Improvement of the rod drive design of the continuous tillage cultivator

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Abstract. A classification of rod drives of the continuous tillage cultivator is given. It is shown that to effectively kill the weeds with a rod cultivator, the rod must be buried in the soil and rotate counter to the rotation direction of the cultivator support wheels. It is shown that the existing designs meeting this requirement are rather complex. A simplified design of the extension without the mechanical rod drive from the cultivator drive wheels, which provides the required direction of rotation of this working tool, is proposed and analysed.

1. Introduction

High quality of soil tillage with the use of the modern machines and implements play an important role in providing the favorable conditions for crop production in agribusiness industry. One of the main cultivation methods for obtaining high crop yields is pre-seeding cultivation and fallow field management which is done using the continuous tillage cultivator (fallow cultivator).

Along with widely used goose-foot shares, another tool is used in the fallow cultivators, and steel rods have bearing supports and are mounted in the direction counter to the movement of the cultivator and parallel to the surface of the field.

In order to effectively kill the weed, this rod must be buried in the soil and rotate counter the support wheels of the cultivator, which is the most important requirement this tool must meet [1].

In agribusiness industry rods of various cross-sections are used; they are square, round, hexagonal with the circumscribed circle equal to 25 and 32 mm [1].

The authors aim to analyze the structural layout of the cultivator rod drives, using the patents, technical and science literature, to study the influence of such rods design on the weed management effectiveness, to analyze some drawbacks of this design, and to present the improved layout of the cultivator rod drive (Figure 1).

Figure 1. Schematics of the cultivator extension and the rod without the drive from the outside power source according to the Inventor's Certificate No. 1604175 (SU).
2. Materials and methods
It was required to justify the proposed simplified design of the cultivator rod, which would provide the direction of its rotation specified by the agrotechnical requirement.

To solve this problem, the magnitude and direction of the force acting on the cultivator rod were determined. For this purpose, the graph-analytical method of Zhukovsky was used. The method was based on the principle of possible displacements. The essence of the method was that if under the action of forces applied to the mechanisms of the cultivator, it was in equilibrium, and rotated 90 degrees its plan. This was considered as a rigid lever with a support in the pole, under the action of the same forces would also be in equilibrium [4].

Thus, the Zhukovsky method allowed us to solve the problem with high accuracy.

3. Results and Discussion
We have determined the following types of the rod drive.

Figure 1 shows the structural layout of a cultivator of the first type (see cultivator types as described in the Inventor's Certificate No. 1604175 (SU), MPK A01B35/00 [2]). The cultivators of the first type contain the frame (1), working body share (2), pivot ball joint of the working body, shares of the cultivator (4), rigid drive (5), and the rod fixed in the bearings (6) (here \(V_m\) is the direction of cultivator movement). The rod is subject to the operational draft force \(R_{df}\) and its horizontal resultant \(R_h\). The rotation of the rod takes place due to the torque which is equal to \(M_t = F\cdot r\), where \(r\) is the radius of the rod which comes as the result of the friction force \(F\) between the rod and the furrow sole in the direction set by cultivator’s forward movement.

The second type of cultivators is presented in Inventor's Certificate No. 1531870 (SU), MPK A01B35/18 [3]. According to the figure provided in the Certificate, it is suggested that the rod is set eccentrically in relation to the support wheels of the cultivator and that the rod drive is done by the chain link connection between two sprockets mounted on the axis of the support wheel and of the rod itself. The cultivator forward movement also sets the rotation direction of the rod in this type of cultivator.

It is typical for the first as well as for the second type of the rod drive that rod rotation results in winding of the weeds and their moving down to the subsurface level, which leads to low effectiveness of getting the weeds on the surface of the soil.

The third type of the rod has the drive from the support wheels of the cultivator. This rod is mounted remotely from the cultivator support wheels. Reverse is used in such rod drive, which means that rod rotates in the direction opposite to the support wheels. Such design of rod drive is used in anti-erosion cultivator KPE-3.8 (Figure 2).

![Figure 2. Drive configuration of the rod of the cultivator KPE-3.8.](image-url)

In this type of the drive, the rod (6) is mounted eccentrically in relation to the support wheels of the cultivator and its rotation is done by the heeled wheel (7) with two chain links which connect two
sprockets – one fitted on the shaft of the wheel (7) and the other fitted on the shaft of the rod (6). The rotational direction of the rod (6) is opposite to that of the drive wheel (7) of the cultivator.

Such rotational direction provides killing of the weeds due to their winding on the rod, uprooting, and getting on the surface of the soil. Thus, we can conclude that only the third type of the rod drive described above can provide the effective killing of the weeds.

However, the configuration of the rod drive of the third type is quite complex since a double-step drive is used.

Technical and science literature and patent literature contain technical solutions for simplifying the design of the third type rod drive.

