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SUBSTANTIATION OF CAPACITY OF SCREW CONVEYER OF HAULM-CUTTING MODULE

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Summary. The haulm-cutting module parameters based on the analysis of technological process of displacement of the plant components cut by a spiral conveyer have been substantiated in the article. Technological interrelation between structural-kinematic parameters of screw conveyer and per-second feed of plant components has been found dealing with the required capacity. To provide the best running of screw conveyer of haulm-cutting module the rational parameters of its process operation have been set.

Key words: haulm-cutting module, screw (spiral) conveyer, auger, per-second feed, haulm.

INTRODUCTION

Sustainable development of agricultural-industrial complex of Ukraine and world is impossible without development and introduction absolutely new and progressive methods which allow to create efficient technical facilities for agricultural crops seeding, cultivating and harvesting [1, 2]. Haulm removing of sugar beet crowns is one of the most work- and power-consuming processes at their harvesting. As Ukraine is one of the leading beet growing countries in the world, it's necessary to produce beet harvesters by national machine building industry according to the highest world standards [3-6].

ANALYSIS OF RESEARCHES AND PUBLICATIONS

Analytical- applied model of supply of the plant components of beet crowns cut by a haulm-cutting module of a spiral conveyer has been developed and per-second feed change limits of plant components have been found on the analytical level which are used to calculate the screw conveyer capacity [7, 8].

OBJECTIVES OF RESEARCH

To formalize the process of displacement of the cut by haulm-cutters beet haulm and pests bulk and for further substantiation of the harvesting module we are going to study the calculation schema of screw conveyer 5 capacity (fig.1) combining functional scheme of the operation process and structural scheme of the tools providing the process [9, 10].

THE RESULTS OF RESEARCH

We are making the substantiation of the haulm-cutting module based on the analysis of technological process of displacement of the plant components cut by a screw conveyer 5 (fig.1) or the plant components displacement by spiral turns 11 of the auger 9 in trough 8 made by guiding jacket 4.

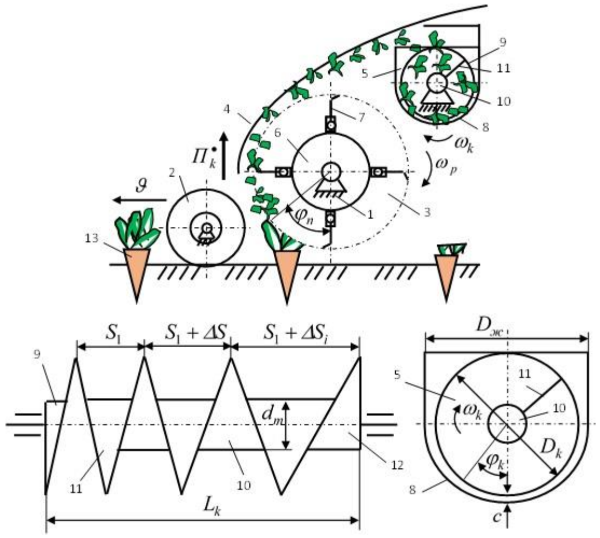


Fig. 1. Calculation schema of the auger capacity: 1 – frame; 2 – supporting wheel; 3 – rotor haulm cutter; 4 – guiding jacket; 5 – screw conveyer; 6, 10 – drum; 7 – knife; 8 – trough; 9 – auger; 11 – turn; 12 – output section; 13 – beet root

We assume that at the time t of the haulm-cutting module displacement along the beet roots rows 13 (fig.1) at forward motion velocity v haulm cutters 7 are cutting the haulm and pests bulk or plant components in amounts of $\Pi_k^{\bullet}(t)$ which are displacing on the directed motion path towards the trough 8, auger 11 of the screw conveyer 5.

Spiral turns 11 are carrying the plant components along the auger rotational axis towards its output section 12 where the plant components after leaving the last spiral turn are either put into the swath or thrown on the harvested field.

We'll find the technological interrelation between structural-kinematic parameters of screw conveyer and per-second feed of the plant components $\Pi_k^{\bullet}$ on the basis of its required capacity analysis, where the screw conveyer capacity is regulated or completely depends on the auger 11 capacity (fig.1).

