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Substantiation Based on Simulation Modeling of Hitch for Tillage Tools Parameters

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Abstract: In contrast to the agricultural, forest objects are characterized by much more difficult working conditions tillage units. Most of the reforestation carried clearings, burnt-out and uncomfortable, saturated many obstacles such as roots, rocks, stumps, branches, etc. The surface topography of forest objects usually not flat, replete with ravines, hills and hillsides with significant slopes and long drops adjustment. In addition, forest soils are highly grassed, saturated vegetable inclusions and even within one estrus have a large scatter in the values of density and hardness.

Key words: Simulation modeling · Hitch · Tillage tools · Penetration · Support wheel

INTRODUCTION

In order to improve the reliability and cross- forest sites tillage supplied predominantly spherical disk working bodies, which, unlike the working bodies ploughshare type are able to avoid obstacles top or side, latter is provided by equipping forest guns spring dampers vertical or horizontal action (Posmetiev, 2001).

At the same time widely used spherical disc working bodies have a significant disadvantage in their poor ability to depth and sustainable move in the soil at a given depth processing. Conventional methods to solve this problem (use of ballast, vibration, force feedback circuit, etc.), or inconvenient to use or are complicated in structure and expensive to manufacture and therefore their use is often economically unfeasible (Posmetiev, Zelikov, Tretyakov, 2013).

From the theory of calculation and design attachments tractors known that the location of the instantaneous center of rotation (SCW) of its links significantly affects the quality of work put in tillage, as well as handling and patency of the tractor. Currently, forestry sites are predominantly used wheeled and tracked tractors for agricultural purposes, equipped with standard rear hitch (OU-2, OU-3, OU-4). Since agricultural tillage work in a much more favorable terms in standard hitch adjust its position SCW provides links attachment, mostly only in the longitudinal axis relative to the horizontal plane of the tractor for the purpose of load balancing on its front and rear wheels or support wheels. Lack of opportunity to adjust the position of SCW longitudinal vertical plane virtually eliminates the ability to effectively influence penetration disk working bodies of forest tools.

In this position SCW regulated standard, fixed at a height of pivots the front ends of the lower links and standard attachments with amounts to 400 mm from the surface of the soil. Such a high position at SCW acceptable Unitized with tractor implements equipped working bodies plow type with high capacity deepened. However, this situation corresponds to SCW unfavorable for forest disk guns conditional corner traction (10-130), contributes not recessed, but on the contrary - the expulsion of disks on the soil surface. For this reason, the state standard (GOST 10677-2001 device attachments back

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agricultural tractors classes 0,6-8. Types, basic parameters and dimensions) does not apply to devices mounted forestry tractors and other special purposes.

It is obvious that the motion of a soil unit on forestry sites, the frame of the tractor continuously commits slopes in the longitudinal and transverse directions. The position of the tractor hitch SCW also constantly changes its position, which leads to uneven progress in depth treatment of disk work working bodies Attachment. Besides the position of the tractor hitch SCW significantly affects the reliability of the instruments, as at a certain, unfavorable combination of factors acting on a moving object in the forest soil cultivating unit (tractor frame slope, topography, shape and size of the obstacles, etc.) might "anchoring" drives and breaking tools. The situation is aggravated by the fact that, unlike the agricultural, forest mounted tillage usually not equipped with support wheels, thereby achieving stability stroke working bodies at a given depth treatment is intractable problem (Zelikov, 2009).

Examining the status of the designated problem allowed to offer the following ways to solve it. In the first stage, based on simulation modeling, it is necessary to investigate the nature and features of the motion of a soil unit on forest property and perform the calculation of the standard parameters of the attachment when unitization tractor with disk tool. When this had two objectives, one of which - the definition of a standard design features of the attachment to ensure sufficient capacity is deepened attachment disk guns on forestry sites. Another objective is to study the influence of the attachment mechanism of the standard tractor disk tools and on this basis to determine the direction of improving its design. The ultimate goal of the second phase of the study is to justify the choice of design and construction of the attachment that best satisfies the requirements of functioning disk guns on forestry sites.

