Mechanism for changing the rear axle clearance of a universal-tiller tractor

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Mechanism for changing the rear axle clearance of a universal-tiller tractor

A Akhmetov[1]*, R Botirov[2] and Sh Abdurokhmonov[2]

[1]LLC "Design and technology center of agricultural machinery", Tashkent, Uzbekistan
[2]Tashkent Institute of Irrigation and Agricultural Mechanization Engineers, Tashkent, Uzbekistan

abduroxmonov.shavkatjon@bk.ru

Abstract. The article is described the design of the mechanism for changing the clearance of the rear axle of a universal-tiller tractor from a low-clearance to a high-clearance position and vice versa. The most loaded place in the design of the mechanism for changing the clearance of the rear axle, which is the clip, is determined. The dynamic analysis of the load on the cage for three cases of loading in two sections passing through the bearing supports is carried out. At the same time, the main recommendations are aimed at ensuring a sufficient margin of safety in dangerous sections of the cage. In particular, one of the ways to ensure a sufficient margin of safety in dangerous sections of the cage is to use a material for its production - 45L steel. In Central Asia, all mechanized work on inter-row processing of cotton crops is carried out by a three-wheeled tractor adapted to the natural and production conditions of the region. Studies have established a negative technogenic impact of the front wheel of a three-wheeled tractor on the soil, which is eliminated by the use of a four-wheeled tractor. However, its use is constrained by the inadequacy of the agrotechnical passage. To solve this problem, LLC “DTCAM” is developing a four-wheeled tractor equipped with mechanisms for changing clearance, which provides sufficient agricultural cultivation for inter-row processing of cotton crops. Identification of dangerous places in the design of the mechanism for changing the clearance of the rear axle and dynamic analysis of the loads at this place, preventing breakdowns, increases the reliability of this tractor. It has been revealed that one of such dangerous places is a cage connected to the DCT cover, which accepts the main load transmitted from the tractor to the wheels and back. Dynamic analysis of the cage loads for various cases of loading in two sections passing through the bearing supports showed that the most loaded section is the section of the bearing support located on the DCT side. There is an insufficient margin of safety in this section when the tractor moves along irregularities. To ensure reliable operation, it is recommended to introduce the hardening of the cage area from the DCT side, where the bearing of the mechanism for changing the clearance of the rear axle is at least 35 HRCe, or use material - steel 45L.

1. Introduction

In Central Asia, all mechanized work on inter-row cultivation of cotton crops is carried out with a three-wheeled tractor adapted to the natural-production conditions of the region [13, 19]. An increase in the width of the grips of the machine guns aggregated with this tractor in order to increase labor productivity requires an increase in the power of these tractors [16]. But as the tractor power increases, its mass and the mass of machine guns aggregated with its increase, which leads to an increase in the negative technological impact machine-tractor unit to the soil. A particularly negative effect on the soil is noticeable in the zone of the passage of the front wheels of the tractor, where the soil density reaches up to 1.5 or more g/cm3, which is undesirable. Since, according to many researchers [8, 12], the optimal soil density for cultivating grain and row crops, including cotton, should not exceed 1.2-1.3 g/sm3.

Excessive compaction of the soil reduces the possibility of cotton assimilating nutrients from the soil and thereby slows down the development of both the root system and the plant part of cotton as a whole, which affects its productivity [18, 20].

Studies [5, 9] showed that to eliminate the negative anthropogenic impact of the front wheel of a three-wheeled tractor on the soil, it is necessary to switch to the use of a four-wheeled tractor. On the one hand, this leads to a decrease in the coefficient of coverage of wheel tracks (two tracks instead of three), and on the other hand, the tractor’s sealing effect on the soil from vertical loads distributed on four wheels instead of three [7]. However, the widespread use of four-wheeled tractors is constrained by the inadequate agrotechnical passage.

In world practice, there are various approaches to changing the clearance of the rear axle of four-wheel tractors. In some cases [6, 10], a change in the clearance of the rear axle is achieved by replacing the tires of the rear wheel with larger or smaller tread radii, and in others [11, 15], the use of special mechanisms allows changing the clearance of the rear axle.

