

Chapter 43

Mobile Worm–Like Robots for Pipe Inspection

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ABSTRACT

Worm-Like Robots (WLR) have a simple construction, and they do not need any special actuators such as wheels, caterpillars, or legs. Therefore, mobile vibration robots can move not only in space, but also in dense materials, which are not available for wheeled or leg-equipped robots. Worm-like motion allows moving on rough surfaces and inside liquid environments. Mobile devices, which can move without special movers interacting with the environment directly by their frame, possess a number of advantages, as compared to wheeled, crawling, and walking systems. This advantage allows creating miniature microrobots capable for moving in narrow channels, slits, vessels, and environments, inaccessible for other mobile objects. In this chapter, design of robots with worm-like locomotion is discussed, as well as an analysis of Worm-Like Robot (WLR) movement.

INTRODUCTION

In this chapter, design of robots with worm-like locomotion principle is discussed. Also, this chapter contains analysis of Worm-Like Robot (WLR) movement with different parameters.

WLR have simple construction and they do not need any special actuators such as wheels, caterpillars, or legs. Therefore, mobile vibration robots can move not only on space, and also

in dense materials, which are not available for wheeled or leg-equipped robots. Worm-like motion allows moving on rough surfaces and inside liquid environment. Mobile devices, which can move without special movers interacting with the environment directly by their frame, possess a number of advantages, as compared to wheeled, crawling, and walking systems, first of all, due to the simple design. This advantage allows creating miniature microrobots capable for moving in narrow channels, slits, vessels, and environments, inaccessible for other mobile objects.

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The mathematical model of a robot, considering as mobile vibration-driven system, consists of two solid bodies, connected by the piecewise linear viscous-elastic element and the electromagnetic drive. The system moves along a rough surface using friction asymmetry at the mass, surface contact. Both shock-free and shock modes of motion are presented to obtain dependences of the average velocity of the system on the frequency of the external periodic control voltage.

In the simplest case, a robot's body moves in one dimension, on a line or in a pipe. The motion is realized by use of changing a shape (worm-like motion). The typical biologic example is insects such as caterpillars and flatworms.

In general, any robotic system is complicated mechatronical system, which consists of mechanic, electronic, and control sub-systems. Mechanical influence to the internal masses of the robot, and the robot body is interacting with an environment with some force. Robot can be equipped of electronic control system with feedback module, which allows to carry optimal motion regime and to keep given parameters of working element under influence different external forces.

The parameters of working elements and regimes of motion depend on robot task and environment conditions. For realizing a one-direction motion, we need to have an asymmetrical dry friction force between robot bodies and surface. This nonlinear friction force could be realized by special form needles or guidelines on the contact place or by special one-way clutch mechanism. A large cycle of papers (Chernous'ko, 2000a, 2000b, 2001a, 2001b, 2002, 2003, 2005; Smyshlyaev & Chernous'ko, 2001; Figurina, 2003, 2004a, 2004b, 2005) is devoted to devices, which represent a chain of rigid links connected by rotary joints in which drives are situated. These drives create control moments internal for the multi-link robot. Dry friction acts between the multi-link robot and the surface along which it moves. By controlling the moments at the joints, and thus, the friction force applied to the mechanism, its motion from

an arbitrary initial state to the given final state can be provided.

In Chernous'ko (2003), controllable rectilinear motion along a rough surface of the system of two bodies interacting with each other via the control force was studied. In Chernous'ko (2006) and Zimmerman, Zeidis, and Pivovarov (2005) the rectilinear motion along a horizontal rough surface of the body with the moving internal mass which also moves along the straight line parallel to the line of motion of the body was addressed. The asymmetry of the friction force necessary for motion in the given direction is provided by the dependence of the friction coefficient on the sign of the velocity of the constituent bodies of the system.

In Zimmerman et al. (2001) the dynamics of the mobile system including two bodies connected by an elastic element with the linear characteristic were analyzed. The motion was excited by the harmonic force acting between the bodies.

In Zimmerman, Zeidis, and Steigenberger (2002) and Yatsun, Pezmen, and Yu (2008) the dynamics of motion of worm-like robots for the cases with infinite and finite number of bodies was discussed.

In Yatsun, Ya, Mishchenko, and Razin'kova (2007), Bolotnik, Zeidis, Zimmerman, and Yatsun (2006), and Grankin and Yatsun (2009) the mathematical model was developed and the motion of the two-mass system was studied with account of characteristics of the electric drive. In this system, one mass directly contacted the rough surface, while the second mass moved with respect to the first mass without friction.

In Chashchukhin (2008) the dynamics of controlled vibration-driven and vibroimpact motion of a mobile system were addressed. Let consider some various schemes of worm like robots, which are represented in papers: Jatsun, Zimmerman, Zeigis, and Jatsun (2007), Jatsun, Bobotnik, Zimmerman, and Zeigis (2007), Tatar, Mandru, and Ardelean (2008), Moghaddam and Hadi (2008), Mistinas and Spruogis (2002), Carnegie Mellon

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