NONLINEAR MODEL OF DELTA ROBOT DYNAMICS AS A PARALLEL MANIPULATOR WITH THREE GEOMETRIC CONSTRAINTS

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Parallel manipulators find more and more widespread use, since, due to the fact that their links work in tension or compression, they have a high stiffness of the actuator [1], and therefore a higher accuracy, as well as a much lower mass [2, 3]. In the presence of an adequate mathematical model, the modern level of development of the element base, control theory and information technologies allows to use control algorithms of almost any complexity in mechatronic systems quite reliably. Such algorithms are most easily implemented in systems with electric drives. However, the weight and size characteristics of the electric drive make its application in technical practice for movable links of the manipulator unprofitable, which imposes certain restrictions on its use. The design of the delta robot, a parallel manipulator invented by Reymond Clavel [4], freed the electric drive from this major drawback, since the actuators are stationary in this manipulator. The executive link of the delta robot, as in any manipulator with parallel kinematics, is the intersection of several kinematic chains. As a result, complex conditional relationships arise between the distances for the manipulator nodes and the coordinates of these nodes, which do not allow describing the system configuration by independent parameters. It is necessary to introduce coordinates in an amount exceeding the number of degrees of freedom of the system, which makes the Lagrange equations of the second kind inapplicable and extremely complicates the analytical solution of the inverse kinematics problem, which is necessary to construct a mathematical model of the dynamics of the system.

The authors are intensively developing the use of differentiated constraint equations and rigorous methods of analytical mechanics of systems with redundant coordinates [5] to obtain nonlinear models of systems with geometric constraints [6, 7]. The proposed application of the developed approach to the delta robot as a manipulator with three geometric constraints and three parallel kinematic chains made it possible to obtain a adequate mathematical model of its dynamics without any analytical solution of the inverse kinematics problem. The presence of a rigorous mathematical model makes it possible to use all the results of mathematical control theory in delta robot control problems. In particular, it is possible to determine the stabilizing control in the problem of stabilizing a given position of the gripper of a delta robot [8] by the method of N.N. Krasovskii [9].

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FIRST ORDER OPTIMALITY CONDITIONS FOR AN OPTIMAL CONTROL PROBLEM WITH NONLOCAL CONDITIONS UNDER IMPULSE ACTIONS

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We consider the following nonlocal boundary value problem under impulse actions: