

# Theoretical justification of fruit separation process by a planetary fruit separator

Sergey V. Belousov<sup>1,\*</sup>, and Evgeny S. Gusak<sup>1</sup>

<sup>1</sup>FSBEI HE Kuban State Agrarian University named after I.T.Trubilin, Krasnodar, Russian Federation

**Abstract.** The article is devoted to the theoretical justification of the process of rolling stems by planetary rollers of the fruit separator in the harvesting of Solanaceae vegetables as reusable as direct full harvest. The article has a theoretical, research character, expressed in the fact that the issue of Solanaceae vegetables harvesting was theoretically considered, the analysis of methods and means for the introduction of dry inorganic substances was given, when considering the process of rolling stems of Solanaceae vegetables as a rolling of elastic-plastic material there were obtained the dependences that determine the kinematic and energy parameters of planetary multi-rolling fruit separators. The type of the proposed design is theoretically justified, its description and the flow of the technological process are given. As a result of the work done, the dependences of the main parameters and values are obtained, which can be used in further work on the study of the parameters and dependencies of the interaction of the fruits of Solanaceae vegetables in interaction with planetary fruit separators.

The research in the field of Solanaceae vegetables harvesting was conducted in Kuban State Agrarian University at the department of "Processes and machines in agribusiness". The work is aimed at the development of working elements of the rotor type for reusable harvesting of Solanaceae vegetables. It is probable, that the present construction allows to improve the qualitative rates of working elements of fruit separators. The bottom of sweet pepper is on a peduncle which is attached to a stem. When separating the fruit, it is necessary to separate the peduncle at the place of its attachment to the stem.

The rupture is provided if the force of compression acts on the peduncle in the transverse direction, and in the longitudinal direction – the tensile force and the variable bending moment in the direction. The combination of these forces and moment is observed in the work of the planetary fruit-separating apparatus. The breaking force of the peduncle in bending tension is reduced by 3-5 times compared to the tension without bending.

The process of main fruit separation is at the third level of the multilevel scheme of justification. Its input parameters are the output parameters of the second level - the operation of the process of rolling stems. The criterion for evaluating this operation is  $\epsilon_{\text{oid}}$  - the degree of fruit separation, which should strive to the maximum value.

---

\* Corresponding author: [sergey.belousov.87@mail.ru](mailto:sergey.belousov.87@mail.ru)

Figure 1 shows the scheme of the influence of forces of normal pressure  $N$ , friction  $T$  and stretching  $P_p$  on the bottom of the fruit and the peduncle. In the case, if the diameters and working surfaces of paired rollers are the same, the angles  $\alpha$  of a coverage of the rollers by a stem and a fruit, forces  $N$ ,  $T$  and the resultant forces  $R$  for both rollers will be the same, and the bending of the peduncle is absent, and its rupture often occurs in the middle. But diameters and working surfaces of the planetary rollers 3 and 4 in general are in pair and they are different, so

