About determination of the bearing capacity of the soil on the route of the walking robot with orthogonal drives

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Abstract. Problems of determining of bearing ability of a ground on a route of the walking robot with orthogonal drives are considered. The approach for definition of bearing ability of a ground with use of a support orthogonal walking drives a method of penetration is offered. The architecture of information - measuring system of the walking robot providing movement on a route with determining of bearing ability of a ground is offered.

1. Introduction
The research in walking mobile robots are carried out in several countries nowadays. Use of a walking way of movement gives qualitative growth of the basic parameters in comparison with wheel and caterpillar drives. There is high profile passableness and a maneuverability admitting movings in any direction and a turn on a place, an opportunity of work on weak grounds, an opportunity of management of basic reactions and maintenance of the set position of the case take place during movement [1, 2].

Practical interest represents application of walking robots in underwater researches, and also at extraction of minerals on a sea-bottom. With their help the following problems can be solved: investigation of a sea-bottom, engineering - geological researches, construction of underwater objects, a lining of underwater communications, drilling and arrangement of underwater chinks, gathering of ground adjournment, liquidation of consequences of emergencies, salvage operations [3].

Figure 1. Dual orthogonal drive of the walking robot "Orthonog".
At a significant variety of types walking drives for movement on a sea-bottom it is expedient to use orthogonal walking drive, which is characterized by high parameters of power efficiency, in a combination to simple way of adaptation to a basic surface.

Other paragraph Orthogonal drives in the dual execution (Figure. 1) are applied in the mobile robot "Orthonog", developed in cooperation by Volgograd state technical university and the Federal research-and-production center "Titans - barricades" (Volgograd), and also in a number of other walking devices.

During movement of the mobile robot parts of the mechanism of stepping orthogonal drive make perform linear movings to mutually perpendicular directions. Adaptation to uneven terrain of a basic surface in this case is carried out due to change of length of promotion of rods of vertical drives [4, 5].

The basic advantages of orthogonal walking drives are:
- An opportunity of significant decrease in expenses of energy on movement at realization of fixing of position (braking) a vertical drive for the period of interaction of its basic element with a ground;
- Use of a minimum quantity of the unified drives as which the fulfilled reliable, serially made linear drives can be applied;
- Rather simple laws of movement allowing considerably to lower the requirement, showed to productivity of means of a control system.

2. Estimation of bearing ability of a ground on a route of the walking robot

On a route of the mobile robot there can be all versions of grounds - from silt up to firm crystal breeds, and also an obstacle: taluses, cracks, etc. Thus, besides recognition and overcoming of uneven terrain of a relief is required the determining of characteristics of a ground for an estimation of its bearing ability and decision of making on an opportunity possibility of continuation of movement in the set direction is required.

Effective and operative variant of an estimation of bearing ability of a ground is its sounding by the special device - penetrometer with a rigid stamp. At sounding pressure under a stamp is measured depending on depth of its immersing.

Bearing ability of a ground is determined by a tension under pressure stamp at which there is no condensation of a ground, i.e. it is not subject to stabilization regarding a deposit and a stamp is rapidly immersed in a ground at insignificant increase in loading.

In case of application orthogonal walking drive as a stamp of penetrometer it is possible to use support of its vertical drive. In this case, at movement of the mobile robot, periodically (for example, before every step) can the sounding of a ground for an estimation of its bearing properties can be is carried out. Taking into account relatively low speeds of movement with the account concerning small speeds of movement of the walking robot, for several grounds, determining of their bearing ability can be carried out during movement without realization of additional operation of sounding.

Questions of deformation of grounds at immersing stamps of the different form are in details considered in basic researches of mechanics grounds, and also in researches on passableness of vehicles. There are several mathematical models describing deformation of a ground at the appendix to it of vertical loading. However, application of the given models in real time during movement of the walking robot is complicated, owing to necessity of the decision of complex systems of the differential equations or using a lot of the empirical factors describing properties of a ground [6].

For peculiar concept to walking robot with orthogonal drives is «a simple drive - the simple law of movement - a simple control system» it is expedient to use maximum simple way of an estimation of bearing ability of a ground.

