Estimated assessment of the power and geometric parameters of the caterpillar mover

Artem Bazhukov[1*], *Sergey* Hoodorozhkov[1], *Andrey* Karnaukhov[2], *Sergey* Voinash[3], *Linar* Sabitov[3,4,5], and *Ilgam* Kiyamov[3]

[1]Peter the Great St. Petersburg Polytechnic University, 195251 St. Petersburg, Russia
[2]Reshetnev Siberian State University of Science and Technology, 660049 Krasnoyarsk, Russia
[3]Kazan Federal University, 420008 Kazan, Russia
[4]Ural Federal University named after the First President of Russia B.N. Yeltsin, Yekaterinburg, 620002, Russia
[5]Kazan State Power Engineering University, 51, Krasnoselskaya Street, Kazan, Russia

Abstract. The article proposes a method for calculating the tension forces in the free and working branches of the bypass, taking into account the deformation of the caterpillar and suspension hinges. Calculation schemes for determining the parameters of the running gear are given. The dependence of the geometry of the caterpillar bypass on these forces is determined, the feature of which is taking into account the change in the position of the machine body in height and angle of inclination, as well as the preload of the road wheels.

1 Introduction

To date, transport tracked vehicles (TTVs) represent a significant sector in the system of ground trackless vehicles. TTVs include tracked transporters, snowmobiles, swamp vehicles, as well as special-purpose vehicles - tanks, infantry fighting vehicles, multi-purpose platforms on tracks.

The undercarriage of the TTV, which includes a caterpillar mover and a suspension system, has a number of advantages compared to the undercarriage of a wheeled vehicle. These are higher cross-country ability and traction and coupling qualities, productivity, as well as higher speed in difficult road conditions.

The development and modernization of the undercarriage are implemented due to extensive theoretical and experimental research: clarification of the interaction of the propulsor with the supporting surface, the choice of optimal modes of operation of the undercarriage, the improvement of calculation and design methods, the use of new technological and design methods [1-14].

The track tensioning mechanism with the idler wheel is part of the track drive and is designed to control the pre-tensioning of the track, which determines the stability of the track in the bypass, the operating conditions for the engagement of the track with the drive wheel, and the loading of the undercarriage elements [15-18].

* Corresponding author: artem_bashukov@mail.ru

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One of the ways to improve the caterpillar mover is to use the automatic track tensioning mechanism. This mechanism will automatically adjust the track tension depending on the mode and operating conditions. Currently, when the machine is moving, the tension is either not regulated, or it is controlled remotely by the driver and, as a rule, at low speed.

When the TTV moves, the caterpillar experiences a complex force effect. A change in traction load and movement speed leads to a redistribution of tension in the bypass branches, as well as to a change in the lengths of these branches [12,19].

To compensate for sagging branches, as well as changes in tension, it is necessary to additionally tighten the caterpillar using the automatic tension mechanism.

The purpose of this work is to propose a calculation method for determining the relationship between the parameters of the undercarriage and the modes of movement of the TTV.

2 Main part

2.1 Track Tension Determination

The forces acting on the caterpillar in the bypass can be divided into constant in magnitude for a given mode of movement (at a given speed, direction and resistance to movement) - constant components of the tension, and time-varying in any steady state - dynamic components [12].

The constant components of the tension usually include: pre-tension Tpr, traction force Pvk, tension from centrifugal forces Tc. These forces reach large values in absolute value and largely determine the loading of the bypass.

In turn, the caterpillar bypass is divided into several sections: the reference branch l_{re} (through which the weight of the TTV is transferred to the bearing surface), the working branch l_w (which transmits traction and is located from the reference branch to the drive wheel) and the free branch l_{fr} (which is not loaded with force traction and is located from the drive wheel to the supporting branch). Moreover, the length of the free and working branches depends on the location of the drive and guide wheels. On Figure 1 shows a bypass scheme with a rear drive wheel.

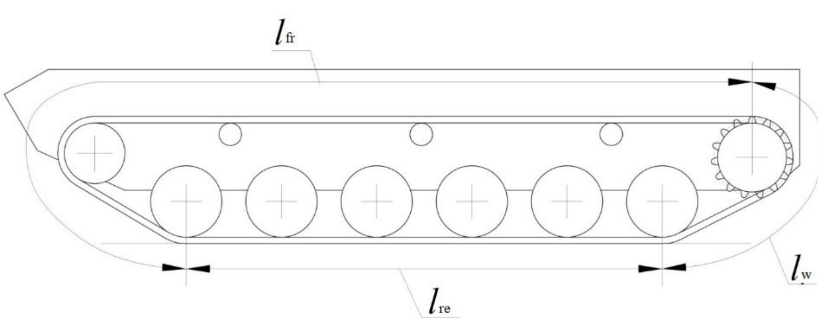

Fig. 1. Sections of the caterpillar bypass: l_{fr} - free branch, l_w - working branch, l_{re} - reference branch.

