ESTABLISHING THE OPTIMUM OPERATING MODE OF SUGAR BEET HEAD CUTTING EQUIPMENT USING A CYLINDRICAL PALPATOR

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Abstract: *The paper established equations of motion cylindrical palpator of the sugar beet head cutting equipment, taking into account the distance between turns beet and its functional parameters. Particular attention is paid to coordination between the palpator and machine movements, correlating to the beet head palpator diameter and arranged correctly knife to tangible elements necessary to ensure the optimum operation of the operating of sugar beet head cutting equipment to harvesting the two phases thereof.*

Key words: *sugar beet, beet head cutting, cylindrical palpator.*

1. Introduction

Beets in the last century was the main source of sugar for Romania and, in general, for European countries. If in 1990 in Romania cultivated with sugar beet approximately 250,000 hectares, which ensured the full needs of the population and a surplus for export, today it is also cultivated beet approximately 25,000 hectares, most of the factories processing the imported raw material obtained from primary processing cane [5], [6]. By this unfavorable situation contributed and unresolved properly mechanization works specific for sugar beet cultivation, from sowing accuracy, thinning, weeding and harvesting. Excluding the manual harvesting is practiced in small peasant farms, beet harvesting can be done partial

mechanized (dislocation mechanical and manual cutting head beet) or mechanized, combines the two phases separated or combined [1]. In the first variant of harvest are still problems with uploading beet field in transport [7].

Particularly importance in the whole beet harvester combines, sugar beet head cutting equipment can greatly influence by building and operating its system of quality of their work [8].

Consisting mainly of a knife for beet head cutting and a palpator witch function to provide a constant height cutting of the beet head, this equipment can present in a variety of construction types. The palpator may depend on the quality performance limits 5 ... 10% sugar beet production delivered to processing plants, in the sense that a working regime by removing

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incorrectly can cause loss of oversized beet head or incomplete cut leaves [2]. A properly functioning system equipment cutting beet head, can ensure that the dimensions and distances of these in turn are quite uniform and if head sugar beet cutting equipment and machine kinematics and settings are correlated as well [3].

2. Materials and methods

2.1. The equations of motion palpator

Functional characteristics of different types of probes can be well highlighted by their motion equations. Thus, the rotary cylindrical palpator, the most commonly used in the construction of sugar beet head cutting equipment of modern beet harvesting machine [4], the movement of any point in the active zone (in contact with the beet head) is the result of their own movement and the movement of rotation ω of the machine translation v_m it serves as outlined in Figure 1.
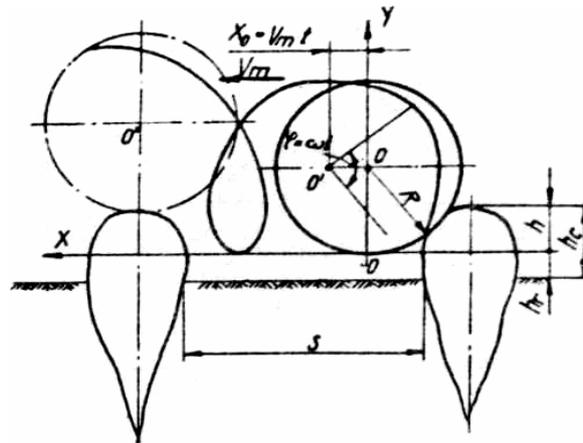

Fig. 1. *Scheme of the cylindrical palpator kinematics of sugar beet head cutting equipment*

Based on Figure 1 can determine the equation of the movement of a point on the periphery of the palpator for a cycle consisting of movement S between two beets and moving in a beet head [1], namely:

$$\begin{cases} x = v_m \cdot t + R \cdot \sin \omega t \\ y = R(1 - \cos \omega t) + y_1 \end{cases} \qquad (1)$$

where: v_m is the forward speed of the machine, in m/s; R – the palpator cylinder radius, in m; y_1 - the amount of vertical displacement of the palpator specific to the crossing of a sugar beet, in m; ω - angular velocity of the palpator, in rad/s.

Dimension y_1 characterize the two stages of the cycle, as follows:

$$\begin{cases} y_1 = 0 & \text{for } 0 < t < \dfrac{S}{v_m} \text{ ,} \qquad \text{by moving between two beet;} \\ y_1 = h \cdot \sin \dfrac{\pi \cdot v_m}{d}(t - \dfrac{S}{v_m}) & \text{for } \dfrac{S}{v_m} < t < \dfrac{1}{v_m}(S + d) \text{ , by moving on beet head.} \end{cases} \qquad (2)$$

where: S is the clearance between two successively beets, in m; d - diameter of palpator, in m.

