MATHEMATICAL MODELING AND GRAPHICAL REPRESENTATION WITH AUTOCAD OF THE FUNCTIONING OF VEGETABLE REMAINS SHREDDERS

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Abstract

Agricultural work is considered the oldest human occupation, being determined mainly by the need for insurance of the food necessary for survival. The positive evolution of human civilization has generated an increase and diversification of food needs, thus contributing to the improvement of work techniques and the modernization of tools and equipment used in agriculture. One of the current scientific research topics in the agricultural field is related to the problem of clearing land of vegetable remains by cutting, chopping and then uniformly distributing the chopped material on the soil surface in order to ensure optimal conditions for carrying out agricultural work necessary for the future crop on that land. This article presents a mathematical modeling of the operation of a vegetable remains shredder, which aims to permanently verify the characteristic working parameters in accordance with the optimal values indicated by the manufacturers of these machinerys. The equations of the mathematical model allow the calculation of the desired working parameters at different time intervals, for certain values of the machinery's travel speed or drum rotation speed. A scale graphic representation of the cutting elements is also made, as well as a graphic simulation of the operation of the vegetable remains shredders. For this, the facilities offered by the commands in AutoCAD are used, which is a computer application that allows drawing and graphic design aided by computer.

***Key words**: shredder, vegetable remains, equation, graphic representation, AutoCAD*

INTRODUCTION

The evolution of human society over time has been closely linked to the evolution of agriculture. As is well known, agriculture is a basic branch of the national economy, as it provides both the food needed by the population and raw materials for other fields of activity.

One of the most important challenges for human society is that of implementing and achieving sustainable agriculture. This principle takes into account, on the one hand the fact that agriculture has an essential role in permanently ensuring the need of food for population, but at the same time must be known and improved the impact of agriculture on the environment and on human health. Putting into practice the implementation of this principle of developing sustainable agriculture has numerous beneficial effects: it preserves fertile soil, water, as well as the genetic resources of fauna and flora. Also, sustainable agriculture is environmentally non-degradable, technologically appropriate, economically viable and socially acceptable.

The development of a sustainable agriculture is based on the fact that soil represents the most important value of human existence. Soil quality can be maintained and even improved by using in practice the latest and most advanced technologies and work equipment.

One of the most well-known methods of conserving soil and even improving its fertile qualities is that of covering with a layer of vegetable remains from the

previous crop before actually starting agricultural work for a new crop. Specialized research have demonstrated that it is indicated that at least one third of the cultivated area be initially covered with a layer of vegetable remains to ensure a reduction of a soil erosion. Other beneficial effects are represented by the decrease in water loss through evaporation and an obvious improvement in soil fertility and productivity qualities by using this layer as a vegetable fertilizer.
Considering all these aspects, one can understand the need to equip agricultural farms with machinery that allows cutting and chopping vegetable remains, which play an essential role in preserving the soil and implicitly the environment, but also for increasing the production at the agricultural crops on those areas.

MATERIALS AND METHODS

A complete aggregate that can be used on farms to perform agricultural work of cutting and chopping vegetable remains is made up of an agricultural machine (usually a tractor), which ensures linear movement on the soil surface and the actual cutting-chopping equipment (figure 1). In turn, this machinery has the following distinct components: a rigid frame on which a towing or suspension mechanism is mounted, support or rolling wheels, the casing, the shaft or rotor which actually forms the active working organ and the exhaust port.

Figure 1: Complete aggregate for cutting and chopping vegetable remains

Thus, the work process carried out by the rotor of an agricultural machinery dedicated to cutting and chopping vegetable remains is made up of the following distinct stages: the penetration of the knives into the vegetable mass, the detachment of the chopped pieces and their engagement in the rotational movement, the collision of the chopped pieces with the counter-knife or the machinery casing, which determines their additional shredding and the spreading of the chopped pieces obtained on the ground.

