THE EFFICIENCY OF USING CAM MECHANISMS TO OPERATE THE EQUIPMENT FOR OPENING AND INTERRUPTING WATERING FURROWS

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EFICIENȚA UTILIZĂRII MECANISMELOR CU CAMĂ PENTRU ACȚIONAREA ECHIPAMENTELOR DE DESCHIS ȘI COMPARTIMENTAT BRAZDE DE UDARE

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DOI: https://doi.org/10.356.33/inmateh-63-07

Keywords: *soil, mathematical modeling, irrigation, tillage*

ABSTRACT

Due to climate change, there have been changes in temperature, distribution and precipitation, phenomena that have led to the development of technologies that increase the efficiency of precipitation water use and support the preservation of soil quality. The paper presents some theoretical considerations on the cam mechanisms for actuating the working parts the equipment for opening and interrupting watering furrows are provided with; setting the optimal dimensions of the blades of the equipment for furrow opening through the experiments performed is also made. By using the cam mechanisms in the equipment for opening and interrupting watering furrows both superior quality indices in the execution of the work but also a quiet operation of the equipment are obtained and by optimizing the size of the working part, the volume of water accumulated between furrows increases significantly.

REZUMAT

În ultima perioadă, din cauza schimbărilor climatice, au avut loc modificări ale temperaturii, distribuției și cantității de precipitații, fenomene ce au condus la elaborarea de tehnologii care să sporească eficiența utilizării apei din precipitații și să susțină conservarea calității solului. În lucrarea de față sunt prezentate câteva considerente teoretice asupra mecanismelor cu camă pentru acționarea organelor de lucru cu care sunt prevăzute echipamentele de deschis și compartimentat brazde de udare, adoptarea dimensiunilor optime pentru paletele echipamentului de deschis rigole prin experimentările efectuate. Prin utilizarea mecanismelor cu camă în componența echipamentelor de deschis și compartimentat brazde de udare se obțin atât indici calitativi superiori în executarea lucrării dar și o funcționare silențioasă a echipamentului iar prin optimizarea dimensiunii organului de lucru crește semnificativ volumul de apă acumulat între minibaraje.

INTRODUCTION

The agricultural plots may lose a large quantity of rainwater by surface drainage and also large quantities of soil by erosion (*Duley, 1940*). Rainwater collection has the potential of reducing soil erosion and increasing the productivity of these areas.

Rainwater harvesting is a general term used to describe the collection and the concentration of the surface draining for different uses, including agricultural and household use (*FAO, 1993*). The “on-site” systems are the simplest and the cheapest approaches for rainwater harvesting and they can be used in many agricultural systems. Also named *water conservation work systems,* they involve some methods to increase the quantity of water stored in the soil profile by capturing or maintaining the rainwater (*Brhane et al., 2006*).

A concept referring to the “on-site” capture of rainwater through different techniques is known under the name of “*Reservoir Tillage*” (RT).

This approach, has been developed considering that the soil work may offer an increase of the surface water storage capacity and can represent one of the most efficient means to fight against both surface draining and soil erosion. RT creates basins or cavities for water retention, allowing it to infiltrate the soil, thus avoiding the drainage (*Rochester et al., 1994*).

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RT has been defined as a system in which numerous, small surface hollows are made in order to collect and retain the rainwater and thus avoid the surface draining (*Patrick et al., 2007*). Currently, RT is used mainly against the soil erosion in areas with large volume annual rainfalls but of reduce intensities.

Along the areas with quick but small volume rainfalls and also with increased droughts, an interrupted-furrows system is used to collect the rainfall water (*Kronen M., 1994*).

The rainfalls are drained in small basins through these capture works, allowing longer times for infiltration, which further reduces the drainage and the erosion potential of soil erosion and soil particles transportation (*Ventura et al., 2005*).

By this method, the large infiltration surface created by cavities and the depth of the still water within, lead to increased infiltration speeds and therefore to the decrease of losses through surface drainages and evaporation (*Patrick et al., 2007*).

Current scenarios foresee that the climate changes will increase the water deficit in Southern Romania (Marica and Busuioc, 2004). The climate changes have the potential to affect the agriculture by rainfall changes on temperature, distribution and quantity. Rainfall changes will be one of the most critical factors that will determine the global impact of the climate changes. This problem shows the necessity to elaborate integrated technologies that will increase the efficient use of rainfall water and to sustain the soil and environment quality, ensuring greater agricultural yields at lower costs.