The constant component of tension forces in the free branch of the bypass [13]:

$$T_{fr} = T_{pr} + T_c . \quad (1)$$

Tension forces in the working branch [13]:

$$T_w = T_{fr} + P_{vk} \quad (2)$$

In a static position, when the bypass is stretched by the pretension force, the length (perimeter) of the bypass S_{by} is equal to the length of the caterpillar (taking into account the deformation of the hinges):

$$S_{cat} = z \cdot t_{cat} + \frac{T_{fr}}{c_{cat} \cdot l_{fr}} + \frac{T_w}{c_{cat} \cdot l_w}, \qquad (3)$$

where z is the number of tracks in the caterpillar, t_{cat} is the track pitch, c_{gus} is the specific longitudinal stiffness of the caterpillar.

As mentioned above, during movement, the tension forces in the caterpillar are redistributed, which leads to changes in the position of the TTV body and the geometry of the bypass. As a result of the difference between the perimeter of the bypass and the length of the caterpillar $\Delta l = S_{by} - S_{cat}$, , an additional tensile force $\Delta T = c_{cat} \cdot \Delta l$, appears where c_{by} is the stiffness of the caterpillar bypass.

Then the actual tension in the free branch becomes:

$$T_{fr} = T_{pr} + T_c - \Delta T \qquad (4)$$

The perimeter of the bypass, shown in Figure 2 can be determined by the formula:

$$S_{by} = S_1 + S_{1\text{in}} + S_{1tr} + S_{re} + S_{2\text{tr}} + S_{2\text{in}} + S_2 + S_{2up} + S_{1up}, \qquad (5)$$

where S_1 is the length of the guide (driving) wheel coverage, S_{1in} is the length of the front inclined branch of the bypass, S_{1tr} is the length of the coverage of the front road wheel, S_{re} is the length of the support branch, S_{2tr} is the length of the coverage of the rear support roller, S_{2in} is the length of the rear inclined branch of the bypass, S_2 - the length of the coverage of the driving (guiding) wheel, S_{2up} - the length of the constant part of the upper branch of the bypass, S_{1up} - the length of the variable part of the upper branch of the bypass.

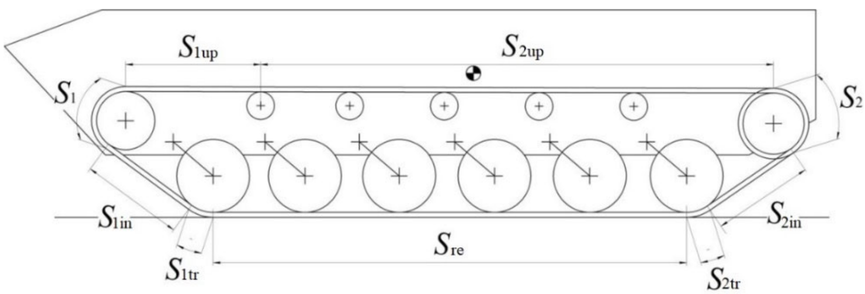

Fig. 2. Calculation scheme for determining the length of the caterpillar bypass.

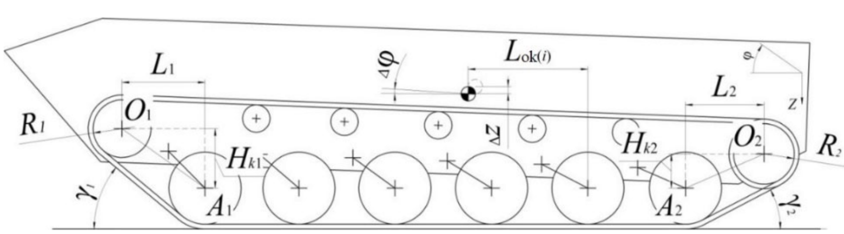

Fig. 3. Calculation scheme for determining the parameters of the caterpillar bypass.

Here: R_1 and R_2 are the radii of the drive or steering wheel located in front (index 1) and behind (index 2), R_{ok} is the radius of the track roller, γ_1 and γ_2 are the angles of inclination of the front and rear branches of the caterpillar bypass, $L_{ok(i)}$ is the distance from the center sprung mass to the axis of the i-th roller horizontally, L_1 and L_2 are the distances along the length from the axis of the front (index 1) and rear (index 2) driving or steering wheel to the axis of the front and rear rollers, H_{k1} and H_{k2} are the distances in height from the axis of the drive or steering wheel located in front (index 1) and behind (index 2) to the axis of the front and rear rollers.