The purpose of this work was to study on the basis of developed simulation model parameters influence the attachment performance- disk tillage.

Unit in the model is considered as a flat mechanism consisting of seven solids (building tractors, four road wheels on one side, the frame of the cultivator, one of the disc batteries) with known coordinates of the center of gravity (x_i, y_i), the rotation angle φ_i, mass mi and the central moment of inertia j_i (here i - the number of the body) [6, 7].

Body linked to the contact points (denoted by the subscript ij, where i - number of the body, j - number of contact points of the body) some connections: using joints and weightless inextensible rods. To describe the motion of bodies is a system of differential equations with Lagrange I kind of uncertain factors in the form

$$\begin{cases} m_i \ddot{x}_{i0} + \sum_{s=1}^{p} \lambda_s \frac{\partial \Phi_s}{\partial x_{i0}} = Q_{xi}, \\ m_i \ddot{y}_{i0} + \sum_{s=1}^{p} \lambda_s \frac{\partial \Phi_s}{\partial y_{i0}} = Q_{yi}, \\ J_i \ddot{\varphi}_{i0} + \sum_{s=1}^{p} \lambda_s \frac{\partial \Phi_s}{\partial \varphi_{i0}} = Q_{\varphi i}, \end{cases} \quad (1)$$

where Q_{xi}, Q_{yi} - Cartesian components resultant forces applied-tion to the i-th body; $Q_{\varphi i}$ - the appropriate time; $\boldsymbol{\lambda}_s$ - Lagrange multipliers; $\hat{O}_s$ - function relationships; p - the number of links. To produce a system of equations used method [8], according to which the general system of equations composed of equations templates for the corresponding relations (joint, rod, cylinder). The resulting system has enlargement, as follows:

$$q(x) = \sum_{i=1}^{N_?} H_i \exp\left(-\frac{(x - x_i)^2}{\sigma_i^2} \right) \quad (2)$$

where M - square matrix of mass and moments of inertia of dimension 3n x 3n (n =2 - number of mobile phone); T - a rectangular matrix of dimension $3n_\lambda$ x $3n_\lambda$ (n_λ - the total number of degrees of freedom, which "take away" from the system all superimposed communication); T '- T is the transposed matrix of dimension $3n_\lambda$ x 3n; O - zero matrix of dimension $3n_\lambda$ x $3n_\lambda$; - unknown vector of linear and angular accelerations of bodies; Q_x - vector of dimension 3n, where each element is the sum of all relevant coefficients of the right side of the original equations template selected and calculated based on the description of the array links and independent perturbations; U - vector of dimension n_λ, formed of a plurality of coefficients U_i equations templates.

Important factor determining the adequacy of the model is the correct assignment of external disturbances in the model. In the process of modeling the movement of the unit at each integration step to calculate the forces exerted by the soil and obstacles on rollers carriages, leading and guiding rollers, disc and working body. Since the model of the caterpillar itself is not considered for the generation of the perturbing function q (x), i.e. surface topography algorithm was used, which allows get enough smooth q (x). In particular, the function q (x) as a superposition of Gaussian asked peaks with parameters x_i (position of obstacles), H_i (height obstacles) and s_i (standard deviation that specifies the width of the obstacle)

$$q(x) = \sum_{i=1}^{N_?} H_i \exp\left(-\frac{(x - x_i)^2}{\sigma_i^2} \right) \qquad (3)$$

Gaussian peaks distributed along the length of the control region (1 km) randomly in a uniform law. The parameters H_i and s_i also randomly chosen in a uniform law of some intervals. Typical values of these intervals from 0 to 0.1 m for Hi and 0.05 to 0.15 m for σ_i. The number of Gaussian peaks N_n control plot length L is obviously associated with a linear density of obstacles ρL the following equation: Nn = ρL*L. To calculate the linear density of obstacles on a plot rut ρL by two-dimensional density of obstacles on the cutting ρS (Zelikov *et al*l 2012).

