MATHEMATICAL MODEL OF THE MATERIAL PASSAGE ON SUCCESSIVE CLEANING DEVICES WITH ROLLING CONVEYORS FROM THE IMPURITIES CLEANING SYSTEMS OF THE BULB AND TUBERCLE HARVESTERS

V.V. Safta

Abstract. *In this paper is presented a mathematical model of the material passage on successive cleaning devices with rolling conveyors from the impurities cleaning systems of the bulb and tubercle harvesters. The mathematic model is done considering both the main parameters of the successive cleaning devices with rolling conveyors and the physical and biological characteristics of the useful products, bulbs and tubercles, by imposing the conditions that during the passage of the material on successive rolling conveyors, they are not producing damages at the useful products and that the feeding of the receptor conveyor is done in a certain zone of its active surface, imposed.*

Key words: *mathematical model, passage on successive cleaning devices, bulb or tubercle harvester.*

INTRODUCTION

The separation of the bulbs or tubercles (useful products) from the broken up soil bed, resulted after the digging is a difficult process because the great quantity of impurities (mainly fragments of soil, but vegetal remaining impurities, boulders, stones too), is done on the harvesters impurities cleaning system. The impurities cleaning system is frequently composed of several separation devices successively traversed by the material that must to be processed. The types of impurities cleaning devices usually used in the bulb or tubercles harvesters construction are the rolling conveyors, the oscillating or vibrating screens or the systems of bitters with bars or roles.

The passages of the mixture of useful products and impurities on the successive separation devices are made by jumps which have as result, at the impact with the active surface of the receptor separation devices, the spreading of the mixture components, which change the orientations anterior to the jumps, fact with extremely favourable consequences for the ulterior separation of the impurities. The problem which must be solved in this case, is the correct lay-out of the successive separation devices, thus, after the jumps, the mixture submitted to the impurities separation, arrives in imposed zones of the separation devices active surfaces, and the useful products from the mixture must not be damaged after the impacts with the receptor separation devices active 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 passage of the material on two, successive separation devices of rolling conveyor type, component of an impurities cleaning system. It can be mentioned that the rolling conveyors are very often met in the bulb and tubercle harvester construction, having the advantage of simplicity and quit functioning, without significant shocks and vibrations transmitted to the machine chassis, but also the disadvantage of a lower efficacy of the impurities separation, because of the fact that the separation process takes place mostly in the shaking organs zones of the active surface of the conveyors, being much blurred and practically insignificant on the unshaken rest of the active surface of the conveyors. Because of that the feeding by jumps of the receptor conveyor constitutes a growing factor of the impurities separation intensity in the feeding zone of the conveyor, which increase significantly the efficiency of the whole impurities cleaning system.

In practice, there are met many cases of bulb and potato harvesters which have the impurities cleaning system composed of two or several successive rolling conveyors, in the figure 1 being presented the principle schema of such a machine, namely a onion harvester.

MATERIAL AND METHODS

For the mathematical modelling of the material passage process on successive rolling conveyors (see figure 2), that must be done the following specifications:

- at the launching (anterior) conveyor the speed of the separation belt is v_{S1}[m/s], the active surface of the belt is inclined towards the horizontal with the angle α[rad] and in the zone of its acting shaft, the belt is disposed at the radius R_{S1}[m];
- at the receptor (posterior) conveyor the speed of the separation belt is v_{S2}[m/s], the active surface of the belt is inclined towards the horizontal with the angle β[rad] and in the zone of its acting shaft, the belt is disposed at the radius R_{S2}[m];
- the material which pass from the launching to the receptor conveyors is considered to be constituted by discreet particles which have a quasi-spherical shape with the radius r[m] corresponding to the biggest useful products (bulbs or tubercles);
- it is considered the co-ordinates system X0'Y which has the origin 0' in the gravity centre of a quasi-spherical particle, in the moment of its detachment from the launching conveyor;
- it is considered the co-ordinates system x0y which has the origin 0 in the rotation axle of the belt acting shaft from the launching conveyor;

