Improving the design of actuator rod cultivator

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Abstract. Classification of continuous tillage cultivator rod drives 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 in the opposite direction of rotation of the cultivator support wheels. It is shown that the existing designs implementing this requirement are rather complex. A simplified design of the extension without mechanical rod drive from the cultivator drive wheels, which provides the required direction of rotation of this working tool, is proposed and analyzed.

1. Introduction

An important role in creating favorable conditions for the cultivation of crops in the agricultural sector is played by high-quality soil cultivation using modern machines and tools. One of the most important agricultural practices for obtaining high yields is pre-sowing treatment and care of fields, which are carried out by cultivators for continuous processing (field cultivators).

Together with the goose-foot shares widely used in field cultivators, rods are used as working bodies - steel rods mounted in bearings transverse to the direction of movement of the cultivator and parallel to the field surface.

The KPE-3.8 cultivator is an anti-erosion agricultural unit designed for primary and pre-sowing tillage with preservation of stubble and other crop residues in areas subject to wind erosion. The KPE-3.8 cultivator consists of a rectangular frame on which working bodies are mounted - goose-foot shares made of steel 65G, mounted on a spring strut made of steel 50KhG, couplers, a hydraulic cylinder for adjusting the depth and lifting to transport position. A cultivator is aggregated with tractors DT-75M, DT-75N, DT-75ml, DT-75D, and T-150. The coverage of the tool is 3.8 m. Two or three tools in the unit with the SP-16 hitch work with the Kirovets K-700, K-701 tractors. It is served by one tractor operator.

The working bodies are flat-cutting goose-foot shares with a grip of 410 mm and a span angle of 65° on spring struts with an overlap of 70–80 mm. The struts are spaced 93 cm apart and 70 cm between rows. During operation, they vibrate due to variable resistance on the working bodies, which helps to reduce the traction resistance of the tool, reduces sticking of the struts and flat-cutting goose-foot shares, eliminates clogging of them with weeds and crop residues.

The position of the cutting edges relative to the horizon of each flat-cutting goose-foot share is adjusted by stop bolts on the front of the strut bracket. The adjusting bolt, abutting while twisting into a spring strut, deflects it from a vertical position. As a result, the cutting angle and the position of the edges relative to the horizon are changed. For good penetration, it is necessary that the nose of the goose-foot shares is 4-5 mm below their edges.

Over each strut, two safety springs 200 mm high are fixed. When the working body meets an obstacle, the springs are compressed, a flat-cutting goose-foot share leaves the soil. Having passed the
obstacles, the goose-foot share deepens again under the action of the springs.

The processing depth is controlled by the movement of the limit stop on the rod of the hydraulic cylinder, which is connected with the parallelogram mechanism of the support wheels.

**Table 1. Technical characteristics of the KPE-3.8 cultivator.**

| Model | KPE-3.8 |
|-------|---------|
| Productivity of the main time, ha/h | 2.35-3.50 |
| Performance of operating time, ha/h | 1.76-2.64 |
| Operating width, m | 3.91 |
| Working speed, km/h | 6-9 |
| Transport speed, km/h | no more than 10 |
| Depth of processing, cm | 8-16 |
| Saving stubble, % | no less than 70 |
| Ground clearance, mm | no less than 300 |
| Weight kg | 1150 |
| Aggregated with tractors of a traction class | 3-4 |

In the working position, the KPE-3.8 cultivator frame should be parallel to the field surface. If the frame is tilted in the direction of movement, the front row of flat-cutting goose-foot shares deepens more than the rear one. As a result, the soil is cultivated poorly. In addition, the horizontality of the tool’s frame during cultivation of 14-16 cm leads to an overload of the attachment points of the most loaded number of working bodies. Therefore, cast brackets for fastening struts of flat-cutting goose-foot shares often break.

The horizontal position of the KPE-3.8 cultivator is achieved by rearranging the drag bar in the holes of the trailer reducer. If this is not enough, the drag bar and tractor yokes are rearranged to the maximum possible height relative to the soil surface.