When calculating the forces acting on the body unit side relief surface was used common viscoelastic model soil. In particular, the force F_k, acting on a roller or disc working body (body k) calculated by the formula

$$F_k = h_{kcp} c_{II} - \frac{dh_{kcp}}{dt} \theta_{II}, \qquad (4)$$

where $h_{kcð}$ - average penetration range of k; $c_{Ï}$ and $\theta_{Ï}$ - stiffness and damping coefficient of the viscoelastic interaction with the surface of the disc.

Calculate the average value of penetration is a complex geometrical problem, since it is necessary to calculate the overlap of lines described by the equation and the equation of the circle to the terrain q (x), representing a superposition of Gaussian peaks. To solve it, the function q (x) is tabulated with a step Δx = 0,01 m and the calculated value of the penetration of each point q (xi) in the range of k, N_k counts the number of points x^i, falling inside the circle k. Then, the magnitude of penetration averaged

$$h_{kcp} = \frac{1}{N_k} \sum_{i=1}^{N_k} \left(R - \sqrt{(x_i - x_k)^2 + (q(x_i) - y_k)^2} \right) \qquad (5)$$

где x_k и y_k – координаты центра круга.

SCW position (xP, yP) is calculated using the known coordinates of the upper and lower hinges connecting the tractor (x_{01}, y_{01}), (x_{02}, y_{02}) and frame guns (x_{11}, y_{11}), (x_{12}, y_{12}). To do this, find the point of intersection of the lines passing through the upper and lower fingers:

$$\begin{cases} y = k_1 x + b_1; \\ y = k_2 x + b_2. \end{cases} \qquad (6)$$

Direct coefficients are determined by formulas

$$k_1 = \frac{y_{01} - y_{11}}{x_{01} - x_{11}}; \quad b_1 = y_{01} - k_1 x_{01};$$
$$k_2 = \frac{y_{02} - y_{12}}{x_{02} - x_{12}}; \quad b_2 = y_{02} - k_2 x_{02}. \qquad (7)$$

Then the coordinates of the point P is calculated by the formulas

$$x_P = \frac{b_2 - b_1}{k_1 - k_2}; \quad y_P = k_1 x_\pi + b_1. \qquad (8)$$

For the convenience of simulation software tool was developed in Object Pascal in an integrated programming environment Borland Delphi 7 (Zelikov *et al*l 2012). The program is designed for optimization, based on computer simulations, design and control parameters of the attachment forest tillage of mounted with a crawler tractor. During the experiment was considered typical computer unit comprising a tractor 90 and BT- forestry disc cultivator CLB - 1, 7 for moving the unit over a certain time on the treated surface with a specified topography. Interface window allow you to specify the basic parameters of the tractor and the attachment of the computer experiment. On the screen continuously displays a schematic representation of the treated surface, moving the tractor hitch, tools, charts and graphs position SCW links attachment, schedule time dependence of the penetration guns into the soil, as well as the numerical values of the output characteristics (Fig. 1).

Optimizing linkage mechanism reduces to finding such a constructive and adjusting its parameters, which provide reliable soil disk working bodies decreases are flaws when driving over uneven surfaces, as well as excluded “anchoring” for the obstacles of working tools and their breakdown.

