Synthesis of Digital Two-Circuit Control Systems With Dynamic Correction for Arm Manipulator

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Abstract— **The method of multicriterial parametric synthesis of two-circuit systems with discrete controllers in the space of parameters of their adjustment, including periods of discreteness of system contours is offered. The example that proves the effectiveness of this method was shown. The developed control system was applied to the simulation model of arm manipulator.**

Keywords— controller, differentiator, parametric synthesis, arm manipulator

I. Introduction

The practice of complicated technological objects automation showed that it is largely unsuccessful to provide an acceptable control quality when implementing an automatic control system with a single-circuit structure by using only the deviation of the controlled value from the task. Especially, when these objects are characterized by a significant delay in the channel of primary control action at high demands on the accuracy of maintaining the control value both in the established and in transition modes. The example of such an object is an arm manipulator, where it is hard to receive a good quality of positioning without control of additional parameters except the angle of the joint [1].

It is possible to increase the quality of control of such objects, in particular, by inclusion into the control circuit the additional signals based on derivatives of one or more intermediate adjustable values. Thus, in systems built on this principle, it is taken into account not only the deviation of the controlled value but also the speed of its change, therefore they are called systems with dynamic correction.

In the simplest case, the derivative of the signal is used only from one auxiliary adjustable value that responds to the control action much faster than the main controlled value, and this signal must only act in transient modes. Using an additional variable causes the system to become two-circuit, and its solving is complicated by the need to provide sufficient stability reserves and quality indicators for both system circuits.

With proportional inertia of the contours, the best result could be received by the method of multidimensional scanning usage [2], but its implementation is quite complicated. Therefore, the described above problems remain relevant.

Therefore, the purpose of this work is the synthesis and research of systems with dynamic correction using the method of multi-criteria parametric optimization [3], which allows improving the quality of control of dynamically complicated objects such as robotized arm manipulators. On the next step, the simulation model of an arm manipulator will be designed. As a result, the simulation model of the manipulator will be implemented with the digital two-circuit control system with dynamic correction.

II. Description of the Method of Synthesis

The peculiarity of systems with dynamic correction is that in the object an inertial main part with a main control value Y and a low-inertial part with an auxiliary adjustable value Q are allocated (Fig. 1). These values with the help of measuring converters are converted into corresponding output signals $y(t), y_1(t)$. The signal $y(t)$, is sent directly to the controller, and the signal $y_1(t)$ – through a differentiator, which is implemented as a real differential transfer function, that helps to improve the dynamics of the system. Therefore in practice, such systems are more often classified as systems with differentiator [2]. The need for a differentiator is determined by the requirements of statics. Otherwise, the system would maintain not a specified value of the main reg controlled signal, but the sum of the main and auxiliary signals.

Where $W_{0q}(s), W_{0y}(s)$– transfer functions of the auxiliary and main parts of the object; $W_p(s), W_d(s), W_q(s)$ - transfer functions of the controller, the differentiator and the measuring converter of the auxiliary adjustable value. In this case, if both controlled values have the same physical nature, the transfer function (TF) of the object, in general, is equal to $W_0(s) = W_{0q}(s)W_{0y}(s)$.

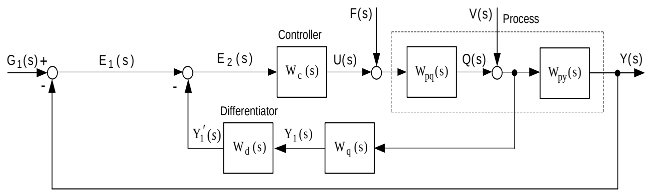


Figure 1. Structural diagram of a two-circuit system with dynamic correction

As can be seen from (Figure 1), the system contains two contours – internal and external with corresponding deviations $E_2(s)$ and $E_1(s)$.

