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TECHNOLOGICAL INTERACTION OF THE ROOTS WITH THE SCREW SURFACE OF THE CLEANING SYSTEM

The theoretical studies of the technological process of the operation of the combined cleaning system are presented on the basis of the analysis of the fodder beet movement by the working surfaces of the feeding conveyor and the screw mounted above it.

We have got analytical and empirical process model of fodder beet oblique sub-hit on the auger turn that characterize the dependence of the total rate of sub-hit coefficient of technological interaction of roots and depth of root damage on the main parameters of the combined cleaning system. We found out the rational limits of basic structural and kinematic parameters of the combined cleaning system by provided minimum of fodder beet damage.

Keywords: *combined cleaning system, root crops, feeding conveyor, auger, sub-hit total rate, the rate of technological interaction, speed of auger rotation, diameter of auger, damage of fodder beet..*

Formulation of the problem. The improvement of structural and technological level and individual work of the root crop machine needs particular attention in general issues of machinery engineering design, improvement of working bodies and other structural elements of root crop machine based on deeper analysis taking into account the physical and mechanical properties of root crops [1]. Characteristics of fodder beet as an element of "machine - work body -root" should be considered as a set of different mechanical properties and parameters that are decisive in total mechanical action on the object of treatment, its acceptable level and range of structural and kinematic parameters of working parts [2].

During parameter optimization of transport and technological systems of root crop machine, which have working bodies of auger mechanisms at the stage of design it is expedient initially to construct a mathematical model of the process of the combined cleaning system to obtain patterns of its functioning according to fundamental structural and kinematic parameters [3].

The purpose of research is the further development of methodology and methods of optimization parameters of root pile combined cleaners root crop machine.

Analysis of recent research and publications. To develop specific processes and operations and to determine the parameters and modes of agricultural machines physical and mechanical properties of plants are taken in considiration. Industrial use of cleaning bodies of machines for harvesting fodder beet showed that total damage to root crops can be up to 35% depending on their agrobiological characteristics. Improving the working bodies and other structural elements root crop machinery should be based on a deep analysis taking into account the physical and mechanical properties of fodder beet [4].

At this stage, it was presented a generalized picture of the behavior of fodder beet at different sub-hit speeds and, above all, those working bodies, which in real terms are used in the design schemes of root crop machine.

To establish the patterns of change of the total sub-hit speed V_{ck} coefficient of technological interaction of root damage K_T and root crops depending on the parameters of the combined cleaning system,it was conducted the experimental research complex of root sub-hit process on the auger [5-6].

The purpose. Further development of the methodology and methods for optimizing the parameters of root crop cleaners of the combine for harvesting root crops.

Main results of the research. The main criteria that characterize the technological process of separation dug pile is the degree of separation of impurities from the roots and exponent of roots damaged in the process of interaction with the work surfaces of the combined cleaning system.

To assess the degree of damage to the roots, the maximum values that arise during their interaction with the auger rotation of the combined cleaning system, we introduce the rate of technological root interaction, which expresses the ratio $K_T = [V_{max}]/V_{ck} \geq 1$.

The maximum permissible hit speed $[V_{max}]$ of fodder beet with working surfaces is limited by allowable data[5], which when exceeded get root damage not exceeding the limits of deeply and non-deeply damaged roots according to the requirements [5].

To determine the total speed rate V_{ck} there is the design scheme (Fig. 1a).

