Method of assessment of special wheel chassis mobility in cases of sand-gravel bases crossing

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Abstract. 6x6 chassis wheel mobility assessment in cases of the movement on the sand-gravel bases is the key point of the article. The relevance of such chassis for monitoring of coastal zones is considered. Standard traffic conditions are defined, and dependences for the main bases physicomechanical characteristics are described. Dependences for calculation of the generalized functions of resistance and cohesion are given. Transport technological vehicles (TTV) chassis constructional parameters assessment and calculation of the efficiency criterion method as well as the Blok diagram is provided for stochastic input of traffic conditions. Calculation of change of efficiency of a design at the movement on the sand-gravel bases at change of parameters of the chassis within 20% is carried out.

1. Introduction

Coastal zones and coastal territories are the place of residence for a large number of people and the areas of their cultural activity. As a result, the accompanying industries, forest, agriculture and fish farms are widely spread there. The production of natural minerals, oil and gas, ores also takes place in such areas. The alternative power engineering is also developed there. The coastal zones were always the objects of tourism and rest and the research activity areas. Therefore, the safety of human activity, state and ecological (technogenic and natural) safety for these territories are an important and relevant task.

The monitoring of the coastal territories and adjacent water areas in a wide spatio-temporal framework is necessary for the safety control. Monitoring can be implemented by means of a large number of stationary posts, or by means of the mobile complexes. The mobile land complexes for monitoring of coastal zones look like the most reasonable solution now. Special chassis and robots for such measurements are very perspective. Such systems are suitable for long-term expansion as they give the chance for a prolonged data acquisition, covering several hundreds meters from the coastline. At the same time there are a number of the problems arising from the need to ensure the mobility in conditions of hardly accessible coastal zones.

The special conditions, not relevant for a standart land chassis, determine the metodology development and researches to echive coast zone data, to give us the possibility to asseses the mobility in such conditions.

2. Traffic conditions

Stepanov A. P. [1], Redkin M. G. [2], Malakhov D. Yu. [3] and others researched coastal zones from the point of view of the movement of the transport technological vehicles (TTV). Their works are generally connected to a research of the buoyancy of the vehicles at different storm conditions, the

movements in a surf zone, an entrance to water and an exit to the coast. Calculations provided are given for average values of physicomechanical characteristics of coastal zones. But for assessment of the TTV movement efficiency, it is necessary to know the nature of distribution of these characteristics and the special operating conditions in coastal zones.

As the researches showed, the sand-gravel and sandy conditions dominate in coastal zones where the supporting surfaces exist.

The TTV movement and the processes of interaction of a propulsions unit and the supporting basis were researched at different times by many scientists and researchers.

The publications by Ageykin Y.S. [4], Bazhenov E .E. [5], Bezborodov G. B. [6], Bekker M. G. [7], Volskay N. S. [8], Rybansky M. [9], and others were devoted to the studies of the statistical distribution of the characteristics of the road-soil foundations. Works of the specified authors, as well as the researches described in chapter 1 of this work, do not completely characterize coastal zones. Therefore the authors of this work made additional experiments to draw up new and to specify the existing models describing the surface of a way in coastal zones.

The main parameters of soil necessary to calculate forces of a resistance and coupling of TTV can be received if resistance of the penetration is known. As the pilot studies showed the calculation of the resistance to penetration probability of density can be described by the logarithmic normal law of the distribution. For the sand-gravel beach, the average value penetration resistance is 75 N/cm^2. For the sandy beach, the average value penetration resistance is 60 N/cm^2. [10-11] The distribution example is shown in the figure.

In compliance with received the data on soil parameters, the mobility of the special wheel chassis on the sand-gravel method of assessment was developed. The special chassis designed for the movement in the conditions of the coastal zones (figure 2) [12] was chosen as an object for the research.
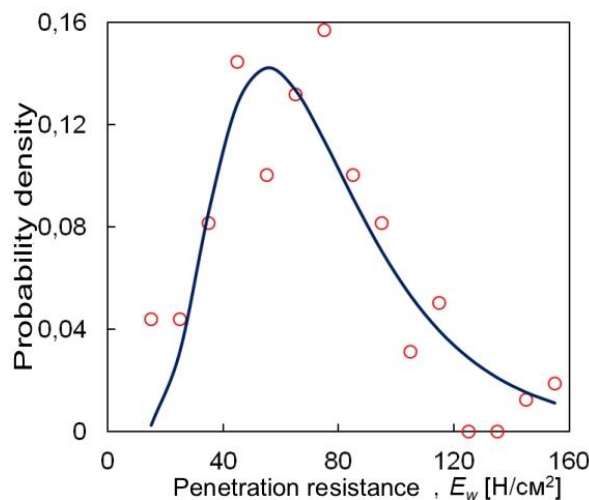

