Calculation of trench width to be overcome by multi-axis wheeled vehicle

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Abstract. The article deals with the problem of overcoming the destroyed moat by a multi-axle wheeled vehicle. The author describe the carried out experimental research on the chassis «Korsak» with the gross weight of 600 kg with a wheel formula “6x6”. The nature of the destruction of the moat walls is shown. The design scheme allowing one to determine the amount of caving is given. A mathematical model allowing one to calculate changes in the width of the moat is given depending on soil parameters, vehicle characteristics and a number of passes of the chassis wheels. The comparison of theoretical and experimental results is given. Conclusions are drawn about further recommendations and improvement of the model in terms of taking into account the heterogeneity of the soil, as well as the dynamics of the vehicle.

1. Introduction

The need to solve transportation and technological problems throughout the country is one of the key factors for the possibility of doing business. Most of the tasks for transporting people and goods are assigned to land transport. In difficult operating conditions, an important property of transport-technological vehicles (TTV) is mobility - the integral operational property of TTV, which determines its ability to perform the task with optimum adaptability to operating conditions and the technical state of the vehicle itself, the ability of the vehicle to withstand external and internal factors that impede the fulfillment of the task [1, 2].

The key criterion of mobility is patency. The permeability is divided into the support and profile [3, 4]. When calculating the profile cross-country, the case is mainly considered when the TTV moves along a solid non-deformable support base [3-5]. But the most difficult case from the point of view of profile cross-country ability is the passage of the destroyed moat. This is justified by the fact that during the passage of obstacles of different types, such as escarp, counterskarpe, hummocks, etc., their destruction contributes to improved patency. For a moat with destructible walls it is characteristic to increase its dimensions and, as a consequence, reduce the patency of the vehicle that travels through it. Therefore, the authors of the work carried out experimental and theoretical studies that made it possible to describe mathematically the nature of the destruction of the walls of the moat.

2. Experimental studies

On October 21, 2018, experimental studies were carried out on the permeability of the breaking down of ditches on the «Korsak» TTV with a wheeled 6x6 cogwheel. Several obstacles of the trench type of...
different widths were prepared for carrying out the experiments. TTV «Korsak», moving with steady speed, alternately crossed ditches, increasing in width. Figure 1 shows the fragments of the tests.

Figure 1. Fragments of the ditching of the ditch TTV «Korsak».

The scheme of collapse of the moat walls was analyzed and a mathematical model for describing this process was proposed. Figure 2 shows the actual picture and the collapse pattern of the moat wall. Figures show characteristic areas of collapse of the moat walls.

Figure 2. The real picture (a) and the collapse pattern of the moat wall (b)

In accordance with the scheme in Figure 2, and also the approach described in [8, 9], a new mathematical model was proposed.

3. Mathematical model

To find the size of the area to be broken, it is necessary to equate the values of the friction force of the wedge of the ground and the load from the chassis wheel.

The frictional force in the slip zone of the wedge of the soil will be determined from the friction condition in this section in accordance with the dependence:

\[ F_{fr} = F_{fr(1,2)} + F_{fr(3)}, \]

where \( F_{fr(1,2)} \) – friction in sections 1 and 2, \( F_{fr(3)} \) – friction in sections 3.

In the general case, the friction of the soil wedge will be determined from expression [3, 5, 9]:

\[ F_{fr} = cA + F \tan \varphi, \]

where \( c \) and \( \varphi \) - connectivity and an angle of internal friction of the soil, \( A \) - shear area, \( F \) - load perpendicular to the shear area.

For the site 1, 2 we assume that:

\[ F_{fr(1,2)} = cA_{(1,2)} \]
where \( A_{(1,2)} \) – shear area. In accordance with the scheme in Figure 2, \( A_{(1,2)} = \xi L_i^2 \cos(y + (i-1)\varphi) \frac{\cos(y + i\varphi)}{2 \sin \varphi} \), where \( \xi \) – coefficient taking into account the actual process of collapse of the moat walls (\( \xi = 1.1-1.4 \)).

For section 3 we assume that:

\[
F_{fr(3)} = cA_{(3)} + F \tan \varphi, \tag{3}
\]

where \( A_{(3)} \) – shear area. In accordance with the scheme in Figure 2 \( A_{(3)} = BL_1 \), \( B \) - track width (wheels), \( L_1 = L_i \frac{\cos(y + (i-1)\varphi)}{\sin \varphi} \), i.e. \( A_{(3)} = B L_i \frac{\cos(y + (i-1)\varphi)}{\sin \varphi}, F = G_k \sin(y + i\varphi) \).