The equations of palpator speed in the two directions are:

$$\dot{x} = \begin{cases} v_m + \omega R \cos \omega t \\ \dot{y} = \omega R \sin \omega t + \dot{y}_1 \end{cases}, \qquad (3)$$

in which:

$$\dot{y}_1 \begin{cases} 0 & \text{for} \quad 0 < t < \dfrac{S}{v_m} \\ \dfrac{\pi \cdot h \cdot v_m}{d} \cos \dfrac{\pi \cdot v_m}{d}(t - \dfrac{S}{v_m}) & \text{for} \quad \dfrac{S}{v_m} < t < \dfrac{1}{v_m}(S+d) \end{cases} \qquad (4)$$

2.2. Coordination the palpator movement with machine motion

Conditions of movement of the palpator should ensure the proper conduct of its work process. Important in this aspect is that while overcoming the beet head, in addition to pressing probe to exert a parallel to the surface, facing opposite direction to the movement of the machine to compensate for tilt forward a trend of beet due to the action of the knife as shown in Figure 2.
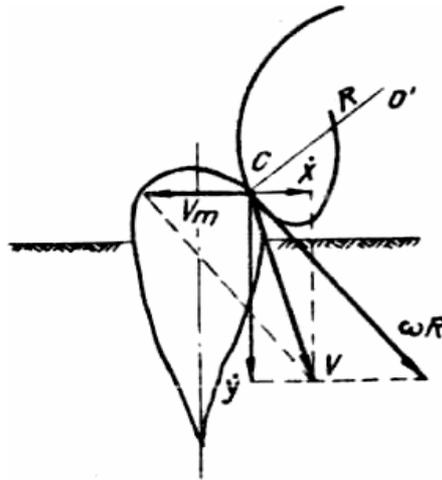

Fig. 2. *Scheme of movement coordination between palpator and machine*

On this line, based on the representation of Figure 2 a prerequisite for achieving this coordination is:

$$\dot{x} \le 0. \qquad (5)$$

Substituting in equations (4), the interval

$$0 < t < \dfrac{S}{v_m}, \; y = h_1 \qquad (6)$$

is obtained:

$$h_1 = R(1 - \cos \omega t), \qquad (7)$$

obtainable from the point of contact angle value:

$$\cos \omega t = \dfrac{R - h_1}{R}, \qquad (8)$$

where h_1 is the height of the initial point of contact of the palpator with the beet head, to control line ($y = 0$).

Component in the forward direction when the resultant velocity palpator contact with the beet head is obtained by substituting in the expression of x in equations (3) the value of $cos \, \omega t$ given by equation (8), ie:

$$\dot{x} = v_m + \omega(R - h_1) \, . \qquad (9)$$

Putting this condition $\dot{x} \leq 0$ result:

$$\omega \geq \frac{v_m}{R - h_1}, \qquad (10)$$

making it possible to calculate the necessary speed of palpator:

$$n \geq \frac{30 \cdot v_m}{\pi(R - h_1)} \, . \qquad (11)$$

2.3. Correlation between palpator diameter and the beet head dimension

Based on Figure 3, in which the forces acting on the point of contact of the palpator with the beet head, provided that the palpator can be set to exceed the beet head without encountering additional strength, ie:

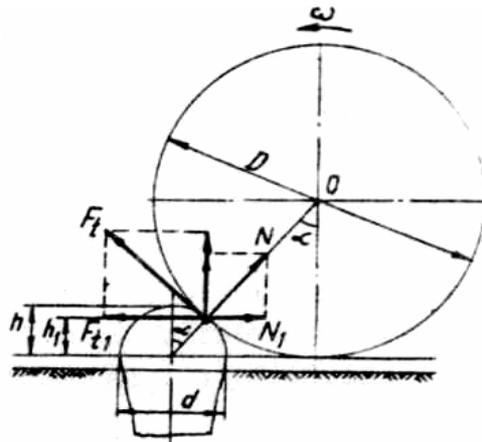$$N_f \cdot \cos \alpha \geq N \cdot \sin \alpha \qquad (12)$$

Fig. 3. C*orrelation scheme between palpator diameter and the beet head dimensions*

Because $F_t = f \cdot N$, and $f = tg \, \varphi$, results:

$$\varphi \geq \alpha \qquad (13)$$

which shows that the angle of the contact point should be lower than the angle of friction between the palpator and the beet head.

