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Energetically efficient modes of the walking robots movement at its displacement across an uneven surface

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Abstract. There is the solution of one of the problems arising in the design of mobile walking robots: the problem of achievement of minimum of energy costs at displacement of a walking robot, increasing the efficiency of a multi-legged mechanism and a reduction of the developed power due to a change in the mode of motion of the multi-legged walking apparatus.

Currently, the need for mobile walking robots is quite large. This is due to the fact that the use of walking robots is the most effective compared to tracked and wheeled vehicles and is widely used at moving in difficult terrain, on a ground surface, the rescue operations in extreme situations, in space exploration in the military sphere.

One of the current challenges facing the developers of multi-legged walking machines is to increase their energy efficiency, as well as reduce the dynamic loads acting on the actuators and the machine body. Low energy efficiency and high dynamic loads are caused by the fundamental imbalance of walking movers of various types and their discrete periodic interaction with the supporting surface [7]. Methods for solving the problem can be based and are based on balancing walking movers as mechanisms, the introduction of energy recuperators [1], which convert the kinetic energy of the transported propulsion into the potential energy of some elastic element and vice versa. With the same purpose, one can purposefully control the gait [3] and the character of the carried movement of the walking mover [4, 5 and 6].

The representative of walking robots is the experimental apparatus "Ortonog" (figure 1). The walking apparatus with the original orthogonal walking movers is intended for testing control systems and demonstrating its capabilities.

Using this mobile robot as the example, we can examine in detail the nature of the motion of the walking machine. The undercarriage of the robot is represented by four blocks of orthogonal walking movers. Each of the four blocks of the undercarriage is conventionally divided into three elements: the mechanisms of vertical movement, the mechanisms of horizontal movement and rotation mechanisms. The first are composed of electric cylinders and are responsible for raising and lowering circular supports, placed on the sliding rods. Ortonog has eight such supports, two for each block of the chassis. Mechanisms of horizontal movements, consisting of guides and actuators, are designed to move the cylinder and rod with the support. Each block of the undercarriage has two sets of guides and drives, one for each cylinder with a support. Finally, the turning gears deploy the entire block of the undercarriage around a vertical axis. The entire undercarriage of the experimental machine is based on electric drives.





Figure 1. The walking robot "Ortonog".

The movement of the robot "Ortonog" on a flat surface can be performed as follows. During the rise and transfer to a new position of one group of four movers, the other group works in the traction mode and moves the robot body with a transferable group of movers forward. Thus, while driving, the Ortonog alternately uses vertical displacement drives, and the horizontal mechanisms operate continuously in traction or transferable mode. If necessary, the mechanisms of rotation are activated. Their synchronous or separate operation ensures rotation to the required angle. As can be seen from the design, the experimental walker can take turns with a minimum radius.

It is known that by choosing the driving mode, instead of the cubic dependence of heat losses in motor drives on the speed of movement [1], we obtain the dependence inversely proportional to speed [8]. This mode was obtained by studying the translational motion of the robot body with a rectilinear motion of the center of mass and propulsion as material points moving along the horizontal axis. However, when moving the walking mover to a new position, the latter, depending on the type and nature of the obstacles, rises to a certain height, in addition to the course movement, and then sinks to the ground. There is known view of the trajectory of the movement of support of walking movers, which was proposed by Professor N. Umnov (figure 2). This type of trajectory is due to the insufficient development of information-measuring systems in the 70s of the last century and the need to raise and lower the foot in any situation without "stumbling" and horizontal sliding on the ground, regardless of the unidentified profile of a ground.

However, if you have information about the profile of the support surface, you can purposefully change the laws of propulsion of the foot in the course and orthogonal directions to it. In particular, it is possible to reduce the distance traveled by the foot (figure 2, curve 2).

Figure 3 shows the translational, with a constant velocity of the body, movement of the robot with orthogonal walking movers and the movement of the foot of mass m , as a material point, in the vertical plane XOY .

The movement is supported by three drives: the drive of horizontal movement of the body, developing a force Q , that is equaled to the force R of interaction of the foot with the ground; the drive of horizontal movement of the transferable foot, which develops the force P ; the drive of the vertical movement of the transferable foot, which develops the force T . The step length along the track is equaled to L , and the distance to a single obstacle of height H is equaled to S .

