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STUDY OF THE KINEMATICS OF MOVEMENT OF AN IMPROVED WORKING CUTTER FOR THE SUGAR BEET TOPS CLEANER

The article is devoted to the issue of development and analysis of the proposed design of working bodies for performing the operation of additional cleaning of beet heads from plant residues. In accordance with the agrotechnical requirements for growing this crop, the developed working body must provide an appropriate degree of cleaning of sugar beet heads. It is also necessary to ensure minimal injury to root crops and prevent them from being knocked out of the soil.

The issue of cleaning sugar beet heads was addressed by both domestic and foreign scientists. Designs of both active and passive working bodies are known. Passive working bodies are quite simple to manufacture, but require a high-quality tracking system and ensuring compliance with the speed of this system and the movement of the unit across the field. At the same time, active working bodies of the disk type also require the use of a tracking system but provide a better degree of cleaning. Active working bodies with flexible cutting elements provide a better degree of cleaning, do not require a tracking system for height correction, therefore their development is an urgent and necessary task.

The publication considers the issue of studying the kinematics of the movement of an improved working body of a sugar beet top cleaner. An analysis of the working environment for this pre-cleaner was carried out. A three-dimensional model of a sugar beet top cleaner was created, and a video sequence of possible movements of the working bodies was obtained. As a result of the analysis of the obtained video sequence, it was noted that the use of this type of drive ensures an increase in the effective overlap of the zone of possible location of root crop heads, as well as the action of the working elements of the pre-cleaner in the direction of maximum rigidity of most of the top residues, which improves the quality of cleaning of root crop heads.

Key words: *top cleaner, three-dimensional model, kinematics, hydraulic drive.*

Introduction. Ukraine occupies a leading position among the world's beet-growing countries, which is facilitated by soil and climatic conditions, as well as the great potential of the country's agro-industrial complex. However, in terms of the efficiency of sugar production, Ukrainian producers are significantly inferior to producers in other countries, which is associated with both the imperfection of the technology of growing and processing, and with large losses of raw materials when harvesting sugar beets using domestic equipment [1,2].

One of the most labor-intensive operations in the production of sugar beets is their harvesting, an important component of which is the removal of the tops from the heads of root crops. The remains of the tops are the cause of sugar losses both during the storage of raw materials and during its processing. According to the Institute of Sugar Industry, an increase in the contamination of root crops with green mass by 1% reduces the yield of sucrose by 0.1%, and when storing beets in cagatae with a top content of up to 4%, daily sugar losses average 0.012%

[1].

The main directions for solving the problem of reducing the number of tops are considered to be the introduction of undercutting of root crop heads and the use of active pre-cleaners of root crop heads [1]. However, in this case, the loss of sugar-bearing mass with cut heads increases noticeably, which reduces the interest of sugar beet producers.

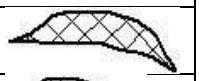
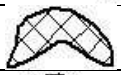
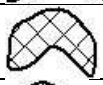
Analysis of recent research and publications. The most widespread are secondary cleaners with a horizontal axis and radial fastening of cleaning elements. Such machines include BM-6B, OGD-6, etc. These secondary cleaners provide a sufficiently high level of secondary cleaning of root crops - at a linear rotor speed of 19.5 m/s, the probability of transition of normally trimmed root crops to secondary cleaning exceeds 62%. At the same time, a significant level of drive power of this cleaner is noted - from 16 to 22 kW, depending on the rotor rotation speed. When the rotation speed increases, which contributes to an increase in the quality of secondary cleaning of heads, the working element deviates in the radial direction, which leads to a decrease in its linear speed and, accordingly, to a decrease in the speed of sliding along the head, which in turn negatively affects the quality of cleaning of root crop heads and increases the number of knocked out root crops. The disadvantages of this pre-cleaner include intensive sweeping and grinding of the surface layer of soil, which negatively affects the environmental performance of the machine [2,3].

