RCL-LAB: MOBILE RESEARCH COMPLEX

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ABSTRACT

Proposed is the concept of a mobile research system, developed by Rover Company LTD (St. Petersburg, Russia). It is a complex of basic chassis carrier and spherical robotic scouts placed on it. The base chassis is a four- or six- support wheel-walking module of high permeability, capable of overcoming obstacles higher than half the wheel diameter. On the base chassis are the sources of energy, set for research equipment and complex control system.

Spherical robots are used individually or in groups to perform tactical tasks associated with the evaluation of the surface condition of the movement, the study separated from the main road traffic complex unique objects or terrain mapping.

RCL-lab is designed to study the surfaces of planets and other space objects. Can be adapted for use in terrestrial conditions.

INTRODUCTION

Experience of developing mobile laboratory facilities, operating under remote control, and in the limit – standalone, go back almost to the projects of the series "Lunokhod" [1]. The composition of the scientific equipment placed on Board of the complex, the degree of autonomy of the work, the duration of the mission are determined by the specificity of the problem, as the limiting overall dimensions [2,3]. It is impossible to offer a universal chassis that could effectively operate in a wide range of environmental conditions. The aim of this work is to increase mobility, efficiency and area coverage of the complex using a range of vehicles to place them on.

A promising solution appears to be a complex, consisting of base chassis-media of high permeability, which, in addition to the scientific equipment are lightweight, compact, relatively cheap self-propelled machine capable of performing tasks of reconnaissance, the study of single objects, separated from the track base chassis, etc. All the machines in the complex are combined into a heterogeneous group and the group itself can be part of a one- or two-component multi-agent systems [4-6].

As a base chassis, it is expedient to use a transport module with six strong conical wheels [7,8]. Currently, such a structure can be considered to be a quite developed one, and it is necessary to create on its basis an adaptive chassis that implements wheeled and walking modes [8]. This chassis is supplied with a positioner [9] the design of which provides the opportunity to work with machine agents (gripping, moving, mounting and fixing agents equipped for their placement sites).

Not less than two spherical robots can be used for that purposes. The selection of the drive mechanism, the design features of the spherical robots, assessing their performance and management are discussed in [10-15].

For choosing geometric parameters and evaluation of energy consumption systems of chassis of machines in use it is necessary to provide a mathematical model of their motion, and those were the tasks solved in the course of this work.

1. PROPOSED SYSTEM

Base chassis must have best reference-coupling and geometric throughput to ensure the delivery of the entire complex to the place of work, considering that it is not required to move at a high speed. The best patency rates has all-wheel drive chassis with six conical wheels that can implement the modes of rolling elements (energetically more favorable), and walking (while overcoming obstacles). The rotation is performed on-Board the scheme. Figure 1 shows a diagram of the chassis, and figure 2 shows a diagram of the walking.

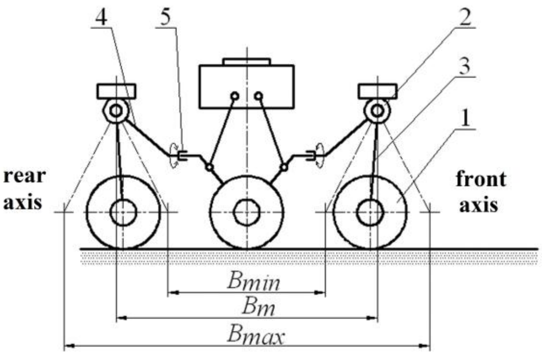

Figure 1. The scheme is adaptive chassis: 1 – the motor-wheel; 2,3 – walking mechanism; 4 – articulated frame, 5 – longitudinal joint; Bmin, Bm and Bmax – minimum, medium and maximum base

Wheel tapered profile, having a width close to half the track width of the machine allows practically to avoid gear landing on the bottom. Walking mode allows to overcome obstacles, commensurate with the height of the wheel axis. Introduction of control over the size of the base and the mutual orientation of the sections of the machine allows you to make adaptive chassis.

For a four-wheel chassis, you can develop a circuit of walking, but walking chassis will be less stable. The use of broad cylindrical wheels increases the rolling resistance and moment of resistance to rotation.

The height of the obstacles overcome in the mode of rolling can be estimated by the following dependence:

$$h \leq \left(1 - \left[\left(\frac{\varphi Z + P}{Z - \varphi P}\right)^2 + 1\right]^{-0,5}\right) R \qquad (1)$$

In the formula (1) R is the greatest radius of the wheel; Z and P are a normal reaction and force of thrust to the wheel; φ is a coefficient of adhesion of wheels with the soil.