Bearing ability and suitability of a ground for movement are offered to estimate the unique characteristic is a parameter of durability:

\[ P_p = \frac{\sum_{i=1}^{n} p(h_i)}{n}, \]
where are $p\ (h_i)$ - pressure under a rigid stamp at its press in a ground on depth $h_i$, $n$-quantity of measurements of pressure under a stamp.

At realization of sounding of a ground (penetration) depth of cave-in (deposit) of a stamp $h$, depends on pressure, characteristics of a ground, the geometrical form and the sizes of a stamp and can be determined by functional dependence:

$$h = f(p, p_p, k),$$

where $p$ - pressure upon a ground under a stamp (pressure upon a support), $p_p$ - is the parameter which describing deformation properties of a ground (a parameter of durability), $k$ -is a factor of the account of the geometrical form and the sizes of a stamp.

At Figure 2 dependences of the pressure working on a support $(p)$ from deposit of a support $(h)$ are submitted. The curve 1 corresponds to the theoretical dependence, which is received under aprioristic characteristics of a ground, a curve 2 - the dependences received as a result of measurements at promotion of a support.

![Figure 2](image_url)

**Figure 2.** To determining of bearing ability of a ground on a route of the walking robot.

The ground under a support possesses sufficient bearing ability, if $pp > pp_d$ that corresponds to performance of conditions.

$$\left[ \frac{\Delta p_i}{\Delta h_i} \right]_{2} \geq \left[ \frac{\Delta p_{i-1}}{\Delta h_{i-1}} \right]_{2}, \quad \left[ \frac{\Delta p_{i-1}}{\Delta h_{i-1}} \right]_{2} \geq \left[ \frac{\Delta p_i}{\Delta h_i} \right]_{2}, \quad \left[ \frac{\Delta h_{i-1}}{\Delta t_{i-1}} \right]_{2} \geq \left[ \frac{\Delta h_i}{\Delta t_i} \right]_{1}$$

In case of default of conditions (3) - is an insufficient bearing ability of a ground a route of the robot needs change.

For check of performance of conditions (3) information - measuring (sensory) system of the robot should provide definition of linear moving of a support of a vertical drive and pressure under a support. Besides at realization of sounding maintenance set (as a rule horizontal) positions of the case of the robot is required. Therefore, the structure of information - measuring (sensory) system of the robot should include the sensor of position (corners of an inclination) of case.

3. **The description of architecture of information - measuring system of the robot**

The architecture information-measuring (sensory) system of the robot contains three levels: executive, tactical and strategic (Figure 3).
Figure 3. The block diagram of information system of the walking platform.

The executive level includes the sensors of position of a rod and a current of the electric motor which is built-in linear drives actuators. The given sensors allow to determine a position of a rod (length of promotion) each linear drive and a current of the electric motor, which is proportional to effort, and accordingly to pressure under a support.

The tactical level includes acoustic and optical sensors of distance up to a basic surface, the sensor of position (corners of an inclination) of a case of the robot, the device of transformation and processing of signals and means of maintenance of information interaction with managing system. At an estimation of a bearing surface of a ground the sensor of position (corners of an inclination) of a case in addition supervises maintenance of its set position.

The strategic level is realized with application of distant action sonar, video cameras with the device of video capture and a scanning range finder. At making a route means of the given level carry out recognition of critical unevenness of terrain and in view of the received data on bearing ability of a ground, determine the zones which is forbidden for a support walking drives.

4. Conclusion

The suggested approach to determining of bearing ability of a ground on a route of the walking robot with orthogonal drives is differed of a simple realization and also does not demand equipment of the mobile robot additional (in relation to necessary for movement on unrecognized district) mechanisms and sensors.

Using of a parameter of durability of a ground as the base characteristic for determining of bearing ability of a ground and the suggested technique of its definition allows to lower requirements to productivity of computing means of the robot.
At application of the underwater walking robots moving on a sea-bottom, the primary goals of arrangement and operation of the underwater deposits demanding definition of bearing abilities of a ground can be solved. Obvious advantage of their application is significant reduction of terms of performance of works (in relation to a traditional way of performance of works from a surface of the sea with use of special courts and the lowered process equipment). Therefore it is actual carrying out of the further researches in a direction of increase of efficiency of the functioning, underwater robots moving on a sea-bottom, including due to development of algorithms of their adaptation to unevenness subsea terrain and to features of a ground on a route of the robot.

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