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Research and Development of a Mechanism for Fixing the Hydraulic Cylinder for Controlling the External Working Element of a Garden Milling Machine and Determining its Optimal Parameters

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ABSTRACT

The article is devoted to improving the operation of the control system of the remote soil-cultivating working element of the garden milling machine (patent of the Republic of Armenia, No. 2993 A, 16.02.2016), as a result of which it becomes possible to bypass the working element of thick-trunked trees and trees deviated from the row line, as well as slippages and other obstacles, with simultaneous near-trunk processing. Based on the research of the Scientific Research Institute for Agricultural Mechanization and Automation of the Armenian National Agrarian University (ANAU), a control system for the remote working body of a tillage machine (patent of the Republic of Armenia, AM20230106Y, 01.07.2024.) has been developed and implemented. To fix the hydraulic cylinder piston in intermediate positions, depending on the total value t of the tree trunk diameter, the width of the protective zone and the amount of overlap of the treatment, a mechanism for adjusting the length of the slider was investigated and developed and its optimal parameters were determined. For the purpose of practical regulation of the slider length for specific values of t, a corresponding nomogram was constructed.

Introduction

It is known that technical means intended for processing inter-trunk and near-trunk spaces in orchards and vineyards are equipped with control systems for the remote working element of mechanical, hydraulic, hydromechanical and other types (patent of the Republic of Armenia, AM20230106Y, 01.07.2024, patent of the Republic of Armenia, No. 2993 A, 16.02.2016, Balasanyan, 1985, Grigoryan and Altunyan, 2018, Petrosyan, et al., 2017, Manaenkov, et al., 2017). Research conducted by the Scientific Research Institute for Agricultural Mechanization and Automation of the Armenian National Agrarian University (ANAU) showed that the main drawback of these systems is the inability of the working element to bypass thick-trunked trees and trees deviating from the line, as well as sleepers and other obstacles, while simultaneously performing near-trunk processing

(Weidong Jia, et al., 2024, Grigoryan and Altunyan, 2018, CN105766098A, 13.04.2016., EP 3 824 708 A1, 26.05.2021., Petrosyan, et al., 2018). It was also revealed that the main reason for this is that the control system of the remote working element does not provide for the possibility of fixing the piston of the hydraulic cylinder of the control of this element also in the middle positions, depending on the total value of the trunk diameter, the width of the protective zone and the amount of deviation from the row of trees (patent of the Republic of Armenia, AM20230106Y, 01.07.2024).

Taking into account the above, a control system for the working body of a tillage machine (patent of the Republic of Armenia, AM20230106Y, 01.07.2024) was developed, the design diagram of which is shown in Fig. 1.

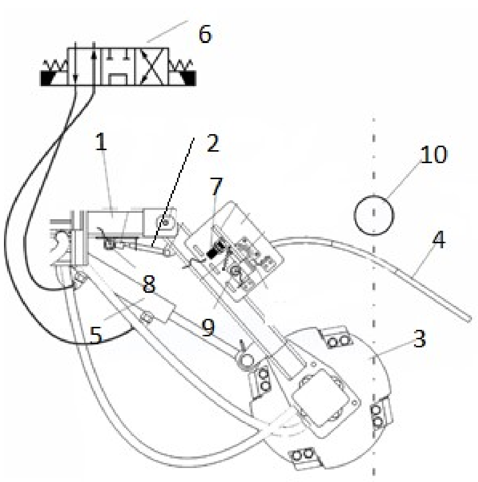

Figure 1. Structural diagram of the control system of the remote working element *1. machine frame, 2. device for fixing the hydraulic cylinder in intermediate positions, 3. working body, 4. sensor rod, 5. hydraulic cylinder, 6. hydraulic distributor, 7, 8, 9. sensors, (10. Tree) (composed by the authors).*

It should be noted that one of the main components of the proposed control system for the remote working body is the device for fixing the hydraulic cylinder in intermediate positions (*2* in Fig. 1). Field tests of the developed model for a garden milling machine (patent of the Republic of Armenia, No. 2993 A, 16.02.2016), with the account of the Control system for the working body of a tillage machine (patent of the Republic of Armenia, No. AM20230106Y, 01.07.2024), showed a number of shortcomings of this device; in particular, there is no precise method for adjusting the position of the slider relative to the sensor (8, Fig. 1) based on the rotation angle of the external working body's rack. Additionally, the device's parameters, such as the slider's size and adjustment limits, are not well-substantiated. In this regard, we have developed a mechanism for securing the hydraulic cylinder (5, Fig. 1) in intermediate positions, with the calculation scheme for determining its optimal parameters shown in Fig. 2.