Screw conveyer or auger capacity Q_k is found by the known formula according to [11-14]:

$$Q_k = 0{,}25(D_k^2 - d_m^2)\vartheta_c \psi_\vartheta \rho_v \varphi_z \qquad (1)$$

where: Q_k – screw conveyer capacity, kg/s; D_k – auger diameter, m; ϑ_c – average theoretical velocity of the cut haulm displacement along the auger rotational axis, m/s; ψ_ϑ – coefficient taking into account deviation (decrease) of average motion velocity of the cut haulm bulk regarding to average theoretical velocity of the cut haulm displacement along the auger rotational axis; ρ_v – haulm bulk weight, kg/m3; φ_z – coefficient of working space of screw conveyer filling with the cut haulm.

Here, according to [11, 15-17] components (1) are found by the formula:

– average theoretical velocity ϑ_c of the cut haulm displacement along the screw conveyer rotational axis:

$$\vartheta_c = \frac{(S_1 + \Delta S_i)\cdot \omega_k}{2\pi} = \frac{(S_1 + \Delta S_i)}{2\pi}\frac{d\varphi_k}{dt}, \qquad (2)$$

where: S_1 – steps if the first spiral turn, m; ΔS_i – stepping increment *i*, m; ω_k – auger angular velocity, rad/s; φ_k – turning angle of the auger, rad.; - coefficient ψ_ϑ taking into account deviation (decrease) of average motion velocity of the cut haulm bulk regarding to average theoretical velocity of the cut haulm displacement along the auger rotational axis:

$$\psi_\vartheta = \psi_a \cdot \psi_y, \qquad (3)$$

where: ψ_a – coefficient showing the impact degree of lead angle *a* of screw line on the mid-radius of the last spiral turn of the auger; ψ_y – compression ratio of chopping plants by spiral turns of screw conveyer:

– space filling factor φ_z of screw conveyer filling with the cut haulm taking into account sectional filling of the volume of trough throat

$$\varphi_z = V_z / V_{жc};\; V_z = V_{жc} - V_k;\; V_k = V_\upsilon + V_b, \qquad (4)$$

or

$$\varphi_z = \frac{V_{жc} - V_k}{V_{жc}} = 1 - \frac{V_k}{V_{жc}} = 1 - \frac{V_\upsilon + V_b}{V_{жc}}, \qquad (5)$$

where: V_z – volume of the trough throat filled with cut haulm; $V_{жc}$ – trough throat volume, m^3; V_k – auger volume, m^3; V_υ – auger turns volume, m^3; V_b – auger drum volume, m^3.

According to [18-20] ratio $\frac{V_k}{V_{жc}}$ stands for k_υ taking into account volume of that part of auger working members (spiral turns and auger tube) which they occupy in the trough throat volume, i.e. $\frac{V_\upsilon + V_b}{V_{жc}} = k_\upsilon$.

Then according to the dependence (5):

$$\varphi_z = 1 - k_v. \qquad (6)$$

Here, according to [11-13] and fig. 1 components (5) are found by the formula:

– trough throat volume:

$$V_z = 0{,}5V_{z1} + V_{z2},$$

where: V_{z1} – cylinder volume, whose base diameter is $D_{жc}$, and height $-L_k$; V_{z2} – parallelepiped volume, whose base length and width are, respectively, $D_{жc}$ and $0{,}5D_{жc}$, and height – L_k.

$$\begin{aligned} V_{жc} &= 0{,}125\pi D_{жc}^2 L_k + 0{,}5 D_{жc} D_k L_k = \\ &= 0{,}5 D_{жc} L_k \left(0{,}25\pi D_{жc} + D_k\right) \end{aligned}, \qquad (7)$$

where: $D_{жc}$ – trough inner diameter, m; L_k – effective auger length, m;

– volume V_v, occupied by auger turns and auger drum volume V_b:

$$V_v = V_{1v} z_k;\; V_{1v} = F_v l_v;\; F_v = \delta_v h_v;$$
$$l_z = \frac{\pi L_k (D_k + d_m)}{2S_1 + \Delta S}\cos arctg\,\frac{2S_1 + \Delta S}{D_k + d_m}, \qquad (8)$$

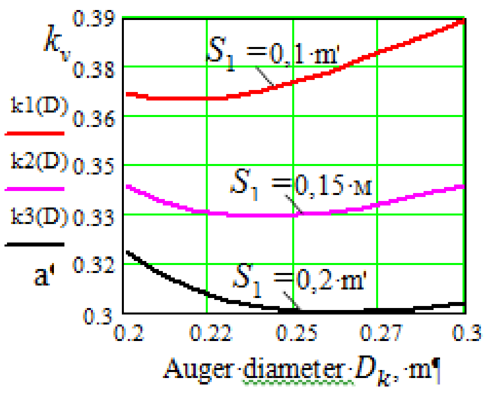
where: V_{1v} – is volume occupied by the turns of one entry of auger (m^3); z_k – number of auger entries, times; F_v – cross-section area of auger turn blade, m^2; l_v – length of screw line on the auger mid-diameter, m, h_v – height of auger turn blade, $h_v = 0{,}5(D_k - d_m)$, m; d_m – drum diameter, m.