To eliminate this drawback, LLC “DTCAM” is developing a four-wheeled tractor with adjustable clearance (Fig. 1), which provides agricultural patency sufficient for inter-row processing of cotton crops [14]. In this tractor, both the front and rear axles are equipped with clearance changing mechanisms. The mechanism of changing the front axle clearance has been comprehensively studied both in terms of the dynamic loading of its structural elements and in terms of their strength and reliability [3]. While the design of the mechanism for changing the clearance of the rear axle has not been practically studied.

Figure 1. Tractor equipped with a front axle with stepless adjustable clearance: a is high clearance and b is low clearance.

1.1. Purpose of research

Determination of dangerous places in the design of the mechanism for changing the clearance of the rear axle and dynamic analysis of the loads at this place in various loading cases that are possible in the work.

2. Methods

To increase the agro-technical cross-country ability of the four-wheeled tractor, DTCAM LLC developed a front axle with steplessly adjustable clearance [4].

The design of this bridge allows the effort of only one operator to move the front axle of the tractor from a low clearance position to a high clearance position or a revolution. Whereas the rear axle of this tractor is transferred from a low clearance position to a high clearance position or vice versa by turning an additional final drive (DCT), which is commonly referred to as a “final drive”. This process is laborious and for dismantling, turning, and then mounting the DCT requires lifting tools and additional labor. To eliminate this drawback, DTCAM LLC has developed a mechanism for changing the rear axle clearance, which allows deploying an additional final transmission of the tractor’s rear axle without installation and dismantling work, without lifting equipment and additional working forces only by turning the valve control lever by the operator-operator from the tractor cab

3. Results and Discussion

The mechanism for changing the clearance of the rear axle (Fig. 2 and 3) of the tractor consists of a cage 6, fitted by means of bearings 13 on the sleeve 10 of the half shaft 1 of the rear axle. The clip 6 has an end flange 5, to which the housing 3 of the additional final gear is fixed by fasteners 4. To the opposite place of attachment of the additional final drive to the side on the neck of the holder 6, a fixing flange 12 is made with two oppositely located grooves 14 for the fasteners 11. In this case, the grooves on the fixation flange are made so that in two extreme positions of the mounting elements in them, the tractor occupies only a high clearance or low clearance position. And the fixing flange 12 of the holder 6 by means of fasteners 11 is fixed to the bracket 9 of the hinge for hanging devices, fixed to the sleeve of the axle shaft of the rear axle.

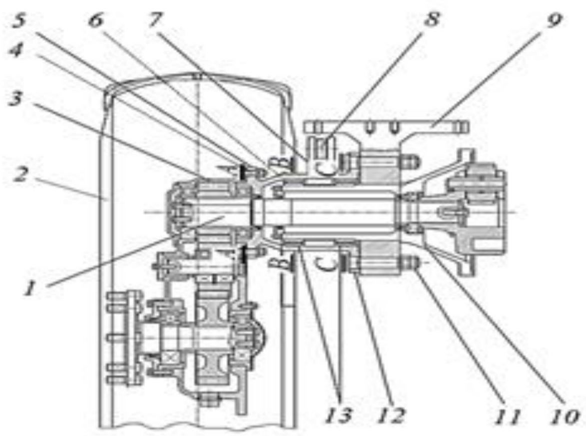


Figure 2. The mechanism for changing the clearance of the rear axle of the tractor, front view.

On the middle part of the cage 6, the lever 7 is mounted externally pivotally by means of a finger 15 with the rod 8 of the hydraulic cylinder 16. The hydraulic cylinder itself is equipped with a hydraulic lock 17 and is pivotally fixed by means of an arm 18 to the frame of the tractor.

Changing the clearance of a tractor equipped with a mechanism for changing the clearance of the rear axle is as follows.

