Mobile Robotic Systems with Walking Movers and Mechanisms of Orientation

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***Abstract* – The expediency and areas of use of walking machines are substantiated. Three simplest diagrams of cyclic (lever) walking mechanisms (four-link, four-link with possibility of changing the position of the rocker arm rotation axis, six-link) are considered. Principal diagram of the lever mechanism of orientation of walking module with two cyclic movers is propounded and its operating features are analyzed.**

Key words – mobile robotic system, walking mover, mechanism of orientation, principal diagram, operation features, motion parameters, mechanical trajectory of the pivot foot.

I. Introduction

Ground-based transport vehicles should be able to move in various operational conditions depending on their designated purpose. In the case when these conditions require vehicles operating at the territory with randomly located roadblocks, the usage of the machines with traditional movers (drives) may be essentially complicated.

The research of alternative movers for transportation vehicles and mobile technological complexes has been held since the time of wheel invention. The caterpillar and walking movers, created in the 19-th century, have steadfastly taken their places in modern technique [1; 2]. The research and development of walking movers and machines are being held in all advanced countries. At the same time because of structure complicity, dynamic unbalance and low power efficiency of walking movers, the introduction of walking machines and robots into industry and agriculture encounters dire difficulties [2; 3]. In spite of the fact that the number of established models of walking machines and robots may be estimated in several hundreds, the overwhelming majority of them are presented as laboratory mock-ups, which cannot be used in actual operating conditions and aren't adapted for real-time use.

The designing of walking machines and robots is hindered by the complexities of practical realization of optimal motion algorithm that meet certain criterions. First of all this problem is associated with difficulty of organization of the interaction between the components of the walking robot and also with the imperfection of the theory of optimal motion of walking machines. For using in various operation conditions and performing large range of tasks, which may be set for walking machines and robots, it is necessary to provide a number of important motion parameters: power efficiency, cross-country capability, roadblocks overcoming, maneuverability, limitation of maximal loads in the transmission, motion comfortableness (limitation of maximal accelerations of the machine body), shockless interaction between the pivot foot and the ground in predetermined positions etc. [1; 2; 3].

II. Cyclic walking movers and lever mechanism of orientation of mobile robotic systems

Over the last few years, a particular interest among researchers and engineers is caused by walking machines based on rigid lever systems, especially movers based on cyclic mechanisms (Fig. 1) [3; 4]. These movers guarantee predefined trajectory of support foot and are characterized as follows: as a walking mechanism they use willing mechanical converter or a new mechanism, synthesized on the chosen trajectory of support foot. The benefits of walking cyclic movers also include the simplicity and reliability of the design of legs (foots) and drives because such mechanisms usually require only one degree of freedom [3; 4].

Let's consider three simplest cyclic (lever) walking mechanisms: four-link, four-link with possibility of changing the position of the rocker arm rotation axis and six-link. Their principle diagrams are presented at Fig. 1.

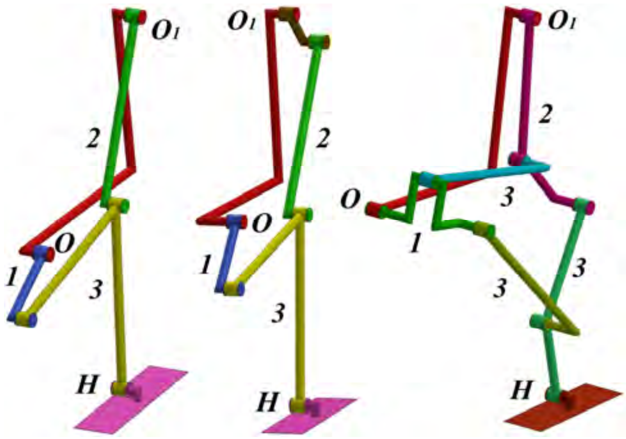

Fig. 1. Principal diagrams of cyclic (lever) walking mechanisms

The motion of all mechanisms occurs due to rotation of the link 1 (the crank). Joints O and O_1 are set on the machine frame (Fig. 1). Link 2 (rocker arm) performs reciprocating rotational (swinging) motion and carries out a role of the supporting element. Other links of the mechanisms are in planar motion and can be used to propel the foot and to provide the support of the machine. The foot is joined to the hinge H that interacts with a support surface, on which the walking machine is moving. The trajectory of the foot depends on the geometric parameters of the machine frame and elements of walking mover. Therefore, to ensure pre-defined parameters of motion (velocity, stride length, height of the foot lifting etc.) structural and kinematic analysis of each of the walking machine movers will be carried out in further stages of research.

In mobile robotic systems based on four or more cyclic walking mechanisms to ensure turning two basic methods are usually used. The first one is based on the difference between angular velocities of the movers on the left and right sides of walking machine. In the second method the additional lifting appliance is used, which raises the machine frame with walking movers above the supporting surface, turns to the desired angle and puts down until the feet contact with the ground.

Talking about the walking machine with two cyclic movers, then the use of the first method of turning in this case is impossible because of the following necessity: walking machine movers must move simultaneously in opposite phase. The second method of turning is too difficult and expensive because it requires additional systems of lifting and turning the machine. Alternative variant in this case can be a lever steering walking mover, which schematic diagram is shown at Fig. 2.

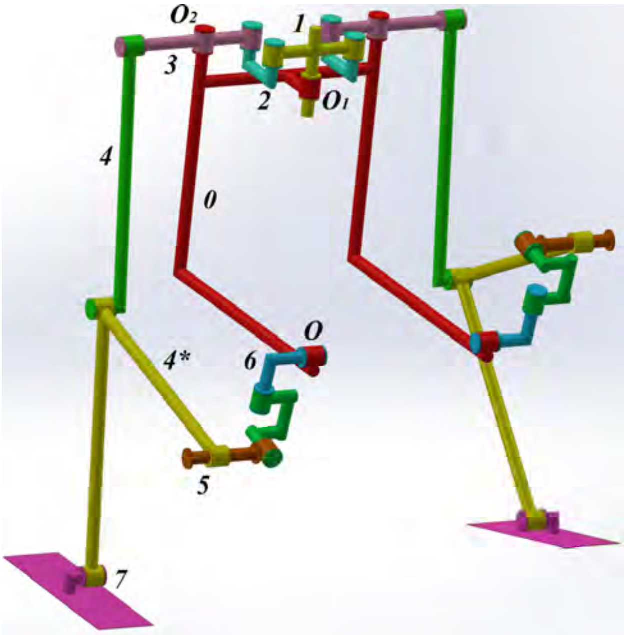

Fig. 2. Principal diagram of lever mechanism of turning of walking module based on two cyclic movers

Cyclic walking mover consists of the crank 6 and rocker arm 4 (Fig. 2), which are pivotally joined to the frame 0 at points O and O_2, respectively. The motion from the crank 6 to rocker arm 4 is transmitted through the floating link 4* designed as a curvilinear rod. In order to provide the opportunity of turning the walking mover the rod 4* joins with the crank 6 by using the slide 5, the directing rail of which can freely rotate around the axis of the crank 6. The axis of rocker arm 4 is set on the rotary shaft 3, the other end of which is connected to the four-link lever mechanism of turning (0-1-2-3). The drive mechanism for turning one link pivotally is joined to the frame 0 point. The drive link 1 of the turning mechanism is pivotally joined to the frame 0 at point O_1.

Lever mechanism of turning (Fig. 2) works as follows. The rotating motion from the crank 1 is transmitted through a system of levers 2 and 3 to the rocker arm 4 of the walking mover. The axis of rotation of the rocker arm 4 changes the angle of its position relative to the machine frame and through the floating link 4* changes the direction of the supporting foot 7. It should be noted that the rotation of the foot 7 is only possible at a time when it is not in contact with the supporting surface, that is in transferring phase. Thus, during the design process of the mechanism it is necessary to ensure alternate turning of the supporting feet on each side of walking machine.

Conclusions

The vast majority of ground-based transport vehicles have wheel or caterpillar movers. The necessity of their usage and further improvement is substantiated by relative simplicity of structure and high efficiency of operation. However, there are such operational situations where the usage of wheel or caterpillar movers is impractical, ineffective, and sometimes even impossible. So the research relating to the development of new types of movers which meet the requirements of high profile and ground permeability, environmental friendliness, mobility, etc. are continually conducted [1-4]. They particularly include walking machines.

The usage of walking method of motion allows qualitative improving of a number of basic indicators of transport vehicles in comparison with the wheel and track movers. In particular, there are more opportunities of adaptation to uneven supporting surface, the higher profile permeability and mobility, the ability of the machine motion in any direction and rotation in place, the ability to work on soils with low bearing capacity, controlling the supporting reactions and stabilizing body position while moving.

The vast majority of modern mobile (walking) robotic systems are equipped with various modifications of pantograph or insectomorphal movers. The main disadvantage of insectomorphal movers is increased power consumption due to the necessity of supporting of the machine weight. Disadvantages of pantograph walking mechanism consist in relatively large size of feet with two or more degrees of freedom, the complexity of structural implementing of legs due to the presence of translational kinematic pairs and the necessity of changing the orientation walking planes for orientation.

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