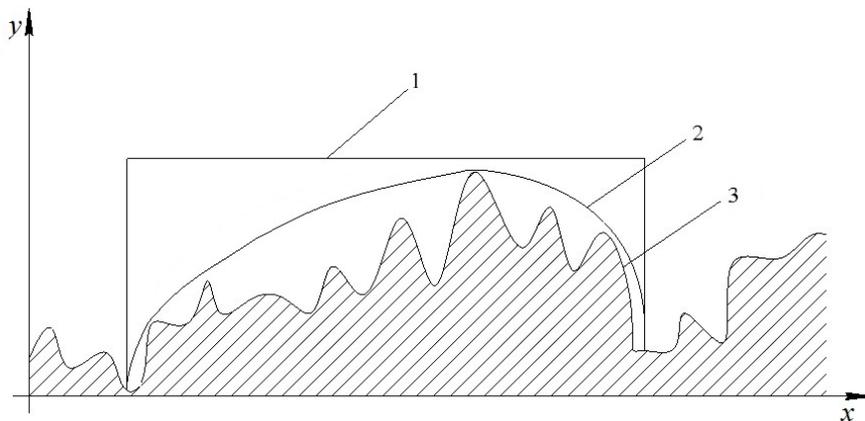


Figure 2. The trajectory of the movement of the foot of the walking mover
 1 – absolute trajectory according to N. Umnov; 2 – possible trajectory;
 3 – profile of the support surface.

The interaction of the transferable foot with the supporting surface is carried out at a height h . Among the indicators characterizing the quality of movement are taken into account: the level of heat loss W and the root-mean-square acceleration a_σ of the body in the translational course motion.

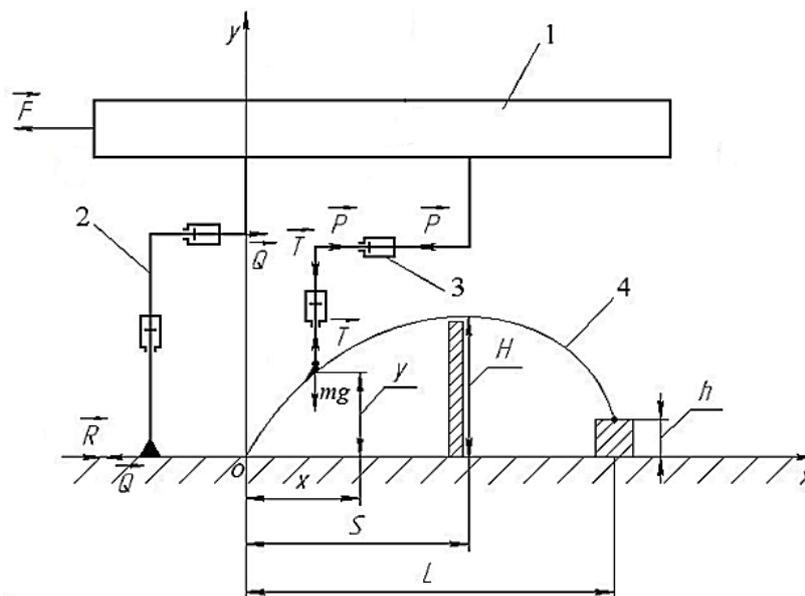


Figure 3. Scheme for settlement

1 – the body of the robot; 2 – the mover, which is interacting with the support surface; 3 – the transferable walking mover; 4 – the trajectory of the movement the foot of the walking mover.

The first indicator characterizes the energy efficiency of the mover, and the second - the comfort of movement. When studying the stationary modes of motion, these indicators are calculated on one period of motion τ (the period of the full cycle of the movement of the mover) [2].

The problem of determining such laws of motion $x(t)$, $y(t)$, which provide both overcoming obstacles and minimality either of level of heat losses W , or of root-mean-square acceleration of a body a_σ , or of complex criterion I , is posed and solved.

Thus, it follows that the movement, in which the path traveled by the foot can be reduced, is carried out by combining the operation of the horizontal and vertical movement mechanisms, therefore, with the simultaneous operation of the drives, the energy consumption should have the minimum value. To

achieve the solution of the formulated task, it is necessary to determine the value of the speed with which the leg will be lifted depending on the distance to the obstacle and its height, to develop a control system for organizing this type of movement and to prove experimentally that during such movement of the walking robot, the energy consumption for moving the walking machine will be minimal.

Acknowledgments

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References

- [1] Lapshin V V 1985 Model estimates of the energy consumption of the walking apparatus *Mechanics of Solids* **5** pp 28
- [2] Okhotsimskiy D E 1989 *Walking machines* (Moscow)
- [3] Maloletov A V 2015 *Optimization of the structure, parameters and modes of motion of walking machines with twin movers : monograph* (Volgograd: VolgGTU)
- [4] Briskin E S, Kalinin Y V et al 2017 Estimates of efficiency of cycle mechanisms *Mechanics of Solids* no 2 pp 13-9
- [5] Briskin E S, Kalinin Y V et al 2017 Assessment of the performance of walking robots by multicriteria optimization of their parameters and algorithms of motion *J. Computer and Systems Sciences Int.* **2** pp 168-76
- [6] Briskin E S, Kalinin Y V et al 2017 On controlling the adaptation of orthogonal walking movers to the supporting surface *J. Computer and Systems Sciences Int.* **3** pp 184-90
- [7] Briskin E S, Kalinin Y V et al 2014 On the energy efficiency of cyclic mechanisms *Mechanics of Solids* **1** pp 18-25
- [8] Okhotsimskiy D E 1984 *Mechanics and motion control of an automatic walking apparatus* (Moscow: Nauka)