If it is necessary to transfer the tractor to a high-clearance version, the operator slightly unscrews the fastening elements 11 and makes sure that the holder 6 can rotate. Then it gives a command to the rod 8 of the hydraulic cylinder 16 to extend outward, which in turn by means of the lever 7 rotates the holder 6. Together with the yoke, the additional final gear housing 3 is rotated, translating it into a vertical position, thereby increasing the clearance rear axle, and the tractor becomes highly clearance.

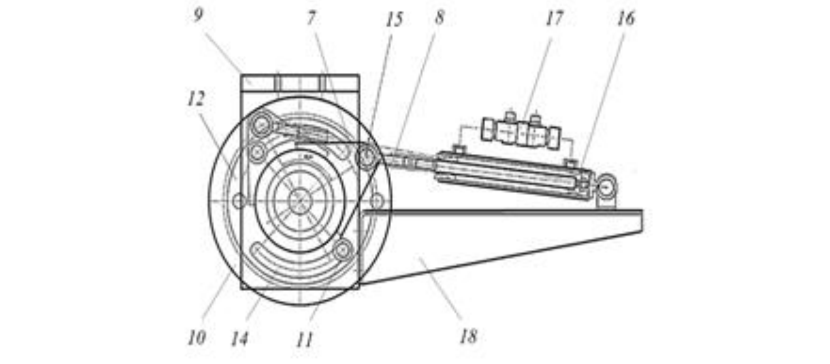


Figure 3. The mechanism of changing the clearance of the rear axle of the tractor, side view.

To transfer the tractor from a high clearance to a low clearance position, the operator gives a command to retract the rod 8 into the inner side of the hydraulic cylinder 16, which in turn using the lever 7 rotates the yoke 6, and together with it rotate the housing 3 of the additional final drive in the opposite direction. As a result, the additional final drive from the vertical position is transferred to a position tilted from the vertical from 0 to 900, thereby continuously reducing the clearance of the rear axle, and the tractor becomes low-clearance.

The position of the additional final drive in all positions is fixed on the one hand by fixing fasteners 11 of the rotation of the fixing flange 12 of the holder 6 relative to the bracket 9 of the hitch for hanging devices, fixed to the sleeve 10 of the axle shaft 1 of the rear axle, and on the other hand, by means of a hydraulic lock 17 of the hydraulic cylinder 16. Thus, the mechanism for changing the clearance of the rear axle is driven in the static position of the tractor by means of a power hydraulic cylinder. The holder (Fig. 4), connected to the DCT casing, rotates around the axis of the rear axle casing under the action of the power hydraulic cylinder, and it accepts the main load transmitted from the tractor to the wheels and back. Therefore, the identification of the most loaded zones of the cage and verification of its static strength is of paramount importance. To do this, we conduct a dynamic analysis of the loads acting on it.

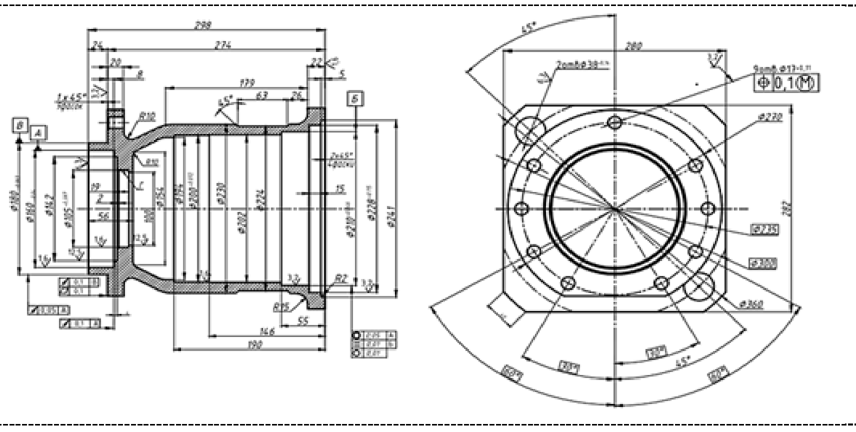
The calculation of static strength was carried out for three possible cases of loading [1, 2]:

I - design mode: the tractor is in a static position, the mechanism for changing the clearance of the rear axle is activated;

II - design mode: the tractor moves uniformly on a horizontal surface;

III - design mode: the tractor moves uniformly along bumps.