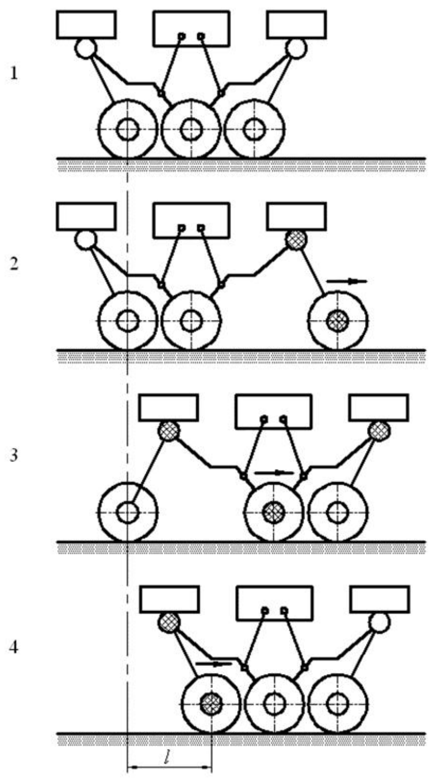

Figure 2. The diagram of realization of the wheel-walking mode (single step l): 1 – initial position; 2 – move the front axle; 3 – moving average axis and moving the rear axle. 4 – move the chassis one step; ● and ○ – traction and inhibited mode of operation of wheel-drive and walking mechanism

For walking mode, the height of the obstacle is limited by the kinematics of the walking mechanism, soil characteristics and capacity of the drives. Obtained was the theoretical relationships linking these parameters with the main parameters of the propulsion. Practically implemented overcoming obstacles at a height close to the radius of the wheel. The increase in torque of the motor drives the walking mechanism will allow to increase the height of overcoming obstacles.

For chassis with wheelbase, variable between 0.7...1.2 m at the height of the center of mass of 0.40 m calculated was value of the critical angle of rollover on the rise of about 30°. The estimated critical angle of rollover on a slope exceeds 45°.

The proposed model of interaction between rigid bevel wheel with deformable bearing surface which can estimate the rut depth and the value of the rolling resistance of the wheel. This model is used when selecting the radius of the wheel and the estimation of the parameters of the motors drive the wheels. The model is based on the approaches described in the monographs [2,3].

Required for the spherical robot-agent is choosing the optimum variant of the organization of the actuator, to estimate the height of overcome obstacles, the value of the required thrust. Important advantages of the spherical propulsion are low ground pressure, high efficiency, Omni mobile, the inability to loss of mobility due to a rollover. When you run the sphere sealed onboard equipment is protected from environmental influences. Spherical robot has a relatively small capacity, so it is possible to install only the necessary minimum of equipment.

To solve the first problem, methodology of integrated assessment of options for the design of the drive system of the spherical robot [14], based on the results of the analytical review [10] and copyright developments was proposed.

According to the results of comparison, a pendulum actuator with three degrees (figure 3 shows a diagram of the position control of the pendulum at the angle of heel), was chosen. The movement of the robot is achieved by moving the center of gravity when the pendulum is deviated by the drive mechanism.

The possibility of a spherical robot with pendulum drive in overcoming obstacles based on the analysis of developed models and conducted experiments to recognize weaknesses. The robot exceeds the threshold height of not more than 10% of the diameter of the sphere.

In the paper [15] we proposed models to estimate the components of power and energy balance of the spherical propulsion.

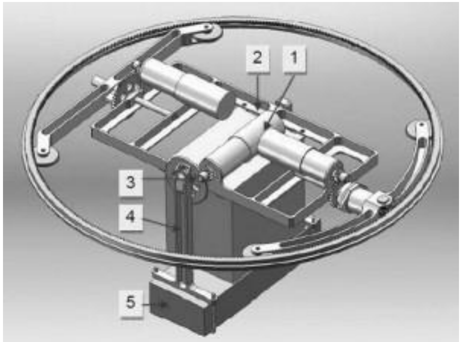

Figure 3. The elements of the pendulum device to drive 1 – drive roll; 2 – frame; 3 – row additional transmission; 4 – pendulum arm; 5 – battery (load of the pendulum)

Maximum depth *h* of immersion of a spherical robot in a deformable soil can be found by joint solution of equations (2) and (3):

$$a = \sqrt{a(D-a)}\ ; \qquad (2)$$

$$h = \left(\frac{0{,}75\, Z/a}{\left[k_c + a k_\varphi\right]} \right)^{1/n} . \qquad (3)$$

In (2) and (3) a is the radius of the imprint areas on the ground (the radius of the contact patch); Z is centered normal reaction; k_c, k_φ, n is a indicators of soil properties [2]. Derivation of expression (3) assumes a parabolic distribution law of the normal load along the axis of the contact patch, and the dependence of load-settlement for soil is based on traditional approaches [2].