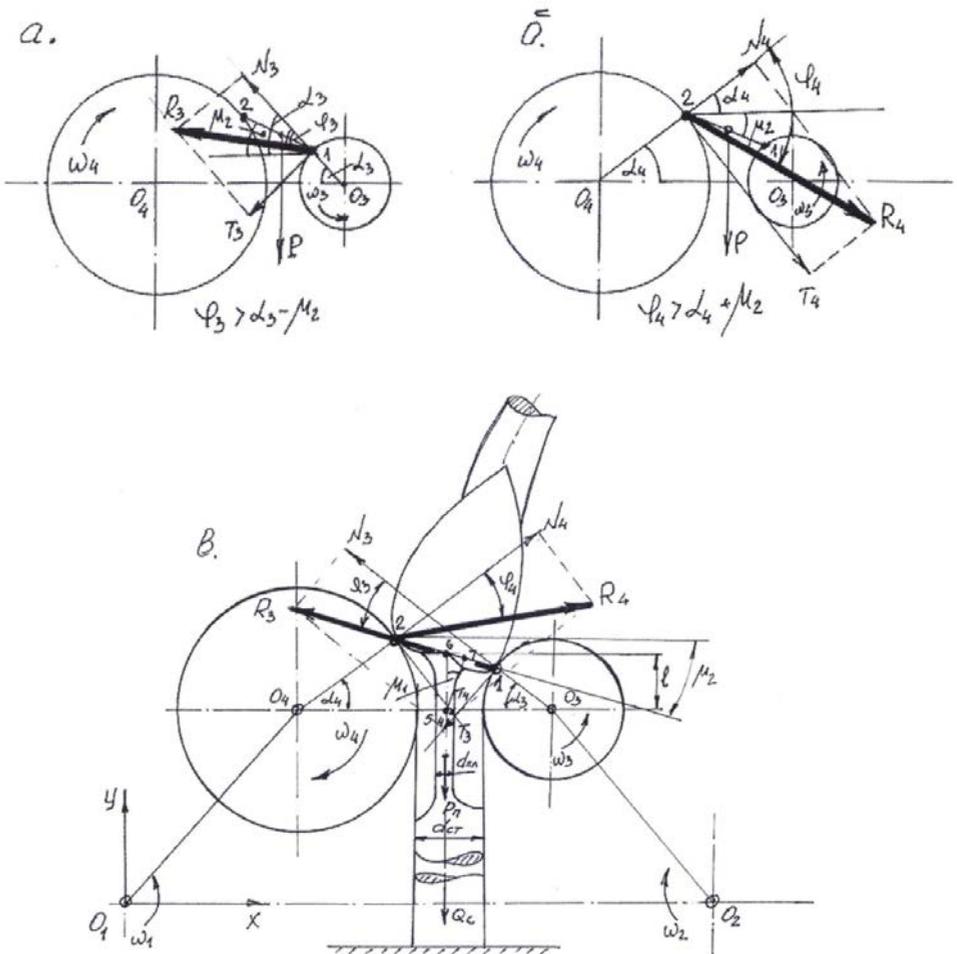
$$\alpha_3 \neq \alpha_4, N_3 \neq N_4, T_3 \neq T_4 \text{ и } R_3 \neq R_4.$$

To separate the fruit, the following condition must be met:

$$Q_c + \Sigma T_y - \Sigma N_y = P_n$$

where  $\Sigma T_y$  and  $\Sigma N_y$  - sum of projections of forces  $T_3$  and  $T_4$  and  $N_3$  and  $N_4$  respectively on direction of stem's motion.

The process of separating the fruit from the stem by the planetary roller consists of two stages: stretching the stem and its double-ended bending.



**Fig. 1.** Sweet pepper fruit separation by the planetary fruit separator

Consider the first step. In the result of the relative movement of the rollers 3 and 4 and the impact on the bottom of the fruit of variable forces  $R_3$  and  $R_4$ , the fruit influences a variable moment in magnitude and direction. The peduncle bends and stretches so, that the most tension influences the extreme external or internal fibers in the place of attachment of the peduncle to the fruit. The rupture of the peduncle will take place as only the tension in the place of connection with the fruit will achieve the critical values.

Suppose, that the peduncle is a flexible fiber attached to the middle of the fruit's bottom and the force  $P$  is directed along the middle fiber of the peduncle,  $d_n$ - diameter of fruit:  $l$  – length of peduncle in the place 5-6;  $\mu_1$ - angle between direct 5-6 and 5-7, defining the direction of force  $P$ ,  $\mu_2$  – angle between direct 1-2 and  $O_3O_4$ , defining the position of the fruit's bottom in a working chink.

According to calculations  $\mu = 0-10^\circ$ . In the result of projecting of sides of trapezoids  $1O_356$  and  $2O_456$  in the direction 5-6 and  $O_3O_4$  and transformations we obtain

$$\sin \alpha_3 = \frac{4 \cdot l \cdot n \cdot r_3 \pm \sqrt{4 \cdot l \cdot n \cdot r_3 - 2(m^2 - 4 \cdot l^2)[n^2 - (2m - r_3)^2]}}{2(m^2 - 4 \cdot l^2) \cdot r_3^2}$$

$$\sin \alpha_4 = \frac{2 \cdot l - r_3 \cdot \sin \alpha_3}{r_3}, \tag{1}$$

where  $m$ - difference of radii of adjacent rollers,  $m = r_4 - r_3$ ;  $n$  – difference between length of peduncle,  $n = 4 \cdot l - r_4 - r_3 + m$ .

