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# THE LAYOUT OF THE SUCCESSIVE IMPURITIES CLEANING DEVICES FROM THE BULB AND TUBERCLE HARVESTERS

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*In lucrare este prezentată o metodologie pentru poziționarea corespunzătoare a separatoarelor succesive cu grătare rulante de la sistemele de curățare de impurități ale maşinilor de recoltat bulbi sau tuberculi. Metodologia cuprinde modelarea matematică a trecerii materialului pe separatoarele succesive şi, pe baza acesteia prin simulare pe calculator, realizarea unui program de calcul a poziției reciproce dintre separatoare.*

*In the paper is presented a methodology for the layout of the successive cleaning devices, namely with rolling conveyors, from the impurities cleaning system of the bulb and tubercle harvesters. The methodology contains the mathematic model of the material passage on successive cleaning devices, the calculus algorithm of the relative position between the cleaning devices and the software based on it.*

**Keywords:** bulb and tubercle harvesters, impurities cleaning systems, the layout of the successive rolling conveyors, mathematic modelling, calculus algorithm, software.

## 1. Introduction

At the bulb and tubercle harvesting, after the digging of the useful products from the soil, it results a mixture formed of dislocated useful products and a great quantity of impurities (mainly fragments of soil, but also vegetal rests, boulders and stones), in most of the cases, several times bigger that the quantity of useful products. Because of that, all the bulb and tubercle harvesters are equipped with impurities cleaning systems, as very important and indispensable elements of their structure. Generally, the impurities cleaning systems used in the construction of the bulb and tubercle harvesters are frequently composed of two or several separation organs successively disposed that are consequently traversed by the mixture submitted to the impurities separation. The most used types of separation organs are the rolling conveyors, the oscillating and vibrating screens, and the systems of bitters with fingers or roles [4, 5, 6].

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The passage of the mixture of useful products and impurities between the successive separation devices, from the impurities cleaning system, is done by jumps, which have as results the spreading of the mixture components and the changing of its orientations, anterior to the jumps, because of the impact with the active surfaces of the receptor separation devices. These results are extremely favourable to the ulterior separation of the impurities. The problem that must be solved in these cases is the correct layout of the successive separation devices,

thus, after the jumps, the mixture, submitted to the impurities separation process, arrives in imposed zones of the consecutive separation devices of the active surfaces and the useful products from the mixture are not damaged after the impacts with these surfaces.

Fig. 1. The principle schema of onion harvester, which has the impurities cleaning system, composed of two successive rolling conveyors

In the present paper it will be analysed the particular case, frequently met in practice, of the layout of successive separation devices with rolling conveyor, component of an impurities cleaning system. For example, in the figure 1 is presented the structural schema of an onion harvester which has the impurities cleaning system composed of two successive separation devices with rolling conveyor [4]. It can be mentioned that the rolling conveyors are very often found in the construction of the bulb and tubercle harvesters. These separators present the advantages of simplicity and quiet functioning, without significant shocks and vibrations transmitted to the machine chassis. The main disadvantage of these separators is a lower efficacy of the impurities separation, because of the fact that the separation process takes place mostly in the acting zones of the active surfaces shaking organs, being much blurred and practically insignificant on the unshaken rest of the active surfaces. Because of that, it can be appreciated that even the displacement by jumps of the material between the successive separation devices constitutes a growing factor of the impurities separation intensity in the feeding zone of the receptor conveyors, which increase significantly the efficiency of the whole impurities cleaning system.

For the purpose of an adequate layout of the separation devices with rolling conveyors, it will be presented a methodology, which contains the mathematic modelling of the material passage between successive rolling conveyors, the calculus algorithm of the relative position between the successive rolling conveyors and the software based on it.

## 2. The mathematic modelling of the material passage on two successive rolling conveyors

The mathematic model of the material passage between successive separation devices with rolling conveyors constitutes the object of an anterior paper [7] published by the first author where was presented in detail.

So, in the figure 2 is presented the analytical representation of the material passage between two successive rolling conveyors. For the process analysis there are considered the following simplifier hypothesis: the processed material is composed only of quasi-spherical shape discreet particles, with dimensions and physical and mechanical features like the most valuable useful products (the biggest bulbs or tubercles of the crop) and the useful products, in free motion, are concentrated in their gravity centres, which represents them during the motion. Based on the analytical representation and considering the simplifier hypothesis, it can be defined the characteristic parameters with the following relations:

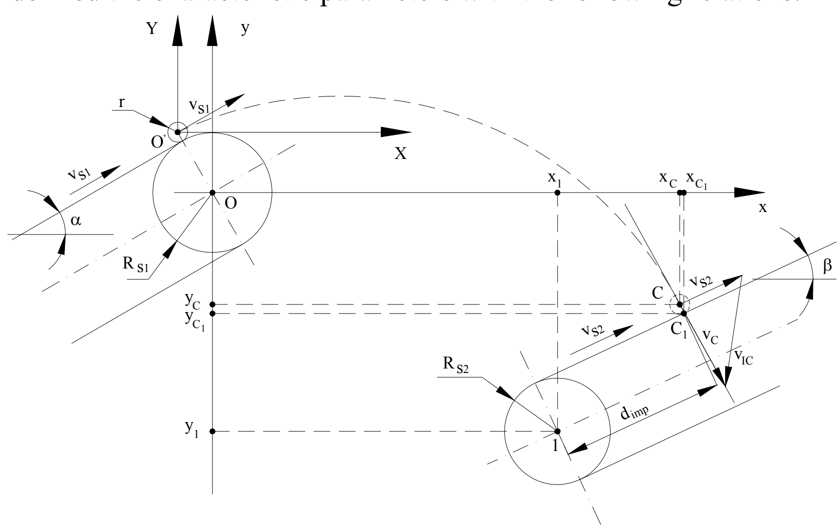


Fig. 2. The analytical representation of the material passage between two successive rolling conveyors [7]

- the speed projections, considered in the co-ordinates system X0'Y, of the particle in free movement, launched by the anterior rolling conveyor:

$$v_X = v_{S1} \cdot \cos\alpha$$
$$v_Y = -g \cdot t + v_{S1} \cdot \sin\alpha \quad (1)$$

- the speed projections, considered in the co-ordinates system X0'Y, of the particle in a certain point, noted with C, wherein the particle impacts the active surface of the posterior conveyor:

$$v_{CX} = v_{S1} \cdot \cos\alpha$$
$$v_{CY} = -g \cdot t_C + v_{S1} \cdot \sin\alpha \quad (2)$$

where: $t_C$[s] is the period of time in what the particle in free movement routes the trajectory from the launching to the point C;

- the relative impact speed module from the point C, if it is considered that the point C is such placed, that the relative impact speed value reaches the critical value, which if it is exceded they appears damages to the useful products:

$$v_{CI}^2 = v_{CIX}^2 + v_{CIY}^2 = v_{cr}^2 \quad (3)$$

where: $v_{CIX}$[m/s] and $v_{CIY}$[m/s] are the projections of the relative impact speed vector, particularised in the point C;

$v_{cr}$[m/s] is the critical value of the relative impact speed;

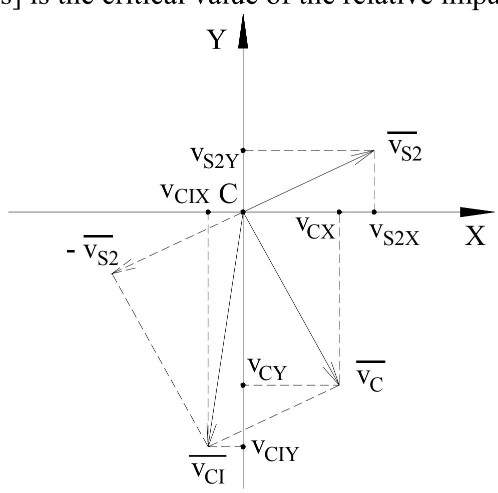


Fig. 3. The relative impact speed $v_{IC}$ in the point C

- the relative impact speed projections, considered in the co-ordinates system X0'Y (see figure 3); it can be mentioned that the relative impact speed is the difference vector between the speed of the particle in free movement and the speed of the receptor conveyor belt in the impact point:

