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DETERMINATION OF THE NUMBER OF ELLIPTICAL CUTTING BLADES OF A ROTARY WORKING ELEMENT

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An active rotary working element with an approach angle was studied. The elliptical cutting blades of the working element are deflected from the rotation plane. The experiment confirmed that the blades form a groove in the shape of a segment of an ellipse in cross-section, and a parallelogram when viewed from above. The bottom of the furrow contains ridges. It was established that the ridge height should not exceed 1/2 of the processing depth. The expression of the dependence of the central angle between adjacent elliptical cutting blades on the ridge height at the furrow bottom was formulated. The experiments were carried out using a physical model of the working element (scale 1:3). The approach angle was 40 degrees, the kinematic parameter was assumed to be equal to: 0.90; 1.20; 1.60; 2.20. The theoretical data are consistent with the data obtained from the experiment. The dependences of the number of elliptical cutting blades of the working element on the kinematic parameter and the approach angle of the working element were identified. It was found that increasing the approach angle and the kinematic parameter requires to reduce the number of blades. At an angle β = 40 °, λ = 0.90, c = 1/2 h, the number of elliptical cutting blades of the rotary working element should be 10-16 pieces.

Key words: *elliptical cutting blade, furrow, ridge, approach angle, kinematic parameter.*

АЙНАЛМАЛЫ ЖҰМЫС ОРГАНЫНЫҢ ЭЛЛИПТИКАЛЫҚ КЕСКІШ ПЫШАҚТАРЫНЫҢ САНЫН АНЫҚТАУ

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Шабуыл бұрышы бар айналмалы белсенді жұмыс органы зерттелді. Жұмыс органының эллиптикалық кескіш пышақтары айналу жазықтығынан ауытқиды. Эксперимент пышақтардың көлденең қимада эллипс бөлігі түрінде бороз түзетінін, ал үстінен қарағанда параллелограмм түзетінін расталды. Бороздың түбінде жоталар бар. Жоталардың биіктігі өңдеу тереңдігінің 1/2 бөлігінен аспауы керек екендігі анықталды. Іргелес эллиптикалық кескіш қалақтардың арасындағы орталық бұрыштың бороздың төменгі жағындағы жотаның биіктігіне тәуелділігінің алынды. Эксперименттер жұмыс органының физикалық моделімен, 1:3 масштабында жүргізілді. Шабуыл бұрышы 40 градус болды, кинематикалық параметр: 0,90; 1,20; 1,60;2,20. Теориялық деректер эксперимент нәтижесінде алынған мәліметтермен сәйкес келді. Кинематикалық параметрге және жұмыс органының шабуыл бұрышына байланысты жұмыс органының эллиптикалық кесу пышақтарының санына тәуелділіктер алынды. Шабуыл бұрышы мен кинематикалық параметрді жоғарылату арқылы пышақтардың санын азайту керек екендігі анықталды. B = 40°, λ= 0,90, c=1/2h бұрышында айналмалы жұмыс органының эллиптикалық кескіш пышақтарының саны 10 – 16 дана болуы керек.

Түйінді сөздер: *эллиптикалық кескіш пышақ, бороздa, жота, шабуыл бұрышы, кинематикалық параметр.*

ОПРЕДЕЛЕНИЕ КОЛИЧЕСТВА ЭЛЛИПТИЧЕСКИХ РЕЖУЩИХ ЛЕЗВИЙ РОТАЦИОННОГО РАБОЧЕГО ОРГАНА

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Исследовался ротационный рабочий орган активного действия, имеющий угол атаки. Эллиптические режущие лезвия рабочего органа отклонены от плоскости вращения. Экспериментом подтверждено, что лезвия образуют борозду в форме части эллипса при поперечном сечении, а при виде сверху – параллелограмм. Дно борозды содержит гребни. Установлено, что высота гребней не должна превышать 1/2 от глубины обработки. Получено выражение зависимости центрального угла между соседними эллиптическими режущими лезвиями к высоте гребня на дне борозды. Эксперименты проводились с физической моделью рабочего органа, в масштабе 1:3. Угол атаки составлял 40 градусов, кинематический параметр принимался равным: 0,90; 1,20; 1,60; 2,20. Теоретические данные совпадают с полученными данными в результате эксперимента. Получены зависимости числа эллиптических режущих лезвий рабочего органа в зависимости от кинематического параметра и угла атаки рабочего органа. Установлено, что увеличив угол атаки и кинематический параметр – необходимо уменьшать число лезвий. При угле β = 40°, λ= 0,90, c=1/2h, количество эллиптических режущих лезвий ротационного рабочего органа должно составлять 10-16 штук.

Ключевые слова: *эллиптическое режущее лезвие, борозда, гребень, угол атаки, кинематический параметр.*

Introduction

Research by scientists from the countries of near and far abroad has established that machines and tools with an active drive of working elements are characterized by lower traction resistance, unlike "passive" action tools [1, p. 217, 2, p. 48]. It is also known that in this case the tillage unit will have a higher efficiency [3, p. 10]. The study, development and construction of new tillage machines and implements equipped with "active" working elements will reduce energy costs for tillage operations, as well as ensure high quality of the process itself, in accordance with agro technical indicators for these operations [4, p. 115, 5, p. 88].

Currently, the use of tillage machines and implements continues to gain popularity, the working elements of which are rotary working elements powered by a tractor. Such machines are widely used in foreign farms in the USA, China, India, etc.

Thus, in order to ensure a high-quality process of surface tillage, scientists pay closer attention to such machines and tools.

However, such machines and tools, the working elements of which are powered by a tractor and have the shape of elliptical cutting blades, are characterized by a lack of knowledge of the selection of their quantity to ensure the required quality.

The purpose of the study is to determine the number of elliptical cutting blades of a rotary working element.

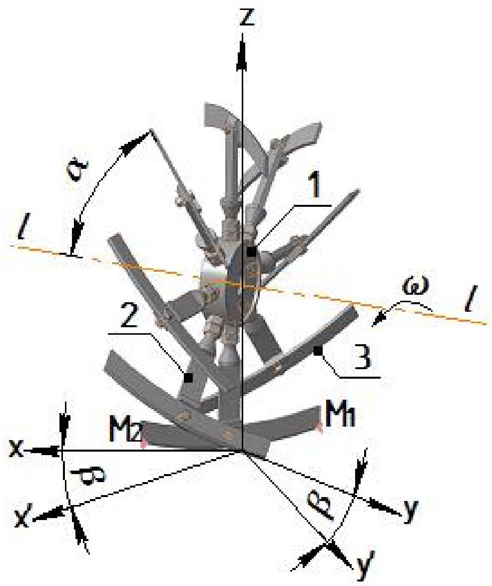
Tasks

To obtain an expression enabling to determine the number of elliptical cutting blades of the rotary working element and to obtain the dependence of the number of cutting blades of the working element on the approach angle and kinematic parameter.

Materials and methods

The studies were carried out with an "active" rotary working element (Figure 1), structurally made of a hub 1, spokes 2 and elliptical cutting blades 3 having an angle α of deviation from the axis of rotation. The RPO itself has an approach angle β [6, p. 60].

These working elements are fundamentally new and can be widely used in pre-sowing tillage and fallow tillage.



1 – hub, 2 – spoke, 3 – cutting blade

Figure 1 – Diagram of the rotary working element

Theoretical studies to substantiate the number of elliptical cutting blades of the working element were carried out using the laws and methods of analytical geometry and theoretical mechanics.

Experimental studies, in turn, were carried out in a soil channel using physics. the RPO model (scale 1:3). Parameters: α = 40°, the kinematic parameter was assumed to be: 0.90; 1.20; 1.60; 2.20.

Research results and discussion

The trajectory of the points (M1, M2, Mp) of elliptical cutting blades in the OXYZ coordinate system (Figure 1) is calculated using the following expression [6, p. 64]:

$$\begin{cases} X = \theta \cdot R/\lambda + R \cdot \cos\beta \cdot \cos(\theta \pm \Delta) + b \cdot sin\beta; \\ Y = R \cdot \sin\beta \cdot \cos(\theta \pm \Delta) - b \cdot cos\beta; \\ Z = R\,[(1 - \sin(\theta \pm \Delta)]. \end{cases} \quad (1)$$

Where:

R: radius of the elliptical cutting blade;

Θ: rotation angle of the radius vector from the axis of rotation;

Λ: kinematic parameter;

Δ: angle between the radius vectors of the two studied points of the cutting blade.

The point of the elliptical cutting blade M_1 has Δ=0 and b=0. The trajectory of the specified point in the cross section has the shape of a segment of an ellipse (Figure 2a).The elliptical cutting blade moves from point A to point B. The AOV figure represents the treated part of the soil (in cross-section in the form of a segment of an ellipse).

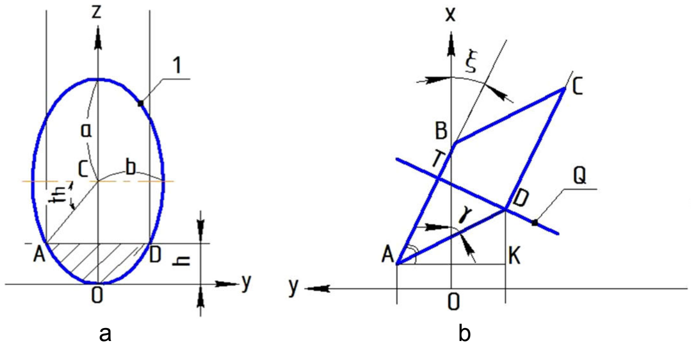
The trajectory of the point M_1 in the XOY plane (Figure 2b) is characterized by a segment AD located at an angle gamma (γ), which can be found from the formula [7, p. 706]:

$$\gamma = arctg[\lambda \cdot sin\beta/(\lambda \cdot cos\beta - 1)]. \quad (2)$$

The trajectory of the extreme point M_2 of the elliptical cutting blade of the RPO is characterized by a segment BC, which, in turn, like the segment AD, is deviated from the movement direction of the RRO by an angle gamma (γ).

The segments AB and DC are deviated from the movement direction of the working element at an angle ξ, which is determined by the following formula [7, p. 706]:

$$\xi = arctg[b \cdot cos\beta/(\pm b \cdot sin\beta + \theta \cdot R/\lambda)]. \quad (3)$$



a – *YOZ* ; b – *XOY* ; c -*Y'O'Z'*

Figure 2 – Projections of the trajectory of the front point of the cutting blade on coordinate planes.

Thus, the ABC figure is a parallelogram (when viewed from above on the furrow being formed) formed by 1 active elliptical cutting blade.

Let us draw the plane Q through the point D. The cross section of the furrow ABCD in the Q plane represents a part of the ellipse 2D with a large semi-axis equal to R (Figure 2c).

The minor axis of the ellipse will be determined from the following expression:

$$b' = R \cdot sin\beta \cdot \sin(\gamma - \xi)\, /sin\gamma. \quad (4)$$

Thus, knowing the parameters of the ellipse enabled to determine the required distance between adjacent elliptical cutting blades of the RPO, which will ensure the required value for the agro technical indicator of the ridge heights at the bottom of the furrow being formed after the passage of the working element.

Figure 3 shows P and T ellipses describing the trajectories of adjacent elliptical cutting blades.

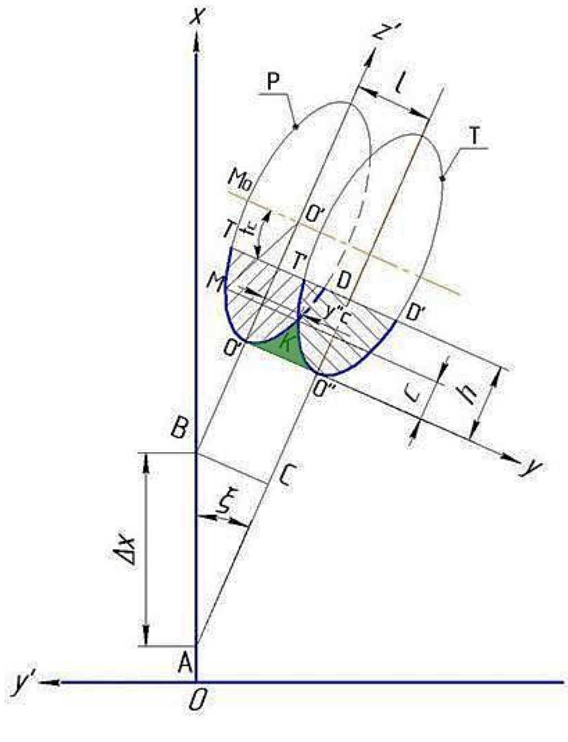


Figure 3 – Determination of the distance between adjacent elliptical cutting blades

1-st elliptical cutting blade forms a furrow T'O'D', 2-d elliptical cutting blade forms a furrow T'O''D', while OCO – "raw" soil, which is the crest, the height of which should not exceed ½ the depth of the tillage (for agricultural requirements). The distance between the ellipses, which will ensure the required ridge height, will be determined from the expression:

$$l = 2y_c' = 2R \cdot sin\beta \cdot \sin(\gamma - \xi) \cdot cost_c / sin\gamma. \quad (5)$$

