Study on working bodies of the soil preparation machine for sowing potatoes

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Abstract. The purpose of the study is to substantiate the parameters of the guide knife and the loosening pointed leg of the machine. The basic principles and methods of classical mechanics, mathematical analysis and statistics were used in this study. Theoretical studies were carried out to determine the parameters of the guide knife and the loosening pointed leg of the machine. It is established that to ensure the required value of the crest height with minimal energy consumption, the height and length of the guide knife should be 8 and 15 cm, respectively, the angle of the knife blade to the horizon - 30\(^\circ\), the longitudinal distance from the toe of the ploughshare body of the knife toe – 13 cm. To ensure the required crumbling of the soil, the width of the pointed loosening paw should be 15 cm.

1. Introduction

Many factors, such as arable land, climate, population, and resources, are now affecting worldwide potato production and food security [1, 2]. To ensure long-term food security, it is critical to achieve high quality, high yield, enhanced efficiency, and sustainability in potato production, as well as to expedite potato industrialization [3].

There are various elements that influence worldwide potato production, one of which is mechanization, which is critical for increasing potato production and yield per unit area. Potato production is divided into three stages: planting, cultivating, and harvesting. Planting is one of the most essential components of potato
production, as it is complex, labor-intensive, and difficult to mechanize, and has a significant impact on potato production quality and final output [4]. Tillage, ditching, spraying, seeding, fertilizing, ridging, and other aspects of the planting process can be separated. These functions are done by multiple machines, or even by one machine in a single pass over the field, depending on the planting method used. Mechanized potato planting has the advantages of reducing labor intensity, increasing working efficiency, and ensuring seeding quality.

In the world, the leading place is occupied by the development and application of energy-saving and high-performance machines for tillage [5, 6] and preparing it for sowing. At the same time, much attention is paid to the development of machines that perform all the technological processes of tillage and preparing it for sowing potatoes on ridges in one pass through the field.

Mamatov [7-29], Mirzaev [10-18, 20-27, 29], Kurdyumov et al. [32], Lakhmakov [33] and others were engaged in research on the creation and use of combined machines for processing and preparing soil for sowing agricultural crops, substantiating the parameters of working bodies, as well as studying their processes of interaction of working bodies with the soil.

However, these studies do not sufficiently study the issues of tillage for sowing potatoes with the simultaneous formation of ridges that ensure high quality work with minimal energy costs. Hence, the purpose of the study is to substantiate the parameters of the guide knife and the loosening pointed leg of the machine.

2. Methods
The basic principles and methods of classical mechanics, mathematical analysis and statistics were used in this study. In order to substantiate the constructive scheme of the machine implementing the proposed technology and the types of working bodies, the constructions of the machines preparing the fields for planting were created in detail by the researchers.

3. Results
As a result, a constructive scheme of the machine was developed, which implements the technology of preparing the soil for planting potatoes for planting (Figure 1). It includes frame 1, tractor mounting bracket 2, base wheels 3, frame-mounted recesses 4, axle softener claws 5, right and left swivel housings 6 and 7, guide blades 8 and The profile consists of 9 reels.

The main working bodies of the machine are the body with a guide plate and a pointed flat-cutting paw. Depending on the nature of the machine, we can determine the parameters of the blade and the axle.

The guide blade is attached to the edge of the 4 l ploughshare (Figure 2). Its main parameters are the distance from the beak to the blade \( l_{gb} \); length and height of guide blade \( l_p \) and \( h_{gp} \); the angle of inclination of the blade of the guide blade relative to the horizon \( \alpha_p \); \( i_o \) the sharpening angle of the blade is thread.
Figure 1. Layout of work tools on the frame: 1 – frame; 2 – wing share; 3 – base wheel; 4 – deep softener; 5 – axial softening claw; 6 and 7 – right and left turning bodies; 8 – guide knife; 9 – profile roller

Figure 2. Diagram for determining the parameters of the guide blade

We determine the angle of inclination of the blade with respect to the horizon by the following expression from the condition of sliding the soil along it.

$$\alpha_p \leq \frac{\pi}{4} - \frac{\varphi_1}{2},$$  \hspace{1cm} (1)

where $\varphi_1$ – is the angle of friction of the soil with the blade.
We put the known values of $\varnothing_1$ (25-30°) in this expression and determine that the angle $\alpha_p$ should be in the range 30-33° and assume $\alpha_p = 30°$.

We choose the height of the guide blade in order to minimize the interaction of the blade with the wall. Due to the fact that the housing works in a completely closed cutting position, the upper edge of the blade is crushed at the beginning of the rotation of the blade. The height of the blade, which guides the blade, can be determined by setting the rest of the blade from crushing and eliminating its interaction with the wall.

$$h_p \geq a - b_k \cdot \tan \tau - \Delta_p,$$

We determine that the minimum height of the blade, which is directed to the expression (2) by $b_k = 0.2$ m, $\Delta_p = 0.05$ m and $\tau = 6°$, is not less than 79 mm. We assume $h_p = 80$ mm.