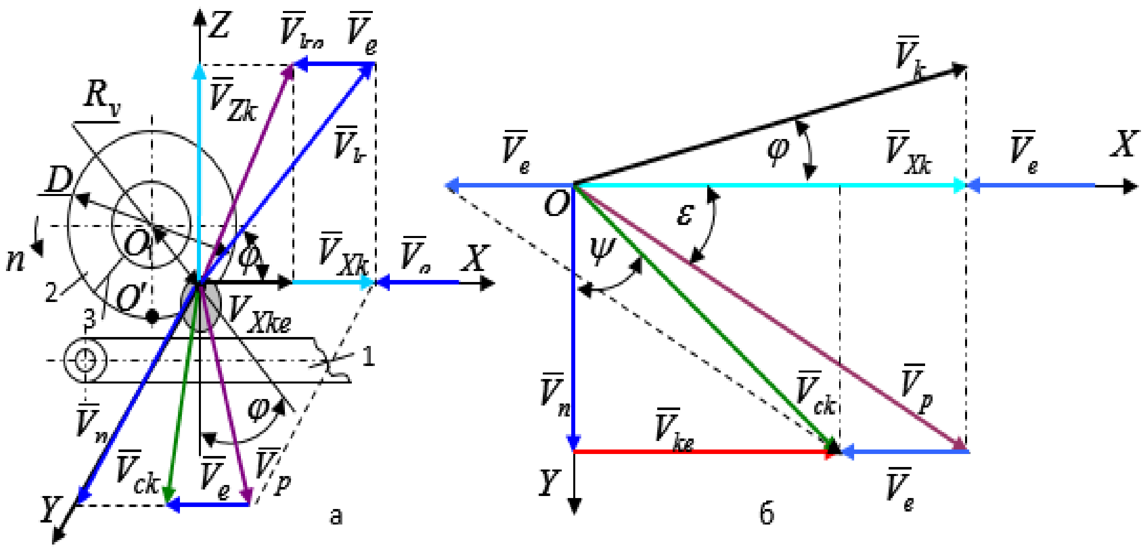

Fig. 1. Scheme (a) and plan of velocities (b) skewed rooting of the root crop with working surfaces of the cleaning system: 1 - conveyor; 2 - screw; 3 - screw thread.

In this case, the interaction of root of the auger 2 rotation 3 we look in terms of striking force action at the material body, and the root interacts with the surface of the auger coil screw at point O, which rotates with frequency n. The initial impact velocity V_e is denoted by a root crop which value corresponds to the speed of the elevator rod 1. The point O of impact is at a distance R_y from the axis of rotation O_1 of the auger. After impact, root reflected from the surface of the final round of the auger overall rate V_{ck} and moving in its direction at an angle ψ.

The general case of hit interaction of two bodies is characterized by a change of angular and translational velocities of the coordinate axes spatial system $OXYZ$.

In an oblique hit there are various types of frictional interaction and compression deformation of roots body, respectively, tangential and normal hit pulse, the result of compression deformation is the appearance of cracks in the body of root or cracking.

Reducing the normal pulse hit possible by reducing the total V_{ck} speed, the implementation of which is achieved by reducing the normal component V_{ck} or as a result - by reducing the angle sub-hit surface β.

From the analysis of speeds schema here are:

$$\left.\begin{aligned} &\bar{V}_k = \frac{d\bar{R}_y}{dt} = \bar{\omega} \times \bar{R}_y; \quad \omega = \frac{d\varphi}{dt} = \dot{\varphi} = 2\pi n; \\ &V_n = V_{nT} K_{Vn} = TnK_{Vn} = \frac{TK_{Vn}\omega}{2\pi}; \quad T = \pi D_y tg\beta; \\ &\bar{V}_e = \frac{d\bar{r}_e}{dt} = \bar{\omega}_e \times \bar{r}_e; \quad \omega_e = \frac{d\varphi_e}{dt} = \dot{\varphi}_e = 2\pi n_e \end{aligned}\right\} \qquad (1)$$

From equations (1) we have the differential equation of scalar total speed V_{ck}

$$V_{ck} = \frac{dl_k}{dt} = \sqrt{\left[\left(\frac{D\cos\varphi}{2}\frac{d\varphi}{dt}\right) - \left(\frac{D_e}{2}\frac{d\varphi_e}{dt}\right)\right]^2 + \left(\frac{DK_{Vn}tg\beta}{2}\frac{d\varphi}{dt}\right)^2}\,; \qquad (2)$$

or simplification dependence on (2) and conditions $K_T = [V_{max}]/V_{ck} \geq 1$

$$V_{ck} = \frac{1}{2}\sqrt{D^2\left(cos^2\varphi + K_{Vn}^2 tg^2\beta\right)\left(\frac{d\varphi}{dt}\right)^2 + D_e\frac{d\varphi_e}{dt}\left(D_e\frac{d\varphi_e}{dt} - 2D\cos\varphi\frac{d\varphi}{dt}\right)}\,; \qquad (3)$$

$$K_T = \frac{2[V_{max}]}{\sqrt{D^2\left(cos^2\varphi + K_{Vn}^2 tg^2\beta\right)\left(\frac{d\varphi}{dt}\right)^2 + D_e\frac{d\varphi_e}{dt}\left(D_e\frac{d\varphi_e}{dt} - 2D\cos\varphi\frac{d\varphi}{dt}\right)}} \geq 1\,; \qquad (4)$$

The resulting differential equation (4) describes the adaptability of the combined cleaning system or technological dependence of the coefficient of interaction of root auger spiral on the basic parameters of the cleaning system.

Given (1) dependence (4) will look like:

$$K_T = \frac{[V_{max}]}{\pi\sqrt{D^2n^2\left(cos^2\varphi + K_{Vn}^2 tg^2\beta\right) + D_e n_e\left(D_e n_e - Dn\cos\varphi\right)}} \geq 1\,; \qquad (5)$$

Analysis of (Fig. 1, a) shows that after hitting the root reflects from the surface of the auger coil with the ultimate total speed V_{ck} and moves in the direction of the vector $\overline{V}_{ck}$ which projection on a horizontal plane OXY of the velocity vector turns axial movement of the auger $\overline{V}_n$, forms an angle ψ. Upon reaching speed $V_{ck} = dl_k / dt = 0$, by root feeding conveyor, root moving back toward the auger and re-experiencing the hit interaction with the working surface of the auger coil.

