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Modeling the dynamics of the Ball and Beam system as a mechatronic system with nonlinear geometric constraint

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Statement of the Problem: To construct an accurate mathematical models for GBB 1005 Ball and Beam system without linearization of the geometric constraint equation. To find stabilization control law supposing that additional voltage at the motor armature is used to control the system.

Methodology & Theoretical Orientation: For mathematical modeling are used the equations of motion in the form of MF Shulgin for systems with redundant coordinates. Two equilibrium positions are found out from the complete geometric constrain equation. One of them has not been studied before. As follows from the equation there are two variants of choosing a redundant coordinate. It is shown that there is principal difference between the equations of the perturbed motion first approximation in the equilibrium positions neighborhood. Two different mathematical models are constructed for each variant. Coefficients of linear stabilization control law are calculated using N N Krasovskii method for both equilibrium positions and two mathematical models. Asymptotic stability with respect to all variables was verified for a complete nonlinear system.

Findings: Graphs of transient processes are demonstrated. It was obtained that corresponding graphs (graphs of the same phase variables) are completely identical for two mathematical models (for initial perturbations compatible with the geometric constraint equations). Thus, it was shown that control as a function of time does not depend on the choice of the redundant variable. At the same time, control is a function of different phase variables for different dependent variables.

Conclusion & Significance: The obtained results demonstrate the importance of taking into consideration equations of geometric constraints quadratic terms in the construction of a mathematical model of systems with redundant coordinates. The conditions were found out when linearization of geometric constraints is permissible.

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