These criteria largely correlated with the position of SCW (point P). Depending on the geometric parameters of the attachment point P in motion unit can describe different trajectories. Privileged position of the point P below the soil promotes good disk working bodies, but when it starts to decrease excessive significantly affect the ability of the disc to roll over obstacles and unfavorable combination of factors may have the effect of “anchoring” of the workers over the hurdle and breakage. In the case of a consistently high position of the point P

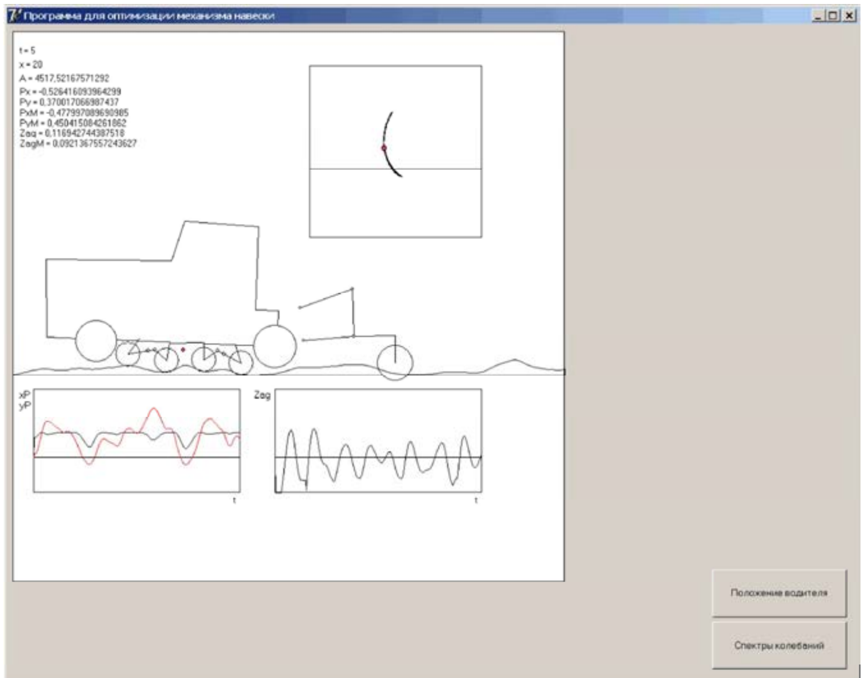


Fig. 1: Image displayed on the computer screen program

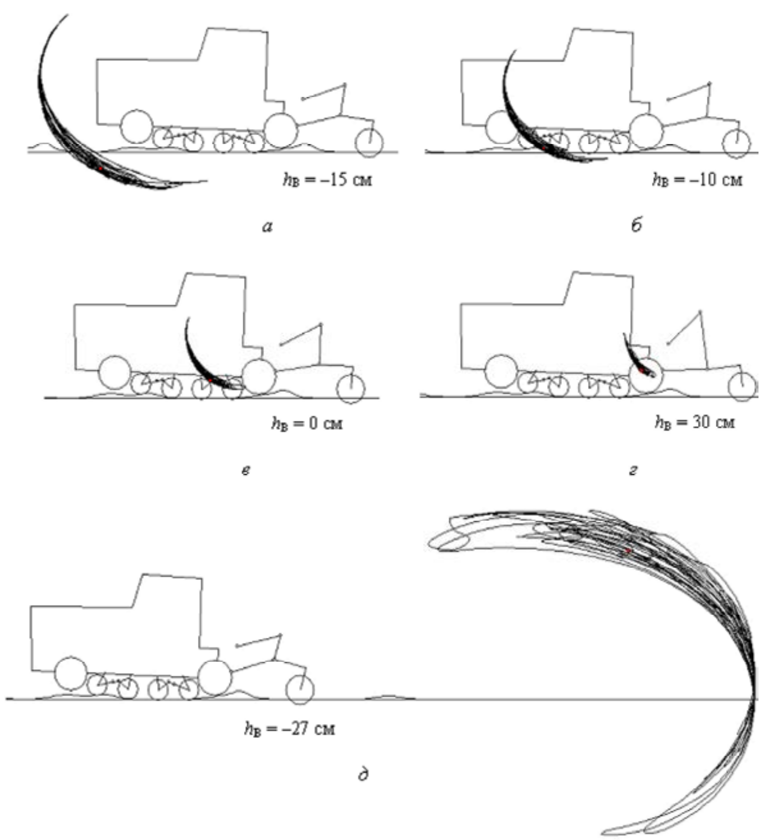


Fig. 2: The path of the SCW units mounted unit in longitudinal vertical plane moving on the cutting unit by varying the vertical displacement strength hB hinge rear end of the top link attachment

the probability of "anchoring" small, but decreases significantly deepened component of traction tractor cultivator working bodies.