As is known from the results of studies conducted by the authors [5], when cleaners interact with root crop heads, the separation of the top and sugar-bearing mass of the root crop occurs based on the difference in strength properties. As noted in [5], the petiole significantly changes the shape of its cross-section depending on the distance to the top of the root crop head (table 1).

As can be seen from table 1, the cross-section of the top at the root crop head has a shape close to a trapezoid. Therefore, to ensure the highest quality cleaning of the beet head from the top, it is necessary to ensure that the cutting force is applied in the direction of maximum rigidity of this material.

It is known that the top has the shape of a cone, a rosette or a half-rosette and, accordingly, if we consider the sugar beet head in a horizontal plane, the growth zone of the petioles has a spherical surface.

Table 1 - Area and shape of the cross-section of the petiole.

Distance from the cross section to the head, mm	Cross-sectional shape
0	
10	
20	
40	
80	
120	

According to the authors [6], working bodies with a vertical axis of rotation provide a higher degree of cleaning of root crops from the top at increased operating speeds. The disadvantage of this working body is the complexity of its application in a real machine, due to the design difficulties that arise during the development and operation of the machine.

Improving the operational characteristics of sugar beet top cleaners is possible by introducing hydraulic drives of the working bodies, which allows significantly expanding the technological capabilities of agricultural machines.

The use of a hydraulic drive to provide rotational motion to the working bodies will simplify the design and reduce the metal consumption of the new machine. In addition, the use of additional oscillatory motion of the working bodies of the pre-cleaner will improve the quality of cleaning of sugar beet heads and reduce shock loads during cutting.

The purpose and objectives of the research. The purpose of this study is to determine the effectiveness of using additional transverse vibrations of the working bodies of pre-cleaners using a hydraulic drive in order to improve the quality of cleaning of root crop heads.

Research materials and methods. The degree of cleaning of root crop heads directly depends on the size of the coverage area of the sugar beet head by the working body of the pre-cleaners. An increase in the coverage area leads to an increase in the quality of the cleaning process.

The publication investigates the hydraulic drive of the pre-cleaner, which allows to increase the coverage area by providing additional movement of the working body.

Fig. 1. Precleaner disc with flexible rods

To conduct a study of the predicted increase in the level and quality of removal of top residues by hydrofication of the pre-cleaner drives and the implementation of additional movement of the pre-cleaners in the direction normal to the conditional middle line of the row, it is planned to use a disk pre-cleaner with a vertical axis of rotation and flexible rods (Fig. 1). Top cleaners of this type are distinguished by their simplicity of design and high technological indicators compared to other types of cleaners.

The structural dimensions of the disk pre-cleaner shown in Figure 1 are as follows - the pre-cleaner disk has an outer diameter of 400 mm, the zone of maximum effective action of the working body, which is determined by the position and dimensions of the flexible rods, has a diameter of 200 mm. The specified structural dimensions of the disk meet the agrotechnical requirements for the dimensions of the row and row spacing.

When working in real conditions, the width of the row and row spacing may change, the BM-6B machine can move with a displacement relative to the row line and at an angle relative to the field plane. These circumstances will lead to the fact that the zone of maximum efficiency of the pre-cleaner will shift relative to the row, a high percentage of under-cleaned or partially cleaned root crops will appear.

It was decided to provide movement to the system of working bodies of the pre-cleaner not only in the longitudinal direction, but also in the transverse direction, normally relative to the conditional middle lines of the rows. Using the new degree of freedom, the pre-cleaner can compensate for the shortcomings of sowing, inter-row cultivation of root crops, deviations from the straightness of the movement of the BM-6B machine and ensure cutting of the sugar beet tops in the direction of its maximum hardness.

To ensure the two-coordinate movement of the pre-cleaner, it is proposed to use a hydraulic drive system with a serial connection of hydraulic motors and a crank-rod drive mechanism that provides oscillatory movement of the pre-cleaners.

Figure 2 shows a three-dimensional model of the proposed pre-cleaner of the tops of sugar beet.

