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DEVELOPMENT OF OPTIMAL CONTROL FOR THE SERVO DRIVE OF THE AVIATION SIMULATOR

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Simulators are used in many areas of technology, especially in modeling of movement of various controlled objects, including airplanes. Electro-hydraulic servo drives (EHSD) are applied to ensure high precision control of the aircraft simulator platform. The problem of synthesizing EHSDs for aircraft simulators is still relevant despite the widespread use of such drives in aircraft control systems, robots, power plants, machine tools and testing machines. This is explained by the fact that real EHSDs refer to nonlinear systems that in general have insufficiently defined and non-stationary parameters when used in simulators.

Modern methods of control theory allow to optimize EHSD, providing the required quality indicators of dynamic characteristics.

However, the successful solution of the problem of optimization of EHSD largely depends on the completeness of information about the influence of various factors on the parameters of the drives. It is advisable to seek a solution in the class of robust systems given the uncertainty of this influence. The widely used EHSD scheme consists of a hydraulic cylinder (HC), a displacement sensor and an electro-hydraulic amplifier (EHA) (Figure 1).

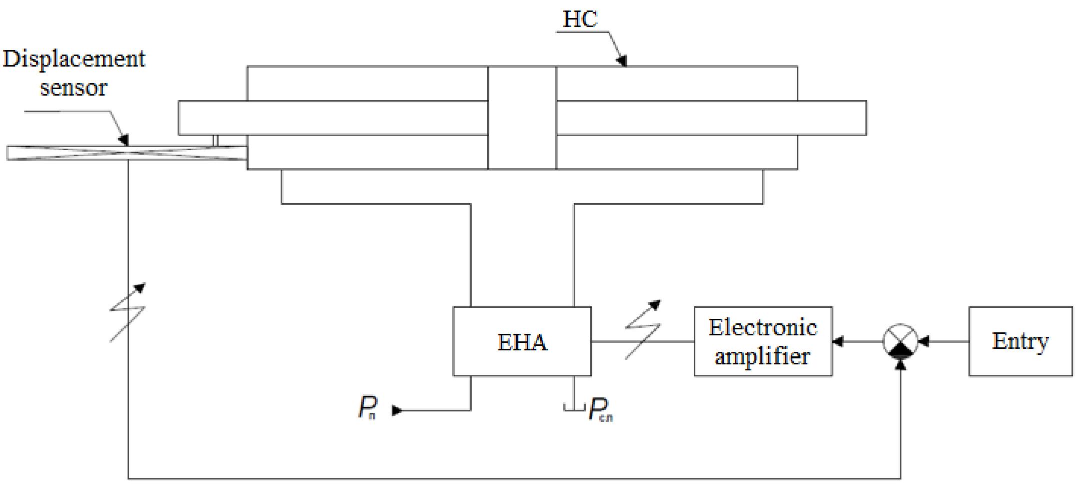

Figure 1. Electro-hydraulic servo drive scheme

The mathematical description of the dynamic processes in such EHSD can be represented by the following equations [1, 2]:

$$\frac{dp_n}{dt} = \frac{2B_f}{V_0}\left(Q_v - F_c\frac{dy}{dt}\right);$$

$$F_c p_n = m\frac{d^2y}{dt^2} + k_{fr}\frac{dy}{dt} + P_f ,$$

where B_f – bulk modulus of fluid;

V_0 – volume of fluid in one cavity of the hydraulic cylinder with the average position of the piston;

Q_v – fluid flow rate through distribution valve of electro-hydraulic amplifier;

F_c – working area of hydraulic cylinder piston;

y – displacement of hydraulic cylinder rod;

m – sum of the masses of the piston, hydraulic cylinder rod and the mass of the control device driven to the rod;

k_{fr} – coefficient of viscous friction;

P_f – external force.