$$V_v = \frac{\pi L_k (D_k - d_m)^2}{4S_1 + \Delta S}\cos\left(arctg\,\frac{2S_1 + \Delta S}{D_k + d_m}\right) z_k; \qquad (9)$$
$$V_b = 0{,}25\pi d_m^2 L_k.$$

After volumes values substitution from (7) and (9) in formula (6) we obtain the dependence to find coefficient k_υ:

$$k_v = \pi\frac{\dfrac{(D_k - d_m)^2}{S_1 + \Delta S}\cos\left(arctg\,\dfrac{2S_1}{D_k + d_m}\right) z_k + d_m^2}{2D_{жc}\left(0{,}25\pi D_{жc} + D_k\right)}. \qquad (10)$$

According to (10) and under initial conditions $d_m = 0{,}1\,m$, $z_k = 1$, $\Delta S = 0{,}05\,m$ the diagram of coefficient k_v changes is shown on fig. 2.



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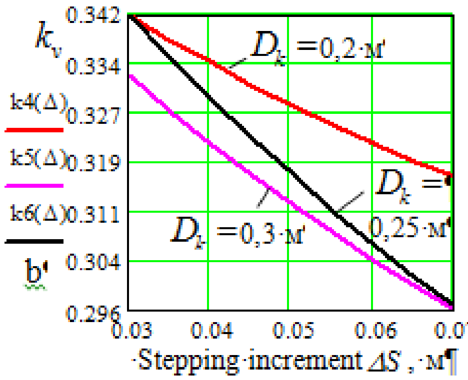


b)

Fig. 2. Dependence of coefficient k_v change: a – $k_v = f(D_k)$, b – $k_v = f(D_k)$

Coefficient k_v varies from 0,3 to 0,39 depending on the auger diameter range $0{,}2 \le D_k \le 0{,}3\,m$. Here step S_1 of the auger first spiral turn and stepping increment ΔS make the greatest impact on the coefficient k_v change – when S_1 increases from 0,1 to 0,2 m the coefficient k_v is 1,3 times smaller (fig. 2.a), and when ΔS increases from 0,03 to 0,07 m coefficient k_v is 1,2 times smaller (fig. 2.b).

According to (1)-(3), (6) and (10) the screw conveyer capacity is found by the formula

$$Q_k = \left(D_k^2 - d_m^2\right)\frac{S_1 + \Delta S_i}{8\pi}\psi_a \psi_y \rho_v \times \left(1 - \pi\frac{\dfrac{(D_k - d_m)^2}{S_1 + \Delta S}\cos\left(arctg\dfrac{2S_1}{D_k + d_m}\right)z_k + d_m^2}{2D_{ж}\left(0{,}25\pi D_{ж} + D_k\right)}\right)\frac{d\varphi_k}{dt}, \quad (11)$$

or

$$Q_k = \left(D_k^2 - d_m^2\right)\frac{S_1 + \Delta S_i}{8\pi}\psi_a \psi_y \rho_v \left(1 - k_v\right)\frac{d\varphi_k}{dt}. \quad (12)$$

Also the screw conveyers capacity can be found by well-known formula [11,12] which functionally to a greater extent depends on the process parameters characterizing the material supply to the working bodies of screw transport mechanisms:

$$Q_k = W_L \vartheta_c \psi_\vartheta \rho_v \varphi_z, \quad (13)$$

where: W_L – material specific volume per auger length unit, m^3/m.

For further analysis we'll express the material specific volume W_L per auger length unit as per-second feed of plant components $\Pi_k^\bullet$, per auger length unit L_k:

$$W_L = \frac{m_{pk'}}{\rho_v L_k} = \frac{\Pi_k^* t}{L_k}, \quad (14)$$

where: m_{pk} – mass of plant components supplied to the screw conveyer (kg) per time $t = 1\,s$.