On the frame of the picker, three axes 1 are installed using brackets, corresponding to the number of pre-cleaner discs, with the help of which rockers 2 are fixed, at one end of which hydraulic motors 3 are attached and pre-cleaner discs are connected to its shaft, which is thus driven into rotational motion. At the other end, a hinged connection is made with a rod 4, which transmits reciprocating motion from the crank 5 to the rod and hydraulic motors together with the pre-cleaner discs. The drive of the crank mechanism is provided by the operation of the corresponding hydraulic motor.

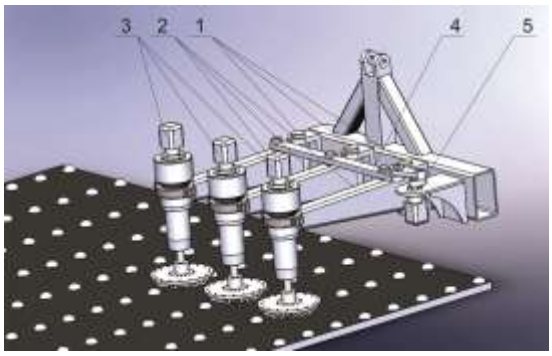


Fig. 2. Three-dimensional model of a sugar beet top cleaner

To drive the hydraulic motors of the cleaners, it is proposed to use a group (multi-drive) hydraulic drive scheme. This scheme involves serial connection of hydraulic motors and the use of one pump for their power supply, which makes such a scheme compact and economical. Such a scheme has become widespread in technological machines for various purposes [4].

The study of the kinematic parameters of the operation of the improved sugar beet top cleaner was carried out using the Solid Works Motion software package.

The working window for studying the movement of the working elements of the improved sugar beet top cleaner. The study of the effect of additional movement of the disk top cleaner in the direction normal to the conventional middle line of the row was modeled by visualizing its movement relative to the rows of sugar beet.

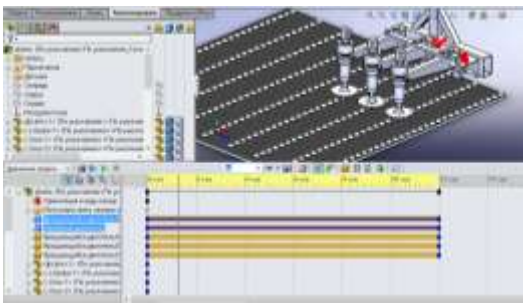


Fig. 3. Solid Works Motion working window

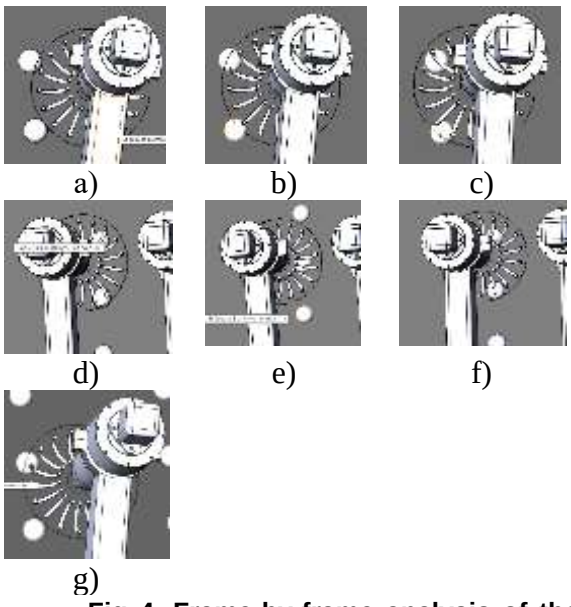


Fig 4. Frame-by-frame analysis of the trajectory of the working body of the sugar beet header pre-cleaner using an oscillating drive.

Figure 4 shows a frame-by-frame video recording of the movement of the improved working body relative to the sugar beet headers. Figures 4a – 4d show the phases of the pre-cleaner movement from right to left. In this case, the pre-cleaner, together with the agricultural machine, moves along the row. In figures 4e – 4g, the pre-cleaner movement occurs from left to right during the longitudinal movement of the agricultural machine. The oscillating movement of the pre-cleaner occurs with an amplitude of 100 mm. at a frequency of 10 Hz.

