THEORETICAL RESEARCH OF CLEANER PRESSURE ON SUGAR BEET ROOT CROP

DrSc., prof., eng., academician of the NAASU Bulgakov V.[1] PhD, DrSc., prof. Nikolaenko S.[1] PhD, Assoc. prof., eng. Boris M.[2] PhD, Eng. Ihnatiev Ye.[3]

[1] National University of Life and Environmental Sciences of Ukraine, 15, Heroyiv Oborony Str., Kyiv, 03042, Ukraine
[2] Podolsky State Agricultural and Technical University, 13, Shevchenko Str., Kamenetz-Podolskiy, 32300, Khmelnytsky region, Ukraine
[3] Tavria State Agrotechnological University, 18, B. Khmelnytsky Ave., Melitopol, 72312, Zaporozhye region, Ukraine
E-mail: vbulgakov@meta.ua, yevhen.ihnatiev@tsatu.edu.ua

Abstract: *Technology incompatibility in the sugar beet harvesting process is established. Beet tops removing by follower cutoff with the subsequent root crop heads cleaning is possible at speed no more than 1.5 m·s^{-1} whereas beet pullers operate at speeds of 1.2... 1.5 times are higher. At a cutting without copier of sugar beet tops a working speed makes more than 1.5 m·s^{-1}, however losses of sugar-bearing plant material exceed agrotechnical requirements twice because of unreasonable height of a cut relative to soil surface. The differential equation of bow-shaped copier movement on a root crop head of sugar beet which is the main equation of functioning root crops heads cleaner is worked out. Components of the differential equation are defined and dependence of normal reaction on design parameters of root crop head cleaner is received. Conditions not of knocking-out of root crops are received and rational values of design parameters and operating modes of root crop head cleaner are proved.*

KEYWORDS: *ROOT CROP, BEET TOPS, ROOT CROP HEAD, CLEANER, WORKING MEMBER, SENSING MEMBER, NORMAL REACTION, DEFOLIATOR*

1. Introduction

There is an incompatibility between the operations of harvesting beet tops and digging sugar beet root crops at working speeds, while observing the requirements of the standard for the quality of raw materials (waste of sugar-bearing mass at cut - no more than 2%, and the tops remains on root crops - no more than 1.5%): beet tops separation by sensing cut with subsequent post-cleaning of the residues is possible at a speed of no more than 1.5 m·s^{-1}, whereas the root-harvesting machines operate at speeds of 1.2...1.5 times higher. However, in the increased operating conditions of the cleaner, dynamic forces arise, causing damage and knocking out the heads of root crops. [1, 3, 4].

Overcoming these contradictions by scientifically justifying the process of non-sensing cutting of beet tops with minimal losses of sugar-bearing content and developing new technical solutions that will improve separation quality of tops residues at speeds close to the working speeds of root harvesting nachines is urgent scientific and production task.

The process of interaction of the working element with the heads of root crops is cyclic and therefore the value of the normal reaction in contact point with the root crop head is variable and has a pulsating character. It is necessary to investigate its change and to estimate the peak loads on the root crop in order to prevent the limiting values of heads damage and knocking out of root crops..

2. Preconditions and means for resolving the problem

2.1. Analysis of recent research and publications

Known method of separating beet tops at operating speeds of about 2 m·s^{-1} using non-sensing cut the bulk of foliage and subsequent passive topping root crops heads with the remains of leaves, but the losses of sugar-bearing plant materials exceeds the standard requirements and can reach 8%.

Currently working bodies which designed for non-sensing separation of the bulk of foliage, which can operate at speeds higher than speed of root crops digging, but there is no justification for the height of non-sensing cut and designs of working bodies for separation beet tops residues on operating speeds over 1.5 m·s^{-1} [1, 3, 4, 13, 14].

2.2. Purpose of the study

Determination of dependence of normal reaction on root crop from constructive and technological parameters.

2.3 Materials and Methods

The object of this research is the process of separating beet tops from sugar beet root crops head by cleaner.

The main provisions of theoretical mechanics and material resistance, as well as previous studies of the physico-mechanical properties of sugar beet roots, were used to conduct research.