Length of peduncle  $l$  can be equal

$$l = r_{cp} \cdot \sin(\arccos \frac{c - d_n}{2r_{cp}}), \tag{2}$$

where  $r_{cp}$  – middle radius of rollers,  $r_{sr} = \frac{r_3 + r_4}{2}$

From the trapezoid  $1O_356$  it follows:

$$\sin \mu_2 = \frac{2(l - r_3 \cdot \sin \alpha_3)}{d_n} \tag{3}$$

If  $\varphi_3 < \alpha_3 - \mu_2$  and  $\varphi_4 < \alpha_4 + \mu_2$ , so from equations of forces  $R_3$ ,  $R_4$  and  $P$  moments relatively to points 1 and 2 it follows:

$$R_3 = \frac{P \cdot d_n \cdot \cos \mu_2 - 2M_\mu}{2d_n \cdot \sin(\alpha_3 + \varphi_3 - \mu_2)}, \quad R_4 = \frac{P \cdot d_n \cdot \cos \mu_2 - 2M_\mu}{2d_n \cdot \sin(\alpha_4 + \varphi_4 + \mu_2)} \tag{4}$$

where  $M_\mu$  – moment of resistance of peduncle to bending ( $M_\mu = 0,04-0,07$  Hm)

If  $\varphi_3 > \alpha_3 - \mu_2$  (Figure 1 a) and  $\varphi_4 > \alpha_4 + \mu_2$ , it follows

$$R_3 = \frac{2M_\mu - P d_n \cdot \cos \mu_2}{2d_n \cdot \sin(\varphi_3 - \alpha_3 + \mu_2)}, \quad R_4 = \frac{2M_\mu - P d_n \cdot \cos \mu_2}{2d_n \cdot \sin(\varphi_4 + \alpha_4 + \mu_4)} \tag{5}$$

We assume that  $\varepsilon_1$  and  $\varepsilon_2$  are angles between the directions of the normal pressure  $N_3$  and  $N_4$  and speeds  $V_1$  and  $V_2$ , respectively. If speeds  $V_1$  and  $V_2$  are directed to angles inside angles of friction  $\varphi_3$  and  $\varphi_4$ , so  $\varepsilon_1 > \varphi_3$  and  $\varepsilon_2 > \varphi_4$ , rollers 3 and 4 slip along the

fruit's bottom, and directions of vectors  $R_3$  and  $R_4$  are defined by values of angles  $\varphi_3$  and  $\varphi_4$ , and modules  $R_3$  and  $R_4$  on formulas (5). If  $\varepsilon_1 < \varphi_3$  and  $\varepsilon_2 < \varphi_4$ , so the direction of vectors  $R_3$  and  $R_4$  coincide with vectors  $V_1$  and  $V_2$ , respectively. Then, determining the modules  $R_3$  and  $R_4$  in the formulas (5) and (6) instead of  $\varphi_3$  and  $\varphi_4$  should be put  $E_1$  and  $E_2$ , respectively.

And so, the position of the bottom of fruit at the beginning of contact with the rollers is determined by the ratio of the roller diameters  $d_3$  and  $d_4$  and the fruit's bottom  $d_n$ . In turn, values and directions of powers  $R_3$  and  $R_4$  depend on position of fruit's bottom in a working chink and as well as on values  $\varphi_3$  and  $\varphi_4$ .

If  $\varepsilon_1 > \varphi_3$ , and  $\varepsilon_2 > \varphi_4$ , the conditions for non-gripping of fruit by rollers 3 and 4 will be:

$$\alpha_3 - \mu_2 > \varphi_3 \text{ and } \alpha_4 + \mu_2 > \varphi_4 \quad (6)$$

where  $\alpha_3 - \mu_2$  and  $\alpha_4 + \mu_2$  – angles, closed between the flatness of fruit's bottom and directions of forces  $N_3$  and  $N_4$  respectively. If  $\varepsilon_1 < \varphi_3$  and  $\varepsilon_2 < \varphi_4$ , the conditions for gripping of fruit by rollers 3 and 4:

$$\alpha_3 - \mu_2 < \varphi_3 \text{ и } \alpha_4 + \mu_2 < \varphi_4, \quad (7)$$

Period of fruit separation from the stem by planetary rollers  $t_0$  was defined by the formula:

$$t_0 = \frac{\varepsilon_0 \cdot l}{\rho_0' \cdot \omega_1 + V_{cr}}, \quad (8)$$

where  $\varepsilon_0$  – relative elongation of peduncle;  $l$  – length of peduncle;  $\rho_0'$  – radius of initial circumference of the rolling of the drum 1 along the drum 2,

$\rho_0' = \frac{A \cdot \omega_2}{\omega_1 + \omega_2}$ ,  $A = O_1 O_2$  – distance between centers of drums 1 and 2;  $V_{cr}$  – speed of stem.