Figure 1. Probability density for the penetration resistance change on the site of sand-gravel beach

Figure 2. The special chassis for the movement in a coastal zone general view

3. Mobility assessment method

The most convenient mathematical model for the sand-gravel supporting bases is the model given by Ageykin Ya. S. [4] and Volskay N. S. [8]. The calculation of normal and shift stresses is made according to the following dependencies.

$$q_\beta = \left[\frac{(Hg - z)}{b(1+1,75\varphi_0)\left(k_{\beta_1} \cdot b \cdot \rho \cdot X_1 + k_{\beta_2} \cdot c_0 \cdot X_2 + k_{\beta_3} \cdot \rho \cdot X_3 \cdot z\right) \cdot \cos\beta} + \frac{a \cdot b}{E \cdot z} arctg \frac{(H_g - z)}{a \cdot b \cdot \cos\beta} \right]^{-1}$$

$$\tau = \left[q_\beta \cdot tg\,\varphi_0 + c_0\left(1 - \frac{S_{t_0}}{S_t}\right) \right]\left[1 - \exp\left(-\frac{S_{t_0}}{k_\tau}\right) \right].$$

Dependences for calculation of the resistance and coupling generalized functions are determined

from values of tension arising in an elementary site with subsequent integration into the contact area:

$$\Phi_f = bM_a^{-1}\int_0^{h_\text{T}} p\,dh \;,$$

$$\Phi_\varphi = bM_a^{-1}\int_A \tau\,dA \;.$$

The resistance generalized functions and coupling ratio analysis allows one to evaluate the possibility of the chassis movement in the conditions of coastal zones on the sandy and sand-gravel supporting bases as well as to estimate the values of constructional parameters, under which the mobility of the chassis will not be lost. According to this, the technique which flowchart is provided in Figure 3 was developed.

In the offered technique, the cycle with the counter is used where the basic parameters of the chassis TTV $\lambda_\text{к} = \{M_a, B, D, n, p_v, \ldots\}$ change the value from the set initial value $\lambda_\text{КН}$ to the final value $\lambda_\text{КК}$ with some step $\Delta\lambda_\text{К}$, and for each parameter, the body of a cycle is carried out once. Initial values of parameters $\lambda_\text{К}$ are set depending on the engineering experience and the design requirements limited by the specification. In this research, the change of the parameters values from an average on 20% is analyzed.

$\lambda_\text{g} = \{E, c, \varphi, \rho\}$ data are used as the characteristics of the supporting basis as well as their statistical characteristics which are set, using a cycle with the counter. The main parameters of the supporting basis λg change the value from the set initial value λ_gH to final value λ_gK with some step $\Delta\lambda_\text{g}$, and for each parameter the body of a cycle is carried out once. At the same time, the value of the probability density $p(\lambda_\text{g})$ corresponds to each value λg.

For each ratio of parameters λg and $\lambda_\text{К}$, the values of the generalized functions of resistance Φ_f and coupling Φ_φ are also calculated. The condition of inequality $\Phi_f < \Phi_\varphi$ is checked. If the condition is true, the coefficient considering probability that the vehical will not lose mobility on the condition of basic passability under the set of conditions, λg and $\lambda_\text{К}$ should be calculated. Changing the parameters of the supporting basis λ_g and receiving values Φ_f and Φ_φ are built in the graph of the dependencies considering the probability characteristics like $p(\Phi_f) = f(\lambda_\text{g}, \lambda_\text{к})$ and $p(\Phi_\varphi) = f(\lambda_\text{g}, \lambda_\text{к})$ on the set $\lambda_\text{К}$.

According to the offered method, the comparative assessment of different chassis parameters was made to choose the rational design and to calculate the probability of the mobility loss.