Theoretical and experimental research and analyses regarding vegetable remains shredders aim to improve agricultural activities to prepare the land for a future crop, which involves cutting and shredding the scrap of plants left on the ground, as well as optimizing the use of these agricultural machinerys depending on the particular situations at a given time. The results obtained from these studies and research will establish the following essential aspects for cutting and chopping equipment: the type or types of active organs (knives or hammers) most suitable depending on the category of vegetable remains to be processed, the optimal speed of movement of the aggregate, as well as the optimal rotation speeds for operation of the rotors with knives, so as to comply with the quality conditions imposed by the standards in force.

As is well known, any work process can be described with the help of some mathematical equations. Therefore, in this article it will be proposed a variant of mathematical modeling of the stages performed during the technological process of cutting and chopping vegetable remains. The equations of this mathematical model are based on knowledge in the fields of algebra, geometry and trigonometry, mainly aiming to describe the functioning of vegetable remains shredders and especially the active organs arranged on the rotor of these machinerys. The experimental results obtained through the selective analysis of certain samples taken during cutting-chopping activities carried out in the field must be very close in value to the theoretical results obtained using the equations that make up the mathematical model in order to demonstrate the operation according to the required standards and at the same time attest to the reliability of the vegetable remains shredders used.

For a better understanding of the technological process, by using the drawing and design commands and facilities offered by the AutoCAD computer application, were made graphic representations of the cutting elements located on the rotor, of the trajectory of a knife located on the rotor and of the complete kinematics of the cutting bodies by combining the horizontal movement speed of the aggregate with the angular speed of the rotor.

The AutoCAD computer application, developed by Autodesk, is specialized for drawing and design aided by computer. The AutoCAD commands used to create the graphic representations presented in this article are:

a) Line: allows drawing one or more successive line segments
b) Rectangle: allows drawing a rectangle when the coordinates of the corners corresponding to a diagonal are known
c) Circle: allows drawing a circle
d) Arc: allows drawing a circular arc
e) Polyline: obtaining a path formed by successive line segments or circular arcs
f) Trim: allows eliminating portions of a geometric figure that exceed the edge of another indicated figure
g) Hatch: for hatching closed contours
h) Dimlinear: for indicating the linear distance between two points:
i) Dimangular: for marking an angular value
j) Multiline text: offers the possibility of writing a text on several lines, but only in the horizontal direction
k) Single line text: allows writing a text on a single line, with the desired inclination.

RESULTS AND DISCUSSIONS

In principle, a cutting-chopping machinery as part of an agricultural aggregate intended for collecting and shredding fodder plants or vegetable remains has the following basic components: the rotor (shaft), the working elements (knives) and the casing. The working (cutting) elements are hingedly mounted on the rotor or shaft by means of some bolts or axles and support ears. These cutting elements can usually be knives or articulated bars with inertial mass (hammers) and are arranged along the rotor or shaft in 2-4 rows placed after a spiral with a single beginning.

At the TR-2.5 type vegetable remains shredder, which was actually used during the experimental research, the knives are distributed evenly on the rotor, and their disposing is made on a propeller so that in a plane there is only one knife. At the TR-2.5 shredders, between the knives is a coverage Δb=7-25 mm, and the knives have a working width b=50-75 mm and different construction forms: with 1 degree of freedom or with 3 degrees of freedom.

With the help of the AutoCAD application, which is used for drawing and design aided by computer, were graphically represented, at a scale of 1:10, the geometric elements that characterize a cutting organ that generally equips machinerys used for cutting and chopping vegetable mass. Thus, two variants of cutting elements were represented: the knife with 1 degree of freedom (figure 2), and the knife with 3 degrees of freedom (figure 3).