In order to produce the interruption, the equipment that opens and interrupts the watering furrows use different mechanisms that produce these repetitive moves.

The interrupted furrow is the result of a mechanical work of the soil that leaves furrows behind, interrupted by soil heaps, at adjustable intervals, in order to create small basins for water accumulation. During the rain, the excess water is accumulated in these basins, so that it can be slowly absorbed by the soil, eliminating the possibility of streaming outside the cultivated perimeter. This is very important, as during the rain showers the intensity of the rainfalls often overcomes the speed of water infiltration into the soil (*Biolan I. et al., 2015*). The purpose of the present study was to look for a system of actuation of the working parts of this equipment so as to obtain the optimum form of the furrow necessary to capture a maximum volume of water from the rainfalls.

Researches on the analysis of mechanisms used in the construction of agricultural machinery were carried out by (*Croitoru Şt. et al., 2017; Ivan Gh. et al., 2017; Moise V. et al., 2017; Vlăduţ V. et al., 2017)*, aiming to optimize the assemblies and subassemblies within these equipment (*Croitoru Şt. et al., 2015; Vlăduţoiu L. et al., 2017*), verified by analysis using finite element (*Biriş S., et al., 2007*), simulated and accelerated regime on hydropulse installation (*Vlăduţ V., et al., 2007*) or in real-field and simulated laboratory (*Matache M., et al., 2015; Vlăduţ V., et al., 2009*), in order to obtain the desired qualitative indices (*Cujbescu D. et al., 2016; Vlăduţ D.I. et al., 2017*).

MATERIALS AND METHODS

In the case of agricultural machines for soil processing, their working parts are controlled by the operator or, if repetitive operations are required along the work, a rigid memory can be used.

Because the cam mechanisms have the great advantage that they can carry out very complicated transmission functions, in order to obtain an optimum form of the furrow, a mechanism with a rotating cam and a rotating roller cam follower is chosen for the machine in question.

The synthesis of the rigid memory for the control of the working parts involves several phases, namely: choosing the type of mechanism for control; establishing the functions of transmission from the cam to the cam follower; determining the minimum size of the mechanism; the synthesis of the cam profile.

The transmission functions used for the control of the cam follower are chosen so that the operation of the mechanism is silent, so there are no shocks in operation, so the reduced accelerations do not exceed certain limits and finally to lead to a convenient shape for the furrows. For the present case, the transmission functions whose diagrams of the reduced accelerations are of sinusoidal and cosine form were considered.

Among the different types of cam mechanisms, a mechanism with a rotating cam and a rotating roller cam follower is chosen, for the machine concerned, according to Figure 1.

The optimization of the dimensions of this mechanism consists in determining the length L of the cam follower and the size of the angle ψ_o, so that in the process of the mechanism operation the permissible pressure angles α_{max} and α_{min} are not exceeded. The angle ψ_o is the angle between the vectors $\overline{BC_0}$ and $\overline{BA}$, Figure 2, (*Lasdon S.L., 1975; Marica and Busuioc, 2004; Moise et al., 2016*).

For the synthesis of the cam profile, the Pelecudi-Sava method is used (*Pelecudi and Sava, 1966*).

The synthesis of the profile of the rotating cam and the rotating roller cam follower

Figure 1 shows the kinematic diagram of the mechanism with rotating cam and the rotating roller cam follower. For the synthesis of the cam profile, the Pelecudi-Sava method is used (*Pelecudi and Sava, 1966*).

Let consider the profiles 1 and 2 of two bodies considered rigid (Fig. 1).

A system of coordinate axes is attached to the two profiles, namely: the system Ax_1y_1 for profile 1 and the system Bx_2y_2 for the profile 2. The parametric equations of the cam profile are:

$$x_1 = (XB - XA)\,cos\,\varphi + (YB - YA)\sin\varphi + L\cdot\cos(\theta-\varphi) + r[\cos\vartheta\cdot\cos(\theta-\varphi) - \sin\vartheta\cdot\sin(\theta-\varphi)] \tag{1}$$

$$y_1 = -(XB - XA)\sin\varphi + (YB - YA)\cos\varphi + L\cdot\sin(\theta-\varphi) + r[\cos\vartheta\cdot\sin(\theta-\varphi) + \cos\vartheta\cdot\sin(\theta-\varphi)] \tag{2}$$

where:

$$XA = const, YA = const, \varphi = \varphi(t), XB + L\cos\varphi, XB + L\cdot\cos\varphi, \theta = \theta(t) \tag{3}$$