We substitute the values of per-second feed of plant components $\Pi_k^\bullet$ from [7,8] into formula (14) and obtain the dependence to find the specific per-second feed of plant components to the screw conveyer or specific per-second feed of plant components per auger effective length unit L_k, or:

$$W_L = \frac{\vartheta b_k Nt\left[0{,}82\cdot 10^{-3}\vartheta b_k \Gamma_{k.c}\left(U_{г.c} \pm \Delta U_г\right) + 0{,}9M_{б.c}\right]}{L_k}. \quad (15)$$

Then the capacity Q_k of screw conveyer is found by the formula

$$Q_k = \frac{\vartheta b_k Nt\left[0{,}82\cdot 10^{-3}\vartheta b_k \Gamma_{k.c}\left(U_{г.c} \pm \Delta U_г\right) + 0{,}9M_{б.c}\right]}{L_k} \times \vartheta_c \psi_\vartheta \rho_v \left(1 - k_v\right)\frac{d\varphi_k}{dt} \quad (16)$$

We equate the right parts of the formula (12) and formula (16) between themselves.

Then we obtain the equality:

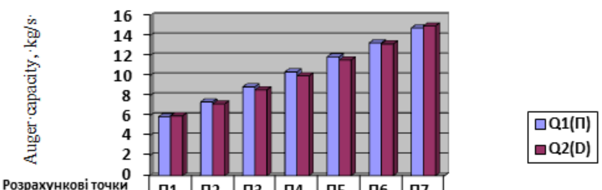
$$\left(D_k^2 - d_m^2\right)\frac{S_1 + \Delta S_i}{8\pi}\psi_a \psi_y \rho_v \left(1 - k_v\right)\frac{d\varphi_k}{dt} = \frac{\vartheta b_k Nt\left[0{,}82\cdot 10^{-3}\vartheta b_k \Gamma_{k.c}\left(U_{г.c} \pm \Delta U_г\right) + 0{,}9M_{б.c}\right]}{L_k} \times \vartheta_c \psi_\vartheta \rho_v \left(1 - k_v\right)\frac{d\varphi_k}{dt} \quad (17)$$

or according to (1), (3) and (6):

$$\left(D_k^2 - d_m^2\right)\vartheta_c \psi_a \psi_y \rho_v \left(1 - k_v\right)\frac{d\varphi_k}{dt} = \frac{\Pi_k^\bullet t}{\rho_v L_k}\vartheta_c \psi_a \psi_y \rho_v \left(1 - k_v\right)\frac{d\varphi_k}{dt}. \quad (18)$$

We'll demonstrate the record (of the equality) legitimacy by means of mathematical modeling of numerical calculations of screw conveyer capacity found by formulae (2.23) and (2.27) and their comparison with one another.

The diagrams of the auger capacity (fig.3) change are made on the basis of numerical calculations of screw conveyer capacity found by formulae (12) and (16).



Розрахункові точки	П1, (Д1)	П2, (Д2)	П3, (Д3)	П4, (Д4)	П5, (Д5)	П6, (Д6)	П7, (Д7)
Q1(П)	5,9	7,4	8,9	10,4	11,9	13,3	14,8
Q2(D)	6	7,2	8,6	10	11,6	13,2	15

Fig. 3. Diagram of auger capacity change in computational points

Analysis of numerical calculations of the auger capacity (fig. 3) proves that capacity indices $Q1$ of the auger found by the formula (16) and capacity indices $Q2$ of the auger found by formula (12) in computational points P1-P7 are practically the same – mean error of values varies from 1,5 to 1,6 %.

Then by formula (18) we find the auger diameter D_k, where:

$$\frac{\left(D_k^2 - d_m^2\right)}{4}\rho_v = \frac{\Pi_k^{\bullet} t}{L_k}; \qquad (19)$$

$$D_k = \sqrt{\frac{4\Pi_k^{\bullet} t}{L_k \rho_v} + d_m^2}\,. \qquad (20)$$

For theoretical substantiation of screw conveyer auger diameter according to formula (20) we have built a nomogram to find D_k depending on per-second feed change $\Pi_k^{\bullet}$ of plant components by knives of rotor haulm-cutter to screw conveyer and auger length L_k as a functional dependence $D_k = f(\Pi_k^{\bullet}; L_k)$ shown on fig. 4.