The sliding force of the soil wedge will be:

\[
F_{fr} = G_k \sin(y + i\varphi). \tag{4}
\]

Thus, substituting the values (2) - (4) into equation (1), we obtain:

\[
G_{kl} \cos(y + i\varphi) = c \xi L_i^2 \frac{\cos(y + (i-1)\varphi) \cos(y + i\varphi)}{\sin \varphi} +
+ cB L_i \frac{\cos(y + (i-1)\varphi)}{\sin \varphi} G_{kl} \sin(y + i\varphi) \tan \varphi.
\]

\[
a_p L_i^2 + b_p L_i + c_p = 0,
\]

\[
a_p = c \xi \frac{\cos(y + (i-1)\varphi) \cos(y + i\varphi)}{\sin \varphi},
\]

\[
b_p = cB \frac{\cos(y + (i-1)\varphi)}{\sin \varphi},
\]

\[
c_p = G_{kl} \sin(y + i\varphi) \tan \varphi - \cos(y + i\varphi).
\]

\[
L_i = \frac{-b_p + \sqrt{b_p^2 - 4a_p c_p}}{2a_p}. \tag{5}
\]

Dependences (1) - (5) make it possible to calculate the magnitude of the moat broadening during the passage of a multi-axial vehicle. When determining the total increase in the width of the moat, it is necessary to take into account the fact that the broadening after each pass is calculated taking into account the redistribution of loads along the propellers. In this case, the values of the total broadening for different walls of the moat (escarp and countereescarp) will be different.

The analytical dependence for calculating the moat widening for each wall is given below:

\[
L_\Sigma = \sum_{i=1}^{n} L_i, \tag{6}
\]

where \( n \) – number of axles.

Figure 3 shows a diagram of the variation in the collapse of the moat walls as a function of the number of wheel passes. The dark columns correspond to the first wall (escarp) of the moat, the light ones to the second one. The data in figure 3 are given for a chassis with wheel arrangement 6x6 with a total mass of 600 kg, a wheel width of 0.24 m and the following soil parameters: \( c = 10.7 \) MPa – connectivity; \( \varphi = 13^\circ \) - angle of internal friction of the soil. The parameters of the soil correspond to those obtained during the experiment.

In accordance with [10], the values for calculating the width of a moat with rigid walls that a multi-axial vehicle can overcome can be determined from an empirical relationship:

\[
b_t = L_{1-2(3-4)} + 0.6D_t, \tag{7}
\]

where \( L_{1-2(3-4)} \) – distance between the wheels of the first and second (third and fourth) axes of the vehicle, \( D_t \) – tire diameter.

When overcoming a fractured moat, its limiting width can be expressed by the following expression:

\[
b_{tb} = b_t - (L_{X2} + L_{X3}). \tag{8}
\]

In accordance with the depicted dependences (1) - (7), the maximum overestimated width of the moat with destructible walls was calculated. The calculated value was 0.66 m.
Figure 3. Ditch widening values for wheel passes

4. Conclusion and future work

A profile cross-country study was conducted, namely, overcoming by a vehicle with wheel formula 6x6 of a fractured moat. Experimental researches were carried out using the transport-technological vehicle «Korsak».

A mathematical model has been developed that makes it possible to calculate the width of the reputable trench being overcome by a multi-axis wheeled vehicle.

Calculations of the parameters of the rupture to be broken, when it was overcome by a car with a wheel formula 6x6 with a total mass of 600 kg, allowed us to estimate the parameters of the profile cross-country of the examined landing gear.

Comparisons of theoretical and experimental data have shown that the calculated values of broadening of the moat take large values by an average of 19%. At the same time, the estimated value of the width of the ditch is less than the real value by an average of 18%.

An analysis of the results obtained made it possible to conclude that the theoretical dependences obtained are valid for homogeneous soil. In practice, the structure of the moat is not uniform and, as a rule, under natural conditions, there is turf, tree roots, branches and other inclusions of anthropogenic nature. Therefore, a study related to the overcoming of a ditch with an inhomogeneous structure will be carried out in subsequent works of the authors.

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