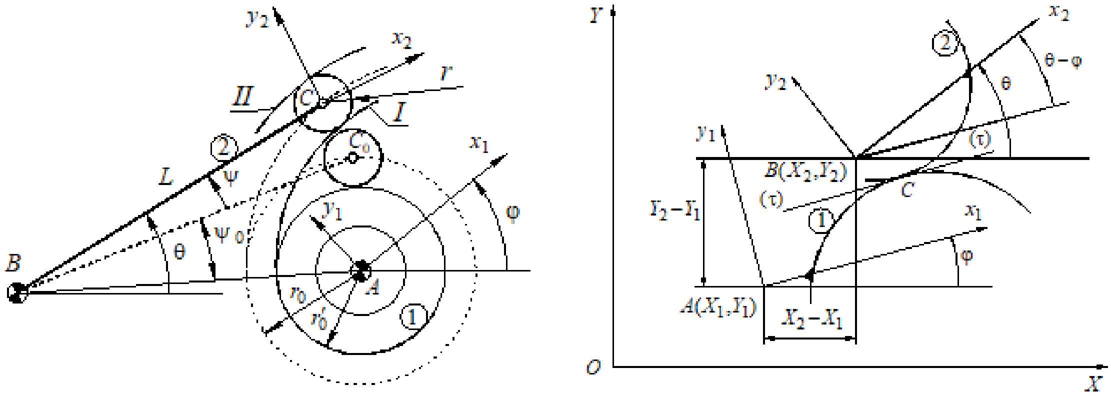


Fig. 1 - The kinematic diagram of the mechanism with rotating cam and the rotating roller cam follower

The expressions of the trigonometric functions *cos v* and *sin v*, from the relations (1) and (2), are determined using the condition of tangency between the cam and the cam follower, according to the relations (4), (5), (6), (7).

$$\sin\vartheta = \pm\frac{B}{\sqrt{A^2+B^2}} \tag{4}$$

$$\cos\vartheta = \pm\frac{A}{\sqrt{A^2+B^2}} \tag{5}$$

where:

$$A = \omega_1[(XB - XA)\cos\theta + (YB - YA)\sin\theta] - L(\omega_2 - \omega_1) \tag{6}$$

$$B = \omega_1[-(XB - XA)\sin\theta + (YB - YA)\cos\theta] \tag{7}$$

If the numerator and the denominator of the functions *sin v* and *cos v*, from the relations (4) and (5), are divided by ω_1, it results (8) and (9):

$$\sin\vartheta = \pm\frac{B_1}{\sqrt{A_1^2+B_1^2}} \quad 8)$$

$$\cos\vartheta = \pm\frac{A_1}{\sqrt{A_1^2+B_1^2}} \tag{9}$$

where:

$$B_1 = -(XA - XB)\sin\theta + (YB - YA)\cos\theta \tag{10}$$

In the end, the parametric equations of the cam profiles are, (11) and (12):

$$x_1 = (XB - XA)\cos\varphi + (YB - YA)\sin\theta + L\cdot\cos(\theta-\varphi) \pm \frac{r}{\sqrt{A_1^2+B_1^2}}[A_1\cdot\cos(\theta-\varphi) - B_1\sin(\theta-\varphi)] \tag{11}$$

$$y_1 = -(XB - XA)\sin\varphi + (YB - YA)\cos\varphi + L\cdot\sin(\theta-\varphi) \pm \frac{r}{\sqrt{A_1^2+B_1^2}}[A_1\sin(\theta-\varphi) + B_1\cdot\cos(\theta-\varphi)] \quad (12)$$

Taking into account the expressions of the parametric equations of the theoretical profile (punctiform cam follower), according to (13) and (14):

$$x_{1p} = (XB - XA)\cos\varphi + (YB - YA)\sin\varphi + L\cdot\cos(\theta-\varphi) \quad (13)$$

$$y_{1p} = -(XB - XA)\sin\varphi + (YB - YA)\cos\varphi + L\cdot\sin(\theta-\varphi) \quad (14)$$

The parametric equations of the two profiles *I* and *II*, of the form, (15), (16), respectively (17), (18) are:

- for profile *I*:

$$x_{1I} = x_{1p} - \frac{r}{\sqrt{A_1^2+B_1^2}}[A_1\cdot\cos(\theta-\varphi) - B_1\cdot\sin(\theta-\varphi)] \quad (15)$$

$$y_{1I} = y_{1p} - \frac{r}{\sqrt{A_1^2+B_1^2}}[A_1\cdot\sin(\theta-\varphi) + B_1\cdot\cos(\theta-\varphi)] \quad (16)$$

- for profile *II*:

$$x_{1II} = x_{1p} + \frac{r}{\sqrt{A_1^2+B_1^2}}[A_1\cdot\cos(\theta-\varphi) - B_1\cdot\sin(\theta-\varphi)] \quad (17)$$

$$y_{1II} = y_{1p} + \frac{r}{\sqrt{A_1^2+B_1^2}}[A_1\cdot\sin(\theta-\varphi) + B_1\cdot\cos(\theta-\varphi)] \quad (18)$$

The equipment for modelling the soil in interrupted furrows, which uses the analysed mechanism with simple cam and cam follower for forming the furrows, has the following main components, showed in Fig. 2: the cam drive-wheel *1*, the ridge plough for opening the watering channel *R*, the chain drive *2*, the cam *3*, the roller *4*, the cam follower *5*, the cam follower holder *6*, the interruption blade *7*.

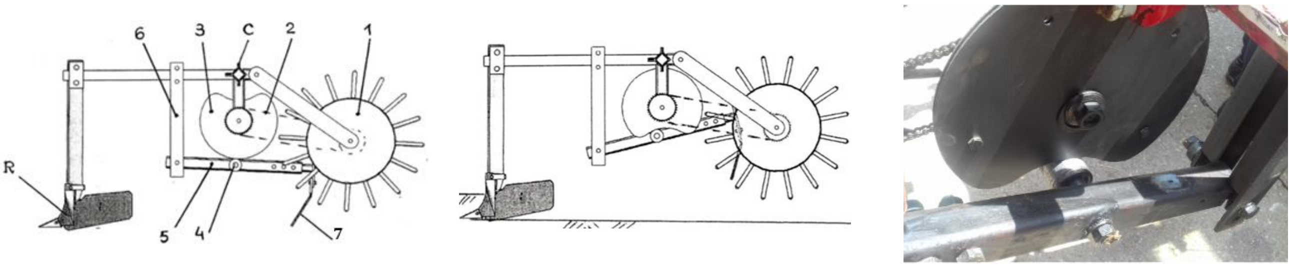


Fig. 2 - The equipment for soil modelling in interrupted furrows

In order to carry out the experiments with the equipment for modelling the soil in interrupted furrows, the mechanism with the simple rotating cam and cam follower for the formation of the furrows, was mounted on a plough for interrupting the watering furrows in vineyards, symbol PCVM 2.2, which was operated by a 45HP vegetable tractor, L445. In Fig.3 are presented aspects during the experiments.

Fig. 3 - Tractor unit L445 and the Plow PCVM 2,2b during the experiments

The qualitative indices of the work performed with the equipment for modelling the soil in furrows, during the experiments are identified in Fig.4a, and the values determined are shown in Table 1.

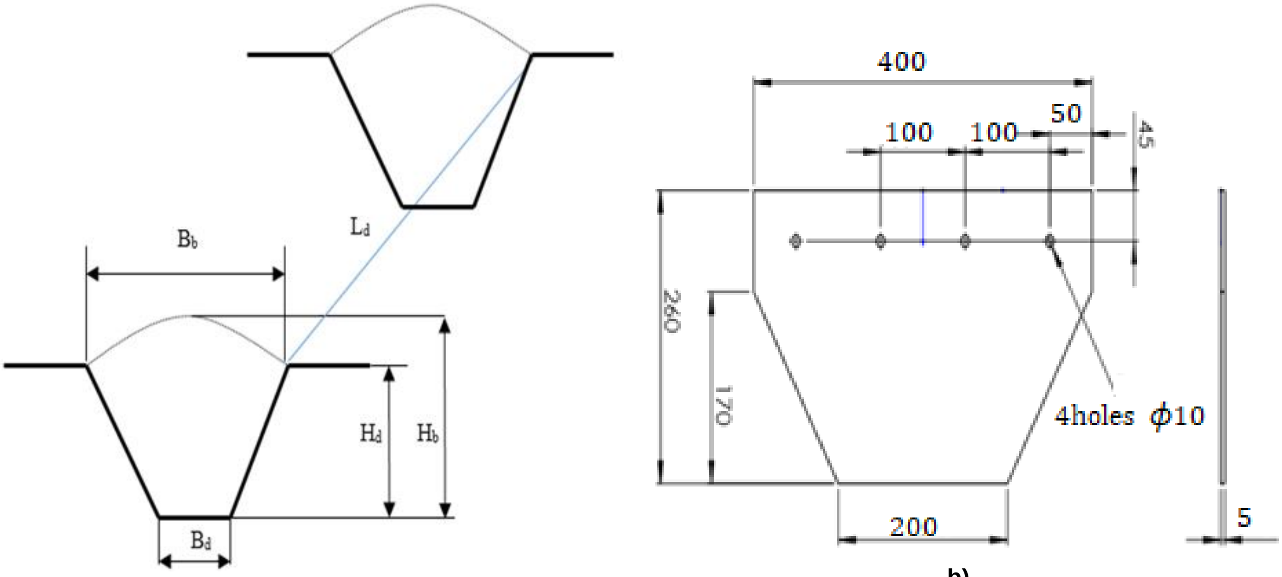
The dimensions of the interrupting blade are those indicated in Fig.4b.