A necessary condition for the functioning of the working element and, accordingly, the stability of the process is characterized by the continuity of the cleaning element from the sensor and the sensor from the root crop. Let's compose the calculation scheme fig. 1 and consider the equation of dynamic equilibrium of copier, which will be equation for functioning of this mechanism [2, 5-8, 11, 12]:

$$J_k \cdot \ddot{\varphi} = -M_k + M_G + M_L\,, \qquad (1)$$

where J_k – inertia moment of copier relative to the suspension point; M_k – force moment of action root crop head on a sensor; M_G – moment of gravity; M_L – force moment of a blade pressure on sensor.

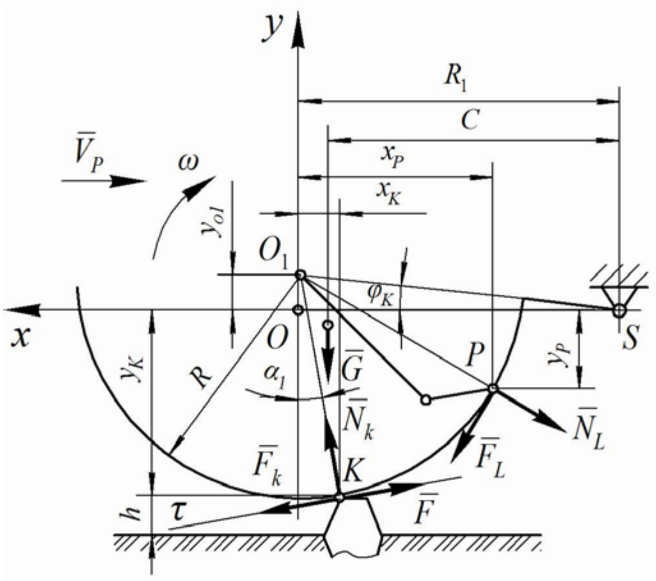

Fig. 1. *The equivalent scheme of interaction cleaner with root crops head*

Value of equality components have been identified (1) with the following form [5-8, 11, 12]:

$$\ddot{\varphi} = \frac{V^2 \cdot R^2}{R_1\left(R^2 - \left(Vt - \sqrt{2Rh - h^2}\right)^2\right)^{2/3}}, \ M_k = N_k\left(a + f_1 b\right),$$

$$M_L = \left(\frac{m\omega^2 r \cdot l \sin\alpha - J \cdot \ddot{\alpha}}{d + fe}\right)\left(d_1 + fp_1\right), \ M_G = G \cdot c,$$

where J, J_k – inertia moments of sensor relative to the suspension points; R_1 – distance from the center of sensor to suspension poin; c, a, b and d_1, p_1 – accordingly shoulders of forces G, N_k, F_k and N_L, F_L – with respect to copier suspension axis; d, e – shoulders of forces of normal reaction and friction of sensor on cleaning element with respect to suspension axis of cleaning element.

Substituting value of resulting constituent expressions in equation (1), we determine the normal reaction force which acting in contact between root crop and sensor:

$$N_k = \frac{1}{a + f_i b}\left[\frac{J_k \cdot V^2 \cdot R^2}{R^1\left(R^2 - \left(Vt - \sqrt{2Rh - h^2}\right)^2\right)^{2/3}} + G \cdot c - \frac{d_1 + fp_1}{d + f \cdot e}\left(m\omega^2 rl \cdot \sin x - J\ddot{\alpha}\right)\right]. \quad (2)$$

3. Results and discussion

When the copier moves on the root crop head, it is possible knock out from soil and damage the root crop. The condition of not knocking out the root crops is:

$$N_k \le [N_k] = \frac{[P_G]}{\sin\alpha_1 + f\cos\alpha_1}, \quad (3)$$

where $[P_G]$ – limiting horizontal component of root crop stability in soil; α_1 – angle between the axis Oy and the force N_k, we assume for calculations $\alpha_1 = 38^\circ$, which corresponds to the beginning of the contact between sensor and root crop height h = 80 mm. At $[P_G]$ = 200 N allowable value of the normal reaction $[N_k]$ = 172 N [9, 10].

The minimum value of the force at which the head of root crops destructed – $[P_k]$ = 200 N [9, 10].

For the dependencies obtained, calculation programs for PC are compiled and results of calculations are shown in fig. 1-7.