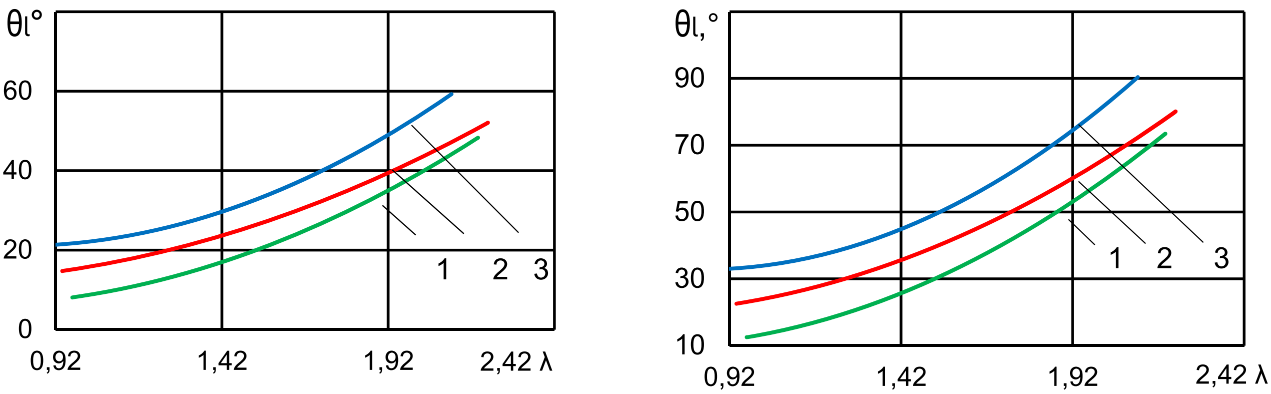
In this case, the central angle between adjacent cutting blades is determined from the formula:

$$\theta_l = 2\lambda \cdot sin\beta \cdot \sin(\gamma - \xi) \cdot cost_c / \, sin\gamma \cdot sin\xi \quad (6)$$

Thus, the number of elliptical cutting blades of the RPO, taking into account the above expressions, will be determined as [8, p. 49]:

$$n = \pi \cdot sin\gamma \cdot sin\xi / \, \lambda \cdot sin\beta \cdot \sin(\gamma - \xi) \cdot cost_c \quad (7)$$

According to formula 7, graphical dependences of the number of elliptical cutting blades on the approach angle of the RPO and the kinematic parameter are plotted (Figure 4).



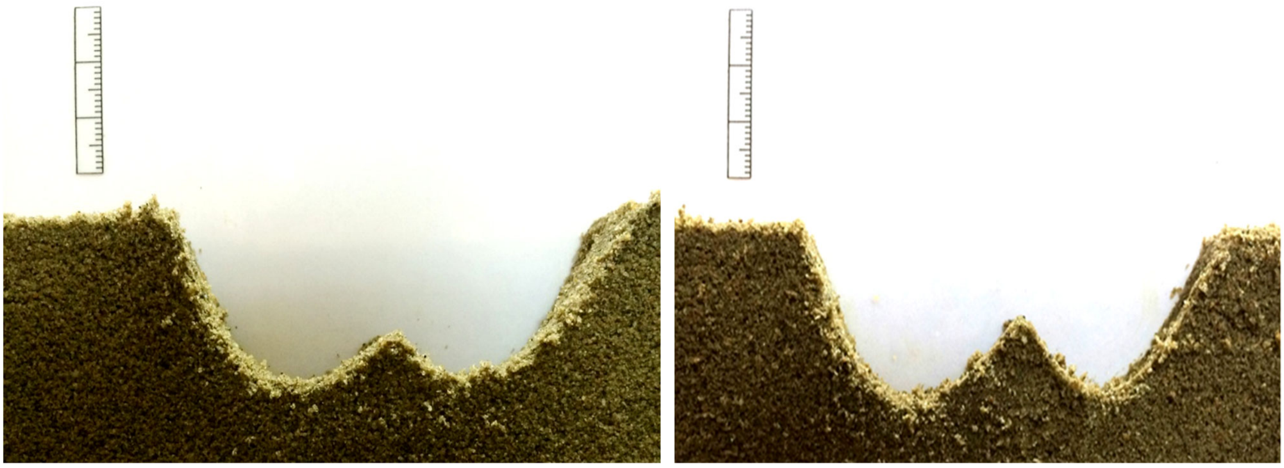
a b

1 – β=20°; 2 – β=30°; 3 – β=40°

Figure 4 – Dependences of the central angle between adjacent cutting blades on the RPO parameters (λ and β), at c = 0.2h (a),c = 0.5h (b)

