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Synthesis of Optimal Efforts Control in Electromechanical Systems with Elastic Mechanical Links

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Abstract

The article presents a solution, in optimal statement, of a problem of efforts control synthesis in elastic mechanisms which comprises significant forces of friction and inertia. Different methods of optimum control of electromechanical systems were compared, and the applicability of the methods based on variations calculus was proved. The application of the integral control quality criterion allowed determining the rational structure and parameters of a force regulator in elastic elements of mechanisms, during the operation in the conditions of uncertain perturbation actions. During the synthesis of the optimum effort regulator, real limitations were considered which are attached to the control impact and the conditions assuring stability of a control system with the synthesized regulator to possible changes of parameters of a controlled object are defined. The performed studies demonstrated the effectiveness of the synthesized force regulator in electromechanical systems with elastic gears in the case of changes in perturbation actions. The proposed method for the synthesis of the optimal effort regulator in elastic mechanisms was applied during the creation of the training simulator "Exit 2", which was designed to train astronauts to work in zero gravity conditions, and during the modification of MP100 balanced type manipulators with 100 kg load-carrying capability.

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Keywords: electric drive; efforts control; speed restriction.

1. Introduction

An increase of operating machines productivity is provided Problems of an improvement of testbed facilities for trying-out space technology [1], astronauts» training simulators [2], modern manipulators and robotics systems [3] led to an emerge and an intensive development of a new class of electromechanical force compensation systems

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(EMFCS) [4]. The main requirement for a practical implementation of EMFCS is a high-precision compensation of components of forces using an electric drive (ED), caused by the gravity of moved objects, forces of friction and elasticity of mechanical gears, as well as the force of inertia of a controlled object and an actuating unit [5]. For determination of limits providing the required quality of forces» control in the discussed EMFCS, it is proposed to perform synthesis of control devices in optimal statement. Analysis and comparison of advantages and disadvantages of nowadays approaches to the synthesis of automated systems, produced with an implementation of the maximum principle of LS Pontryagin [6], analytical design of optimal reg lators [7], adaptive methods [8], neural networks [9] and fuzzy logic [10] showed that the synthesis of EMFCS is reasonable to perform with implementation of calculus» methods variations [11].

2. Mathematical description

At the initial study stages of EMFCS, the solution of a problem of synthesis of force regulator is offered to be carried out with use of the linearized mathematical model of the dual-mass electromechanical system [12]. A mathematical description of a system, which regulates forces in elastic elements (EE) of the mechanical gear obtained in [13]. In the modern control theory, structural and topological methods of problem solving of analysis and synthesis of multicircuit automatic systems with application of directed graphs are widely used. An application of Mason's directed graph [14] and correct standard allowances allowed obtaining the mathematical description of EMFCS, which is presented in the form of Mason's graph in Fig. 1.

In the graph given in Fig. 1бcoordinates of the studied system have the following notations: Ω_D, Ω_M – speeds of the motor and the object; M_0– the constant component of the moment generated by gravity of the weight relieved object; M_{Ea} – the moment, proportional to a value of changing external force, applied to the object of control for its movement; M_D and M_{EL} – moments of the drive and EE; U_{AC} – the signal of the drive's current specification, which is proportional to moment M_0; U_{FF} – the feedback signal by force. In the presented mathematical model, EMS with EL moment M_{EL}, speed Ω_M and perturbance ($M_0 + M_{Ea}$) must be set to a drive's shaft.

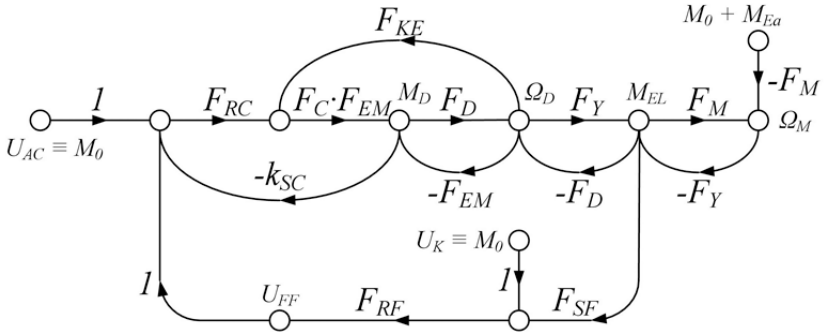

Fig. 1. Mason's directed graph of studied EMFCS.

For a small size of notes in Fig. 1, in the designation of units and transfers of graph's edges, Laplace (S) operator is not shown. The graph's transfers characterizing the properties of the unchangeable part of the system have the following notations set using Laplace transform: $F_C(S) = k_C/(T_C \cdot S+1)$ – describes properties of the converter feeding electric motor with the transfer$F_{EM}(S) = k_{EM}/(T_{EM} \cdot S+1)$. Inertial properties of the motor and the mechanism are described by transfers $F_D(S) = 1/(T_D \cdot S)$ and $F_M(S) = 1/(T_M \cdot S)$ and elastic-dissipative properties of the mechanical part of the system by transfer $F_Y(S) = (T_d \cdot S+1)/(T_C \cdot S)$. The system parameters are the following: k_{EM}, T_{EM} – the coefficient of the transfer and the electromagnetic constant of the motor's time; T_D, T_M – mechanical constants of time of inertial masses of a motor and an object, separated by EE; T_C, T_d – constants of time, considering equivalent rigidity and dissipative properties of mechanical gears; k_{SC}, k_E – coefficients of the transfer of feedback of current and feedback of the counter electromotive force of a motor.