$$v_{CIX} = v_{CX} - v_{S2X}$$
$$v_{CIY} = v_{CY} - v_{S2Y} \quad (4)$$

- the equation with the single unknown $t_C$ obtained from the processing of the system of three equations (formed by the expressions 2 and 3) with three unknowns ($v_{CX}$ and $v_{CY}$ and the period of time $t_C$), if they are introducing the first two equations in the third one, considering also the relations 4:

$$g^2 \cdot t_C^2 + 2 \cdot g \cdot \left(v_{S2} \cdot \sin\beta - v_{S1} \cdot \sin\alpha\right) \cdot t_C + v_{S1}^2 + v_{S2}^2 - v_{cr}^2 - 2 \cdot v_{S1} \cdot v_{S2} \cdot \cos(\alpha - \beta) = 0 \qquad (5)$$

- the determination of the period $t_C$ value, which is the positive root of the equation 5 (which is the only root with physical signification);

- the co-ordinates of the point C, in the co-ordinates system X0'Y, which can be calculated, if it is known the period $t_C$ value, by using the parametric equations of the trajectory of the particle in free movement:

$$X_C = v_{S1} \cdot t_C \cdot \cos\alpha$$
$$Y_C = -\frac{g \cdot t_C^2}{2} + v_{S1} \cdot t_C \cdot \sin\alpha \qquad (6)$$

- the co-ordinates of the point C, in the co-ordinates system x0y, determined with transforming relations:

$$x_C = -\left(R_{S1} + r\right) \cdot \sin\alpha + X_C$$
$$y_C = \left(R_{S1} + r\right) \cdot \cos\alpha + Y_C \qquad (7)$$

- the co-ordinates of the point $C_1$, of contact between the particle of material and the receptor conveyor active surface, in the co-ordinates system x0y:

$$x_{C1} = x_C + r \cdot \sin\beta$$
$$y_{C1} = y_C - r \cdot \cos\beta \qquad (8)$$

- the co-ordinates of the point 1 in the co-ordinates system x0y, namely the co-ordinates of positioning of the returning drum axle of the receptor conveyor belt towards the driving drum axle of the launching conveyor belt, considered like origin of the co-ordinates system x0y, which can be calculated in relation with the co-ordinates of the points $C_1$, or respectively C:

$$x_1 = x_{C1} - d_{imp} \cdot \cos\beta + R_{S2} \cdot \sin\beta = x_C - d_{imp} \cdot \cos\beta + \left(R_{S2} + r\right) \cdot \sin\beta$$
$$y_1 = y_{C1} - d_{imp} \cdot \sin\beta - R_{S2} \cdot \cos\beta = y_C - d_{imp} \cdot \sin\beta - \left(R_{S2} + r\right) \cdot \cos\beta \qquad (9)$$

For the homogeneity of the relations, it is mentioned that the parameters of length type are expressed in [m], the parameters of speed type are expressed in [m/s], the parameters of time type are expressed in [s] and the parameters of angle type are expressed in [rad].

## 3. Calculus algorithm of the relative position between the successive separators with rolling conveyors and the software based on it

The mathematical model for the material passage between two successive separators with rolling conveyors offered the possibility to achieve a calculus algorithm for the determination of the relative position between the consequent separators.

In figure 4 is presented the structural chart of the calculus algorithm.

Based on the calculus algorithm it was realised an interactive software that allows the fast and easy determination of the relative position between the successive separators.