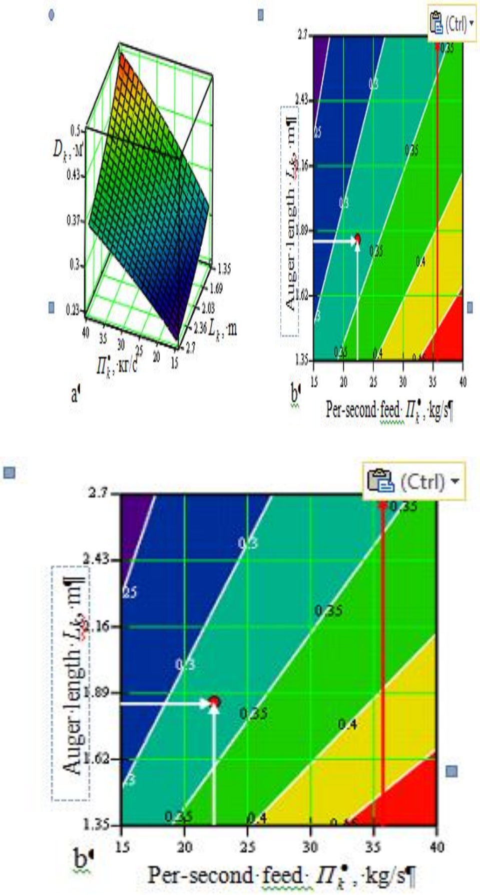


Fig. 4. Dependence of auger diameter D_k change: a – as function $D_k = f(\Pi_k^{\bullet}; L_k)$; b – nomogram to find auger diameter D_k

On the basis of fig.4 analysis we have found that to provide per-second feed of plant components within limits $\Pi_k^{\bullet} = 15...40$ kg/s, found according to [7] the auger diameter D_k must be limited from 0,25 to 0,4 m depending on its effective length L_k. Here the auger effective length is found structurally and depending on the haulm-cutting module rows number (or root-harvesting machine rows number) and root crops planting width. Thus, at root crops planting width $b_k = 0{,}45$ m and number of rows which are picked simultaneously $N = 3$, auger effective length $L_k = 1{,}35$ m, respectively at $N = 6 - L_k = 2{,}7$ m.

To find D_k a nomogram shown on fig.4b is used. For example, at per-second feed of plant components to the screw conveyer $\Pi_k^{\bullet} = 35$ kg/s at simultaneous haulm cutting of rows $N = 6$ (auger effective length $L_k = 2{,}7$ m) the required diameter of auger providing the material displacement equals to $D_k = 0{,}34$ m. Thus, at $\Pi_k^{\bullet} = 22{,}5$ kg/s and $N = 4$ (auger effective length $L_k = 1{,}8$ m) – $D_k = 0{,}32$ m.

A step of auger spiral turns is chosen structurally under condition [3], when $S_1 = (0{,}5...0{,}6)D_k$, i.e. $S_1 = 0{,}12...0{,}2$ m.

The auger angular velocity ω_k is found under condition characterizing the screw conveyer operation without plant components "unloading" during their carrying by the auger turns. The condition is satisfied when screw conveyer capacity Q_k is larger or equal to per-second feed $\Pi_k^{\bullet}$ i.e. $Q_k \ge \Pi_k^{\bullet}$

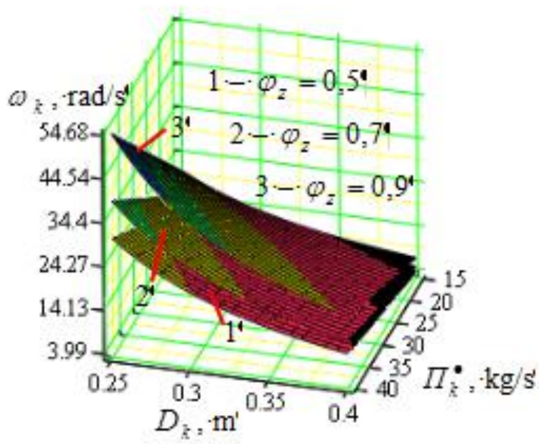
Then according to (12) and taking into account (13) we can write:

$$\left(D_k^2 - d_m^2\right)\cdot\frac{S_1 + \Delta S_i}{8\pi}\psi_v \rho_v \left(1 - k_v\right)\omega_k \ge \Pi_k^{\bullet}. \qquad (21)$$

From dependence (21) we find the auger angular velocity:

$$\omega_k = \frac{8\pi \Pi_k^{\bullet}}{\left(D_k^2 - d_m^2\right)\left(S_1 + \Delta S_i\right)\psi_v \rho_v \left(1 - k_v\right)}. \qquad (22)$$

With found values of the auger structural parameters and according to (22) and under initial conditions $S_1 = 0{,}15$ m, $\Delta S = 0{,}005$ m, $k_v = 0{,}35$, $\psi_\vartheta = 0{,}7$ [3] a dependence of auger angular velocity change as a function $\omega_k = f_\omega(D_k; \Pi_k^{\bullet})$, shown on fig. 5.