It can be seen from the graphs shown in Figure 4 that the number of cutting blades of the RPO decreases with increasing kinematic parameter and approach angle of the working element. By changing the approach angle from 20 to 40 degrees, the number of elliptical cutting blades will be significantly reduced to 10-12 pieces, while at the same time increasing the kinematic parameter to 2.20, it enables to achieve the number of blades up to 5-6 pieces, while maintaining the agro technical requirements for surface tillage.

Figure 5 shows photographs obtained from physical modeling of soil tillage with neighboring cutting blades of RPO [9, p. 184].



a b

a – $\theta_l = 22°$; b – $\theta_l = 34°$;

Figure 5 – Cross-sections of the furrow obtained by physical modeling of the radar at an approach angle β = 40 °; and λ= 0.90

From Figure 5, it can be concluded that as a result of RPO-based experiments, with the following parameters: an approach angle of 40 degrees, a kinematic parameter of 0.90, a processing depth of 26 mm and a central angle between adjacent blades equaling to 22 degrees, a furrow with ridges of no more than 6 mm is formed, which meets the agro technical requirements for surface tillage. At the same time, with an angle between adjacent cutting blades of 34 degrees, the height ridge is equal to half the processing depth, which also meets agricultural requirements. However, a further increase in the central angle between adjacent blades will lead to a violation of the requirements and an increase in the height of the furrow bottom ridges. Thus, the optimal angle between adjacent cutting blades is 22-34 degrees.

Figure 6 shows the dependence of the ridge height of the furrow bottom and the number of elliptical cutting blades on the central angle between them.

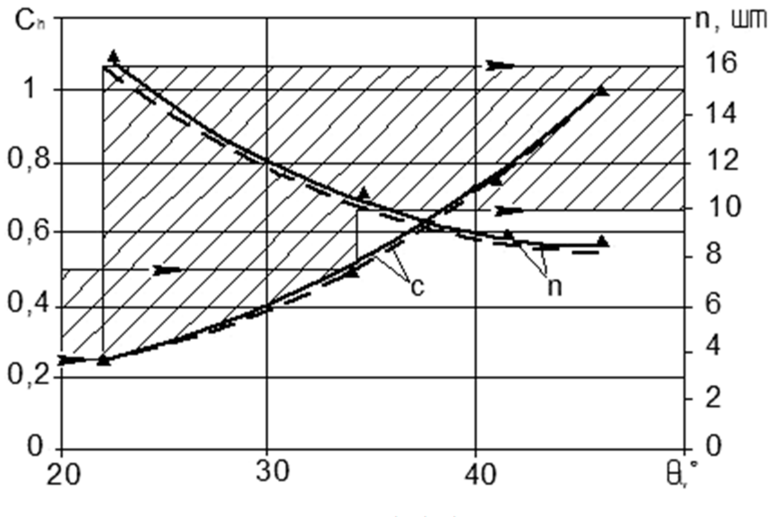


Figure 6 – The dependence of the ridge height and the number of elliptical cutting blades on the central one between them at β =40 °, λ = 0.90

Figure 6 demonstrates that the ridge height of the furrow bottom directly depends on the central angle between the adjacent blades of the RPO. As mentioned above, with an increase in this angle, the ridge height of the bottom of the furrow increases. For example, at l= 22°, the ridge height = ¼ of the processing depth, but already at a central angle of about 48°, the ridge height will be 9/10 of the processing depth.

With an increase in the central angle between adjacent blades, the number of cutting blades themselves decreases. By increasing the central angle from 22° to 46°, the number of cutting blades will be reduced from 16 to an optimal 10 pieces (Figure 7).

Figure 7 – Rotary working element with elliptical cutting blades

Conclusion

An expression has been formulated, allowing determining the number of elliptical cutting blades of the RPO.

The dependences of the number of cutting blades of the RPO on its parameters (approach angle and kinematic parameter) have been identified.

At β = 40 °, λ = 0.90, c = 0.5 h – the number of elliptical cutting blades of the RPO to ensure fulfillment of agro technical requirements for surface tillage ranges from 10 to 16 pieces.

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