DEVELOPMENT OF A ROBUST AIRCRAFT CONTROL SYSTEM IN CONDITIONS OF DISTURBANCES

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In this paper a mathematical model of the dynamics of an airplane in a vertical plane is developed. The features of the robust structural synthesis procedure as applied to the system of the type under study are presented. The optimization problem for the system under study was solved using the mixed sensitivity method. The modern approach to solving the problem of robust structural optimization is based on the formation of the desired frequency characteristics of the system by expanding the object by introducing weighted transfer functions.

Introduction

The problem of ensuring quality control of the aircraft, especially in the case of a disturbed atmosphere, is currently relevant. To solve this problem, robust regulators based on H_∞ – control theory are used. In recent years, methods for the synthesis of optimal robust controllers have been one of the central issues of control theory, which remains somewhat unresolved [1–3].

I. Mathematical description of the control system

Consider the dynamics of the aircraft in a vertical plane. The dynamic airplane model in the vertical plane is described by a 5th order equation with phase coordinates: x_1 – relative height, m, x_2 – translational speed, m/s, x_3 – pitch angle, $deg.$, x_4 – pitch angular velocity, $deg./s$, x_5 – vertical speed, m/s. The first three coordinates are measured. The control variables are: u_1 – spoiler angle, $deg. \times 0.1$, u_2 – translational acceleration, m/s^2, u_3 – elevator angle, deg.

Taking into account the parameters of the aircraft, as well as the moments of inertia and their derivatives, the matrix coefficients are obtained:

$$A = \begin{pmatrix} 0 & 0 & 1.1320 & 0 & -1 \\ 0 & -0.0538 & -0.1712 & 0 & 0.0705 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0.0485 & 0 & -0.8656 & -1.0130 \\ 0 & -0.2909 & 0 & 1.053 & 0.6859 \end{pmatrix}$$

$$B = \begin{pmatrix} 0 & 0 & 0 \\ -0.12 & 1 & 0 \\ 0 & 0 & 0 \\ 4.42 & 0 & -1.665 \\ 1.575 & 0 & -0.0732 \end{pmatrix},$$

$$u = (u_1, u_2, u_3).$$

The system has poles of $-0.78 \pm 1.03j, -0.0176 \pm 0.1826j, 0$. There are no zeros.

II. Research methods

Consider the method of weight functions, which allows you to improve the efficiency of the control system [4–7]. This method is described below.

Let $z(s) = W(s)y(s)$, where $W_z(s)$ – is the matrix weight function, which can be selected depending on the characteristics of the systems. The block diagram of the system is shown in Figure 1.

The transfer function matrix T_{wz} of the closed-loop system has the form [6,7]:

$$T_{wz} = W_z(1 - GK)^{-1}W$$

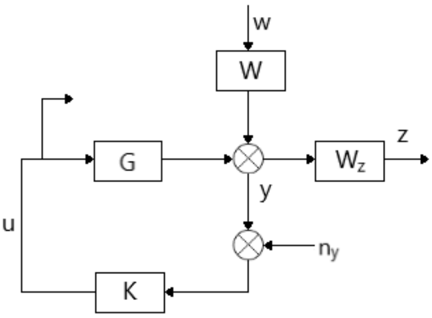

Fig. 1 – Block diagram of a system with weight functions

It can be noted that weight functions allow you to set requirements in the frequency domain for the characteristics of a closed system in terms of the quality of transients and robust stability [4,6].

, Based on the flowchart (Figure 1), we can write $T_{wz} = W_z T_{wy}$, if W_z is reversible correct. Then it turns out $T_{wy} = W_z^{-1} T_{wz}$, and then

$$\|T_{wy}\|_\infty \leq \left\|W_z^{-1}\right\| \|T_{wz}\|_\infty$$

or

$$\|T_{wy}\|_\infty \leq \gamma_{min} \left\|W_z^{-1}\right\|_\infty \tag{1}$$

if W_z is a diagonal matrix and has the form:

$$W_z = \begin{bmatrix} W_{ze} & 0 & \cdots \\ 0 & W_{ze} & \cdots \\ \vdots & \vdots & \ddots \end{bmatrix}$$

where W_{ze} — correct stable transfer function, from (1) it follows:

$$\bar{\sigma}(T_{wy}(jw))) \leq \gamma_{min} \left| W_{ze}^{-1} \right|, \forall w, \qquad (2)$$

where $\bar{\sigma}$ – maximum singular number, γ_{min} – optimality level.

Inequality (2) is considered the main one for choosing W_{ze} (as well as W_z).

III. Research results

Weighted frequency functions are selected as follows [8–9]:

$$W_1 = \frac{1}{s+0.01} \begin{bmatrix} 1 & 0 & 0 \\ 0 & 10(0.02s+1) & 0 \\ 0 & 0 & 1 \end{bmatrix},$$

$$W_3 = \frac{s^2}{k} diag(3)$$

Graphs of singular values of SV and frequency characteristics are shown in Figure 2.

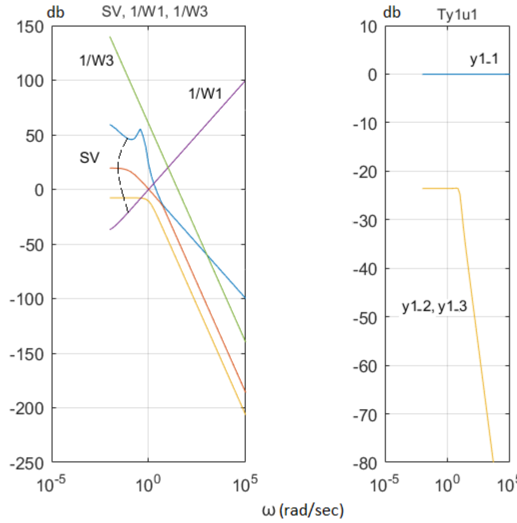

Fig. 2 – Graphs of singular values of SV and frequency characteristics

Figure 3 shows the graphs of transients with a step change in the task at each input. It can be seen that the processes are well damped, and the mutual influence of the channels is absent.

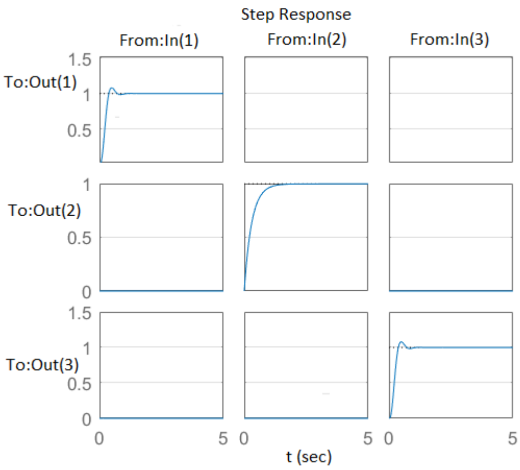

Fig. 3 – Transients of an aircraft in a vertical plane

IV. Findings

The paper presents the main approaches to the robust structural synthesis of an aircraft control system. A mathematical description of the aircraft dynamics control system in the vertical plane is obtained taking into account wind disturbances. The movement of the aircraft in the vertical plane is a special case of the longitudinal movement of the aircraft and is described by a system of fifth-order equations. We consider the method of weight functions, which helps to improve the operability of the aircraft control system in conditions of wind disturbances. Matrices of weight transfer functions are selected that provide requirements for robust stability and the quality of transients to the characteristics of the system under study in the frequency domain. The effectiveness of the proposed method is confirmed by the results of modeling a synthesized system.

V. References

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