# THEORETICAL AND EXPERIMENTAL STUDY REGARDING AN APPARATUS FOR PLANTING POTATOES WITH CHAIN EQUIPPED WITH COMPLEX CUPS, WITH RIGHT-ANGLED TRIANGLE CIRCUIT AND VERTICAL, HORIZONTAL AND OBLIQUE BRANCH

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The apparatus for planting the potato tubers [2] is made up of a link chain on which there are erected complex cups, spaced at a certain pitch (Fig. 1).

The link chain is made up of three main branches: AB portion, a branch with an ascending vertical movement having the role of overtaking the potato tubers from the feeding hopper; BC – portion representing a circular arc with the apical angle of 90°; CD – portion representing the horizontal branch of transporting the planting material; DE – portion with the wrapping angle bigger than 90° (90 +  $\alpha$ ) on which the release of the potato tubers takes place; EF – portion represents the oblique branch of the planting apparatus on which the cups are in contact with the potato tubers on their rear part.



Fig. 1. Apparatus for planting the potatoes with complex cups-equipped chain

From kinematic and dynamic reasons of the process of planting the potato tubers it is necessary to present the geometry of a complex cup (Fig. 2).



Fig. 2. Geometry of the complex cup of the planting apparatus

From an analysis of the cup geometry it results that it is made up of a semicylindrical surface (ab) continued with another semi-cylindrical surface (bc), both of them being positioned between them by an obtuse angle. The last cylindrical surface is assembled with a quasi-spherical cap (cd). This cap is in fact the supporting area of the tuber, which is to be distributed. The cups may be erected on a chain on one single row or on two rows created by their alternative fixing.



Fig. 3. Construction of the complex cup of the planting apparatus

From the point of view of the component parts the complex cup (Fig. 3) is made up of the following parts: disc support 1 with the upper surface being concaved and provided with an orifice; the cup 2 of a special shape being assembled to the disc support; the metallic cup 3 made up of two continuous cylindrical surfaces which are assembled with the component parts 1 and 2.

# THEORETICAL STUDIES ON THE PROCESS OF PLANTING THE POTATO TUBERS WITH CHAIN-TYPE DISTRIBUTION APPARATA WITH COMPLEX CUPS AND HORIZONTAL BRANCH

The chain-type distribution systems equipped with complex cups are analyzed in different papers. The papers [1, 3] refer to the following aspects: types of distribution apparatus, types of potato planting machines manufactured by various companies (REEKIE, CRAMER, HASSIA, GRUSE) on the process of planting the potato tubers with chain (belt) type distribution apparatus with cups. The theoretical study in the respective papers referred to the type of chain (belt) distributor with vertical ascending and descending branches, equipped with simple cups and watched the process of overtaking and distributing the potato tubers from a kinematic and dynamic point of view on chain portions, as well as the working process in the exhausting area of potatoes into the gutter.

The theoretical analysis performed on the conveyor chain (belt)-type distribution apparatus, with vertical branches can be extended also on some other constructive types of chain distributors, as the one presented in Figure 1. Specific to this type of distributor is the existence of three branches: the vertical branch AB, the horizontal branch CD and the oblique branch EF. Between these there are the chain portions wrapping on the sprockets, respectively BCand DE (Fig. 1).

The theoretical study of the process of overtaking and distributing the potato tubers takes into account their geometry. The planting material is usually made up of calibrated tubers in the fractions 30-45 mm and 45-55 mm with a different shape: round, oval and long. The presented study refers to the tubers having a round and oval shapes because the long form, in interaction with this type of a cup, presents some specific features.

## STUDY OF THE WORKING PROCESS IN THE TUBER OVERTAKING AREA (AB)

The working process refers to the vertical chain branch. The shape of the cup is characterized by the cylindrical position (ab) inclined to the horizontal, the horizontal cylindrical portion (bc) and the quasi-spherical assembly (cd) in the vertical position (Fig. 2). Once the cup crosses the potato mass in the feeding system, it charges the tubers. When the cup comes out of the potato mass, a part of the tubers fall down again in the feeding system, but, as a rule, as a result of its geometry, more tubers remain in the cup. The excess of tubers is to be removed while the cup moves on the circular portion BC (Fig. 1 and 4).

The potato tubers removing is due both to the unstable equilibrium between the tubers propped on the tubers in the cup and to the forces actuating the tuber weight and the centrifugal force (Fig. 4).



Fig. 4. Forces acting on the tuber on the circular branch BC

#### STUDY OF THE WORKING PROCESS ON THE HORIZONTAL BRANCH (CD)

In this working process the mechanical state between the tubers and the cup on which they are propped up should be considered. The mechanical state is assimilated to "the equilibrium stability of the material point subdued to connections", whose condition is:

$$\vec{F} = \frac{d\vec{r}}{dq} = gradU \frac{d\vec{r}}{dq} = \frac{dU}{dq} = 0$$

where the force F is a conservative force in the study the tuber weight and the force function is U:

$$\vec{F} = -G\vec{k}$$

If the basic cup is considered to be a spherical surface with the radius l and the centre in the origin of the reference point Oxyz (Fig. 5), we have U = -mgz + C. On the sphere -l = z = l and U is maximum for z = -l, minimum for z = l, when x = 0 and y = 0.



