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MULTICRITERION SYNTHESIS OF MULTIMASS ELECTROMECHANICAL SYSTEMS BASED ON STOCHASTIC MULTIAGENTS OPTIMIZATION ALGORITHMS BY PARTICLE SWARM

A method of multicriterion anisotropic regulators synthesis of combined robust control by multimass electromechanical systems based on stochastic multiagents optimization algorithms by particle swarm is developed. The examples of dynamic characteristics comparison of multimass systems with multicriteria synthesized anisotropic regulators and standard regulators.

Key words: multimass electromechanical system, multicriteria synthesis, multiagents optimization algorithm.

Statement of the problem, the connection with scientific and practical tasks. Creation of systems, capable of providing greater precision in defining the intense and disturbing influences a wide range of frequencies, is the central problem of the modern automatic control theory and practice [1].

Analysis of recent achievements and publications. To design dynamic control systems imposed various requirements for their work in different modes: the quality of transients given time the first agreement, regulation time, overshoot, etc.: at working randomly assigned, or compensation given by random disturbances or tracking error variance stabilization [2]. For such systems, in most practical cases using standard PID controllers can not perform the technical requirements for the system, which leads to the use of more complex controls and modern methods for their synthesis. One of the main requirements for modern control systems is the requirement of robustness of the synthesized system, ie system's ability to maintain applicable to her specifications when changing certain parameters within the control object and external influences [3-4]. One of the rapidly developing approaches to the synthesis of robust control systems is the synthesis of regulators, minimizing different norms target vector control [5-7]. To improve the accuracy of the control system is implemented in a robust combined control, which combines control with output feedback control object and open-loop control for both sets, and the perturbing effects [1, 8]. Combined effect of the control is determined by the fact that the synthesis of robust control is used all the available information about the desired and disturbing influences [9-10] .However, when designing real control systems do not claim to norms target vector , and the vector itself the goal of robust control is not set.

The purpose of this paper is to develop a method of multicriterion synthesis of combined multimass electromechanical systems stochastic robust control, which uses information about the desired and to minimize disturbing influences for minimizing the system anisotropic norm based on stochastic multiagents optimization algorithms by particle swarm. Aim of the paper is the multicriteria synthesis and study of dynamic characteristics of stochastic robust control system by two-mass electromechanical system.

Presentation of the research material and the results obtained. Consider the original discrete system having n dimensional state vector x, m-dimensional input vector ω и p-dimensional target vector z, specified in the state space matrices A, B, C, D, so that

$$x_{k+1} = Ax_k + B\omega_k,\ z_k = Cx_k + D\omega_k, \qquad (1)$$

Average anisotropy of this system is

$$\overline{A}(G) = -\frac{1}{2} ln\, det\left(\frac{m\sum}{Trace\left(LPL^T + \sum\right)}\right), \qquad (2)$$

where the matrix $P \in R^{n \times n}$ there controllability gramian G satisfying the Lyapunov equation, and the matrix L и $\sum$ correspond to the solution R Riccati equation [6]. Problem of synthesis of the anisotropic regulators in the time domain in the form of matrices A, B, C, D implementation, by which minimizes the average anisotropy of the system (2) reduces to the calculation of three algebraic Riccati equations, the Lyapunov equation and the equation of a special form to calculate the level of anisotropy of the input signal [7].

If the anisotropy of the input sequence of discrete systems are in the range $0 < a < \infty$ the value of the anisotropic norm system $|||w|||_a$ restricted to the values H_2 and H_∞ standards system. Moreover, the average anisotropy at zero synthesis optimal controller that minimizes the anisotropic norm is reduced to the solution of two Riccati equations and such anisotropic optimal control corresponds to the optimal stochastic regulator minimizes the variance of the output signal - H_2 norm. Average anisotropy at infinite input signal corresponding to a particular fully deterministic signal anisotropic regulator is optimal deterministic robust controller that minimizes H_∞ norm. When the values of the average anisotropy in the range of input signal $0 < a < \infty$, anisotropic controller occupies an intermediate position between the regulators, minimizing H_2 and H_∞ norms. Currently almost fully developed theory of deterministic robust control based on solutions of Riccati equations for synthesis in the time domain robust controller and robust observer. Thus it is possible to synthesize the regulator which minimizes the criterion mixed based on the minimization of H_2 and H_∞ norms taken with certain weight factors. At the same time, the role of the weight factor actually plays parameter tolerance γ.

Thus there is a correlation of various problems in the theory of stochastic robust control with the objective of synthesizing anisotropic controllers for linear systems, the classical H_2 and H_∞-regulators are limiting cases of the anisotropic optimal control and optimal anisotropic regulator minimizes the functional H_∞ entropy of a closed system for certain values of its parameters γ.