In the process of increasing the tension of the tracks, the position of the hull changes in height and angle of inclination, as well as the parameters of the undercarriage: the angles of inclination of the caterpillar branches, the distances between the axes of the track rollers, the base, etc. [14,20].

Using the schemes presented in Figures 2, 3, the following dependencies were obtained to determine the lengths of individual sections of the caterpillar bypass:

$$S_1 = \left(\pi\text{-}\gamma_1\left(f_1\right)\right)\cdot R_1, \tag{6}$$

where f_1 is the stroke of the 1st track roller;

$$S_{1in} = \sqrt{O_1A_1\left(f_1\right)^2 - \left(R_{ok} - R_1\right)^2}\text{, where } O_1A_1 = \sqrt{L_1\left(f_1\right)^2 - H_{k1}\left(f_1\right)^2}; \tag{7}$$

$$S_{1tr} = \gamma_1\left(f_1\right)\cdot R_{ok}; \tag{8}$$

$$S_{re} = L_{\text{ok}(1)}\left(f_1\right) - L_{ok(n)}\left(f_n\right), \tag{9}$$

where $L_{ok(1)}$, $L_{ok(n)}$ are the distances from the center of the sprung mass to the axes of the 1st and nth road wheels, f_n is the stroke of the nth roller.

$$S_{2\text{in}} = \sqrt{O_2A_2\left(f_n\right)^2 - \left(R_{ok} - R_2\right)^2}\text{, where } O_2A_2 = \sqrt{L_2\left(f_n\right)^2 - H_{k2}\left(f_n\right)^2}; \tag{10}$$

$$S_2 = \left(\pi\text{-}\gamma_2\left(f_n\right)\right)\cdot R_2; \tag{11}$$

S_{2up} is a value that depends on the geometric dimensions of the caterpillar mover;

S_{1up} is a value that depends on the position of the guide wheel.

Most of the values depend on the strokes of the road wheels, which are defined as follows [21]:

$$f_i = \Delta z + \Delta\varphi\cdot L_{ok(i)}, \tag{12}$$

where Δz is the vertical displacement of the center of the sprung masses of the TTV, $\Delta\varphi$ is the angle of rotation of the longitudinal axis of the hull passing through the center of the sprung mass.

2.2 Hull position determination

The calculation scheme for determining the position of the hull, taking into account the tension forces of the caterpillars (for the undercarriage with the rear drive wheel) is shown in Figure 4.

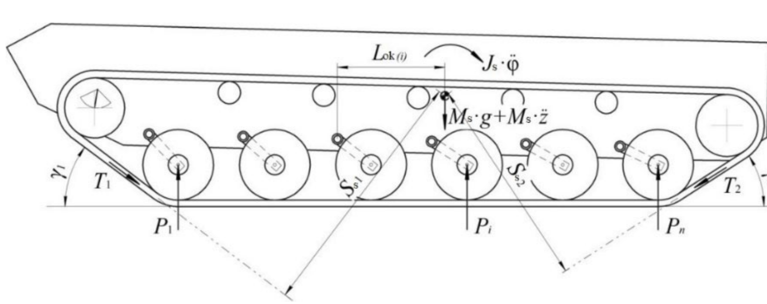

Fig. 4. Calculation scheme of forces acting on the undercarriage: M_s - sprung mass of the machine, g - free fall acceleration, P_i - elastic suspension force reduced to the i-th track roller, T_1 - force acting in the front branch of the bypass, T_2 - force acting in the rear branch of the bypass, S_{s1} and S_{s2} are the shoulders of the moments of the caterpillar tension forces relative to the center of the sprung mass, n is the number of road wheels on board, J_s is the moment of inertia of the sprung mass.

The body of the machine is in equilibrium if the following condition is satisfied:

$$\begin{cases} \sum_{i=1}^{n} P_i - T_1 \cdot \sin\gamma_1 - T_2 \cdot \sin\gamma_2 - 0,5 \cdot M_s \cdot g - M_s \cdot \ddot{z} = 0 \\ \sum_{i=1}^{n} P_i \cdot L_{ok(i)} - T_1 \cdot S_{s1} + T_2 \cdot S_{s2} - J_s \cdot \ddot{\varphi} = 0 \end{cases} \quad (13)$$

Otherwise, the body tends to take an equilibrium position with accelerations

$$\ddot{z} = \frac{\Delta P}{M_s} \; and \; \ddot{\varphi} = \frac{\Delta M}{J_s}, \quad (14)$$

If the values of the sum of forces ΔP and the sum of moments ΔM are not equal to zero, then we eliminate the resulting mismatch by moving the body along the height z and the angle of inclination φ, as a result of which we find the increment of the suspension strokes of the i–th rollers, new values of the strokes f_i and new values of elastic forces P_i, etc.