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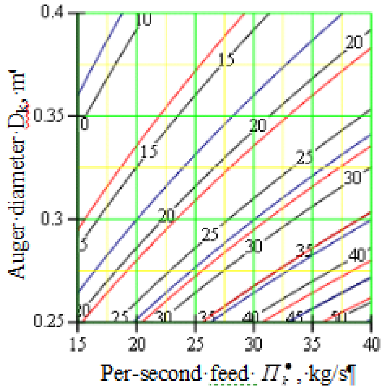

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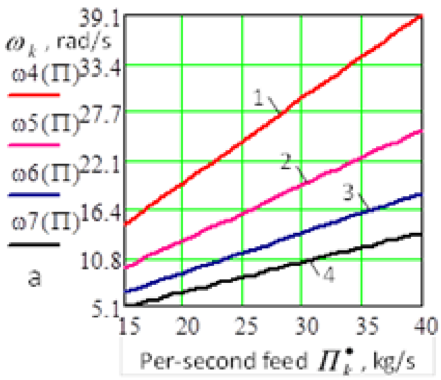
Fig. 5. Dependence of auger angular velocity change as a function $\omega_k = f_\omega(D_k; \Pi_k^\bullet)$



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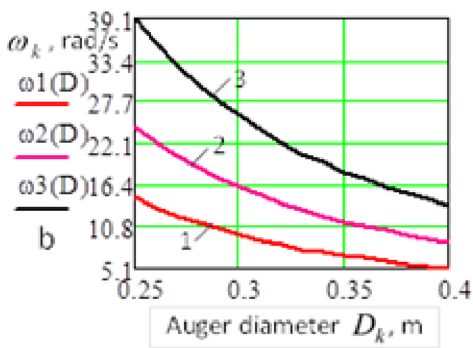


b)

Fig. 6. Dependence of auger velocity change ω_k a – on per-second feed of plant impurities $\Pi_k^\bullet$; 1, 2, 3, 4 – respectively, $D_k = 0{,}25; 0{,}3; 0{,}35$ and 0,4 m; b – on auger diameter D_k 1, 2, 3 – respectively

Functional change of auger angular velocity depending on the change of per-second feed of plant impurities $\Pi_k^\bullet$ to screw conveyer and auger diameter D_k (fig. 5) is of dual character: is in direct proportion to per-second feed $\Pi_k^\bullet$ increase – when $\Pi_k^\bullet$ increases the auger angular velocity ω_k increases; is reciprocal to the auger diameter D_k increase – when diameter D_k increases the auger angular velocity ω_k decreases.

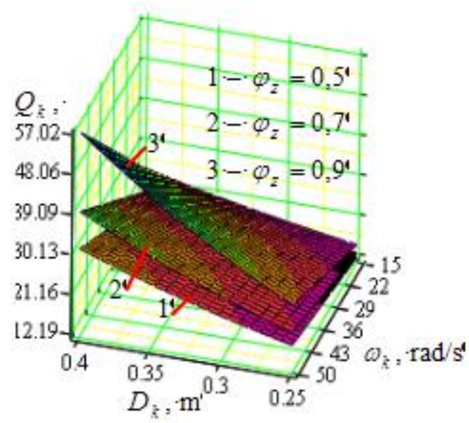
We have found that basic values of auger angular velocity ω_k are within limits $\omega_k = 5..39$ rad/s (6), and ω_k change is mostly caused by both per-feed of plant components $\Pi_k^\bullet$ to the screw conveyer and by auger diameter D_k as well – under condition of $\Pi_k^\bullet$ change from 15 to 40 kg/s and D_k from 0,25 to 0,4 m the value of auger angular velocity ω_k is approximately increasing into 2…2,5 times.

Figures 7 and 8 present the diagrams of screw conveyer capacity change Q_k depending on the auger parameters which are built according to formula (18) as a functional dependence; $Q_k = f_Q(D_k; \omega_k)$, fig. 7; $Q_k = f_Q(\omega_k)$, fig. 8a; $Q_k = f_Q(D_k)$, fig. 8b.

Under conditions when $S_1 = 0{,}15$ m, $\Delta S = 0{,}005$ m, $k_v = 0{,}35$, $z = 1$ and change of auger parameters the screw conveyer capacity Q_k is changing at rather great range – from 12 to 57 kg/s and is increasing due to both auger rotational frequency ω_k increase and auger diameter D_k increase as well.