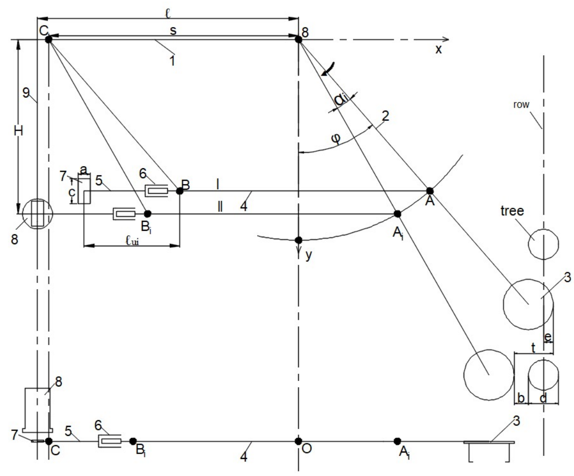

Figure 2. Calculation scheme for determining the parameters of the hydraulic cylinder fixation mechanism in intermediate positions *1. machine beam, 2. leading link of the four-link mechanism, 3. working element, 4. driven link of the four-link mechanism, 5. slider, 6. slider length adjustment mechanism, 7. slider contact, 8. sensor, 9. sensor stand. I - the working body processing the space between tree trunks, II - the working body bypassing the tree trunk (composed by the authors).*

During the processing of the inter-trunk space (Fig. 1, position I), the hydraulic cylinder (5) remains in the open position (with the rod at its farthest extreme) based on a signal from sensor 7 (Fig. 1). In this state, the contact (7) of the slider (5) is positioned at a certain distance from sensor 8 (Fig. 1, 2). When the working element (3) encounters a tree trunk (as detected by the probe making contact with the tree), it rotates by an angle α_i (Fig. 1, position II). As the slider's contact reaches the sensor's (8) action zone, the sensor transmits a signal, causing the distributor (6, Fig. 1) to halt the flow of liquid to the hydraulic cylinder (5, Fig. 1). This action fixes the piston's position at an intermediate stage. For thick tree trunks or trees deviating from the row, the probe rotates at a larger angle, activating sensor 9 (Fig. 2). In this case, sensors 7 and 8 disengage, and the hydraulic cylinder moves into the closed position.

Materials and methods

The main parameters of the mechanism for fixing the rod of the control cylinder of the working element in intermediate positions are the lengths of the links of the four-link mechanism (m, s, are set based on design considerations, respectively 80 and 100 mm), the length of the slider ℓ_s, the width and length of the contact of the slider (a and c), the distance of the rack of the sensor for fixing the cylinder in intermediate positions from the center of rotation of the rack of the working element ℓ, the length of the sensor rack H, the adjustment range of the slider length $\Delta\ell_s$ (Fig. 2).

It is obvious that with a change in the total value $t = e+0.5d+b$ (e is the overlap value during inter-trunk processing, d is the tree diameter, b is the width of the protective zone), the position of the working body stand will also change (it turns in the opposite direction by an angle of α_i, i.e. $\alpha_i= f(t)$), and the length of the slider ℓ_s will change accordingly. In this case, it will be necessary to increase this length for small values of t, and decrease it for large values of t. Therefore, it is necessary to clarify the pattern and changing range of ℓ_s depending on the angle of rotation of the working body rack α_i ($0 \le \alpha_i \le \varphi$), where zero corresponds to the open position of the hydraulic cylinder when processing the inter-trunk strip, and φ corresponds to the closed position (set value, $\varphi=41°$). To determine the above-mentioned parameters, we use the calculation scheme (Fig. 2).

Taking into account the fact that when the working body rack rotates, the slider contact moves in the directions of the x and y axes, we determine the values of these movements (Danielyan, 2016, Weidong Jia, et al., 2024):

$$\Delta x_i = x_A - x_{Ai}\ ,\ \Delta y_i = y_{Ai} - y_A\ , \qquad (1)$$

where

$$x_A = m\sin\varphi,\ x_{Ai} = m\sin(\varphi - \alpha_i),$$

$$y_A = m\cos\varphi,\ y_{Ai} = m\cos(\varphi - \alpha_i).$$

Inserting the values x_A, x_i, y_A, y_i into expression (1) we obtain:

$$\Delta x_i = m[\sin\varphi - \sin(\varphi - \alpha_i)],$$
$$\Delta y_i = m[\cos(\varphi - \alpha_i) - \cos\varphi]. \qquad (2)$$

Results and discussions

Figure 3 shows graphs of the change in the above-mentioned movements of the slider in the x and y directions and the value of Δx_i depending on the rotation angle of the working body rack α_i.

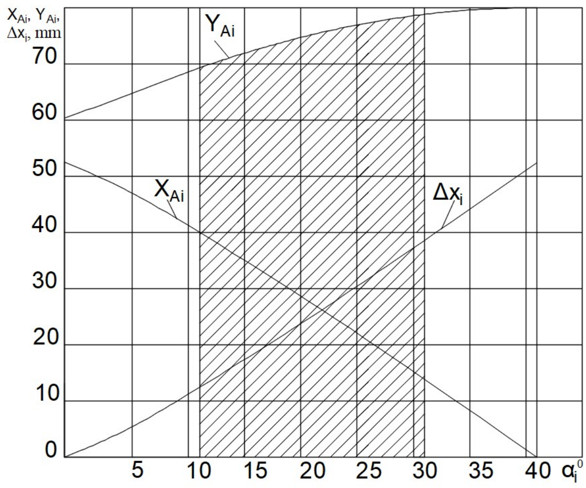

Figure 3. Dependencies of changes in the slider displacement x_i, y_i and the value of Δx_i depending on the angle α_i, at $m=80$ mm, $\varphi=41°$ *(composed by the authors)*.