In this case, it can be concluded that minimal damage to roots and maximum adaptability will also be provided when the angle is of $\psi \leq 0$ or when roots move along the axis of auger rotation.

According to (Fig. 1,a) here are

$$V_{ke}^2 = V_n^2 + V_{ck}^2 + 2V_nV_{ck}\cos\psi\,, \qquad (6)$$

or

$$\left(\frac{dl_k}{dt}\right)^2 + 2\left(\frac{DK_{Vn}tg\beta}{2}\frac{d\varphi}{dt}\right)\left(\frac{dl_k}{dt}\right)\cos\psi + \left(\frac{DK_{Vn}tg\beta}{2}\frac{d\varphi}{dt}\right)^2 - \left(\frac{D\cos\varphi}{2}\frac{d\varphi}{dt} - \frac{D_e}{2}\frac{d\varphi_e}{dt}\right)^2 = 0\,. \qquad (7)$$

Marking in (7) through the appropriate parts: $\frac{dl_k}{dt} = x$; $DK_{Vn}tg\beta\cos\psi\frac{d\varphi}{dt} = p$;

$$\left(\frac{DK_{Vn}tg\beta}{2}\frac{d\varphi}{dt}\right)^2 - \left(\frac{D\cos\varphi}{2}\frac{d\varphi}{dt} - \frac{D_e}{2}\frac{d\varphi_e}{dt}\right)^2 = q\,;$$

obtain harmonized quadratic equation, the solution is according to x looks like:

$$\frac{dl_k}{dt} = -\frac{DK_{Vn}tg\beta}{2}\frac{d\varphi}{dt} \pm \frac{1}{2}\sqrt{\left(DK_{Vn}tg\beta\frac{d\varphi}{dt}\right)^2\left(cos^2\psi - 1\right) - \left(D\cos\varphi\frac{d\varphi}{dt} - D_e\frac{d\varphi_e}{dt}\right)^2}\,, \qquad (8)$$

with two valid datas dl_k / dt are provided:

$$-\left(D\cos\varphi\frac{d\varphi}{dt}-D_e\frac{d\varphi_e}{dt}\right)^2\le 0. \qquad (9)$$

Thus, the theoretical dependence that characterizes the correlation coefficient K_T and the basic parameters of the cleaning system is as follows:

$$K_T=\frac{2[V_{max}]}{-DK_{Vn}tg\beta\frac{d\varphi}{dt}\pm\sqrt{\left(DK_{Vn}tg\beta\frac{d\varphi}{dt}\right)^2\left(cos^2\psi-1\right)-\left(D\cos\varphi\frac{d\varphi}{dt}-D_e\frac{d\varphi_e}{dt}\right)^2}}\ge 1. \qquad (10)$$

Given (1), for the practical use of dependency (7), (10) we can write:

$$\left.\begin{aligned}V_{ck}&=-\pi DnK_{Vn}tg\beta\pm\pi\sqrt{\left(DnK_{Vn}tg\beta\right)^2\left(cos^2\psi-1\right)-\left(Dn\cos\varphi-D_en_e\right)^2};\\ K_T&=\frac{[V_{max}]}{-DnK_{Vn}tg\beta\pm\pi\sqrt{\left(DnK_{Vn}tg\beta\right)^2\left(cos^2\psi-1\right)-\left(Dn\cos\varphi-D_en_e\right)^2}}\ge 1\end{aligned}\right\}. \qquad (11)$$

The dependence of the angle ψ between the vector projection $\overline{V}_{ck}$ on a horizontal plane of OXY of axial movement velocity vector auger turns $\overline{V}_n$ on the basic parameters of of the combined cleaning system can be represented as [6]:

$$\psi=arcsin\left(\sqrt{1+\frac{D^2tg^2\beta\left(\frac{d\varphi}{dt}\right)^2}{\pi\left(D\cos\varphi\frac{d\varphi}{dt}-D_e\frac{d\varphi_e}{dt}\right)^2}}\right)^{-1}. \qquad (12)$$

Step of spiral T and angle lifting spiral β on the outside diameter in the design of auger working bodies select by the condition of free passage fodder beet (at their total length), and maximum speed of movement along the centerline of rotation of the auger, with which $\beta=45^o-0{,}5\varphi_k$, when φ_k = 35^0, then β = 27,5 degrees [7].