- *The absolute mean,* V_{ma}, is calculated by the following formula (23):

$$V_{ma} = \frac{\sum_1^n \vartheta_i}{n},\ [\text{cm}] \tag{23}$$

where: v_i – the measured value, cm;

n – the number of measurements made.



a) **b)**

Fig. 4 a) The dimensions of the ditch and of the soil stopper; b) The dimensions of the blade

RESULTS

For the equipment for opening and interrupting watering furrows, the optimal synthesis has been done for the mechanism with rotating cam and roller cam follower, Fig.5, knowing the following data:

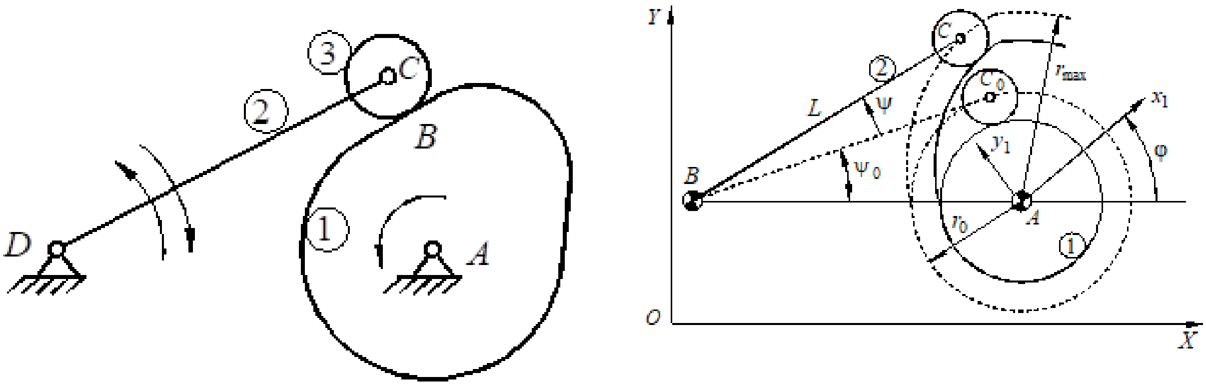


Fig.5 - Mechanism with rotating cam and rotating roller cam follower

Ψ_{max} rad or Ψ_{max} ° – maximum oscillation angle of the cam follower; α_{max} rad or α_{max}° – maximum pressure angle; α_{max} rad or α_{max}° – minimum pressure angle; Φ_1=0.785398 rad or Φ_1=45°–cam rotation angle, corresponding to the lifting phase; Φ_2=260 rad–cam rotation angle, corresponding to the upper stationary phase; Φ_3=0.872665 rad or Φ_3=50° – cam rotation angle, corresponding to the descent phase; Φ_4=0.0872665 rad or Φ_4=5°–cam rotation angle, corresponding to the lower stationary phase; $XA=0$ mm, $YA=0$ mm – the coordinates of the base cam joint in relation to the base; $XB=-300$ mm, $YB=-200$ mm–the coordinates of the cam follower joint in relation to the base.

Following the synthesis of the rigid memory, it results:

$$L_{cam\ follower} = BC_2 = 327 \text{ mm} \tag{19}$$

$$r_{max}=198.223 \text{ mm} \tag{20}$$

$$r_{min}=107.499 \text{ mm} \tag{21}$$

$$r_{cam\ follower\ roller} = 33 \text{ mm} \tag{22}$$

Fig.6 presents the kinematic diagram of the single cam mechanism, resulting from the synthesis and the dimensions of the blade for interrupting watering furrows.