At the beginning of the rotation of the pelvis, the pelvis is in a state of tension due to the compression of its inner upper edges. In this case, it is difficult for the blade to penetrate the blade, which can lead to the accumulation of soil in front of the housing and disruption of the technological process at the beginning. Therefore, it is advisable to place the blade as close as possible to the line of the ploughshare beak in the direction of movement. In this case, the crushing of the slab with the wall is replaced by the crushing of the soil with a steel knife. Plus, you'll be getting rid of clutter you don't need. Due to the design difficulties associated with the installation of the blade, the blade nozzle can be installed at the following distances from the body ploughshares nozzle.

$$l_{lp} = (0.5 \div 0.6) h_p \cdot \tan \gamma_l.$$

Substituting $b_k=0.2$ m and $\gamma_l=42°$ into expression (3), we determine that the longitudinal distance from the beak of the body ploughshares to the beak of the blade is $l_{lp} = 0.22$ m.

From Fig.2, we determine the length of the guide blade by the following formula

$$l_p = b_k \cdot \tan \gamma_l - l_{lp} + \Delta l,$$

where $b_k$ – is the width of the ploughshare heel; $\Delta l$ – is the length of the blade, which allows the blade to touch the wall of the ridge after rising above the heel of the ploughshare.

Because the blade has a trapezoidal shape

$$\Delta l = h_p \cos \alpha_p.$$

Substituting the value of $h_p$ for expression (5) into expression (2), we obtain

$$\Delta l = (a - b_k \cdot \tan \tau - \Delta_p) \cos \alpha_p.$$

In that case

$$l_p = b_k \cdot \tan \gamma_l - l_{lp} + h_p \cos \epsilon + \frac{a - b_k \cdot \tan \tau - \Delta_p - \Delta l}{\cos \alpha_p}.$$

Add the values $b_k=0.2$ m, $\gamma_p=42°$, $a = 15$ cm, $l_{lp} = 0.22$ m, $\Delta_p = 0.05$ m, $\epsilon=25°$, $\tau = 6°$ and $\alpha_p = 30°$ to the expression (7). Calculated calculations showed that the
length of the guide blade was 0.14 m.

The gravitational resistance of the guide blade is the resistance of its blade, bevel and sides (Figure 3).

\[
R_{xp} = R_{xp}^f + R_{xp}^l + R_{xp}^r. \tag{8}
\]

![Figure 3. Scheme for determining the forces acting on the blade](image)

The resistance of the blade, chamfer and sides of the guide blade to the impact soil can be determined by the following formulas: where \( \delta \) – is the resistance of the soil to crushing in the horizontal direction; \( \beta_p \) – is the sharpening angle of the guide blade; \( f \) – is the coefficient of friction of the soil on the steel; \( \rho_1 \) – is the specific pressure of the soil on the sides of the blade, Pa; \( p \) – is the specific pressure of the soil in the chamfer, Pa.

Then

\[
R_{xp} = \sigma h_p \delta (1 + f \cos \alpha_p) + p \frac{t_p}{\sin \beta_p} h_p (1 + f \cos \alpha_p) + 2 f \rho_1 (l_p - h_p \cot \alpha_p) h_p, \tag{12}
\]

\( h_p = 0.1 \text{ m}; \ l_p = 0.032 \text{ m}; \ \sigma = 2,10^5 \text{ Pa}; \ d = 0.004 \text{ m}; \ f = 0.95; \ r = 1,9210^4 \text{ Pa}; \ r_1 = 1,64 \cdot 10^5 \text{ Pa}; \ b_l = 25^\circ; \) Assuming \( h_p = 25^\circ \) and \( t_p = 0.006 \text{ m}, \) the calculations carried out by expression (12) show that the tensile resistance of the guide plate in the velocity range 1.5-2.0 m/s is 157,8 N showed.

The total resistance of the housing with the guide blade
Calculations from expression (13) showed that the total resistance of the guide blade housing in the velocity range of 1.5 – 2.0 m/s was 2065 – 2138 N.

We choose an oversized softening pad as a softener to be installed in front of the housings. It cuts weeds to a depth of 8-10 cm and grinds the soil well. We determine the part of the row spacing that the softener softens, that is, the width of its coverage, provided that the softener claws along the axis of symmetry of the formed groove. From Figure 4:

\[
R_{k} = \left( a_{b} - \frac{1}{2} b_{l}^{2} \sin \delta \right) \left( K + \alpha \nu^{2} \right) + \sigma h_{p} \hat{\delta} \left( 1 + f \cos \alpha_{p} \right) + \overline{p} \frac{t_{p}}{\sin \beta_{n}} \nu_{p} \left( 1 + f \cos \alpha_{p} \right) + 2 f \rho_{l} \left( l_{p} - h_{p} \cos \alpha_{p} \right) h_{p}.
\]  

(13)

where 

\[
\nu_{p} = \overline{B_{k}} - \overline{b_{l}} - 2 \left( a_{c} - a_{p} \right) \cos \psi_{1}.
\]  

(14)

4. Conclusions

It is established that to ensure the required value of the height of the ridge with minimal energy consumption, the height and length of the guide knife should be 8 and 15 cm, respectively, the angle of the knife blade to the horizon – 30º, the longitudinal distance
from the toe of the ploughshare body of the knife toe – 13 cm. Additionally, the width of the pointed loosening foot should be 15 cm to ensure the required crumbling of the soil.

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