Synthesis of the control system of the manipulator robot

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Abstract. The manipulator robot is composed of a series of subsystems: actuators (DC motors); mechanical transmissions (gear reducers); articulated bars connected by rotational couplings (mechanical structure). According to the control strategy of sequential positioning of the robot's individual joints, the controlled elements are the DC motors in each coupling, while the mechanical structure subsystem becomes a source of disturbances.

In this case, the control problem with the manipulator is reduced to the determination of the mathematical model of the DC motor and the synthesis of the control algorithm (PID controller) that ensures the imposed performance of the system.

The mathematical model of the selected DC motor СЛ-361 has been determined analytically and is represented by the transfer function

$$H_m(s) = \frac{\Theta_m(s)}{U_a(s)} = \frac{3027.2}{s^3 + 223.52s^2 + 12133.14s}, \tag{1}$$

where U_a is the voltage applied to the rotor (control value); θ_m – rotor position (the control parameter, in radians).

Analyzing the transfer function (1), it is observed that the control object contains astatism. The presence of astatism leads to zero steady-state error for the unperturbed closed-loop system. It follows that it is sufficient to use a proportional P controller to achieve a zero steady-state error.

In accordance with [1, 2], for industrial robots performance indices, are required that lead to a critically damped response and it is recommended the overshoot σ<5% and settling time t_s<1*s.*

For synthesis of the P controller, the Maximum Stability Degree method is proposed, which provides the designed systems with aperiodic processes and a short settling time [3]

$$J = \sqrt[r-1]{\frac{a_{r-1}}{ra_0}} = \sqrt{\frac{a_2}{3a_0}} = \sqrt{\frac{12133.14}{3}} = 63.6; \quad (2)$$

$$k_p = \frac{1}{k}\left[a_0 J^r + a_r\right] = \frac{1}{k}\left[a_0 J^3 + a_3\right] = \frac{63.6^3}{3027.2} = 84.98, \quad (3)$$

where *J* is the maximum stability degree; k_p - the tuning parameter of the controller; $a_i, i = (0,...,r)$ - the coefficients of the transfer function (1); r - the order of the transfer function of the control object.

However, as a result of the simulation in Matlab Simulink of the designed control system, it was found that the use of a proportional controller does not eliminate the steady-state error in the case of the disturbed system.

To solve this problem, a disturbance compensation circuit was implemented

$$H_c(s) = \frac{H_T(s)}{H_R(s)H_m(s)} = 0{,}00567s + 0{,}44 \cdot \quad (4)$$

As a result, disturbances of constant character, caused by resistive moments in the couplings, are eliminated, the steady-state error becomes zero, and the transient process of the disturbed system is critically damped, with a settling time t_s=0,11*s* (ε_{st}=±2%) that is almost identical to that of the undisturbed system.

References

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