Analysis of the graphs shows that with an increase in the angle α_i, the movement of the slider in the direction of the x-axis decreases, and in the direction of the y-axis it increases with different intensities and is 1.28 mm/deg and 0.479 mm/deg. respectively, while the intensity of the increase Δx_i is 1.28 mm/deg. It should be noted that as a result of numerous field measurements we conducted, the established range of values of t is (64.4-181.5 mm), at which the rod of the hydraulic cylinder for controlling the working body should be fixed in intermediate positions. Calculations performed for the given milling machine parameters ($\varphi = 41°$), stand length (580 mm), and remote working element diameter (320 mm), along with the structurally selected values of m and s, showed that the minimum value of t corresponds to $\alpha_i = 11°$, while the maximum is 31°. Therefore, to establish the adjustment interval of the slider length $\Delta\ell_s$, it is necessary to proceed from the condition $11° \le \alpha_i \le 31°$ (shaded area, Fig. 3), while it is necessary to take into account that the largest size ℓ_{smax} of the slider length corresponds to the lower limit of α_i, and the smallest size ℓ_{smin} to the upper limit. The length of the slider can be determined by the expression:

$$\ell_{si} = \ell_o + \Delta x_i, \qquad (3)$$

where ℓ_0 is the design size (50 mm). Therefore:

$$\Delta\ell_s=\ell_{smax} - \ell_{smin}.$$

By determining the maximum and minimum values of Δx_i (respectively: 38.59 mm and 12.48 mm, shaded area,

Fig. 3), we obtain:

$$\ell_{smin}=\ell_0=50 \text{ mm},$$

$$\ell_{smax}=\ell_0+\Delta x_{imax}-\Delta x_{imin}=50+38.59-12.48=76.1 \text{ mm},$$

therefore:

$$\Delta\ell_s=\ell_{sma}-\ell_{smin},=76.1–50=26.1 \text{ mm}.$$

From Figure 3 we receive:

$$\ell= s – m\sin\varphi + \ell_{smax} , H= m\cos\alpha_{imax}. \quad (4)$$

Putting the corresponding values into formula 4, we obtain: $\ell=123.6$ mm, $H=68.5$ mm.

The width of the slider contact is set based on design considerations - 5 mm, and the value of the length is determined by the expression:

$$c = 2(y_{imax}– y_{imin})=2(78.5– 68.5)=20 \text{ mm}.$$

In view of practical regulation of the slider length for a specific total value *t*, it is convenient to use the nomogram shown in Fig. 4.

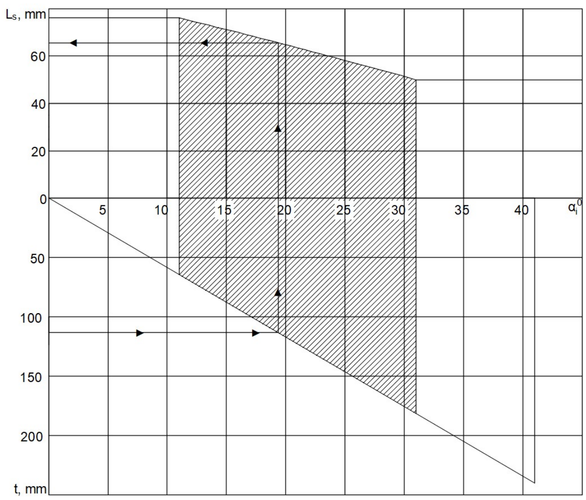

Figure 4. Nomogram for determining the length of the slider for specific values of *t* and α_i in practice *(composed by the authors)*.

Conclusion

A mechanism has been developed for fixing the hydraulic cylinder of the control system of the external working body of a garden milling machine in intermediate positions.

The intervals of changes *t* ($64.4 \leq t \leq 181.5$ mm) and α_i ($11° \leq \alpha_i \leq 31°$) are established, according to which the rod of the control cylinder of the remote working body should be fixed in intermediate positions.

A mathematical relationship was derived between the rotation angle of the remote working body and the main parameters of the cylinder locking mechanism in intermediate positions, and its optimal parameters were established: $m=100$ mm, $S=100$ mm, $\ell=123.6$ mm, $H=68.5$ mm, $c=20$ mm, $a=5$ mm, $\ell_{scmax}=76.1$ mm, ℓ_{smin}=50 mm, $\Delta\ell_s=26.1$ mm.

A nomogram for determining the length of a slider for specific values of *t* and α_i in practice has been developed.

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Declarations of interest

The authors declare no conflict of interest concerning the research, authorship, and/or publication of this article.

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