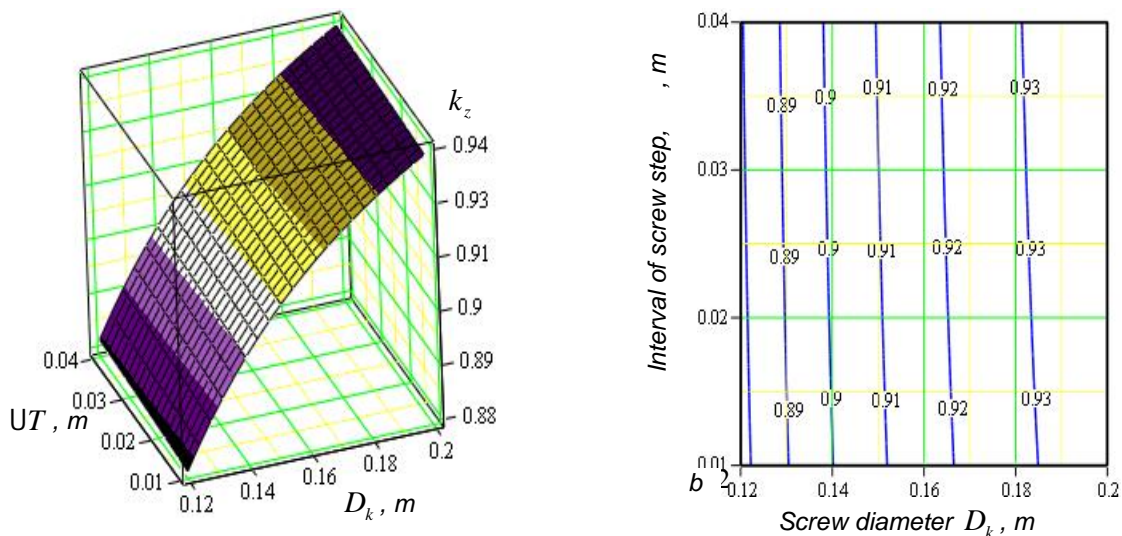


Fig. 4 - Dependence of change of filling coefficient k_z as functional $k_n = f_n(D_k; UT)$ on $n_1 = 3$
 – three-dimensional surface; b – two dimensional surface cross section

It was established that the functional change of filling factor k_z depending on the diameter changes D_k and step T of the screw conveyor (fig. 3, fig. 4), in contrast to the structural changes of geometric coefficient k_n of combined SGC has reversible type - with increasing D_k and T filling factor k_z and also growing in the range 0.87...0.94. In this case dominant factor that largely regulates the quantitative value of

filling factor k_z , is the diameter D_k of the screw conveyor, and a significant increase of k_z occurs when the value $D_k \geq 0.12$ m - in the range of change D_k from 0.12 to 0.16 (m) filling factor k_z growing on 0.05. Step change T and increasing of interval UT of the screw conveyor has insignificant impact on the quantitative value k_z by increasing step T from 0.04 to 0.08 (m) and increasing the step interval UT from 0.01 to 0.04 (m) filling factor k_z increases, respectively, on 0.004 and 0.001.

CONCLUSIONS

The obtained values of filling factor $k_z = 0.87...0.94$ by its analytical nature, is the most-possible technological parameters of the transporting process of chopped root crops by working bodies of combined SGC and characterizes its maximum degree of workspace filling i.e. it can be stated that the maximum value of filling factor k_z ranges within $k_{z,max} = 0.87...0.94$.

Thus, we established at analytical level, the numerical value of the maximum filling factor $k_{z,max} = 0.87...0.94$, is a further step for research of technological and energy parameters of chopped roots transporting process justification of combined SGC productivity and energy costs that are necessary for the simultaneous grinding and transportation, which ultimately will lead directly to a rational justification of structural and kinematic parameters of combined SGC working bodies.

REFERENCES

- [1] Baranovsky V., (2014), Methodological and structural-technological aspects of development of adapted root crop machinery (), *Science journal. Journal of TNTU* (), tom 2 (74), pp.106-113, Ternopil/Ukraine;
- [2] Baranovsky V.M., Potapenko M.V., (2016), Improvement of the clearing of systems of chicory root heaps. (), *Scientific journal. Innovative solutions in modern science*, # 1(1), pp.138-146, Dubai/OAE;
- [3] Byrd J., (2008). *Engineering Mathematics* (), Dodeka-XXI, Moskva/RF;
- [4] Hevko Iv.B., (2008), *Spiral transport and technological mechanisms, calculation and design* (), Ternopil, TNTU Ivan Pul'uj, Ternopil/Ukraine;
- [5] Hevko Iv.B., (2013), *Scientific and applied basis for the creation of screw transport and technological mechanisms: dissertation thesis* (), Doctor. Sc. Sciences, National University "Lviv Polytechnic, Lviv/Ukraine;
- [6] Hevko R.B., Dzyura V.O., Romanovsky R.M., (2014), Mathematical model of the pneumatic-screw conveyor screw mechanism operation, *INMATEH, Agricultural Engineering*, vol.44, no.3, pp.103-110, Bucharest/Romania;
- [7] Hevko R.B., Klendiy O.M., (2014), The investigation of the process of a screw conveyer safety device actuation, *INMATEH, Agricultural Engineering*, vol.42, no.1, pp.55-60, Bucharest/Romania;
- [8] Hevko R.B., Zalutskyi S.Z., Tkachenko I.G., et al., (2015), Development and investigation of reciprocating screw with flexible helical surface, *INMATEH Agricultural Engineering*, vol.46, no.2, pp.133-138, Bucharest/Romania;
- [9] Rogatinsky R., (2012), Model of construction and choice of screw conveyors with advanced technological capabilities (), *Science journal. Journal of TNTU* (), tom 3 (67), pp.197-210, Ternopil/Ukraine;
- [10] Shipachev V.S., (2003), *Book of problems in higher mathematics* (), 3-rd ed., Moskva/Russia;
- [11] Voytyuk D.G., Aniskevych L.V., Baranovsky V.M., et al., (2015), *Agricultural machines* (), Ahroosvita, Kijv/Ukraine.