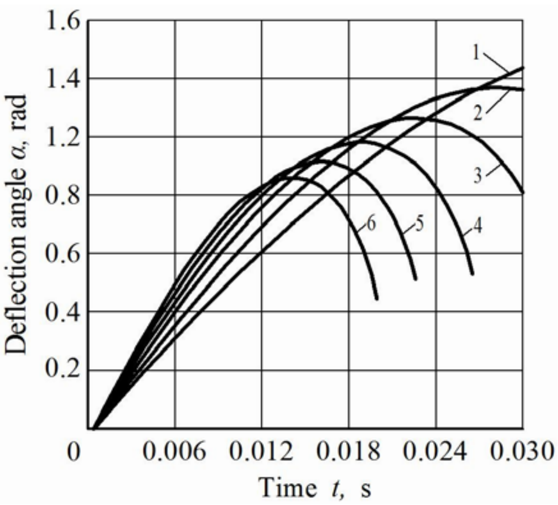

Fig. 2. *The deflection angle α cleaning element of the radial position: 1 – ω = 60 deg; 2 – ω = 80 deg; 3 – ω = 100 deg; 4 – ω = 120 deg; 5 – ω = 140 deg; 6 – ω = 160 deg*

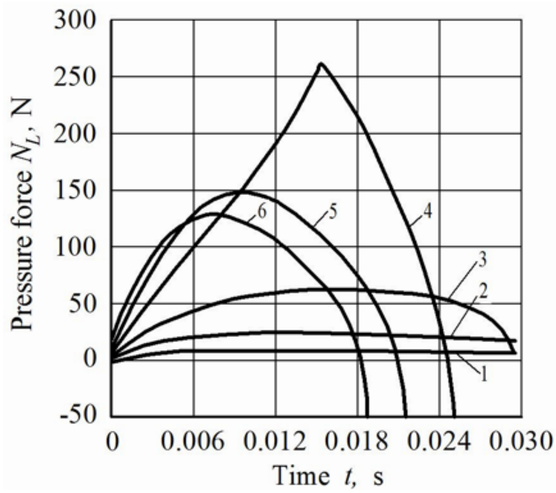

Fig. 3. *The pressure force N_L cleaning member for copier: 1 – ω = 60 deg; 2 – ω = 80 deg; 3 – ω = 100 deg; 4 – ω = 120 deg; 5 – ω = 140 deg; 6 – ω = 160 deg*

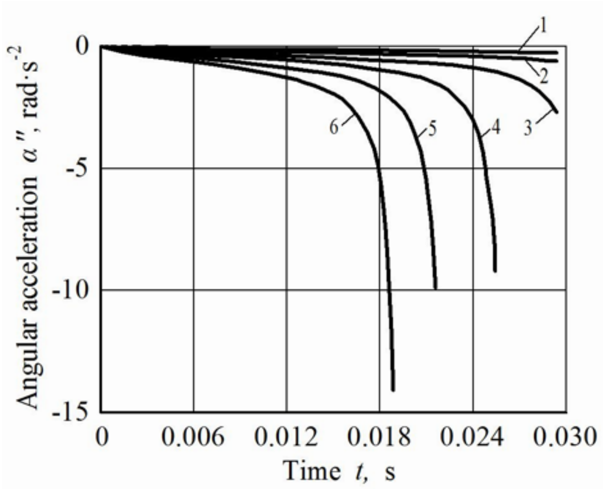

Fig. 4. *The angular acceleration of the cleaning member: 1 – ω = 60 deg; 2 – ω = 80 deg; 3 – ω = 100 deg; 4 – ω = 120 deg; 5 – ω = 140 deg; 6 – ω = 160 deg*

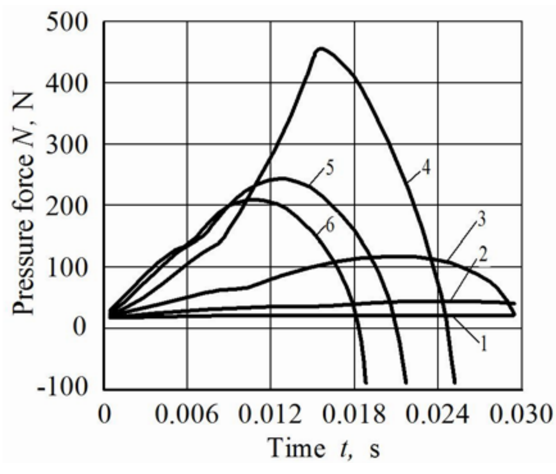

Fig. 5. *The pressure force N copier cleaner on a root vegetable at different angular velocities: 1 – ω = 60 deg; 2 – ω = 80 deg; 3 – ω = 100 deg; 4 – ω = 120 deg; 5 – ω = 140 deg; 6 – ω = 160 deg*