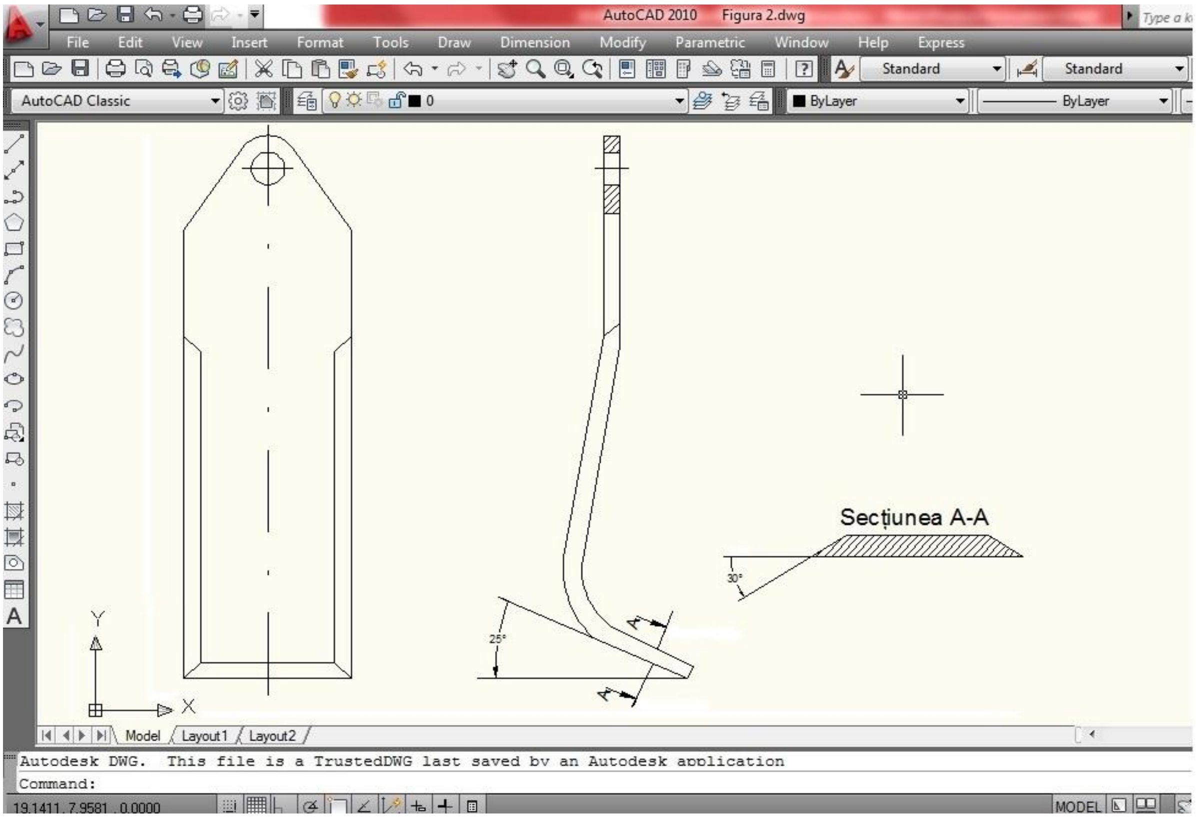

Figure 2: The characteristic geometric elements of a knife with 1 degree of freedom