Below are the results of a simulation on the effect of various combinations of h_b shifts up and down h_N hinges rear ends of the upper and lower links of the tractor hitch BT-90, with respect to their attachment lugs on the frame serial cultivator CLB -1, 7. Simulations are carried out for two cases - for standard attachment (OU- 3 according to GOST 10677-2001) on the traditional pattern (Fig. 2) and with a device developed by the authors (Fig. 5). In the simulation accepts the following average values : height machined surface roughness - 12 cm, the distance between the tops of irregularities - 140 cm, speed unit - 1 m / s.

Analysis of the results of modeling to determine the effect of location of the hinge rear end of the top draft standard attachment into the path of SCW attachment showed the following (Fig. 2). Lowering the position of said hinge leads to the fact that the upper and lower links become more parallel, whereby the movement trajectory while working cultivator SCW preferably moves forward in the direction of movement of the tractor (Fig. 2a... c). At the same time lowering the hinge aso leads to a decrease in SCW and that contributes to a better recessed disk working bodies. Thus, lowering the upper hinge 25 cm relative to the base (standard) standard position of the attachment leads to the increase in the average depth of processing asr working bodies cultivator 10.26 to 11.64 cm (Fig. 3a). This increases the disparity in the depth of tillage σ_a from 3.01 to 3.63 cm (Fig. 3b).

By lowering the upper hinge by about the same amount of load F_k increases slightly to the front support roller and reduces the load on the rear (Fig. 3c).

When lowering the hinge more than 25 cm (h_b = -27 cm) SCW is already far behind the unit (Fig. 2e). This case is of some interest, but requires a separate study, not included in the scope of this study.

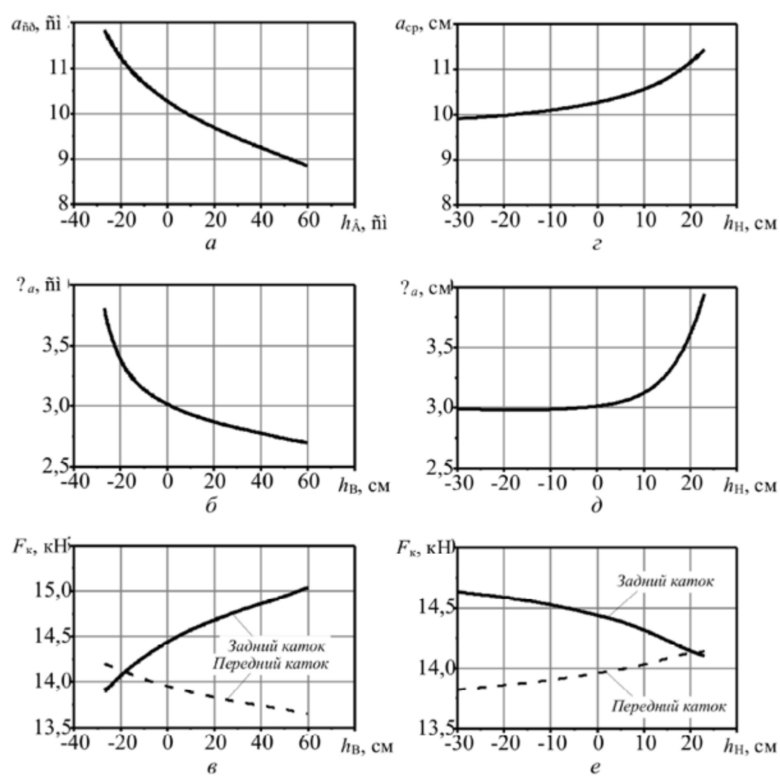
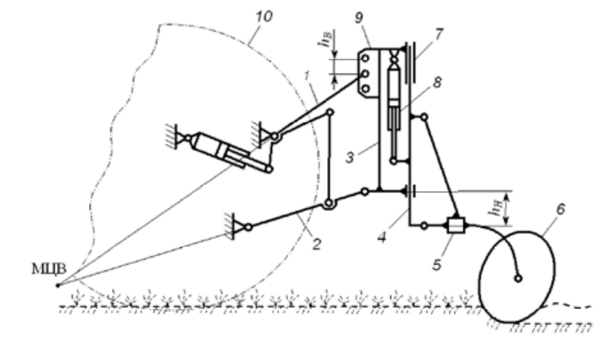