Power which is necessary for fruit's separation from the stem by rollers of two-drum device  $W_n$ , is equal:

$$W_n = t_0 \cdot e_c \cdot e_n [M_3'(\omega_3 - \omega_2) + M_4'(\omega_4 - \omega_1)], \quad (9)$$

where  $e_c$  – amount of stems which are simultaneously in the working chink;  $e_n$  – average amount of fruits on the stem;  $M_3$  and  $M_4$  – moment of resultant forces  $R_3$  and  $R_4$  relatively to momentary axes of rotation of rollers 3 and 4.

Power for fruit's separation by rollers  $W_q$  is defined by the formula

$$W_q = \frac{q}{g} \cdot e_c \cdot e_n (V_{cr} + \rho_0' \cdot \omega_1)^2, \quad (10)$$

where  $q$  – mass of one fruit.

Thus, it is theoretically defined the rationale of the fruit separation process by the planetary fruit separator. The obtained dependences of the main parameters and values can be used to study similar structures and parameters and dependencies of the interaction of fruits of Solanaceae vegetables in the interaction with planetary fruit separators in a further study.

## References

1. Trubilin E.I. Results of experimental studies determining the degree of traction resistance of the plowshoe in the treatment of heavy soils / Trubilin E.I., Belousov S.V., Lepshina A.I. // The Political Network Electronic Scientific Journal of the Kuban State Agrarian University. -2014. -No. 103.-C. 673-686.
2. E.I. Trubilin. Economic efficiency of the dump cultivation of soil developed by a combined plowshoe / Trubilin E.I., Belousov S.V., Lepshina A.I. // The political network electronic scientific journal of the Kuban State Agrarian University. -2014. - No. 103.-C. 654-672.
3. E.I. Trubilin. The main soil cultivation with the formation turnover in modern working conditions and devices for its implementation / Trubilin E.I., Belousov S.V., Lepshina A.I. // The political network electronic scientific journal of the Kuban State Agrarian University. -2014. - No. 104.-C. 1902-1922.
4. Belousov S.V. Communication of science and technology in the field of development of machines for the basic tillage of the soil with the circulation of the bed / Belousov S.V. // The political network electronic scientific journal of the Kuban State Agrarian University. -2015. No. 109.-C. 468-486.
5. Belousov S.V. Modern technologies of soil cultivation / Belousov S.V. // Scientific provision of the agro industrial complex. -2012. -FROM. 3-4.
6. Parkhomenko G.G. Perfection of working organs for tillage / Parkhomenko GG, Bozhko I.V., Semenikhina Y.A., Pantyukhov I.V., Drozdov S.V., Gromakov A.V., Kambulov S.I., Belousov S.V. // State and prospects of the development of agricultural machinery. Collection of articles of the 9th international scientific and practical conference within the framework of the 19th international agro-industrial exhibition "Interagro-mash-2016". -2016. -FROM. 27-30.
7. Belousov S.V. Development of the construction of a plow for the treatment of heavy soils / Belousov S.V., Trubilin E.I. // Science of the Kuban. -2013. -No 1.-C. 37-40.
8. Belousov S.V. Patent search for structures that provide soil treatment with the turnover of the reservoir. Search method. The proposed technical solution / Belousov S.V. // The political network electronic scientific journal of the Kuban State Agrarian University. -2015. No. 109.-C. 416-450.
9. Belousov S.V. Decrease in energy intensity of the process of basic processing of soil with turnover of the bed / Belousov S.V. // Fundamental foundations of modern agrarian technologies and technology. Collection of works of the All-Russian Youth Scientific and Practical Conference. -National Research Tomsk Polytechnic University. -2015. -FROM. 280-283.
10. Belousov S.V. Role and prospects for the development of small-scale mechanization in the context of co-temporary engineering / Belousov S.V. / Scientific support of the agro-industrial complex. A collection of articles on the materials of the 72nd Scientific and Practical Conference of pre-applicants on the results of research work for 2016 - 2017.-C. 277-278.