Also according to Figure 3 we can write:

$$R(1 - \cos \alpha) = h_1 \qquad (14)$$

Considering that in the vertical section of the beet head is a semicircle, height h_1 can be expressed by the equation:

$$h_1 = \frac{d}{2} \cos \alpha \qquad (15)$$

Substituting h_1 in (14) and considering the limit $\alpha = \varphi$, finally gives the equation for calculating the diameter of palpator:

$$D = \frac{d \cdot \cos\varphi}{2(1 - \cos\varphi)} \qquad (16)$$

where *d* is the diameter of the beet head at the line height adjustment.

2.4. Position the cutter to palpator

Positioning the cutter to palpator must meet two conditions [l], [2]:
• ensure the beet head cutting height agro conditions imposed;
• keep the height constant during cutting.
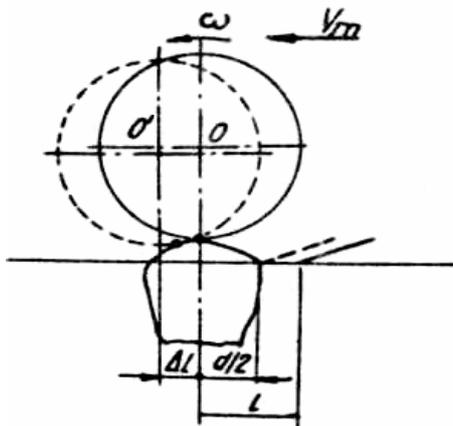
In Figure 4 is the position of the cutter face.

Fig. 4. *Palpator position scheme when the knife head beet cutting*

For the palpator leaf mass does not influence much the height of the beet head was ordered so early cutting knife corresponds to the time that has exceeded the palpator axis by a distance beet $\Delta l = 2\text{-}3$ *cm*.

Thus, the distance between the feeler knife and the horizontal is given by:

$$l = \frac{d}{2} + \Delta l \qquad (17)$$

The shape of the beet head, approximately spherical calotte and palpator form, toothed cylinder, forcing the knife firmly fixed in relation to the palpator to cut the beet head after a curve as shown in Figure 5 by the dashed line.
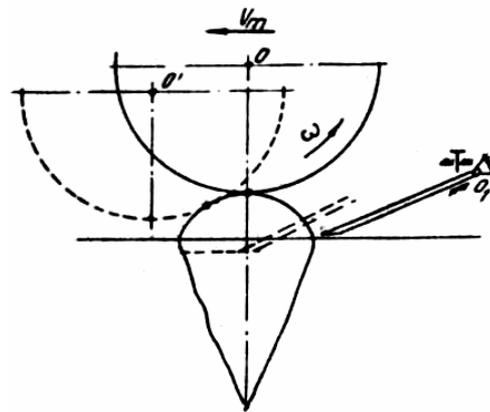

Fig. 5. *Trajectory of the cutter cutting beet head*

To some extent offset from cutting parallel to the ground surface is compensated by changing the position of the knife due to the inclination beet in the soil as a result of cutting effort, if the probe, losing contact with the package during the advance, not may act to prevent tilting. Also in order to compensate for this deviation could be provided constructive a certain mobility within the 1 ... 2 *cm* vertically between knife and palpator. In this way it would be possible to maintain the cutter cutting head engaged in initial beet cutting quota, when the palpator descending.

3. Conclusions

• The beet head cutting equipment of harvester machine has a particularly important role in the process of harvesting. Functional parameters and constructs this equipment may influence the quality of the whole machine.

• The palpator rotations speed must respected the condition (11) to maintain the best beet normal position during cutting.

• Moving the machine into service to be made only with speed v_m always ensuring horizontal components of velocity resultant of the probe, zero or negative (condition $\dot{x} \leq 0$).

• The palpator diameter is chosen so as to meet less resistance when passing over beet heads.

• Fixing knife cutting head are made with beet providing the possibility of position adjustment both vertically depending on beet head height and horizontally depending on the diameter of the beet head.

• For sealing cut beet head in a direction normal to the axis inclined to the beet as a result of lowering the palpator beet head must provide a vertical mobility to feeler blade, whose amplitude can be adjusted.

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