The KPE-3.8A cultivator (Figure 1, a) is equipped with 40 cm wide goose-foot shares arranged in three rows. The beams with goose-foot shares are attached to the frame with an arm 10 (Figure 1, b) with springs 4. When faced with an obstacle exceeding the spring pressure, the goose-foot share is deepened, and then, under the action of the spring, returns to its working position. A bolt 9 adjusts the compression of the springs and achieves horizontal positioning of the goose-foot share blades. The processing depth within 5 ... 16 cm is regulated by the movement of the stop 6 on the hydraulic cylinder rod7.
Figure 1. KPE-3.8A cultivator with a rod device: a - general view; b — working body; c — diagram of the technological process of the bar; 10 - brackets; 2 - bar; 3 - goose-foot share; 4 - springs; 5 - frame; 6 - stop; 7 - a hydraulic cylinder; 8 - elastic strut; 9 — bolt.

Equipped with springs and elastic struts, the goose-foot shares vibrate during operation, so they are well buried in the soil and are not clogged with crop residues. However, they damage up to 50% of the stubble and create a crested surface of the soil. Therefore, a rod fixture is mounted on the cultivator. The rod 2 (Figure 1, c) rotates in the soil at a given depth, breaks the roots of weeds, brings to the surface part of the stubble embedded in the soil, and levels the field surface.

Rod accessories for the KPE-3.8A cultivator are used for pre-sowing treatment of fields under winter crops and for the tillage of soil to a depth of 5 ... 10 cm with preservation of 80 ... 90% of stubble. It can work both in trailed and mounted versions.

The rod is driven by the cultivator wheels. A ballast box is mounted on the frame. The rod buried in the soil rotates in the direction opposite to the rotation of the wheels and makes 0.91 turns per 1 m of the path.

The rod breaks the roots of the weeds and loosens the soil without bringing the lower layers to the surface. The main purpose of the rod is the effective destruction of weeds by winding them, breaking off the roots of the weeds and removing them from the soil. In world production practice, the following rod designs are known:
- a rod attached to the goose-foot share of the cultivator with chains [1];
- a rod rigidly connected with a goose-foot share using leashes [2];
- a rod driven in rotation from the support wheel of the cultivator [3].

The most important requirement for this working body is that for the effective removal of weeds, it is necessary [4] that the rod is buried in the soil and rotates in the direction opposite to that specified by the rotation of the support wheels of the cultivator. The above constructions do not allow fulfilling this requirement.

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 that is steel rods which have bearing supports and are mounted transverse the direction of the movement of 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 to the support wheels of the cultivator – this is the most important requirement this tool must meet [1].

In agribusiness industry, rods of various cross-section are used – square, round, hexagonal – with the circumscribed circle equal to 25 and 32 mm [1, p.60-61].

The present work aims 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.

2. Results and Discussion

We have determined the following types of the rod drive.

Figure 2 shows structural layout of a cultivator of the first type (see cultivator types as described in the Inventor's Certificate №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 \( v_n \) is the direction of cultivator movement.)

The rod is a 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 forward movement.

The second type of cultivators is presented in the Inventor's Certificate №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. Direction of rotation of the rod in this type of cultivator is also set by the cultivator forward movement.

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 (see Figure 3.)

In this type of 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 rod drive described above can provide effective killing of the weeds.

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

Technical and science literature as well as 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 (see 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 №287434, MPK A01B35/18) [5]. According to our classification, this is the fourth type of rod drive.
The cultivator (see Figure 4) includes the frame (1), shank (2), joint of the drag bar (3), share (4), rigid drive (5), rod (6) and hinged carriage spring (7).

Using 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 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] – see Figure 5.

![Figure 5](image-url)

Cultivator includes the frame (1) which is connected with the shanks (2) that, in turn, end up with the cultivator shares (4), rigid suspension, which are attached to the shanks (2) with the help of joint (3), rod (5) with the spring (6) on suspension capable of rotating in the bearings. 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 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, rod moves in the depth of 10-12 cm, uproots the weeds and carries them out on the surface of the soil. 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 $\omega$, which 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 to the rod from the support wheels.

Nut (11) of the extension can be used to change the pressure load of the spring which affects the sector (7) and rod (9) in the holes (8) can be used to adjust 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.

3. Conclusion
1. Schematics of rod drive according to the patent RU №287434, MPK A01B35/18, though it simplifies the design of the rod drive of the third type (see our classification), it yet does not provide the solution to the task of increasing the effectiveness of weed management during the tillage by the fallow rod cultivator.
2. The rod drive design described in this article is simpler than the design with the drive from the drive wheels of the cultivator used in the cultivators KPE-3,8, and is more effective in weed management due to the rod rotation in the direction opposite to the rotation direction of the drive wheels of the cultivator.

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