One of such technical solutions contains the following description: a plate spring (7) is installed in front of the rod (figure 3) in the direction of travel of the cultivator (as an example see the configuration of the cultivator according to the Inventor's Certificate No. 287434, MPK A01B35/18) [5]. According to our classification, this is the fourth type of the rod drive.

Using the graph-analytical method of Zhukovskiy [4], we can analyze whether the installation of this spring provides the change in rotation of the cultivation rod in relation to the travel direction of the cultivator.

In order to analyze the forces that affect the rod, we locate the point (8) of intersection of the vectors of the working draft force \( R_{df} \) and the elastic force of the spring (7) – \( F_{sp} \). By connecting the points (3) and (8), we will get the direction of the resultant \( R \) of these forces.

Drawing of the forces diagram for the forth type of rod drive will allow us to calculate the torque which affects the rod \( M_t = Rh \). As we can see in Figure 3, this torque, in relation to the rotation axis of the rod, acts in the counterclockwise direction.

Therefore, schematics of the cultivator rod drive, as illustrated in Figure 3, does not eliminate the limitation of the rod drive of the cultivator diagnosed earlier.

We suggest the following design of the cultivator’s rod drive [6,7] (Figure 4).

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**Figure 3.** A schematic design of the cultivator rod suspension according to the Inventor's Certificate USSR No. 287434.

The cultivator (figure 3) includes the frame (1), shank (2), joint of the drag bar (3), share (4), rigid drive (5), rod (6) and the hinged carriage spring (7).

Using the graph-analytical method of Zhukovskiy [4], we can analyze whether the installation of this spring provides the change in rotation of the cultivation rod in relation to the travel direction of the cultivator.

In order to analyze the forces that affect the rod, we locate the point (8) of intersection of the vectors of the working draft force \( R_{df} \) and the elastic force of the spring (7) – \( F_{sp} \). By connecting the points (3) and (8), we will get the direction of the resultant \( R \) of these forces.
Figure 4. Schematics of the improved cultivator extension according to patent RU No. 2672398.

The cultivator includes the frame (1), which is connected with the shanks (2). That, in turn, ends up with the cultivator shares (4), rigid suspension, which are attached to the shanks (2) with the help of joint (3), rod (5) with spring (6) on suspension capable of rotating in the bearings. The loose part of the suspension, located behind the rod (5) (in the direction of travel), has the shape of the sector (7) with the holes (8). The holes (8) are fixed with the threaded parts of the loose ends of the rods (9). The opposite loose ends of the rods (9) are attached to the frame (1) through the hinge. There are permanently fixed washes (10) on the rods (9). Adjustable springs (6) rest upon the washes (10) and sectors (7) and are fixed by the nuts (11) on the threaded parts of the rods (9).

Here:
- $V_m$ is the direction of the cultivator travel;
- $\omega$ is the direction of the rod rotation;
- $\delta$ – the angle of power $F_{sp}$, relative to the horizon;
- $\alpha$ is the angle of application of the resulting $R_h$ which is equal to the sum of $R_{df}$ and $F$ relative to the horizon;
- $\psi$ is the angle of power $R_{df}$ relative to the horizon.

This is how this implement functions: when the cultivator is set into its working position, its frame goes down and buries the rod (5) into the soil. Having the rotation opposite to that of the support wheels of the cultivator, the rod moves in the depth of 10-12 cm, uproots the weeds and carries them out on the surface of the soil. The opposite direction of the rod rotation takes place due to the spring (6) attached to the cultivator frame (1) in such a way that the point of application of the elastic force of the spring is located behind the rod in the direction of travel of the extension. If we make a force triangle in relation to the common point of intersection of forces $R_h$ and $F$, we will see that torque of the resulting force $R_h$ applied to the rod through the sector (7) with the arm $h$ with respect to the central point $O$, rotates the rod in the direction $\omega$. It is opposite to the rotation direction of the drive wheels of the cultivator (counterclockwise). Besides, due to the additional compression force of the spring (6), the rod can be buried into the soil and can copy the soil surface more effectively.

Thus, there is no need to use the chain drive in the rod from the support wheels.

The nut (11) of the extension can be used to change the pressure load of the spring which affects the sector (7), and the rod (9) in the holes (8) can be used to adjust the point of application of the spring force applied to the sector (7).

Use of this designed implement leads to the increased effectiveness of weed management during the tillage by the steam cultivator since this cultivator uproots the weeds and carries them out on the surface of the soil.
4. Conclusion
The design of the pivotal actuator, the circuit of which is made according to patent RU No. 287434, IPC A01B35 / 18, simplifying the design of the pivotal drive, does not allow increasing the efficiency of weed control.

2. The design of the rod drive proposed under our patent and described in this article is simpler than the design driven by the drive wheels of the cultivator used in cultivators KPE-3.8.

3. The cultivator rod according to patent No. 2672398 is effective in weed control due to its rotation in the direction opposite to the rotation direction of the cultivator driving wheels.

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