Analysis of the Influence of the Parameters of the Object of Labor on the Geometric Characteristics of the Levers of the Skidder

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Abstract. The following logging technologies are known today: logging in the form of trees, whips, assortments and wood chips. The most common are logging in the form of whips and assortments. When logging in the form of whips or trees, a skidder is used, which carries out transportation of felled whips or trees to a loading dock. Blockless skidding machines equipped with technological equipment in the form of a manipulator with a gripper and a conic clamping device are widely used in the Russian forest industry. In the process of moving trees into a conical clamping device, as well as in the process of skidding, interaction forces arise between the grip and the tree, which must be taken into account when designing technological equipment for skidding machines. Due to the large variety of trees, it is also necessary to take into account the mass and geometric characteristics of trees. The article publishes the methodology and results of the study of the influence of breed and category of trees on the geometric characteristics of the capture skidder.

1. Introduction
Technological processes of mechanization of logging in the form of whips and trees include the operation of skidding, which is carried out by choker or chokerless skidding machines. At present, the most widely used are chokerless skidders, consisting of a base tractor and technological equipment (a manipulator with a grip and a conical clamping device) [1]. Since skidding machines operate under conditions of an exceptionally large variety of trees as a mechanical object of labor, loads arising on the technological equipment of the machine have the same variety, which, in turn, affect the geometric characteristics of machine structural elements during design. To ensure efficiency in work, it is necessary to take into account the greatest number of all possible factors that arise during skidding of trees [2].

Despite the large number of published studies on the dynamics of forestry machines, there are no studies that take into account the influence of wood species and discharge on the geometrical characteristics of the capture of a chokerless skidder during the movement of trees in a conical clamping device and during skidding. Therefore, the topic aimed at studying the influence of discharge and tree species on the geometric characteristics of the capture of a skidder is relevant.
2. The theoretical part

The modern chokerless skidder (Figure 1) is a basic tractor, on which technological equipment is installed.

To simplify the task, we consider the case of uniform motion with a constant maximum speed of the boom.

![Figure 1](image.png)

**Figure 1.** Scheme of interaction of the skidder with the subject of labor: 1 – base tractor, 2 – swivel column, 3 – conical clamping device, 4 – arrow, 5 – gripper, 6 – tree or tree pack.

Design experience shows that one of the most dangerous types of loading of the gripping device is observed when lifting the maximum volumetric tree at one end; in this case, the tree is fixed in a conical clamping device on such a reach of the manipulator, in which the handle drive experiences maximum loading with the maximum arm of force on the rod of the drive hydraulic cylinder [3].

Based on Figure 1, taking into account the transformation of the expression for determining the forces $P_z$ and $P_x$ have the following form:

$$ P_z = \frac{f_2 \cdot \tan \beta + n}{1 + f_2 \cdot \tan \beta} \cdot G; $$

$$ P_x = \frac{(1-n) \cdot f_2}{1 + f_2 \cdot \tan \beta} \cdot G; $$

where $f_2$ – the drag coefficient of tree dragging along the soil depends on the condition of the drag, the type of soil, etc. The average values when dragging trees or whips along the fiber: in the summer of 0.4-0.6; on a wet surface of 0.6-0.8; in winter 0.3-0.5; on loose snow 0.5-0.7;

$n$ – tree gravity distribution coefficient (whip): when dragging over the top $n \approx 0.3$; when dragging the butt $n \approx 0.5-0.6$.

Figure 2 shows a diagram of the interaction of the gripper with the tree being pulled. In this case, you can observe a turn of the clamping levers at a certain angle relative to the longitudinal axis of the tree, as well as a turn about a vertical axis at a certain angle $\alpha_1$. At the same time, the levers of the gripping device abut the lower parts against the tree trunk at the conditional points A and B, and the upper - at the points $A_1$ and $B_1$, thereby jamming the tree [4, 5]. The lever of each capture in the transverse plane $X-X$ (Figure 3) is tested at a point $C_2$ force action:

$$ P_3 = P_{bc} \cdot \cos \left( \frac{G}{2} \right), $$

at point A (B) - force:

$$ R_{AX} = nG \cos \alpha_1 + f_2 (1-n)G \sin \alpha_1, $$

and reaction $N_L$, which loads the lever with a bending moment $M^T_B$ in this plane.
In section I – I (Figure 3):

\[ M_{ii}^T = \frac{h_{NL}}{h_L} \left( P_u \cdot h_u - G (1 - h_1) [n \cdot \cos \alpha_i + f_z (1 - n) \sin \alpha_i] \cos \alpha_i \right); \] (5)