The holder is presented as a three supporting continuous beam. This design is a statically indefinable system.



IOP Conf. Series: Materials Science and Engineering **883** (2020) 012125 doi:10.1088/1757-899X/883/1/012125

Figure 4. The holder of the mechanism for changing the clearance of the rear axle.

Static indeterminacy is revealed using the equation of three moments. Three support beam is presented in the form of paired two support beams, in the joints of the parts of the beam additional concentrated forces and moments are applied. For the intermediate support, an equation of three moments is made [17].

$$M_A \frac{l_1}{I_A} + 2M_B\left(\frac{l_1}{I_A} + \frac{l_2}{I_C}\right) + M_C \frac{l_2}{I_C} = -6\frac{F_1 \cdot a_1}{l_1} - 6\frac{F_2 \cdot a_2}{l_2} \quad (1)$$

where M_A; M_B; M_C – cross-sectional bending moments *A-A*, *B-B* and *C-C* (fig.2);

l_1; l_2 are the distances between supports;

F_1; F_2 are areas of diagrams of bending moments;

I_A; I_C are moments of inertia of the sections in the supports *A*, *C*;

a_1; a_2; b_1; b_2 are the distances to the centers of gravity of the diagrams.

$$a_1 + b_1 = l_1; \quad a_2 + b_2 = l_2 \quad (2)$$

The magnitude of the support reaction is determined by the formula

$$Q_n = Q_o\ \text{left} + Q_{noright} + \frac{M_{n-1} - M_n}{l_n} + \frac{M_{n+1} - M_n}{l_{n+1}} \quad (3)$$

where $Q_n = R_B$; $Q_{noleft} = R_{Bleft}$; $Q_{noright} = R_{Bright}$.

Bending moments in supports A, C

$$M_A = R \cdot a; \quad M_C = 0 \quad (4)$$

where R is soil reaction to the rear tire;

a is the distance from the axis of the tire of the wheel to the section.

The calculations performed based on them plots of bending moments showed that the most loaded is the support A.Bending stress support section A

$$\sigma_A = \frac{\left(M_A^B\right)^2 - \left(M_A^G\right)^2}{W_A} \quad (5)$$

$$\sigma_A = \frac{\left(M_A^B\right)^2 - \left(M_A^G\right)^2}{W_A} \quad (6)$$

where M_A^V; M_A^G; M_B^V; M_B^G are bending moments in the supports A and B in the vertical and horizontal planes;

W_A; W_B are the cross-sectional bending moment in supports A and B.

Tangential stress

$$\sigma_A = \frac{\left(M_A^B\right)^2 - \left(M_A^G\right)^2}{W_A} \quad (7)$$

where M_{cr} is torque moment;

W_{cr} is torsion resistance moment.

Equivalent voltage in supports A and B

$$\sigma_{EA} = \sqrt{\sigma_A^2 + 4\tau_{cr}^2} \quad (8)$$

$$\sigma_{EB} = \sqrt{\sigma_B^2 + 4\tau_{cr}^2} \quad (9)$$

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The margin of safety for yield strength

$$n_T = \frac{\sigma_T}{\sigma_E} \quad (10)$$

Strength condition

$$n_T \geq [n]_T \quad (11)$$

The results of the calculation method described above are presented in table. 1.

Table 1. Margin of safety by yield strength of holder.

Calculation mode	The margin of safety for yield strength n_T		$[n_T]$
	A	B	
I	18.68	57.82	
II	5.51	9.81	3.15
III	2.75	4.91	

4. Conclusions

Dynamic analysis of the load of the cage for three cases of loading in two sections passing through the bearings A and B showed that the most loaded is the support A. There is an insufficient margin of safety in section A when the tractor moves along irregularities. To ensure the reliability of the mechanism for changing the clearance of the rear axle, it is recommended to introduce the hardening of the area where bearing A is installed at least 35 HRCe, or use material - steel 45L.

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