The parameters of the proportional controller were selected in the presence of feedback on state variables in order to ensure the stability of the closed system and optimize the transient characteristics. The solution is obtained using the Riccati equation and the system control equation [1,3,4,5].

$$PA + A^T P - PBR^{-1}B^T P + Q = 0\,;\qquad u = -Kx\,, \tag{1}$$

where $K = R^{-1}B^T P$ – coefficient matrix of state variable regulators;

P – nonnegatively defined symmetric matrix;

Q и R – positive definite symmetric weight matrices. In this case: $Q = I$ – unit matrix, $R^{-1} = \frac{1}{r}$, where $r = 1$ – weight coefficient.

Regulators in the form of corrective devices can also be designed based on search optimization methods [5].

The standard form of the equations of state of a linear stationary continuous system is:

$$\frac{dx(t)}{dt} = Ax(t) + Bu(t)\,;\qquad y(t) = C(t)\,, \tag{2}$$

where $\frac{dx(t)}{dt}$ – time derivative of the state vector $x(t)$ of dimension $(n \times 1)$;

A – system coefficient matrix $(n \times n)$;

B – entry matrix $(n \times m)$;

C – exit matrix $(r \times n)$;

$u(t)$ – entry vector of dimension $(m \times 1)$;

$y(t)$ – exit vector of dimension $(r \times 1)$.

The optimal values of the regulator coefficients were determined so as to ensure the minimum value of the integral criterion, which takes into account the time and error modulus, with a step input signal [6]:

$I = \int_0^T t\left|e(t)\right|dt$,

where T – the upper limit of integration is chosen arbitrarily so that the integral tends to the final value. It is usually convenient to choose T equal to the settling time T_{SET};

e – error after adder (Figure 2).

The block diagram of EHSD with feedbacks on state variables is presented in Figure 2 [6, 7, 8, 9,10].

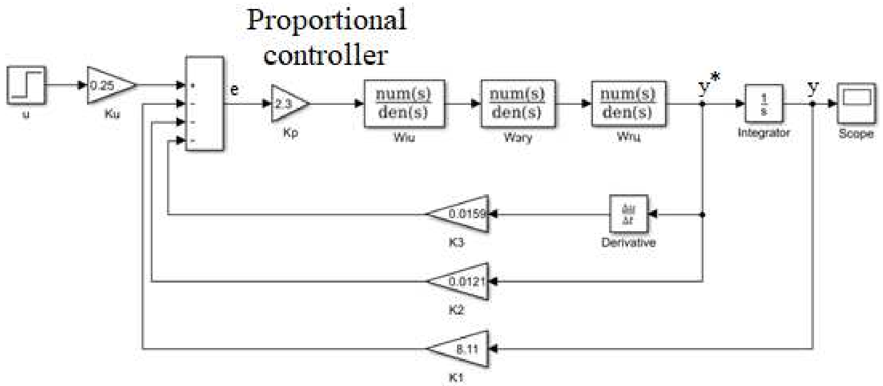

Figure 2. The block diagram of EHSD with feedbacks on state variables

Figure 3 shows the transient characteristics of EHSD with a synthesized regulator for state variables.

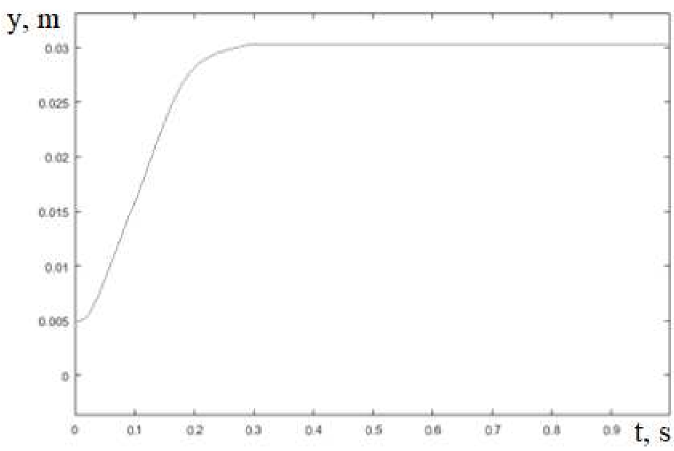

Figure 3. Transient characteristic of EHSD with an additional regulator for state variables

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