Substituting the data (12) in relation (8) we obtained mathematical model that describes the technological process of kinematic interaction of fodder beet with auger rotation and functionally connects the magnitude and direction of the total sub-hit velocity of roots V_{ck} with options of the combined cleaning system:

$$2\frac{dl_k}{dt}+DK_{Vn}tg\left(45-\frac{\varphi_k}{2}\right)\frac{d\varphi}{dt}=$$

$$=\sqrt{\begin{aligned}&\left(DK_{Vn}tg\left(45-\frac{\varphi_k}{2}\right)\frac{d\varphi}{dt}\right)^2\left\{cos^2\left[arcsin\left(\sqrt[-\frac{1}{2}]{1+\frac{D^2tg^2\left(45-\frac{\varphi_k}{2}\right)\left(\frac{d\varphi}{dt}\right)^2}{\pi\left(D\cos\varphi\frac{d\varphi}{dt}-D_e\frac{d\varphi_e}{dt}\right)^2}}\right)\right]-1\right\}-\\&-\left(D\cos\varphi\frac{d\varphi}{dt}-D_e\frac{d\varphi_e}{dt}\right)^2\end{aligned}}, \qquad (13)$$

or coefficient K_T

$$K_T = \frac{2[V_{max}]}{-DK_{Vn}tg\left(45-\frac{\varphi_k}{2}\right)\frac{d\varphi}{dt} \pm \sqrt{\left(DK_{Vn}tg\left(45-\frac{\varphi_k}{2}\right)\frac{d\varphi}{dt}\right)^2 \left\{cos^2\left[arcsin\left(\sqrt[-\frac{1}{2}]{1+\frac{D^2tg^2\left(45-\frac{\varphi_k}{2}\right)\left(\frac{d\varphi}{dt}\right)^2}{\pi\left(D\cos\varphi\frac{d\varphi}{dt}-D_e\frac{d\varphi_e}{dt}\right)^2}}\right)\right]-1\right\} - \left(D\cos\varphi\frac{d\varphi}{dt}-D_e\frac{d\varphi_e}{dt}\right)^2}} \geq 1 \quad (14)$$

Considering previously adopted hypothesis that minimizing damage fodder beet and maximum adaptability of the combined cleaning system will be provided when the angle of $\psi = 0$ or expression $cos^2\psi - 1 = 0$ (adequacy of which follows from the analysis of dependence (8), mathematical models (13) (14) are given as follows:

$$\left.\begin{aligned} &2\frac{dl_k}{dt} + DK_{Vn}tg\left(45-\frac{\varphi_k}{2}\right)\frac{d\varphi}{dt} = D_e\frac{d\varphi_e}{dt} - D\cos\varphi\frac{d\varphi}{dt};\\ &K_T = \frac{2[V_{max}]}{-DK_{Vn}tg\left(45-\frac{\varphi_k}{2}\right)\frac{d\varphi}{dt} \pm D_e\frac{d\varphi_e}{dt} - D\cos\varphi\frac{d\varphi}{dt}} \geq 1 \end{aligned}\right\}. \quad (15)$$

The obtained dependences (15) are mathematical models which functionally regulate kinematic technological process of interaction of fodder beet with auger revolution by minimum of their damage.

Conclusions

Built determined theoretical mathematical models of the interaction of root with the auger rotation of the combined cleaning system may, along with empirical derived regression equation (17), (18) be used for further study of structural and kinematic parameters of transport and technological system of fodder beet pile cleaners of root crop machine.

The minimum damage to the root crops and the maximum working capacity of the combined treatment system will be provided when the angle is $\psi \leq 0$.

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ТЕХНОЛОГІЧНА ВЗАЄМОДІЯ КОРЕНЕПЛОДІВ З ГВИНТОВОЮ ПОВЕРХНЕЮ ОЧИСНОЇ СИСТЕМИ

Наведено теоретичні дослідження технологічного процесу функціонування комбінованої очисної системи на основі аналізу руху буряків робочими поверхнями подавального транспортера та встановленого над ним шнека. Одержано аналітичні моделі процесу косого співудару коренеплодів кормових буряків з гвинтовою поверхнею шнека, які характеризують залежність зміни сумарної швидкості співудару, коефіцієнта технологічної взаємодії коренеплодів і глибини пошкодження тіла коренеплоду від основних параметрів комбінованої очисної системи. Визначено раціональні межі основних конструктивно-кінематичних параметрів комбінованої очисної системи з умови забезпечення мінімізації пошкодження кормових буряків.

Ключові слова: комбінована очисна система, коренеплоди, подавальний транспортер, гвинтова поверхня, шнек, сумарна швидкість співудару, коефіцієнт технологічної взаємодії, частота обертання шнека, діаметр шнека, пошкодження коренеплодв кормових буряків.

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