Fig. 5. Equillibrum of the tuber in the cup in the working process on the horizontal branch (CD)

The equilibrium position is the point  $P_0(x = 0, y = 0, z = l)$ , which is a stable equilibrium position. If the upper part of the tuber propped up in the cup is considered to be a quasi-spherical surface, then the further tuber will be propped

up in the point P, which is an unstable equilibrium position. Consequently, the respective tuber will leave the cup, only a single one remaining. On the basis of the presented theoretical study the interaction between the tuber and the cup in the working process on the horizontal branch CD is analyzed (Fig. 6).



Fig. 6. Working process on the horizontal branch (CD)

Figure 6b presents the situation in which only one tuber in a stable equilibrium remains in the cup and Figure 6c when two tubers remain here, but the tuber propped up on the one localized in the cup is in an unstable equilibrium. However, if this mechanical state does not take place, the conveying chain is provided to slip over a cam which gives the tubers the vertical speed V' (Fig. 6a) which is compounded with the absolute speed  $V_a$ , resulting in the impulse H = mv. This impulse will force the tuber propped up on the upper part of the one in the cup to leave this space.

# STUDY OF THE WORKING PROCESS ON THE BRANCH

The *EF* branch is inclined to the advancing direction of the planting machine, so that the potato tuber movement presents some kinematics and dynamic specific features to its displacement on the vertical branch studied in the paper [1, 3].

This branch represents the transfer zone of the tuber in the cup on the upper part of the front cup. The potato tuber is under the action of its weight and of the centrifugal force  $F_c$  (Fig. 7).



Fig. 7. Forces acting on the tuber on the DE branch

Taking into account the forces size the following situation can be analyzed: a)  $F_c > G$ ; b)  $F_c = G$ ; c)  $F_c < G$ , presented in the papers [1, 3].

#### STUDY OF THE WORKING PROCESS ON EF BRANCH

Figure 8 presents the mechanical interaction between the tuber, the cup rear part and the tubular carcass wall where the distribution apparatus is erected. In fact the tuber mechanical state depends on the friction coefficient between the tuber, the cup and the wall.



Fig. 8. Mechanical interaction between the tuber, the rear part of the cup and the carcass, on the EF branch

From the experimental observations it was seen that the tuber displacement is a translation having the direction of *EF* branch.

## THE RESULTS OF EXPERIMENTAL RESEARCHES

The experimental researches [1] were performed on the cup conveyor-type distribution apparatus, formerly presented, under the aspect of keeping the tubers into the cups in the significant zones of the performed working process (see Fig. 1): AB – the zone of overtaking by the cup of the potato tuber from the system of feeding and ascending the conveying chain; CD – the transport zone of the planting material with working speeds of the aggregate ranging from 2.75 to 6.85 km/h, by using potatoes having a: round, round-oval and oval shape, calibrated in the size fraction of 45-55 mm (considered to be the most uniform one. The experimental results lead to the following interpretations:

- generally in zone AA' most of the cups contain 1.2 or even 3 potato tubers (only 1-3% out the cups are empty). At the displacement speed of the aggregate of 2.75; 3.18 and 4.65 km/h the number of the cups without any tuber does not exceed 1%, while with higher speeds it reaches the value of 3%;

- in the ascending zone of the conveying chain (A'B) a removal of the tubers which are in an unstable equilibrium is noticed;

- in the *CD* zone, constructively performed for the uniformisation of the number of tubers into the cups, through the presence of the vibratory system by most of the cups of only one potato, max. 3% two and max. 4% missing (according to the valid technical norms) we can conclude that:

- at the speed of 2.75 km/h, 94-96% out of all the cups contain only one tuber each; 3-4% only two tubers each and 1-2% represent tuberless cups;

- at the speed of 3.18 km/h in 91-94% out of all the cups there is only one tuber, 3-4% have two tubers each and 3-4% don't transport any tuber;

at the speed of 4.65 km/h 91-94% out of all the cups contain only one tuber; 3-5% contain two tubers each and 3-4% no one;

- at the speed of 5.51 km/h out of the total number of the cups only 90-93% transport only one tuber, 3-4% two tubers each and 4-7% do not contain any potatoes;

at the speed of 6.85 km/h 89-91% of the cups contain one tuber each; 4% two tubers each and 5-7% represent tuberless cups.

The results obtained for the size fraction 30-45 mm, experimented in the same conditions, have presented a difference of  $\pm 5\%$ , namely an insignificant one, as compared to the analyzed values.

#### REFERENCES

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#### SUMMARY

The paper presents theoretical aspects regarding the kinematics and dynamics of the potato tuber in interaction with the planting apparatus made up of a chain equipped with complex cups and horizontal branch. It presents the skeleton diagram of the apparatus and the constructive form of the active bodies it is equipped with. The theoretical studies are completed with the results obtained after the experimental researches.