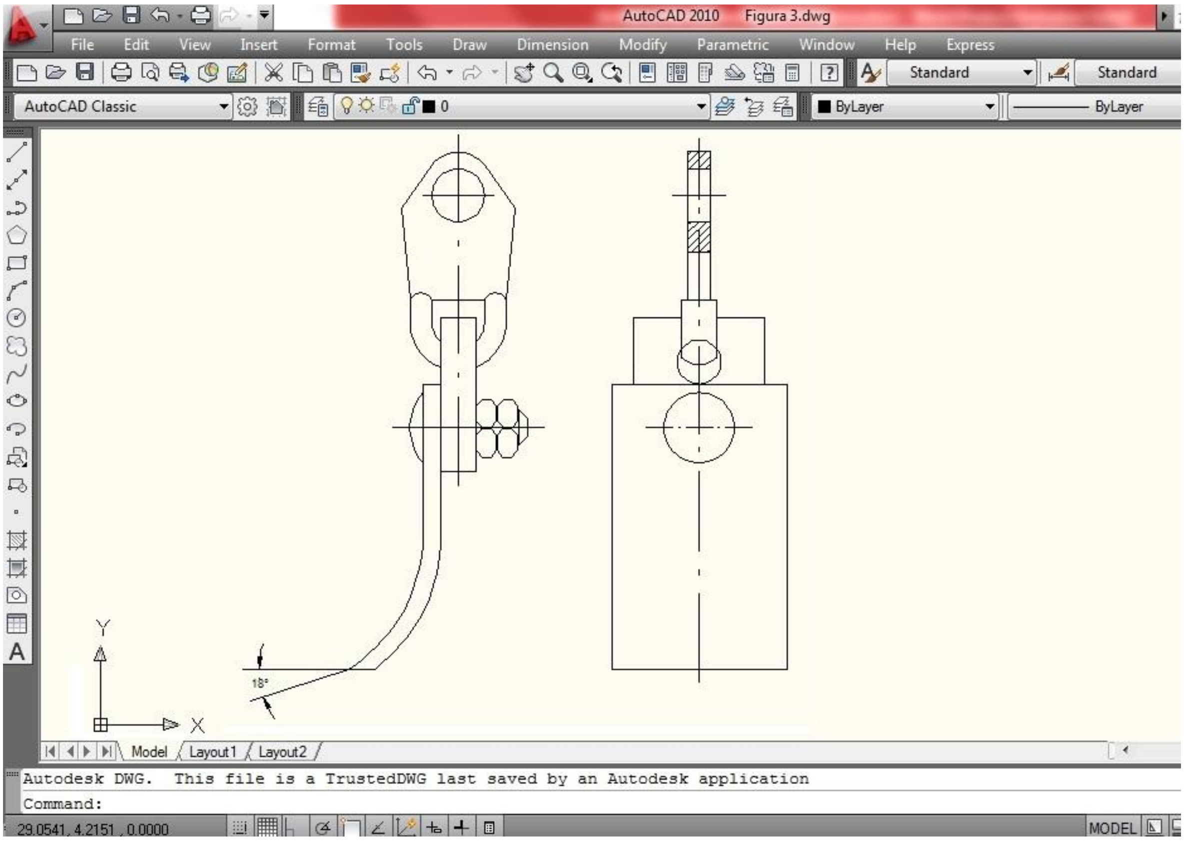

Figure 3: The geometric elements that characterize a knife with 3 degrees of freedom

The machinerys for cutting and chopping plants and vegetable remains will be given a horizontal translational movement at a certain speed, which is actually equal to the travel speed of the agricultural machine from the composition of the aggregate. In reality, the technological process performed by this machinery is very complex when we have to analyze it as a dynamic physical process, because horizontal translational movement is combined with the rotational motion of the cutting elements (knives, counter-knives, hammers) around the fixed axis of the rotor.

For a understanding as correct as possible of this dynamic physical process, also by using the AutoCAD computer application, was graphically represented the kinematics of the cutting elements (knives) located on the rotor of a vegetable remains shredder (figure 4). For correct analysis, can be done a mathematical modeling of the kinematics of these cutting elements located on the rotor of the machinery for cutting and chopping of vegetable remains (equations 1÷15). The values of these mathematical calculations have the role to verify the accuracy of experimental measurements obtained in the field during the work process.