Fig. 3: Effect of vertical displacement hb hinges rear end of the top link (a, b, c) and hN hinge rear end of the lower links (r, d, e) relative to the frame on the gun, respectively: the average value of the depth of processing A_{sr} - a, g, uneven depth processing sa (standard deviation) - b, d, mean values F_k forces acting in the vertical direction on the rear and front road wheels of the tractor - a, e



1 and 2 - the upper and lower links, 3 - frame coupler, 4 - hour, 5 and 6 - frame and disc cultivator battery 7 - guide, 8 - cylinder displacement control of the Lower hinge 9 - eye holes for adjusting the bias hinge rear end of the upper rod, 10 - tractor

Fig. 4: Kinematic diagram of the test unit with tillage device for the attachment of the tractor

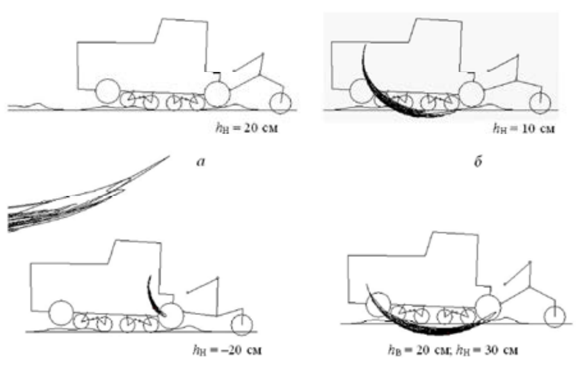


Fig. 5: The path of the SCW units mounted unit in longitudinal vertical plane moving on the cutting unit for different values of vertical displacement hN hinges rear ends lower - a...b while mixtures schenii rear ends of rods - g attachment

In the case of increasing the hinge rear end of the top link on the maximal possible values (30 cm from the base position) SCW close to the hinges of the front ends of the lower links hinged device properties (Fig. 2d). This leads to a maximum increase of the possible cases SCW (up to 400 mm from the surface of the soil) and, consequently, contribute to a reduction burylities disk cultivator working bodies. This is explained by the maximum value of the vertical component of traction tractor attached to the axis of the disc batteries, upward buoyancy and in this case the working bodies of the cultivator on the surface of the treated soil.

One way to effectively manage the situation is to install SCW between the tractor hitch 13 (Fig. 4) and Nave Shiva tillage tools (item 3, 4, 7, 8, 9 in Fig. 4) allows to shift vertically upwards and downwards hinges mounting the rear ends of the upper and lower 1 and 2 rods on their attachment lugs on the frame 5 tools (Posmetiev, 1999).

Change parameter h_N using the proposed adaptations authors can achieve a substantial bias in SCW longitudinal- vertical plane. Thus, with increasing h_N on more than 15 cm typical trajectory of the SCW is significantly below the level of the soil (Fig. 5a), which is beneficial to zaglublyaemosti guns. With an increase of the lower hinge 20 cm relative to the base of his position zaglublyaemost asr disk increases with 10.26 to 11.13 cm (Fig. 3d). It also increases the unevenness σ_a depth of tillage with a 3.01 to 3.57 cm (Fig. 3e).