According to condition (21), to provide the most effective operation of screw conveyer or plant components carrying by auger without their "loading" the screw conveyer capacity Q_k must be not less the range of per-second feed change:

– of plant components 16…39 kg/s. Then on the basis of diagrams analysis presented by figures 7 and 8 we can prove that the condition is satisfied at the following parameters of auger:



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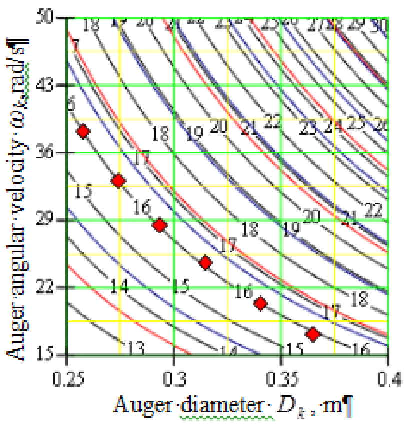

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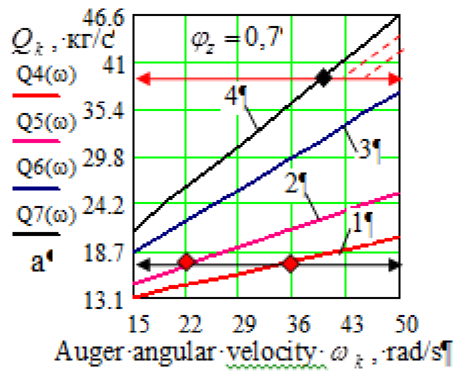
Fig. 7. Dependence of screw conveyer capacity change as function $Q_k = f_Q(D_k;\omega_k)$



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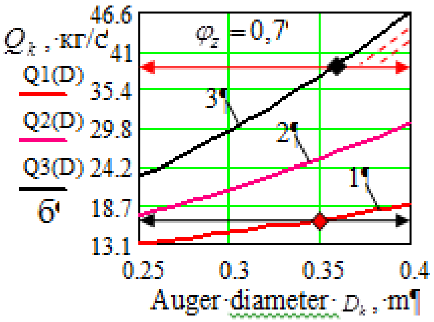

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Fig. 8. Dependence of screw conveyer capacity change Q_k : a – on the auger angular velocity change ω_k; Q 1, 2, 3, 4 – respectively, $D_k = 0{,}25; 0{,}3; 0{,}35$ and 0,4 м; b – on the auger diameter D_k; 1, 2, 3 – respectively, $\omega_k = 15; 35; 50$ rad/s

– the low limit of per-second feed of plant components is achieved or the condition when $Q_k \geq \Pi_k^\bullet \geq 16$ kg/s is satisfied when the auger diameter $D_k \geq 0{,}35$ m and auger rotational frequency $\omega_k = 15$ rad/s;

– the upper limit of per-second feed of plant components is achieved or the condition when $Q_k \geq \Pi_k^\bullet \geq 39$ kg/s is satisfied when the auger $D_k \geq 0{,}4$ m and auger rotational frequency $\omega_k = 40$ rad/s.

Thus $S_1 = 0{,}15$ m, $\Delta S = 0{,}005$ m, $\psi_z = 0{,}7$.

CONCLUSIONS

On the basis of analytical research we have found that to provide the most efficient operation of screw conveyer of haulm-cutting module the auger diameter must have limits from 0,25m to 0,4m, and its effective length is 1,8m. Diagrams of dependence of screw conveyer capacity change on the structural-kinematic parameters of the auger, namely dependence of auger angular velocity change on per-second feed of plant impurities and on its diameter have been built.

REFERENCES

1. **Rybak T.I., Tson O.P. 2013**. Review of wiping machines of beet-cutting machines and ways to improve them. Bulletin of the Kharkiv National Technical University of Agriculture named after Petr Vasilenko. "Technical service of machines for plant growing". Kharkiv № 134. 203 - 207. (in Ukrainian).
2. **Volodymyr Bulgakov. 2004**. Designing of Agricultural Machinery, Its Compliance with International Quality, Standardization and Certification Requirements / Volodymir Bulgakov, Oleksandr Sidorchuk // Motrol. Motorization And Power Industry in Agriculture. - Lublin - Tom 9, 207 - 211. (in Russian).
3. **Tson O.P., Stashkiv M.Y. 2017**. Investigation of the residual resource of the flat knife of the jig of the active type of work. Proceedings V of the International scientific and technical conference "Damage of materials during operation, methods of its diagnosis and prognostication". Ternopil, TNTU them. I.Puluj. 240-244. (in Ukrainian).
4. **Pogorely L.V. 2004**. Beet harvesters: history, design, theory, forecast / L.V. Pogorely, N.V. Tat'yanko. - K.: Phoenix. 232. (in Russian).
5. **Sydorchuk O. 2007**. Designing agricultural machinery, its confor-mity to international requirements of quality, standardization and certification. – MOTROL. Motorization And Power Industry in Agriculture. Volume 9 A. Lublin. Poland, – 207-211. (in Russian).
6. **Holovach I., Berezovyy M., Eremenko O. 2006**. Working out and research of the new car for cleaning of a tops of vegetable. – MOTROL. Motorization and power industry in agriculture. Volume 8A. Lublin. Poland. – 80-97. (in Russian).
7. **Tymofiy Rybak; Anna Tson; Mykola Stashkiv; Oleg Tson. 2018**. Analytical and applied model of the process of the cut vegetable components feeding to the screw conveyor of the top gathering module. Scientific Journal of the Ternopil National Technical University, № 2 (90) – 105-114.