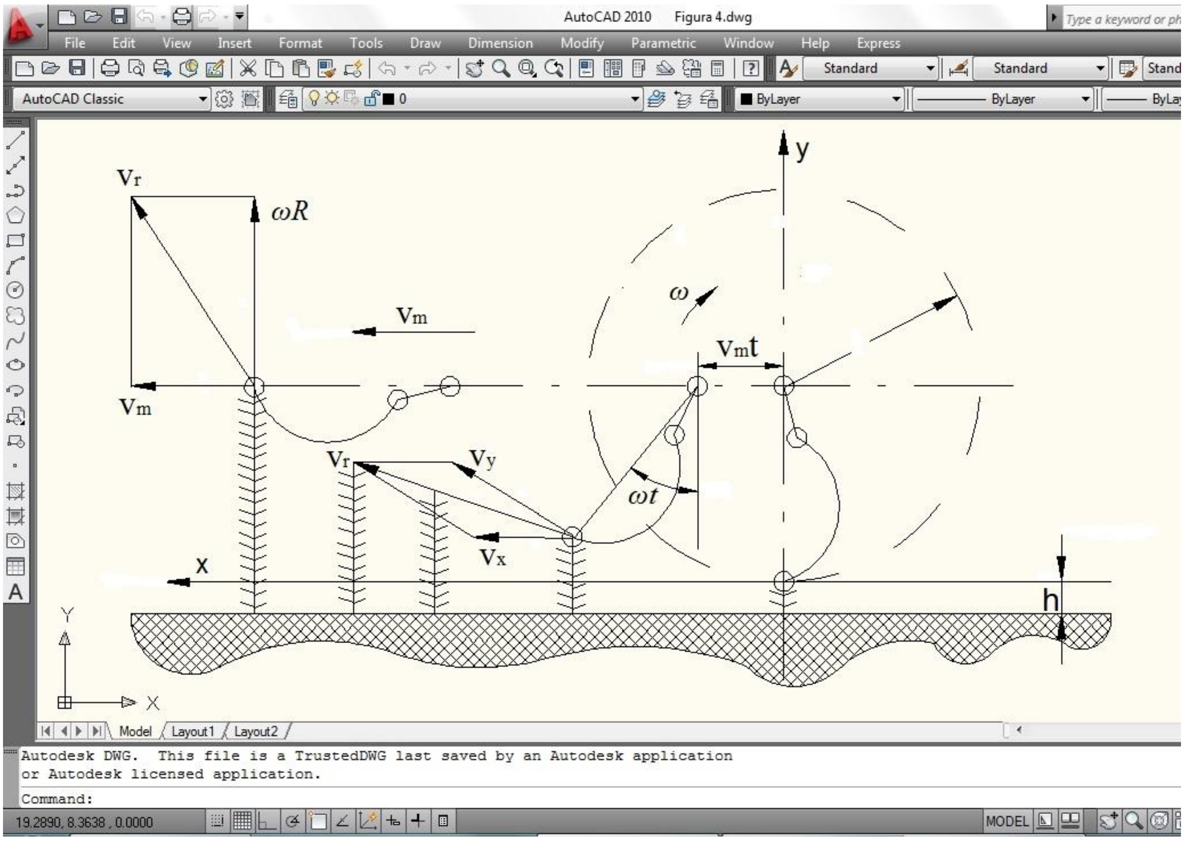

Figure 4: Kinematics of a machinery of cutting and chopping vegetable remains

Under these conditions, the equations of movement of a point on the knife, located at radius r∈[0, R], R being the radius of the extreme point of the knife, are:

$$x = v_m t + r\sin\omega t,\quad y = r(1-\cos\omega t) \tag{1}$$

and the components of the speed:

$$v_x = v_m + R\omega\cos\omega t,\quad v_y = R\omega\sin\omega t \tag{2}$$

where: v_m is the speed of travel of the agricultural machine towing the vegetable remains shredder, ω is the rotation speed, t is the time from the start of the machinery's movement.

The absolute speed of the knife (the speed of cutting the plants or the resulting speed) is given by the mathematical equation:

$$v_r = \sqrt{v_x^2 + v_y^2} = \sqrt{v_m^{\ 2} + \omega^2 r^2 + 2 v_m \omega r \cos \omega t} = v_m \sqrt{1 + \lambda^2 + 2\lambda \cos \omega t} \qquad (3)$$

where λ represents the kinematic regime of the machinery and is given by the mathematical formula:

$$\lambda = \frac{\omega r}{v_m} = \frac{v_p}{v_m} \qquad (4)$$

To ensure a inertial cutting, i.e. without support (or without counter knife), it is necessary for the speed of the knives to be higher than a limit speed at which inertial cutting is performed, which mathematically means:

$$v_p > v_{\lim} \qquad (5)$$

where v_{lim} is the speed at which inertial cutting is performed. Generally v_{lim} = 8 - 12 m/s.