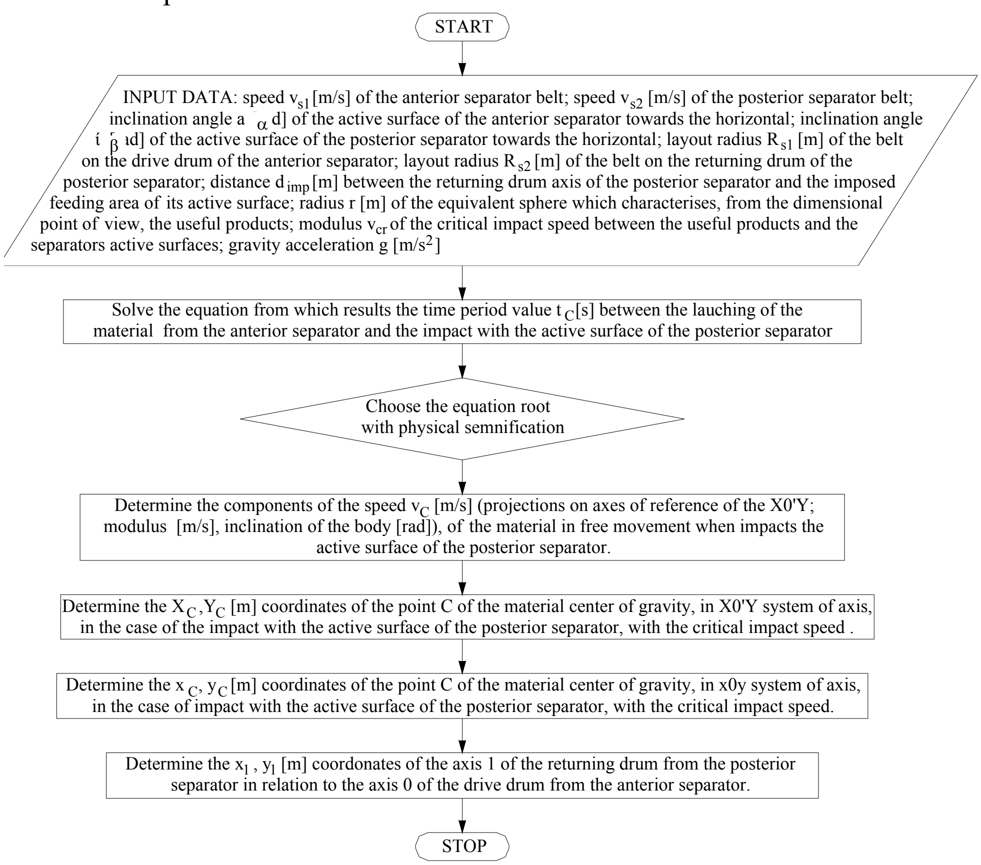


Fig. 4. The structural chart of the calculus algorithm of the relative position between successive separators with rolling conveyor

Using the software, it can be done thorough analyses for the optimum layout of the successive separators with rolling conveyors, considering many possible constructive options obtained by varying the values of the different characteristic parameters of the separators or of the useful products.

The input data necessary for the software running are referring to the construction and the working regime of the impurities cleaning system with successive rolling conveyors (the speeds of the impurities separation belts of the conveyors, the inclination angles towards the horizontal of the active surfaces of the conveyors separation belts, the layout radius of the impurities separation belts on the drive drum of the anterior conveyor, respectively on the returning drum of the posterior conveyor, the positioning distance of the posterior conveyor feeding zone, measured along its active surface) and to the impact damages specific features of the useful products (the radius of the equivalent sphere which characterizes from dimensional point of view the most valuable useful products and the critical value of the impact speed modulus between the useful products and the active surfaces of the conveyors).

The output data of the software are the layout coordinates of the returning drum axis of the posterior conveyor in relation with the drive drum axis of the anterior conveyor.

For an adequate usage of the software, it must be taken in consideration the following recommendations:

- the critical impact speed values, which if it is exceeded, they appears damages to the useful products, correspond to the most detrimental cases, when direct impacts take place between the useful products and the active surface of the separators; the critical impact speed value varies as a function of the considered useful products nature (bulbs or tubercles from a specific variety) and of its physical and mechanical characteristics and mass;
- after the determination of the positioning co-ordinates of the receptor conveyor belt returning drum axle towards the launching conveyor belt driving drum axle, it must be verified if they appears geometrical interferences between the two separators, and if it is so, it will be tried new alternatives by modifying the input data regarding the separators characteristics until it will be obtained the appropriate positioning parameters