Often control systems, except mining accuracy requirements or compensation of random inputs, must meet certain quality requirements for transient - since the first agreement, the regulation time, overshoot, etc. Thus, in addition to the requirements of the system under random input signals must meet certain requirements to test the effects of deterministic system - step signal. Moreover, these requirements may differ significantly for transients when developing a system of "small" and "large" effects [2].

In addition, the system often must meet certain requirements to test the harmonic signals fixed frequency, or a specified range of frequencies that are also deterministic signals. Naturally, these requirements can be satisfied by a deterministic approach, the synthesis of the designed system.

Naturally, the projected system must simultaneously satisfy all requirements of the system in different modes and with different input signals.

The basic approach to the synthesis of robust control in the time domain based on the solution of the problem of optimal control. However , in contrast to the classical approach to the synthesis of optimal control systems , the robust control in the equation of state of the original object except the control vector control is also included vector external influences. The vector of external influences characterizes the change in state of the system due to parametric and structural changes to the model of the control object.

The central idea of synthesis of robust control systems associated with the synthesis system that minimizes the criterion of quality control in the norm, but maximizing the same criterion in the norm of the vector of external influences. At the same time, by introducing into the Hamiltonian vector norm external influences with a minus sign, the synthesized system minimizes the sensitivity of the system to the changing parameters of the control object, and hence provides the robustness of the

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system. Such an approach is consistent with the game approach to an optimization problem when the first player "control" minimizes the objective function, and the second player "uncertain parameters control object" maximizes the same objective function. Moreover, since the original system described by a system of differential equations - matrix equation of state, and both players use the same objective function, then this game is called the differential zero-sum game. Original system, closed synthesized anisotropic regulator has certain dynamic characteristics, which are determined by the target vector. The possibility of solving the problem of multi-synthesis anisotropic regulators multimass electromechanical systems by appropriately selecting the target vector is shown based on the concept of functional multi-tenant state vector that can satisfy various requirements that apply to the work of multimass electromechanical systems in different modes.

We introduce the vector of the desired parameters $\chi = \{C, D\}$ whose components are the elements of the matrices C and D source system (1), which is formed using the target vector of the stochastic robust control (2). We define the initial value of the vector χ, synthesize anisotropic control and define the following parameters of quality of a closed system in different modes: the time of processing the given angle mismatch – $t_{рег}$; acceleration time to nominal speed and time, stopping - $t_{раз}$, mining harmonic error signal predetermined amplitude and frequency $\varepsilon_{гар}$, error stabilization random changes in load torque $\varepsilon_{сл}$, maximum speed of the guidance ω_{max}, minimum speed guidance ω_{min}, harshness aiming at a minimum rate $\Delta\omega_{min}$, state variables and controls that you want to restrict. Normalize these particular criteria y_i, so that they are in the range $0 \le y_i \le 1$. Approximation of the normalized value of private i-criterion corresponds to one tense situation, and if the value of the normalized value of the private criterion approaches zero, this corresponds to a calm situation. To solve this problem we use a nonlinear multiobjective optimization scheme compromises [2]

$$\chi^* = \arg\min_{z} \sum_{i=1}^{J} \alpha_i \left[1 - y_i(\chi)\right]^{-1}, \tag{3}$$

where α_i – weighting factors characterizing the importance of particular criteria.

When multicriterion synthesis control system except local criteria must take into account constraints on the state variables and control specified in the form of inequalities. Usually there is a situation when the reference point for some restrictions is invalid. In particular, it concerns the first time setpoints harmonization, deregulation, accurate processing and payment of random external influences and many other indicators of quality requirements of the system. Moreover, certain criteria as a result of the local fusion of multi may generally be fulfilled. However, a number of criteria such as the amount of control and state variables are valid. Therefore, in the nonlinear scheme of compromise (3) a combination of penalty function method [11-13] with an interior point for the local criteria and restrictions that are valid, and with an external point method for the local criteria and restrictions that are not valid, so that the objective function in (3) takes the form

$$f(\chi,r,\lambda)=\sum_{i=1}^{J}\alpha_i\left[1-y_i(\chi)\right]^{-1}+s(r)L(z)+p(\lambda)T(\chi), \tag{4}$$

where $s(r)$ and $p(\lambda)$ – weighting functions that take into account the effect of the penalty function $L(\chi,r)=r^2\sum_{i=1}^{m}\frac{1}{g_i(\chi)}$ for the interior point method and the penalty function $T(\chi)=\sum_{i=1}^{m}\frac{1}{2r}\{min[0,g_i(\chi(r))]\}^2$ for external point method. To obtain optimum performance limitations and solutions needed to $r\rightarrow 0$, a $\lambda\rightarrow\infty$.