In practice, the effective cutting speed is higher than the limiting speed.

Since the analysis is done on a cutting machinery with rotational motion, the effective cutting speed is dependent on the radius of the cutting machine, in which case the peripheral speed of the knives is actually the speed of a point located on the edge of the knife and is given by the mathematical equation:

$$v_p = \omega R \qquad (6)$$

where: ω is the angular velocity of a point located on the knife edge and R is the radius of the circle described by a point on the knife edge. Generally ωR = 30 ÷ 50 m/s.

In figure 5, the trajectory of a knife during work is represented with a dashed line, and the working area of that knife is marked with a hatching.

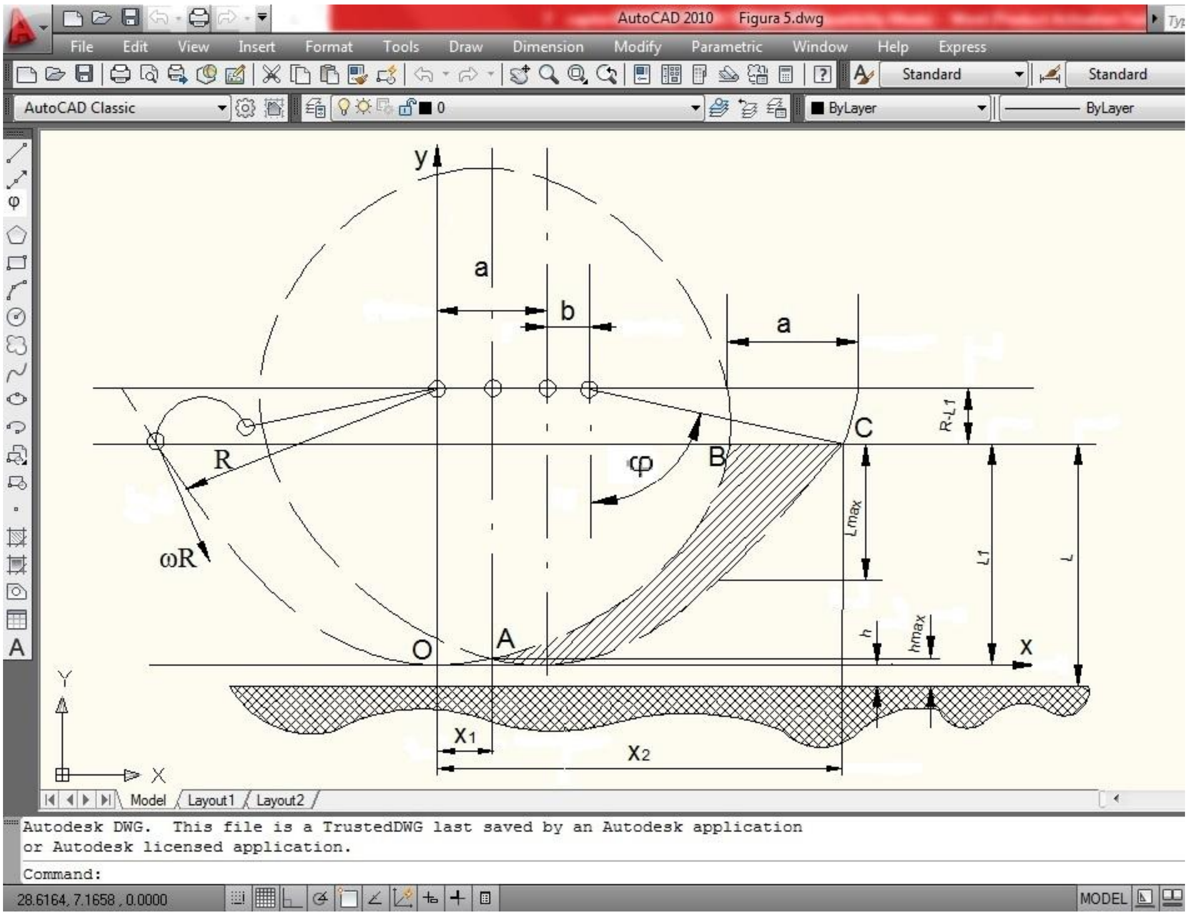

Figure 5: The trajectory of a knife during the cutting and chopping process

The length of the chopped material, if the plants remain vertical during cutting, varies from zero at points A and C to l_{max} at point B. If the stems are vertical during cutting, then the stubble height varies between h and h_{max}. Under these conditions, the average length of the chopped material is considered to be given by the fraction:

$$l_{med} = \frac{S_{ABC}}{x_2 - x_1}, \quad (7)$$

where: S_{ABC} is the surface of the working area of a knife; x_1 and x_2 represent the abscissas of points A and C; A is the point where the working area begins; C is the point where the working area ends.

The supply of the chopping machinery, which means the advance of the machine at a rotation of the chopping machinery shaft, is denoted by „a" and has the following mathematical equation:

$$a = \frac{2\pi v_m}{\omega} \quad (8)$$

where: v_m is the advancement speed of the machinery at work; ω is the angular velocity of the knife.

The working area of a knife is given by the mathematical formula:

$$S_{ABC} = \frac{2\pi v_m L_1}{\omega} \quad (9)$$

where: $L_1 = L - h$

and: L represents the height of plants;
h represents the cutting height.

The abscissas x_1 and x_2 of points A and C are:

$$x_1 = \frac{a}{2} = \frac{\pi v_m}{\omega} \text{ and } x_2 = a + b + R\sin\varphi \quad (10)$$

where: $$b = \frac{v_m \varphi}{\omega} \quad (11)$$

$$\cos\varphi = \frac{R - L_1}{R} \quad (12)$$

$$\sin\varphi = \frac{\sqrt{2RL_1 - L_1^2}}{R} \quad (13)$$

Result:

$$x_2 = \frac{v_m(2\pi + \varphi)}{\omega} + \sqrt{2RL_1 - L_1^2} \quad (14)$$

With this last relationship, the average length of the fragments of the chopped material, l_{med} becomes:

$$l_{med} = \frac{2L_1}{1 + \varphi/\pi + (\omega/\pi v_m)\sqrt{2RL_1 - L_1^2}} \quad (15)$$

All results obtained from these mathematical calculations had values approximately equal to the experimental measurements performed during the use of the TR-2.5 vegetable remains shredder, which confirms both the correctness of the mathematical model and the reliability of the type of vegetable remains shredder analyzed.

CONCLUSIONS

The use of innovative technological methods and modern work equipment on agricultural farms that allow cutting and chopping vegetable remains automatically results in a series of advantages which cannot be neglected by any farmer.

In addition to the beneficial effects on the soil of cultivated areas, the use of vegetable remains shredders also ensures the achievement of higher quality agricultural production at the lowest possible cost, by reducing expenses with irrigation, with combating erosion and with spreading additional fertilizers.

As a result of the results provided by the experimental research, it can be concluded that the use of these work technologies involving the use of vegetable remains shredders does not determine an immediate increase in the harvest obtained on a unit area, but has as its main purpose the improvement of the state of soil fertility and productivity, as well as the conservation and protection of the natural qualities of the soil and other environmental resources against degradation.

Regarding the AutoCAD computer application, it can be said that it is a professional software product, which, through the commands and work facilities offered, creates optimal conditions for the development of technical projects in the most varied fields. That is why AutoCAD is used by specialists in drawing and graphic design aided by computer, from the most diverse technical fields of activity: mechanics, architecture, geography, agriculture, geodesy, topography, cadastre, etc.

To create the graphical representations in this article, several common AutoCAD commands were used. It should be noted that at the basis of drawing and graphic design in AutoCAD are the same principles as classic technical drawing.

The implementation and use of some computer graphics programs increases the effectiveness of projects in technical fields by describing certain graphic details much more clearly and precisely.

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