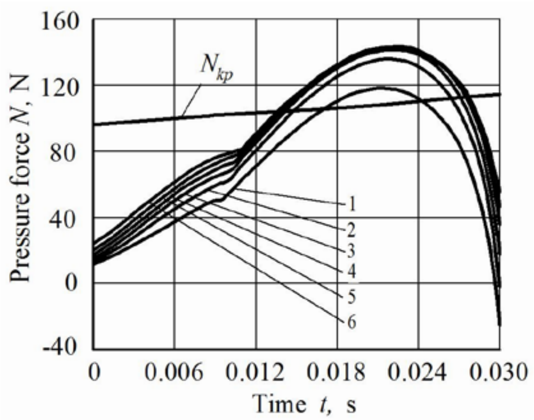

Fig. 6. *The pressure force on the copier cleaner N_{kp} root vegetable with angular velocity $\omega = 100\ s^{-1}$ and different translational velocities: 1 – $V_p = 0.5\ m{\cdot}s^{-1}$; 2 – $V_p = 1.0\ m{\cdot}s^{-1}$; 3 – $V_p = 1.5\ m{\cdot}s^{-1}$; 4 – $V_p = 2.0\ m{\cdot}s^{-1}$; 5 – $V_p = 2.5\ m{\cdot}s^{-1}$; 6 – $V_p = 3.0\ m{\cdot}s^{-1}$*

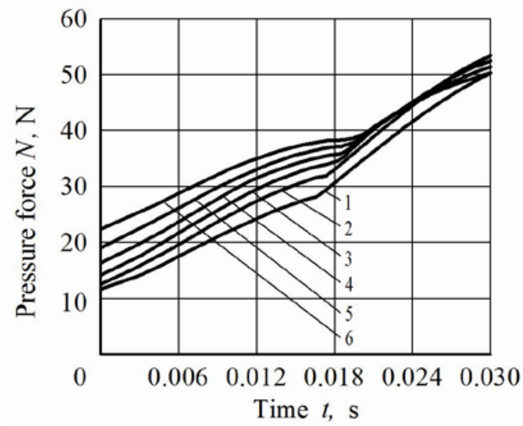

Fig. 7. *The pressure force copier cleaner on a root vegetable with angular velocity $\omega = 60\ s^{-1}$ and different translational velocities: 1 – $V_p = 0.5\ m{\cdot}s^{-1}$; 2 – $V_p = 1.0\ m{\cdot}s^{-1}$; 3 – $V_p = 1.5\ m{\cdot}s^{-1}$; 4 – $V_p = 2.0\ m{\cdot}s^{-1}$; 5 – $V_p = 2.5\ m{\cdot}s^{-1}$; 6 – $V_p = 3.0\ m{\cdot}s^{-1}$*

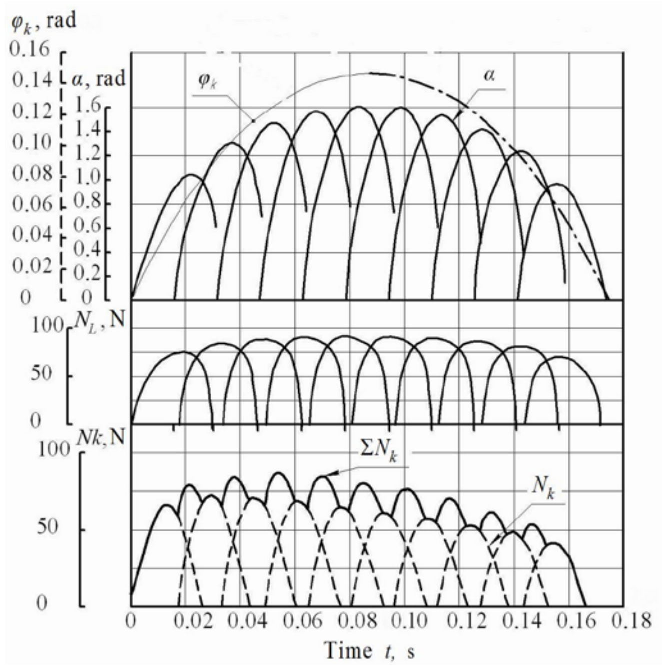

Fig. 8. *Dependence of cleaner element rotation angle and normal reaction at machine translational speed $V_p = 2\ m{\cdot}s^{-1}$ and the rotor angular velocity $\omega = 100\ s^{-1}$.*