As an example, next, it is presented the usage of the software for the positioning of the successive separators in the concrete situation of the impurities cleaning system design from the experimental model of the onion and garlic harvester MRCU. This impurities cleaning system is composed of two successive separators with rolling conveyors which have the following characteristics: the anterior conveyor belt speed is 2.1 m/s, the posterior conveyor belt speed is 2.2 m/s, the inclination angle of the active surface of the anterior conveyor belt is 0.523599 rad, the inclination angle of the active surface of the posterior conveyor belt is 0.488692 rad, the layout radius of the belt on the drive drum of the anterior conveyor is 0.12 m, the layout radius of the belt on the returning drum of the posterior conveyor is 0.07 m, the imposed distance which characterize the position of the posterior conveyor feeding zone is 0.2 m, the radius of the equivalent sphere for the most valuable bulbs is 0.03 m and the critical value of the impact speed modulus between the useful products and the active surfaces of the conveyors is 2.04 m/s (these values were estimated for onion bulbs from the variety “Giant of Stuttgart”, a frequently cultivated onion variety in Romania, taking in consideration the references from the papers [1,2,3]). After running the software they result the relative layout co-ordinates between the posterior conveyor belt returning drum axle and the anterior conveyor belt driving drum axle which are (0.176 m, -0.047 m) which are satisfactory even from the point of view of the geometrical interferences.

**CALCULUS PROGRAM FOR THE LAYOUT OF TWO SUCCESSIVE CLEANING DEVICES WITH ROLLING CONVEYORS FROM THE IMPURITIES CLEANING SYSTEMS OF THE BULB OR TUBERCLE HARVESTER**

**Data about the construction ofthe impurities cleaning system with successive rolling conveyors from the bulb or tubercle harvesters**

| | |
|---|---|
| vs1 [m/s] - speed of the impurities separation belt from the anterior conveyor | $vs1 := 2.1$ |
| vs2 [m/s] - speed of the impurities separation belt from the posterior conveyor | $vs2 := 2.2$ |
| $\alpha$ [rad] - the inclination angle towards the horizontal of the separation belt active surface from the anterior conveyor | $\alpha := 0.523599$ |
| $\beta$ [rad] - the inclination angle towards the horizontal of the separation belt active surface from the posterior conveyor | $\beta := 0.488692$ |
| Rs1 [m] - the layout radius of the belt on the drive drum of the anterior conveyor | $Rs1 := 0.12$ |
| Rs2 [m] - the layout radius of the belt on the returning drum of the posterior conveyor | $Rs2 := 0.07$ |
| dimp [m] - the distance between the returning drum axis of the posterior conveyor and the imposed feeding area of its active surface (measured along the active surface of the conveyor) | $dimp := 0.2$ |

**Data about the bulb and tubercle specific features regarding their impact damages**

| | |
|---|---|
| r [m] - the radius of the equivalent sphere which characterises from dimensional point of view the useful products (bulbs or tubercles) | $r := 0.03$ |
| vcr [m/s] - the critical value of the impact speed modulus between the useful products and the active surfaces of the conveyors, which if it is exceded they appears damages to the useful products | $vcr := 2.04$ |
| g [m/s2] - the gravity accelaration | $g := 9.81$ |

**THE WORKING ALGORITHM**

**The determination of the period tC between the launching of the material from the anterior conveyor and the impact with the active surface of the posterior conveyor, if the impact speed corresponds to the critical value vcr**

A,B,C - the coefficients of the displascement period equation of the material in free mouvement

$$A := g^2$$

$$B := 2 \cdot g \cdot (vs2 \cdot \sin(\beta) - vs1 \cdot \sin(\alpha))$$

$$C := vs1^2 + vs2^2 - vcr^2 - 2 \cdot vs1 \cdot vs2 \cdot \cos(\alpha - \beta)$$

$$tC1 := \frac{-B - \sqrt{B^2 - 4 \cdot A \cdot C}}{2 \cdot A}$$

tC1 [s] - the first root of the displascement period equation of the materialin free mouvement $\quad tC1 = -0.206$

$$tC2 := \frac{-B + \sqrt{B^2 - 4 \cdot A \cdot C}}{2 \cdot A}$$

tC2 [s] - the second root of the displascement period equation of the materialin free mouvement $\quad tC2 = 0.209$

$$tC := \begin{vmatrix} tC1 \text{ if } tC1 > 0 \\ tC2 \text{ if } tC2 > 0 \end{vmatrix}$$

tC [s] - the value of the displascement period of the material in free mouvement, which has phisical signification $\quad tC = 0.209$

**The determination ofthe speed vC components,of the material in free mouvement, when impacts the active surface of the posterior conveyor**

$vCX := vs1 \cdot \cos(\alpha)$ vXC [m/s] - the projection of the speed vC on the horizontal axis $vCX = 1.819$

$vCY := -g \cdot tC + vs1 \cdot \sin(\alpha)$ vYC [m/s] - the projection of the speed vC on the vertical axis $vCY = -1.003$

$vC := \sqrt{vCX^2 + vCY^2}$ vC [m/s] - the modulus of the speed vC $vC = 2.077$

$\gamma := \operatorname{atan}\left(\frac{vCY}{vCX}\right)$ γ [rad] - the inclination angle towards the horizontal of the speed vector vC $\gamma = -0.504$

$\gamma g := \frac{180}{\pi} \cdot \gamma$ γg [degrees] - the inclination angle towards the horizontal of the speed vector vC $\gamma g = -28.887$

$\gamma a := 2 \cdot \pi - |\gamma|$ γa [rad] - the absolute inclination angle of the speed vector vC $\gamma a = 5.779$

$\gamma ag := \frac{180}{\pi} \cdot \gamma a$ γag [degrees] - the absolute inclination angle of the speed vector vC $\gamma ag = 331.113$

**The determination of the coordinates XC, YC of the point C, in the coordinates system X0'Y, in the case of impact with the critical impact speed**

$XC := vs1 \cdot tC \cdot \cos(\alpha)$ XC [m] - the coordinate of the point C on the horizontal axis, in the coordinates system X0'Y $XC = 0.381$

$YC := \frac{-g \cdot tC^2}{2} + vs1 \cdot tC \cdot \sin(\alpha)$ YC [m] - the coordinate of the point C on the vertical axis, in the coordinates system X0'Y $YC = 4.877 \times 10^{-3}$

**The determination of the coordinates xC, yC of the point C, in the coordinates system x0y, in the case of impact with the critical impact speed**

$xC := -(Rs1 + r) \cdot \sin(\alpha) + XC$ xC [m] - the coordinate of the point C on the horizontal axis, in the coordinates system x0y $xC = 0.306$

$yC := (Rs1 + r) \cdot \cos(\alpha) + YC$ yC [m] - the coordinate of the point C on the vertical axis, in the coordinates system x0y $yC = 0.135$

**The determination of the coordinates x1, y1 of the point 1, in the coordinates system x0y, representing the coordinates of the returning drum axis 1 of the posterior conveyor in relation with the drive drum axis 0 of the anterior conveyor**

$x1 := xC - dimp \cdot \cos(\beta) + (Rs2 + r) \cdot \sin(\beta)$ x1 [m] - the coordinate of the point 1 on the horizontal axis, in the coordinates system x0y $x1 = 0.176$

$y1 := yC - dimp \cdot \sin(\beta) - (Rs2 + r) \cdot \cos(\beta)$ y1 [m] - the coordinate of the point 1 on the vertical axis, in the coordinates system x0y $y1 = -0.047$

## 5. Conclusions

The mathematical simulation of the material passage on the successive separators with rolling conveyors from the impurities cleaning system of certain bulbs or tubercles harvesters, the calculus algorithm of the relative position between the successive separators with rolling conveyors and the software based on it are presented in this paper.

The software has as input data specific characteristics referring to the construction and the working regime of the impurities cleaning system with successive rolling conveyors and specific features of the useful products from the point of view of the impact damages. The output data of the software are the layout coordinates of the successive conveyors.

In the paper is presented, as a concrete example, the usage of the software for the layout of the successive separators at the designing of the experimental model of the onion and garlic harvester MRCU.

The adequate solving of the successive separators layout problem from the impurities cleaning systems of the bulbs or tubercles harvesters is very useful to the agricultural machinery researchers and designers, which receive another new instrument for the appropriate designing of the onion, potato or even other root harvesters. The interest area of the methodology presented in this paper can be supplementary extended by adapting it to other types of separators used in the impurities cleaning systems of the bulbs, tubercles or root harvesters. This kind of approach can be also used for the designing of the agricultural products sorting and conditioning lines, ensuring appropriate positioning of the impurities cleaning organs.

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