Required additional movement of the body along the angle of inclination [14]:

$$d\varphi = \frac{\Delta M \cdot \sum_{i=1}^{n} c_i - \Delta P \cdot \sum_{i=1}^{n} [c_i \cdot L_{ok(i)}]}{\sum_{i=1}^{n} [c_i \cdot L_{ok(i)}^{\;2}] \cdot \sum_{i=1}^{n} c_i - \{\sum_{i=1}^{n} [c_i \cdot L_{ok(i)}]\}^2} \quad (15)$$

and in height [14]:

$$dz = \frac{\Delta P - d\varphi \cdot \sum_{i=1}^{n} [c_i \cdot L_{ok(i)}]}{\sum_{i=1}^{n} c_i} \quad (16)$$

Increment of the static stroke for the i-th roller:

$$\Delta f_i = dz + L_{ok(i)} \cdot d\varphi \quad (17)$$

New travel value for the i-th track roller:

$$f_i = f_i + \Delta f_i \quad (18)$$

Depending on the course of the i-th roller, we specify the values of the lengths of the bypass sections, the angles of inclination of the tracks γ_1 and γ_2 and determine the new values of the sum of forces ΔP and the sum of moments ΔM.

When the specified accuracy $\ddot{z}$ *and* $\ddot{\varphi}$ is reached, the calculation can be completed.

3 Discussion

This method made it possible to obtain the required values of the undercarriage parameters after almost three or four approximations.

Test case calculation results

As an example, the parameters of the undercarriage of a tracked vehicle were calculated, the description and technical characteristics of which are given in the literature [21].

The rectilinear motion of the machine is considered under various modes of motion. The results of the calculation, namely the tension in the free branch of the bypass from the forces of traction and speed, are presented in the form of graphs in Figures 5, 6.

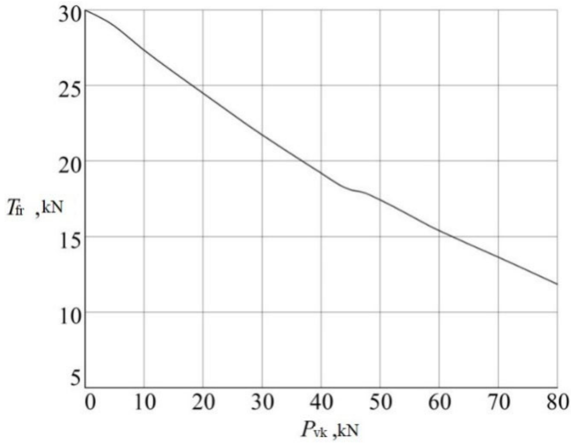

Fig. 5. Dependence of the tension in the free branch of the bypass on the traction force.

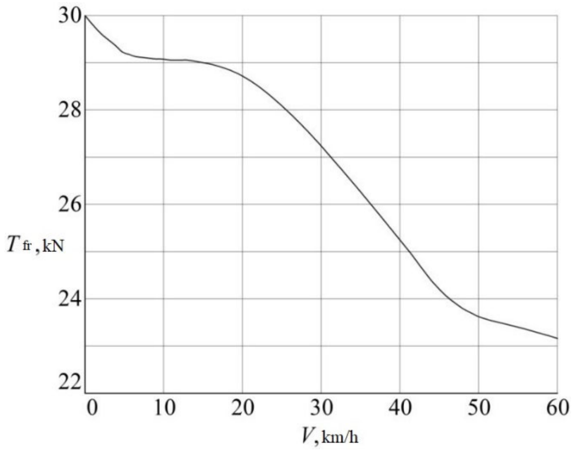

Fig. 6. Dependence of the tension in the free branch of the bypass on the speed of movement.

As can be seen from the graphs, driving in difficult road conditions or at high speed significantly reduces the tension of the free branch of the bypass. Moreover, the influence of traction force is more significant.

4 Conclusions

The main conclusions and recommendations can be summarized as follows:

- The actual contour perimeter differs from the track length. The proposed technique makes it possible to take into account the relationship between the forces acting in the bypass and the value of the bypass perimeter, taking into account the deformation of the hinges and suspension;
- The difference of this technique is taking into account the height of the machine body and its angle of inclination, depending on the forces acting in the bypass;
- The application of the calculation method allows for a specific machine under given driving conditions to estimate the value of the required pre-tensioning of the caterpillar. Such an assessment allows us to proceed to the design of the automatic track tensioning mechanism and the development of a tension control algorithm.

The work is carried out in accordance with the Strategic Academic Leadership Program "Priority 2030" of the Kazan Federal University of the Government of the Russian Federation.

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