In section II – II:

\[ M_{ii}^T = P_u \left( \frac{h_{NL}}{h_L} - h_{hc} \right) - \frac{h_{NL}}{h_L} G (1 - h_1) [n \cdot \cos \alpha_i + f_z (1 - n) \sin \alpha_i] \cos \alpha_i; \] (6)

Force \( P_{hc} \) defined according to the expression:

\[ P_{hc} = \frac{2 h_i \cdot G \cdot \left\{ n \cdot \sin \beta + \cos \beta \left[ f_z (1 - n) + n \cdot f \cdot \cos^2 \alpha \right] \right\}}{n_3 \cdot n_1 \cdot f \cdot h_{hc} \left( 1 + \cos \alpha \right) \cos \Theta}; \] (7)

where \( f \) – the coefficient of friction of the barrel on the levers (in the presence of comb 0.8–1);
\( n_3 \) – number of captures;
\( n_1 \) – number of levers in one grip.

In the case of pulling the tree to the conic, the combined action of external forces and reactions on the clamping levers in a plane perpendicular to the plane X-X is observed (Figure 4); while the grip experiences bending and torsion. Bending arises from the action of forces \( P_x = F_{\text{link}} \) and \( P_z = G_{\text{max}} \), attached to the hinge O, which connects the handle and the grip of the manipulator [6].

**Figure 2.** The scheme of interaction of the gripper with a tree

**Figure 3.** The scheme of interaction of the gripping lever with the tree

**Figure 4.** Estimated interaction scheme of capture with a tree

Bending moment in the vertical longitudinal plane of the capture relative to the section I – I:

\[ M_{ii}^T = (P_z \cdot \sin \alpha_i - P_x \cdot \cos \alpha_i) l_i \cdot C_{II}; \] (8)

where \( C_{II} \) – dynamic coefficient, 1.2 – 1.4;

\[ M_{ii}^T = \left( (P_z \cdot \sin \alpha_i - P_x \cdot \cos \alpha_i) l_i + R_{Al} (l_i - l_1) \right) \cdot C_{II}; \] (9)

where \( R_{Al} = \frac{(l_2 + l_i) (P_x \cdot \cos \alpha_i - n \cdot G \sin \alpha_i)}{2 l_2} \).
Reaction $R_A$ determined by the condition of equilibrium of the lever with respect to the support $A$:

$$ R_A = \frac{(P_x \cdot \cos \alpha - P_z \cdot \sin \alpha) l_1}{2l_2}; $$

(10)

Torque acting on clamping lever:

$$ M_t = R_A \cdot h_t \cdot C_D. $$

(11)

The normal reaction acting on the clamping lever from the side of the tree is determined by the expression:

$$ N_t = \frac{G[n \cdot \sin \beta + \cos \beta[f_1(1-n) - n \cdot f \cdot \cos \alpha]]}{f \cdot n \cdot n \cdot (1 + \cos \alpha)}. $$

(12)

The normal force arising in the lever of the gripping device is found by the expression [8]:

$$ N = R_{ax} \cdot \cos \alpha + N_L \cdot \cos \alpha + P_{h_1} \cdot \cos \Theta $$

(17)

Figure 5. Section diagram

Normal stresses in section:
\[ \sigma_a = \frac{N}{F} + \frac{M_y}{J_x} \cdot y_{\text{max}} + \frac{M_x}{J_y} \cdot x_{\text{max}} \]  \hspace{1cm} (18)

Based on the calculated voltage, the optimal section of the box-shaped structure is selected by the selection method [5] based on the methods of calculus of variations.

Axial moments of inertia of the cross section in Figure 5:

\[ J_x = \frac{BH^3 - bh^3}{12}; \quad J_y = \frac{HB^3 - hb^3}{12} \]

3. Practical relevance
Since the most common tree species in forests of Eastern Siberia are pine and spruce II...IV categories [9, 10], we will plot the heights of the capture cross section depending on the category and type of tree.

Using the above methodology, we determine the height of the capture cross section of the skidder depending on the species and category of the tree and construct a graph (Figure 6).

Figure 6. The dependence of the maximum lateral force on the diameter at the height of the chest

The change in the geometric characteristics of the capture cross section depends on the species and category of the tree, which is associated with the difference in their masses and heights within the same category, moreover, the density has different values depending on the type of tree, which affects the mass characteristics of the subject of labor. So for the II category, the increase in the height of the capture cross section with increasing diameter at the height of the chest from 0.28 to 0.6 meters is: for pine – 1.74 times, for spruce – 1.78.

With an increase in the depth of stands, a decrease in their heights is observed, and as a result, an increase in the intensity of the change in mass. So for the IV category, the increase in the height of the
capture cross section with increasing diameter at the height of the chest from 0.28 to 0.52 is: for pine – 1.57 times, for spruce – 1.62.

The data obtained must be taken into account when designing skidders.

4. References
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