Due to the specified offset SCW average load F_k changes to front and rear road wheels of the tractor (Fig. 3f). With increasing joint effort on the front bogie wheels slightly increases and decreases in the background and h_b = 20 cm, these efforts are equal in value $F_k = 14.2\ k_N$.

In the case of lowering the hinge to h_b = - 20 cm (Fig. 5c), a picture emerges similar cases considered earlier (Fig. 2d), when highest position SCW deepened markedly reduces the ability of workers disk cultivator.

To find out how a simultaneous displacement of the rear ends of the upper hinge and the lower links of the attachment relative to the frame of the cultivator affect indicators of its effectiveness was carried Dehn series of computer experiments, which simultaneously measured h_b nyali from -30 to 40 cm in increments of 10 h_N cm and -20 cm to 40 cm in 10 cm

Total number of computer experiments was 56 (Table 1). Almost half of the combinations (hb, h_N) resulted in inoperable instruments in the model (empty cells in Table 1).

Analyzing the location of cells in Table 1 with the highest levels penetration A_{sr} (over 11 cm), it can be concluded that the optimum ratio between h_b and h_N is $h_{\hat{A}} = h_{\hat{i}} - 20$,(9)

where $h_{\hat{A}}$ and $h_{\hat{i}}$ are in santimeters.

The greatest amount of penetration drives asr = 11.3 cm is achieved at h_b = 10 cm, 10 cm = h_N This uneven progress on this disc a depth reaches relatively large quantities σa = 3.51 cm, which is due mainly lack of support wheels mounted cultivators and on unfavorable terrain surface to be treated in clearings. Found the

Table 1: Influence of parameters of h_b and h_N on indicators of penetration tools

	$h_{\grave{A}}$, cм							
h_i, cм	-30	-20	-10	0	10	20	30	40
40						10,9		9,6
						4,20		2,86
30					11,2	10,3	9,8	9,5
					3,83	3,12	2,90	2,82
20				11,1	10,5	10,0	9,7	9,4
				3,57	3,14	2,95	2,86	2,80
10			11,3	10,5	10,2	9,8	9,6	9,3
			3,51	3,11	2,98	2,90	2,84	2,79
0			10,7	10,3	10,0	9,7	9,5	9,3
			3,15	3,01	2,94	2,88	2,83	2,79
–10		10,8	10,4	10,1	9,9	9,6	9,4	9,2
		3,18	3,06	2,98	2,93	2,87	2,82	2,78
–20	10,9	10,5	10,2	10,0	9,8	9,6	9,4	9,2
	3,27	3,13	3,04	2,98	2,93	2,87	2,82	2,77

Note: in the numerator - the value of penetration asr, cm in the denominator - the uneven completely burying σa see darken cases corresponding to the position of the point P below the soil level. Empty cells correspond to the cases of impossibility of attachment.

combination of parameters h_b and h_N can be recommended as the best in improving the design on - equilibrium device. It allows forestry disc harrow without useless ballast VEHICLAR provide reliable penetration disc batteries to a predetermined depth processing and accordingly improve the quality of soil treatment in the care of forest plantations in clearings.

Thus, using simulations of motion of a soil unit on the timber object to study the effect of the attachment on the effectiveness of forest disc cultivator. In particular, it was determined the effect of offset hinges rear ends of the rods relative to the tractor hitch frame guns on indicators embedment depth and uneven treatment of its working bodies. Embedment best achieved in the case of adaptation to a standard hitch, which gives a displacement of the upper hinge mounting guns down to 10 cm and the bottom hinge - up to 10 cm

The proposed design of devices to the standard canopy on device improves embedment and, consequently, the quality of tillage and other mounted disk forest and agricultural implements (plows, harrows, harrows, etc.).

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