Calculations were made for the TTV basic chassis with the wheel propulsion unit with the following parameters: the fully loaded mass is $M_a = 1000$ kg, tire radius is $R = 0{,}41$ m, tire width is $B = 0{,}32$ m, deformation of the tire with a normal pressure in the tire is $\Delta_t = 0{,}05R$ m, the number of propulsions unit on each board for wheel is $n_\text{К} = 3$. And the mobility parameters in the change of chassis parameters were also within 20%.
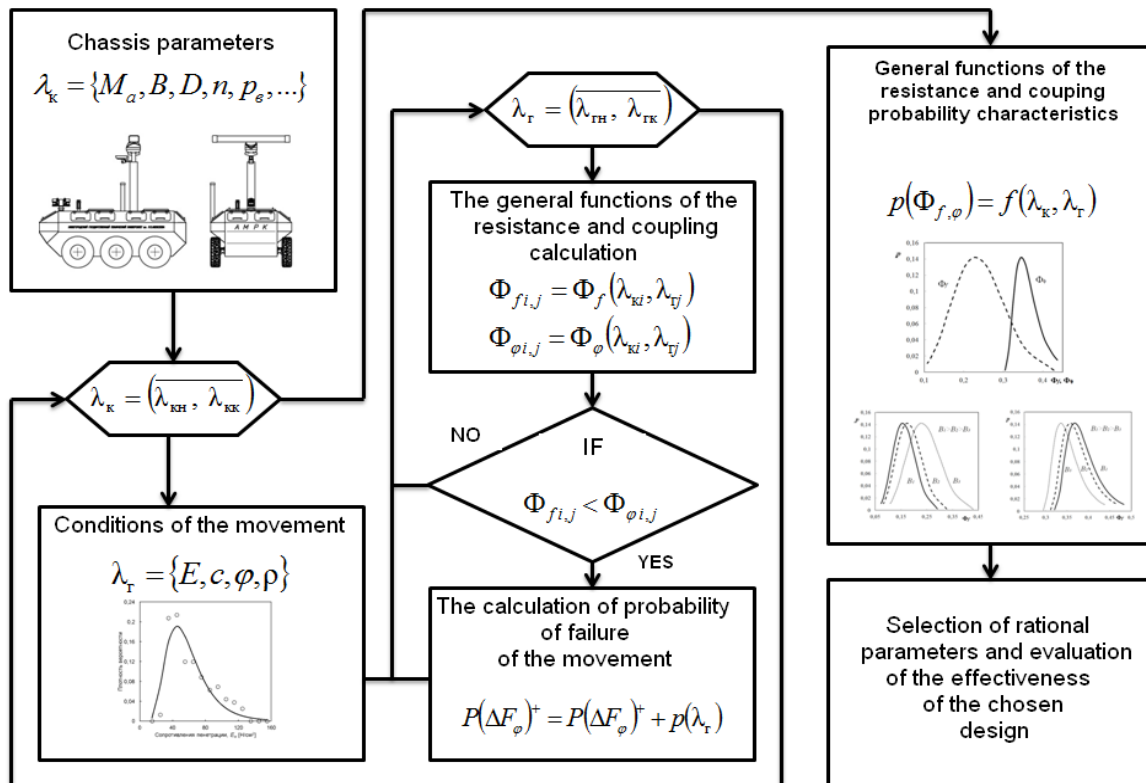
Figure 3. A block diagram of an assessment method of constructional parameters of the TTV chassis and efficiency criterion calculation

4. Conclusion

The need for a special chassis to carry out monitoring in coastal zones was analyzed.

The analysis of a research of the TTV movement in coastal zones, as well as the analysis of the researches of the road and soil bases of statistical distribution of characteristics, was carried out.

It is shown that sand-gravel and sandy territories can be considered as dominant in coastal zones where the most part of supporting surfaces is situated. The carried-out analysis shows that the resistance of a penetration is subject to a logarithmic normal law of the distribution. The average value resistance of a penetration for the sand-gravel beach is 75 N/cm². The average value resistance of a penetration for the sandy beach is 60 N/cm².

The TTV chassis constructional parameters assessment method and the calculation of the efficiency criterion are described and the block diagram for the method provided.

The calculations show that the TTV basic chassis with the wheel propulsion unit has: the fully loaded mass is $M_a = 1000$ kg, tire radius is $R = 0,41$ m, tire width is $B = 0,32$ m, deformation of the tire with a normal pressure in it is $\Delta_t = 0,05R$ m, and the number of propulsions unit on each board for wheel is $n_K = 3$, the permeability of the movement without loss of possibility is 99% for sand-gravel and 98% - for sandy supporting bases of a coastal zone.

At the same time, with an increase of a fully loaded mass of the chassis by 20%, the probability of loss of permeability increases by 4% for the sand-gravel base (at an increase in weight by 50% – 14%) and by 9% - for the sandy base (at an increase in weight by 50% – 25%).

A decrease in weight by 20% provides the full movement of the chassis without loss of permeability. A radius reduction by 20% leads to a decrease in permeability by 6% for the sand-gravel basis and by 13% - for the sandy basic basis. An increase by 20% provides the full movement of the chassis without loss of permeability.

Tire width reduction by 20% leads to a decrease in possibility by 8% for the sand-gravel basis and for 15% - for the sandy basis, an increase by 20% provides the full movement of the chassis without loss of permeability.

Deformation of a tire reduction by 20% leads to a decrease in permeability by 3% for the sand-gravel basis and for 5% - for the sandy basis. An increase by 20% provides the full movement of the chassis without loss of permeability.

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