4. Conclusions

With translational speed V_p = 1…3 m s^{-1}, rotor angular velocity ω = 90…105 s^{-1}, number of cleaning elements z = 4…6 and diameter of cleaning rotor D = 0,55…0,65 m the rational normal reaction force in the contact point of sensor-root crops is ensured at level – N_k = 60…100 N.

5. Literature

1. Bulgakov V.M. Teoriya sveklouborochnyih mashin. Monografiya / V.M. Bulgakov. – Kiev: Izdatelskiy tsentr NAU, 2005. – 245 p.

2. Gulyaev V.I. Kolebaniya sistem tverdyih i deformiruemyih tel pri slozhnom dvizhenii / V.I. Gulyaev, P.P. Lizunov. – Kiev: Vyisshaya shkola, 1989. – 197 p.

3. Vasilenko A.A. Kompleksnaya mehanizatsiya proizvodstva saharnoy sveklyi / A.A. Vasilenko, P.T. Babiy, P.V. Savich i dr. – Moskva, 1962. – 243 p.

4. Pogorelyiy L.V. sveklouborochnyiy mashinyi: istoriya, konstruktsiya, teoriya, prognoz / L.V. Pogorelyiy, N.V. Tatyanko. – K.: Feniks, 2004. – 232 p.

5. Filchakov P.F. Spravochnik po vyisshey matematike / P.F. Filchakov. – Kiev: Naukova dumka, 1974. – 743 p.

6. Targ S.M. Kratkiy kurs teoreticheskoy mehaniki: uchebnik / S.M. Targ. – Moskva: Vyisshaya. shkola, 1986. – 416 p.

7. Pisarenko G.S. Spravochnik po soprotivleniyu materialov / G.S. Pisarenko, A.P. Yakovlev, V.V. Matveev. – Kiev: Naukova dumka, 1975. – 704 p.

8. Vodnev V.T. Osnovnyie matematicheskie formulyi / V.T. Vodnev A.F. Naumovich, N.F. Naumovich; pod red. Yu.S. Bogdnova. – Minsk: Vyisheyshaya shkola, 1988. – 255 p.

9. Helemendik N.M. Povyishenie mehaniko-tehnologicheskoy effektivnosti trudoemkim protsessov v sveklovodstve: avtoref. dis. na soiskaniyu nauch. stepeni dokt. tehn. nauk.: spets. 05.20.01 "Mehanizatsiya selskohozyaystvennogo proizvodstva" / N.M. Helemendik. – Ternopol: TPI, 1996. – 48 p.

10. Helemendik N.M. Issledovanie tehnologicheskogo protsessa i rabochih organov dlya uborki saharnoy sveklyi v usloviyah Zapadnoy Stepi USSR: Diss. . kand. tehn. nauk.: 05.410 / N.M. Helemendik. – Voronezh, 1968. – 31 p.

11. Bat M.I. Teoreticheskaya mehanika v primerah i zadachah: uch. posobie / M.I. Bat, G.Yu. Dzhanilidze, A.S. Kelzon. – Moskva: Nauka, 1973. – 488 p.

12. Butenin N.V. Kurs teoreticheskoy mehaniki. Tom 2 / N.V. Butenin, Ya.L. Lunts, D.R. Merkin. – M.: Nauka, 1985. – 496 p.

13. VISHOM. Fiziko-mehanicheskie svoystva rasteniy, pochv i udobreniy: metodyi issledovaniya, priboryi, harakteristiki. – M.: Kolos, 1970. – 417 p.

14. Bulgakov V., Adamchuk V., Nozdrovicky L., Boris M., Ihnatiev Ye. Properties of the sugar beet tops during the harvest // Proceeding of 6th International Conference on Trends in Agricultural Engineering 2016. – 7-9 September 2016. – Prague, Czech Republic. p.p. 102-108.