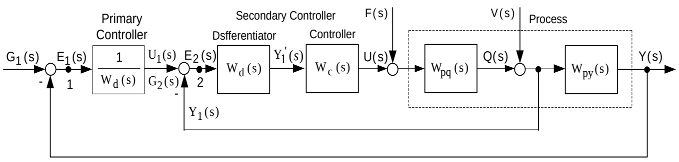
Typically, when implementing such systems, a differentiator is used in the form of a real differential link with the operator:

$$W_d(s) = \frac{K_d T_d s}{T_d s + 1}, \quad (1)$$

where K_d – gain coefficient, T_d – the time constant of differentiation.

This two-circuit system can be presented as a complex of two independent external and internal circuits. This can be used for step by step calculation of the system. Partially the interrelation of the contours can be taken into account by introducing the concept of an equivalent object for the controller. Thus, the system with a differentiator can be calculated in stages, starting from the external circuit by any method of calculation of single-circuit systems.

A different approach may be proposed to improve the process of synthesizing systems with a differentiator. To purpose, the structure of a system with a differentiator (when $W_q(s) = 1$) is reduced to the structure of an equivalent cascade system with corrective and stabilizing controllers (Fig. 2). Typically, the main and auxiliary parts of an object are classified as Primary Process and Secondary Process and the primary and auxiliary controllers, as the Primary Controller and the Secondary Controller, respectively.



Structure of a system with a differentiator, equivalent to a system with corrective and stabilizing controllers

Research shows us that a PD algorithm with a filter with a differential component is implemented in the internal loop of the system. Thus, the structure of the system with a differentiator corresponds to the structure of a cascade system of type PD2-PI1. So, it gives us a possibility to calculate such systems by the corresponding algorithm for cascade systems, which are given in [3].

Unlike a one-circuit system in which, for a given stability reserve, this parameter for any point of its structure should not be less than a given allowable value; for a two-contour system, this requirement must be fulfilled at two points, each of which should reflect the behaviour of its contour. It is advisable to select these points in such a way that during the loop it is stable. This makes it possible to use the Nyquist criterion in its usual wording.

Since the structure of systems with dynamic correction is reduced to the structure of cascade systems, the methods of their calculation generally coincide. In this case, it is advisable to perform synthesis in the space of configuration parameters, using the method of multi-criteria parametric optimization adapted to digital systems [3-5].

These principals of synthesis were implemented at the model of arm manipulator (Fig.3) that was developed using the Matlab software, including the Simscape Multibody package, which is part of the Simulink simulation environment.

It consists of several main parts, which are grouped into subsystems. Model configuration is needed to connect the whole system with Solver, World frame that makes the system inertial and the Mechanism configuration block in which we can define the gravity force and its direction. The Base element is motionless and acts as a basic platform for two successively connected by joints kinematic chains.

Both chains consist of graphical elements, which also gives inertia to the whole system by defining their mass in properties settings. The chains are driven with joint element that defines the angle between them by the signal from the control subsystem.

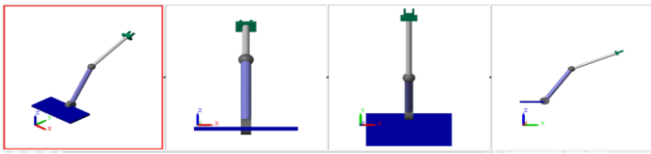


Figure 2. Structure of a system with a differentiator, equivalent to a system with corrective and stabilizing controllers

The time of discreetness during the simulation was set to 0.001s with the step of value in the channel of control 0…1 at zero point of time. The implementation of such a control system gives us that settling time that does not exceed 1.5 seconds without overshooting.

III. Conclusion

The digital two-circuit control systems with dynamic correction for arm manipulator was synthesized. The simulation model of arm manipulator was developed and supplemented with such a control system. The received dynamic characteristics show us that such control systems could be used for movement control of cinematic chains of similar arm manipulators with high speed and accuracy of stabilization.

The developed simulation model could be easily adapted to the new simulation tasks by changing the setting of the element. That also means that different types of control systems could be designed and tested without using the real arm manipulator.

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