Strategy of using spherical robots in groups is studied in [6]. This provides the option of deploying in the composition of a two component system that includes the aircraft for relaying signals.

2. RESEARCH RESULTS

The composition, structure, deployment scenarios of RCL-lab complex and the basic characteristics of the chassis used in its composition machines were determined. The obtained mathematical model of motion of complex machines (chassis with wheels conical, spherical robots), allowing selection of the main parameters of the chassis, to assess the mobility, energy efficiency, etc. For chassis layout with conical wheels worked out experimentally, overcoming difficult obstacles, and for a spherical robot movement in the group.

3. CONCLUSION

The principle of construction RCL-lab allows to extend the functionality of the research complex.

Options RCL-lab can be adapted to work on the Earth and planets of the earth type.

RCL-lab can be used both independently and as part of a two-component multi-agent system.

REFERENCES

1. Barsukov, V.L. (1978) Peredviznaya laboratoriya na Lune Lunokhod-1 (Mobil1 laboratory Lunokhod 1 on the Moon). Vol.2. “Nauka”. Moskau. (In Russian).
2. Bekker, M.G. (1969). Introduction to terrain-vehicle systems. University of Michigan Press, USA.
3. Wong, J.Y. (2001). Theory of ground vehicles -3rd ed.
4. Stoeter, S.A., Rybski, P.E., Erickson, M.D., Wyman, M., Gini, M., Hougen D.F., Papanikolopoulos, N. (2000). A Robot Team for Exploration and Surveillance: Design and Architecture. Proc. of the Intern. Conf. on Intelligent Autonomous Systems 6, Venice, Italy, pp. 767–774.
5. Papanikolopoulos, N., Stoeter, S.A., Rybski, P.E., Gini, M., Hougen, D.F., Erickson M. (2000). Experiments with a Team of Miniature Robots. Proc. of the IEEE Mediterranean Conf. on Control&Automation, Rio, Greece.
6. Borisov, E.G., Dobretsov, R. Yu., Matrosov, S.I. A ground-based multi-agent system on the basis of the group of spherical robots (2016). Transport and transport-technological system. Tumen, pp. 32-37. (In Russian).
7. Kemurdjian, A., Gromov, V., Kadjukalo, I., Malenkov, M., Mishkiniuk, V., Petriga, V., Rozentsveig, I. (1993). Planetokhody (Planet Rovers). 2-nd revised and added edition. Moscow, “Mashinostroenie”, 1993. (In Russian).
8. Avotin E.V., Dobretsov R.Yu., Matrosov S.I. (2013). Adaptive chassis of mobile robots. Nauchno-tekhnicheskie vedomosti SPbGPU. Vol. 3 (178), pp. 230-237. (In Russian).
9. Bogatchev, A., Kutcherenko, V., Matrossov, S., Vladykin, S., Petriga, V., Halme, A., Suomela, J., Leppanen, I., Yionen, S., Salme, S. (2002). Joint RCL & HUT developments for mobile robot locomotion systems during 1995-2002. 7th ESA workshop on advanced space technologies for robotics and

automation, ESA/ESTEC. Noordwijk, The Netherlands, November 19-21.

10. Chase, R., Pandya, A. (2012). A Review of Active Mechanical Driving Principles of Spherical Robots. Robotics. No. 1, pp. 3-23.
11. Zhang Sheng, Fang Xiang, Zhou Shouqiang, Du Kai. (2014). Kinetic Model for a Spherical Rolling Robot with Soft Shell in a Beeline Motion. Journal of Multimedia. Vol. 9. No. 2, pp. 223-229.
12. Hernández, J.D., Barrientos, J., del Cerro, J., Barrientos, A., Sanz, D. (2013). Moisture measurement in crops using spherical robots. Industrial Robot: An International Journal. Vol. 40, pp. 59-66.
13. Ocampo-Jiménez, J., Muñoz-Meléndez, A., Rodríguez-Gómez, G. (2014). Extending a spherical robot for dealing with irregular surfaces: a sea urchin-like robot. Advanced Robotics. Vol. 28. Issue 22, pp. 1475-1485.
14. Borisov, E.G., Dobretsov, R. Yu., Matrosov, S.I. (2016). The choice of the type of actuator for the spherical robot. Transport. Transport facilities. Ecology. No 2, pp. 17-29. (In Russian).
15. Borisov, E.G., Dobretsov, R. Yu., Matrosov, S.I. (2016). Energy expenditure forecasting at path generation of spherical robots within multi-agent system. Indian Journal of Science and Technology. Vol. 9(44), pp 1-9.