8. **Rybak T.I., Tson G.B. 2018**. Substantiation of the parameters of the jigging module. Materials of the International Scientific and Technical Conference "Fundamental and Applied Problems of Modern Technologies". Ternopil. 153-154. (in Ukrainian).
9. **Patent No. 127089, 2018**. Ukraine, IPC A01D 23/02. Spit-cleaning machine / Rybak T.I., Tson G.B., Stashkiv M.Ya. and so on. Applicant and patent owner Ternop. nats tech un - № u2018 02684; stated. March 16, 2018, Bul. No. 13 – 5. (in Ukrainian).
10. **Patent No. 86895, 2013**. Ukraine, IPC A01D 23/02. Sharpener with active knife / Rybak TI, Tsion O.P., Stashkov M.Ya., Popovich P.V., Tson G.B .; Applicant and patent owner Ternop. nats tech un - № u201309816; stated. 08/07/2013; Bul. №1. (in Ukrainan).
11. **Grigoriev A.M. 1972**. Screw conveyors. Moscow, Klos, 286. (in Russian).
12. **Voytyuk D.G. 2005**. Agricultural machinery. Fundamentals of theory and calculation: subcategory. [for the studio. higher tutor shut up] / Voytyuk D.G., Baranovsky V.M., Bulgakov V.M. [etc.] ; under ed. D.G. Voytjak - K.: Higher education. 464. (in Ukrainian).
13. **Dubrovin V. 2013**. Identification of the development process of an adapted root harvesting machine / Valery Dubrovin, Gennady Golub, Viktor Baranovsky, Viktor Teslyuk // MOTROL. Commission of motorization and energetics in agriculture. An international journal on the operation of farm and agri-food industry machinery. - Lublin-Rzeszow,. - Vol. 15. - No. 3. 243-255. (in Rusian).
14. **Bosoy E.S. 1978**. Theory, design and calculation of agricultural machines / E.S. Bosoy and others - M.: Mechanical Engineering, 567. (in Russian).
15. **Baranovskiy V.M. 2003**. Prediction of the amount of soil on the body of the root crop / V.M. Baranovskiy, D.G. Voytyuk, Kropivko S.V. [et.] // "MOTROL 03", IV. - Lyublin-Kiev. -T 6. - Avg. NAU - 164-172. (in Ukrainian).
16. **Vladimir Bulgakov, Nikolai Berezovoi, Oleg Chernysh. 2013.** Theoretical research of the cutting of sugar beet tops by the MOTROL coprinorot separator. Commission of Motorization and Energetics in Agriculture -. Vol. 15. No 3. 84 -90. (in Russian).
17. **Martynenko V.Ya. 1997**. Hoeing machines / V.Ya. Martynenko - Ternopil: Polygraphist Ltd. 108. (in Ukrainian).
18. **Rybak T.I. 2014**. Effect of redistribution of the cutting force of the active knife of the knife cutter of beets on its durability / T.I. Rybak, O.P. Tson, M.Ya. Stashkiv, GB Tsion // Bulletin of the Kharkiv National Technical University of Agriculture named after Petr Vasilenko. "Problems of reliability of machines and means of mechanization of agricultural production". - Kharkiv: KhNTUSG them. P. Vasilenko. No. 151. 222-227. (in Ukrainian).
19. **Gevko R. B. 1999**. Directions of improvement of beet-harvesting machinery / R. B. Hevko, IG Tkachenko. Lutsk: LDUU. 168. (in Ukrainian).
20. **Vladimir Bulgakov, Andrey Boris. 2013**. Mathematical model of contact interaction of the new working body for cleaning the bottle of the sugar beet. Motrol. Commission of Motorization and Energetics in Agriculture. Vol. 15. No 3. 202-206. (in Russian).

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