Research objective function resulting problem (4) has shown that it is has multiextremal land type gullies and "plateau". To find the global optimum of the objective function at the beginning of such a method is used sequential quadratic programming - SQP method with random assignment multistart points covering the range of the required parameters. However, in the areas of multidimensional ravines and "plateau", this approach has proven ineffective and led to a "wandering" on the bottom of the ravine slow progress towards the global optimum in the neighborhood area of the "plateau". To increase the speed of finding the global optimum use stochastic algorithms based on multiagents particle swarm optimization [14-15].

Results of experimental investigations of electromechanical two-mass system. On the basis of experimental studies the two-mass electromechanical system found that the use of synthesized anisotropic regulators compared with standard regulators reduced the time of the first five-fold coordination, improve fluidity of movement at low speeds by 1.7 times, to reduce the error variance of the random mining master control four times. Synthesized system is less sensitive to changes in the parameters of the control object compared to a system with standard controllers.

Conclusions from the above study, the prospects of this direction. Developed a method for the synthesis of multi- anisotropic regulators multimass electromechanical systems, allows you to meet a variety of requirements that apply to the work multimass electromechanical systems in different modes. The possibility of such an approach is shown based on the concept of functional multi-tenant of the state vector. Substantiated and developed a method of choice of the matrices by which formed the target vector stochastic robust control by solving a nonlinear programming problem. To solve such multicriterion nonlinear programming problem used stochastic multiagents optimization algorithms by particle swarm. Synthesized systems are robust with respect to changes in the parameters of plant models and control of external influences by minimizing the anisotropic norm. The experimental results of the two-mass electromechanical system is developed.

REFERENSES

1. Kuntcevich V.M. Invariance and quasi-invariance of control systems / Pratsi mizhnarodnoї konferentsiї “50 rokiv institutu kibernetiki imeni VM Glushkov NAS of Ukraine”. – Kiev: Institut kibernetiki im. V.M. Glushkov NAS of Ukraine, 2008. – Pp. 61-74.

2. Voronin A.N. Multicriterion synthesis of dynamical systems. – Kiev: Naukova Dumka, 1992. – 160 p.

3. Kuntcevich V.M. Quasi-invariance, robustness and adaptation in control systems / Proceedings of scientific seminar "70 - years invariance theory." – M.: Izdatelstvo LKI, 2008. – Pp. 61 – 90.

4. Kuntcevich V.M. From one object control problems - the problems of control object classes / Problemy-upravlenija-i-informatiki. – 1994. - № 1-2. – C. 3-15.

5. Diamond P., Vladimirov I.G., Kurdjukov A.P., Semyonov A.V. Anisotropy – based performance analysis of linear discrete time invariant control systems // Int. J. Control. – 2001. – V. 74. – Pp. 28 – 42.

6. Vladimirov I.G., Kurdjukov A.R, Semyonov A.V. State-space solution to anisotropy-based stochastic H_∞ – optimization problem // Proc. 13th IFAC World Congress. – San-Francisco (USA). – 1996. – Pp. 427 – 432.

7. Semyonov A.V., Vladimirov I.G., Kurdjukov A.P. Stochastic approach to H_∞– optimization // Proc. 33rd IEEE Conf. on Decision and Control. – Florida (USA). – 1994. – Pp 2249 – 2250.

8. Kuntcevich V.M. Control under uncertainty: guaranteed results in problems of control and identification / K.: Naukova Dumka, 2006. – 264 p.

9. Hoyle D., Hyde R., Limebeer D.J.N. An H_∞ approach to two-degree-of-freedom design / Proceedings of the 30 th IEEE Conference on Decision and Control. – Brighton: 1991. – P. 1581-1585.

10. Limebeer D.J.N., Kasenally E.M., Perkins J.D. On the design of robust two degree of freedom controllers / Automatica. – 1993. – №29. – Pp. 157 – 161.

11. Batishchev D.I. Multicriteria selection to suit individual preferences / D.I. Batishchev, D.E. Shaposhnikov. – Nizhny Novgorod: IPF RAN, 1994. – 92 p.

12. Shtouer R. Multicriterion optimization. Theory, computation and application / – M.: Radio-i-svjaz, 1992. – 504 p.

13. Nogin V.D. Multicriteria decision making environment: a quantitative approach / V.D. Nogin – M.: Fyzmatyzdat, 2004. – 176 p.

14. Clerc. M. Particle Swarm Optimization. – London: ISTE Ltd, 2006. – 244 p.

15. Gazi V., Passino K.M. Swarm Stability and Optimization. – Springer, 2011. – 318 p.

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