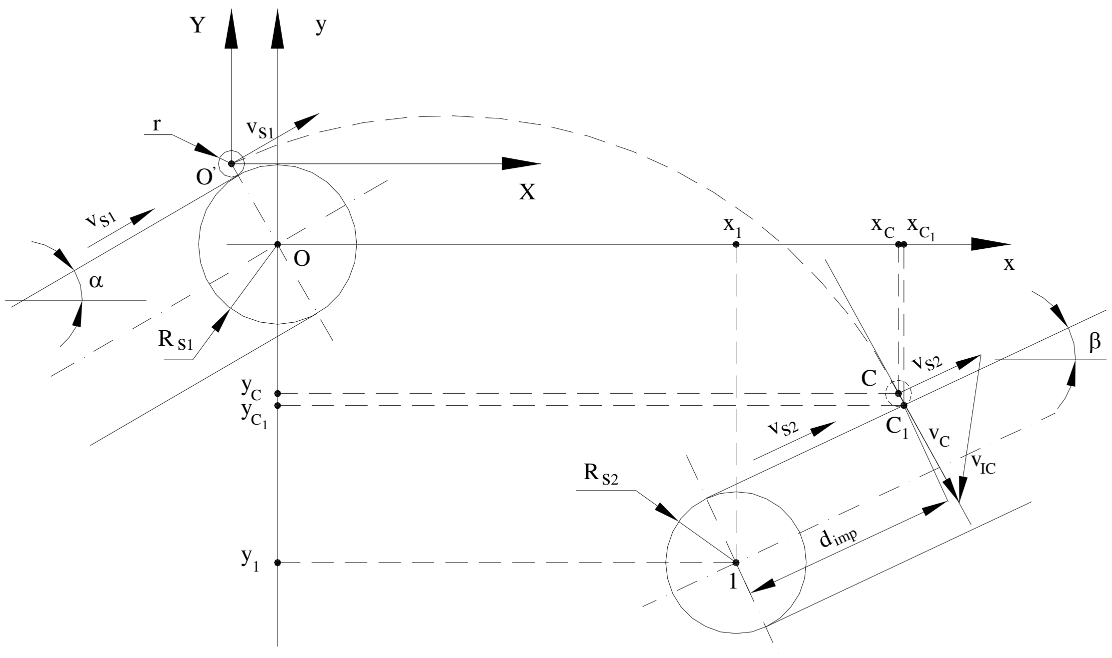

Fig. 2 The schema of the passage of the material on successive rolling conveyors

- the feeding zone of the receptor conveyor is positioned on its belt active surface by the imposed distance d_{imp} [m], measured from the belt returning shaft axle, along the active surface;

The problem which has to be solved is the determination of the co-ordinates of point 1 (x_1[m],y_1[m]), which represents the position of the returning shaft axle towards the origin of the co-ordinate system x0y, by respecting the restrictions that the relative impact speed v_I[m/s] between the particle of material (namely the considered useful product) and the active surface of the receptor conveyor do not exceed the critical value v_{cr}[m/s] of the impact speed, which if is over fulfilled they appears damages of the useful products, and that the impact take place in the zone of the receptor conveyor active surface placed to the distance d_{imp} from the belt returning shaft axle of the receptor conveyor.

Thus, considering that the launching speed of the material from the launching conveyor is precisely the speed v_{S1} of its belt, vector which has the support inclined with the angle α towards the horizontal, from the kinetic study of the particle in free movement (represented by its gravity centre where it is considered that all the extern forces act), it results that the parametrical equations of the free movement speed projections v_X[m/s] and v_Y[m/s], considered in the co-ordinates system X0'Y, for any point of the trajectory routed by the particle, have the following expressions:

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

In a certain point, noted with C, of its gravity centre trajectory, the particle knocks with the belt active surface of the receptor conveyor, which is moving with the speed v_{S2}, vector which has the support inclined with the angle β towards the horizontal, while the relative impact speed v_{CI} between the particle of material and the receptor conveyor active surface takes the critical value v_{cr}. It is mentioned that the relative impact speed v_{CI} is the vectorial difference between the gravity centre speed vector v_C of the particle in free movement and the receptor conveyor belt speed vector (see figure 3).

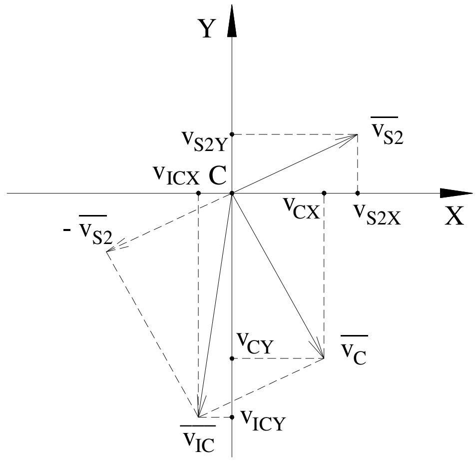

Fig. 3 The relative impact speed v_{IC} in the point C

Thus, in the point C, they can be written the following speed equations:

$$v_{CX} = v_{S1} \cdot \cos\alpha$$
$$v_{CY} = -g \cdot t_C + v_{S1} \cdot \sin\alpha \tag{2}$$
$$v_{CI}^2 = v_{CIX}^2 + v_{CIY}^2 = v_{cr}^2$$

where: v_{CX}[m/s] and v_{CY}[m/s] are the projections of the particle in free movement speed vector, particularised in the point C;

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;

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

Considering that in the third equation of the system of equations 2, the projections v_{ICX} and v_{ICY} have the following expressions:

$$v_{CIX} = v_{CX} - v_{S2X}$$
$$v_{CIX} = v_{CX} - v_{S2X} \qquad (3)$$

it can be observed that the system of equations have that unknowns the projections v_{CX} and v_{CY} and the period of time t_C.