In figure 4a, the pre-cleaner is in the phase of cutting into the header. With further movement of the pre-cleaner, as shown in Figure 3, the pre-cleaner actually completely bypasses the root crop head and at the same time acts in the direction of maximum stiffness of most petioles, which ensures an increase in the quality of root crop cleaning.

Analysis of the overlap of the possible area of placement of root crop heads in accordance with existing agrotechnical requirements when introducing additional movement ‘of the pre-cleaner normal to the conditional middle line of the row at a frequency of oscillation of 10 Hz reaches 98%, which is not provided by various mechanical designs of pre-cleaners.

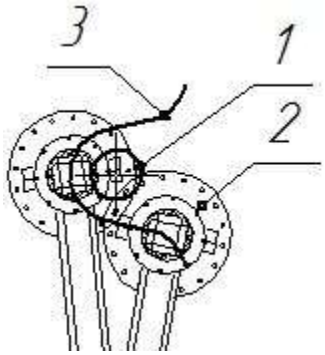


Fig. 5. Trajectory of movement of the working body of the sugar beet top cleaner
1 – sugar beet head;
2 – working body;
3 – trajectory of movement of the working body.

Conclusions and directions for further research. The use of hydrofication means for the drives of the working bodies of the root crop harvesting machines allows to improve the technological process of removing the tops from the heads of root crop harvesting machines. The convenience and flexibility of the hydraulic drives allows to implement additional movements of the pre-cleaner in the direction normal to the conventional middle line of the row during the removal of the tops. As a result, this ensures an increase in the effective overlap of the zone of possible location of the heads of root crops, as well as the action of the working elements of the pre-cleaner in the direction of maximum stiffness of the majority of the tops, which improves the quality of cleaning the heads of root crops.

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ДОСЛІДЖЕННЯ КІНЕМАТИКИ РУХУ ВДОСКОНАЛЕНОГО РОБОЧОГО ОРГАНА ДЛЯ ОЧИЩНИКА ГИЧКИ ЦУКРОВОГО БУРЯКА

Стаття присвячена питанню розробки та аналізу роботи запропонованої конструкції робочих органів для виконання операції доочищення головок буряка від рослинних залишків. Відповідно до агротехнічних вимог по вирощуванню даної культури, розроблений робочий орган має забезпечувати відповідний ступінь очищення головок цукрового буряка. Також необхідно забезпечити мінімальне травмування коренеплодів та запобігти їх вибиванню з грунту.

Питанням очищення головок цукрового буряка займались як вітчизняні так і закордонні вчені. Відомі конструкції як активних так і пасивних робочих органів. Пасивні робочі органи, є досить простими, у виготовленні, але потребують якісної слідкуючої системи та забезпечення відповідності швидкодії даної системи та руху агрегату по полю. В той час, активні робочі органи дискового типу, також потребують застосування слідкуючої системи але забезпечують кращий ступінь очищення. Активні робочі органи із гнучкими ріжучими елементами забезпечують кращій ступінь очищення, не потребують слідкуючої системи корекції по висоті, тому їх розробка є актуальним і необхідним завданням.

У публікації розглянуто питання дослідження кінематики руху удосконаленого робочого органа доочисника гички цукрового буряка. Проведений аналіз робочого середовища для даного доочисника. Створено тривимірну модель доочисника гички цукрового буряка, та отримано відеоряд можливих переміщень робочих органів. В результаті аналізу отриманого відеоряду було зазначено, що застосування даного виду приводу забезпечує підвищення ефективного перекриття зони можливого розташування головок коренеплодів, а також дія робочих елементів доочисника у напрямку максимальної жорсткості більшості залишків гички, що підвищує якість очищення головок коренеплодів.

Ключові слова: *доочисник гички, тривимірна модель, кінематика, гідравлічний привод.*

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