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Modeling of vibroimpact processes which occurs in feet changing of the walking units at viscoelastic grounds

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Abstract

At research of planets walking machines could be more effective than wheeled and tracked ones. They have higher ground and shape passableness. Walking machines traction properties, in execution of ground works for example, are also higher. It is especially important in traction weight deficit, characterized by weakened gravity. In the paper executed mathematical modeling of vibro-impact processes, which appears during feet changing, and investigated influence on walking unit dynamic in weakened gravity. During modeling on feet changing walking unit has been investigated as system of bodies — frame and weightless movers (feet). As design scheme was accepted the two-feet one with vertical translational motion of frame and antiphase leg motion. The frame movement is executed by the impact of kinematic impulses created by the movers, their character determined by relative contact points motion of walking mechanisms in contact phase with ground. Modes with periodical feet motion have been modelled. Time dependencies of relative vertical motions of walking mechanisms contact points was approximated by trigonometric polynomial. In mathematical describing of grounds was used the viscoelastic model with different relations of viscous and elastic properties. Elastic force, which proportional to the ground deformation and unidirectional viscous friction force, which proportional to deformation speed, were introduced. The modeling results have shown, in feet changing occurs their oscillations at the ground. The oscillations are accompanied by support reactions alteration and their maximum values could be bigger than static by few times. The effect occurs at different grounds. This property can be used for implementation of increased traction forces in individual cycle phases. At increasing of movement speed the amplitude of support reactions changing is rising. In weakened gravity conditions that could result in transformation of static stable walking to running already at low velocities. The results can be demand in walking robots development, designed to planet surface investigation.

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Keywords: mobile robots, rovers, walking mover, the interaction with the soil, the vibroimpact processes, support reactions, periodic gaits, mathematical modeling

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1. Introduction

During the research of planets walking machines could be more effective than wheeled and tracked ones [1-3]. In extreme conditions they have higher ground and shape passableness [4-9]. Also, walkng machines have decreased tractional forces costs on movement resistance — for walking movers, in contrast of wheeled and tracked, ground is not an obstacle for movement, it only requires a necessary power costs on its pressing [10-13]. That's why traction properties of walking machines in ground work execution, for example, are also higher. This is significantly important in adhesion weight deficite, provided by weakened gravitation. Field tests of walking modular hardware system MAK-1 (Fig. 1), designed in Volgograd State Technical University (VSTU) for investigation of traction properties and optimization of control methods of walking robotic systems movement, have shown that traction properties significantly depends on foot interaction dynamic with ground. In the works some results of mathematical modeling of vibro-impact processes, occured in feet changing, and investigated their influence on walking unit dynamic in weakened gravitation conditions.

Fig. 1. Walking machine MAK-1

Nomenclature

A_i	coefficient of the trigonometric polynomial
B_i	coefficient of the trigonometric polynomial
c_z	normal rigidity of a ground
F_i	force, proportional to ground deformations
h	depth of footprint
j	number of the harmonic wave
k_{Cz}	coefficient, which characterize increasing of ground rigidity as result of his ductile deformations
$N_i(t)$	normal reactions under feet
m	quantity of the function values
M	mass of walking machine frame
R_i	force of viscous friction
T	cycle period
U_i	unit function, described state of i-th leg
z_0	initial state of first foot relatively to machine body
$z_a^{(r)}$	the amplitude of relative movements of feet in vertical direction
$z_{i\,max}$	maximum ground deformation
$z_i^{(r)}$	vertical movement law in relative motion