If in the system of equation 2, they are introducing the first two equations in the third one, after the processing, it is obtained the following equation with the single unknown t_C:

$$g^2 \cdot t_C^2 + 2 \cdot g \cdot (v_{S2} \cdot \sin\beta - v_{S1} \cdot \sin\alpha) \cdot t_C + v_{S1}^2 + v_{S2}^2 - v_{cr}^2 - 2 \cdot v_{S1} \cdot v_{S2} \cdot \cos(\alpha - \beta) = 0 \qquad (4)$$

By solving the equation 4 they are obtained two roots for the period t_C, from which only the positive one has physical signification.

Knowing the value of the period t_C, they can be calculated the co-ordinates X_C[m] and Y_C[m] of the point C, in the co-ordinates system X0'Y, by particularising the parametric equations of the trajectory of the particle in free movement, namely:

$$X_C = v_{S1} \cdot t_C \cdot \cos\alpha$$
$$Y_C = -\frac{g \cdot t_C^2}{2} + v_{S1} \cdot t_C \cdot \sin\alpha \qquad (5)$$

In the co-ordinates system x0y, the co-ordinates of the point C, x_C[m] and y_C[m], can be calculated using the following relations:

$$x_C = -(R_{S1} + r) \cdot \sin\alpha + X_C$$
$$y_C = (R_{S1} + r) \cdot \cos\alpha + Y_C \qquad (6)$$

The co-ordinates of the point C_1, of contact between the particle of material and the receptor conveyor active surface, are calculated with the following relations:

$$x_{C1} = x_C + r \cdot \sin\beta$$
$$y_{C1} = y_C - r \cdot \cos\beta \qquad (7)$$

The co-ordinates of the point 1 in the co-ordinates system x0y, namely the co-ordinates x_1[m] and y_1[m] of positioning of the receptor conveyor belt returning shaft axle towards the launching conveyor belt acting shaft axle, considered like origin of the co-ordinates system x0y, can be calculated, depending on the demands, in relation with the co-ordinates of the points C_1, respectively C, with the following relations:

$$x_1 = x_{C1} - d_{imp} \cdot \cos\beta + R_{S2} \cdot \sin\beta = x_C - d_{imp} \cdot \cos\beta + (R_{S2} + r) \cdot \sin\beta$$
$$y_1 = y_{C1} - d_{imp} \cdot \sin\beta - R_{S2} \cdot \cos\beta = y_C - d_{imp} \cdot \sin\beta - (R_{S2} + r) \cdot \cos\beta \qquad (8)$$

RESULTS AND DISCUSSION

The mathematical model of the material passage on successive cleaning devices with rolling conveyors presented in the paper is original and constitutes a base for the achievement of a calculus algorithm of the relative position between the successive rolling conveyor in the condition of an adequate working regime, with a correct feeding of the receptor conveyor and without damages of the useful products.

Based on the calculus algorithm it can be made a simulation computer program which aloud to determine rapidly and correctly the optimal relative position between two successive rolling conveyors, after the analysis of a multitude of constructive variants. The program of determination of the relative position between two successive rolling conveyors will be a powerful and extremely useful instrument for the designers of bulb and tubercles harvester, especially, and other kinds of agricultural and food industry machinery which contain such working organs.

CONCLUSIONS AND FUTURE WORK

In this paper is presented a mathematical model of the material passage on successive cleaning devices with rolling conveyors from the impurities cleaning systems of the bulb and tubercle harvesters. The mathematic model is done considering both the main parameters of the successive cleaning devices with rolling conveyors and the physical and biological characteristics of the useful products, bulbs and tubercles, by imposing the conditions that during the passage of the material on successive rolling conveyors, they are not producing damages at the useful products and that the feeding of the receptor conveyor is done in a certain zone of its active surface, imposed.

Based on this mathematic model, in the early future they will be achieved a calculus algorithm and a computer program for the optimization of the lay-out of successive separating devices with rolling conveyor.

REFERENCES

[1]. Safta V.V. 2002.-The mathematic modelling of the passage of material on successive working organs from the impurities cleaning systems of vegetables of bulb, tubercles and root kinds. *The Jubilee Scientific Communications Session "Achievements and perspectives in biotechnical systems engineering* ISBTeh–2002*", University " Politehnica " of Bucharest*

ABOUT THE AUTHORS

Victor-Viorel Safta, Dipl. Eng. Ph.D., Universitary lecturer at the University "Politehnica" of Bucharest, Department of Biotechnical Systems, 313 Splaiul Independentei, Sector 6, 060042, Bucharest, Romania, saftavictorviorel@yahoo.com