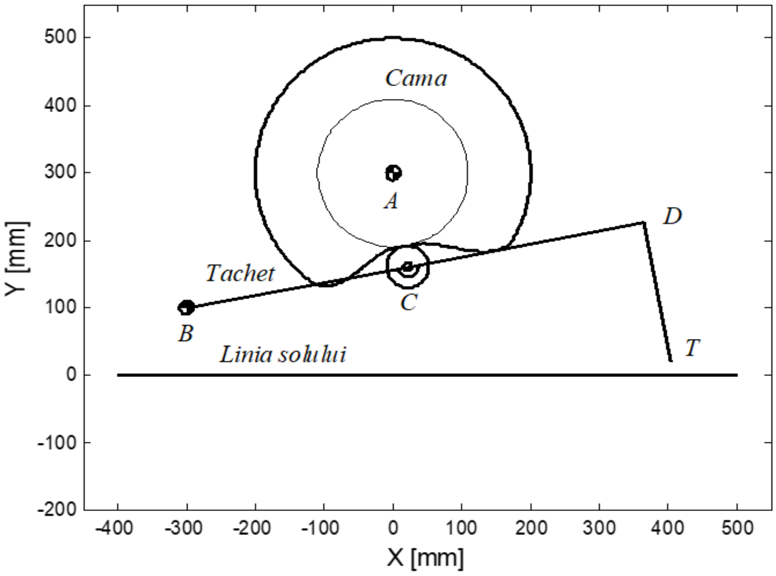


Fig.6 - Kinematic diagram of the mechanism with a simple rotating cam

- *The average square deviation*, σ_a is determined by the relation (24):

$$\sigma_a = \pm\sqrt{\frac{\sum_{i=1}^{n}(\vartheta_i-\vartheta_{ma})^2}{n-1}},\ [\text{cm}] \tag{24}$$

- *The variation index,* V_a, is calculated with the relation (25):

$$V_a = \frac{\sigma_a}{\vartheta_{ma}} \mathrm{x}100\ [\%] \tag{25}$$

Table 1

Qualitative working indices of the equipment with blades

Test	**Qualitative working indices**				
	Soil stopper height, H_b, [cm]	**Ditch depth H_d, [cm]**	**Ditch' upper width, B_b, [cm]**	**Ditch' bottom width, B_d, [cm]**	**Intervals between stoppers L_d, [cm]**
1	26.00	19.50	50.00	19.50	280.50
2	27.00	19.00	51.00	19.00	281.00
3	26.50	18.50	50.00	20.00	279.50
4	27.50	20.00	50.50	19.00	278.00
5	26.00	18.50	51.00	19.50	281.00
6	26.60	19.00	50.50	19.40	280.00
The absolute mean, V_{ma}, [cm]	26.60	19.08	50.50	19.40	280.00
The average square deviation, σ_a, [cm]	0.584	0.584	0.447	0.374	1.14
The variation index, V_a, [%]	2.19	3.10	0.90	1.90	0.40

CONCLUSIONS

Following the theoretical considerations and the results of the experiments, the following conclusions are drawn:

- the mechanism that activates the equipment with blades must have a quiet operation, and without shocks, reduced accelerations within certain limits and lead to the achievement of the convenient forms of the furrows;

- from the performed analysis, it was found that the mechanism with the rotating cam and cam follower performs the requirements mentioned in the previous paragraph in very good conditions;
- the values of the qualitative working indices, which actually represent the dimensions made by the equipment blade to make the earth stoppers are almost equal to those of the blade itself, which indicates a high precision of the equipment fit with the mechanism with rotation cam and cam follower that actuates the equipment with blades;
- the average square deviation, σ_a and the variation index, V_a, have very small values, which means that the mechanism used on the working equipment from the experiments is appropriate.

ACKNOWLEDGEMENT

This work was supported by Romanian Education and Research Ministry, through *Programme 1 – Development of the national research-development system, sub-programme 1.2 – Institutional performance – Projects for financing excellence in RDI, contract no. 16PFE* and Romanian Ministry of Research and Innovation CCDI -UEFISCDI, “Complex system of integral capitalization of agricultural species with energy and food potential”, project number PN-III-P1-1.2-PCCDI-2017-0566, Contract no. 9PCCDI/2018.

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