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MODELING AND RESEARCH CONTROL SYSTEMS WITH USING PID CONTROLLER

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Abstract. Recently, digital technologies and software packages as MATLAB and MATCAD are widely used for modeling and research of control systems. When analyzing and synthesizing the control system, "manual" operations do not allow one to cover fully the systematic approach both from the constructive and computational points of view. The most widely used in practice and at the same time simplest control device is the linear PID controller. However, computer modeling and digital studies of this controller are not at the required level. This paper reveals some features of the functioning of a linear digital PID controller with three settings on a 2nd order object. Considering these assumptions, in the paper, the object modeled in the terms of output and state variables and the known theoretical parameters occurring in the ACS with a PID controller are more adequately confirmed. For the experiments, the Matlab/Simulink system with the "Simulink Response Optimization/Signal Constraint" package was used. In order to facilitate access to the package, some important features of the algorithm for solving the control problem are revealed using a specific example.

Keywords: control system, feedback, PID controller, settings, engineering quality indicators, Matlab/Simulink, block diagram, state models, transient and static characteristics.
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1 Introduction

The automatic control system (ACS) consists of the unity of the controller and the control object. Since the main principle of regulation is the principle of feedback (Rustamov, 2012, 2015; Rustamov & Mammadova, 2015), this article is devoted to the principle and study of the establishment of a feedback regulation system. Figure 1 shows the structural diagram of the feedback control system.

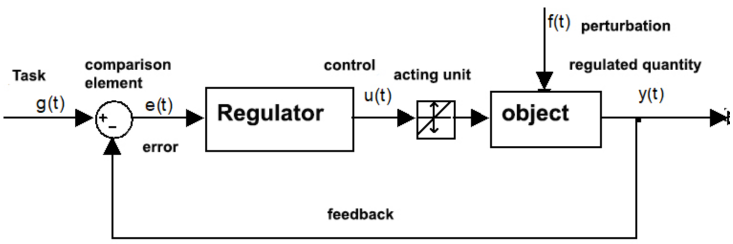

Figure 1: Structural diagram of the feedback control system

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In Ang et al. (2005); Wang et al. (2008), PID controller with various modifications were presented. From a theoretical point of view, these works are of some interest. However, due to poor digital processing, it is impossible to fully assess the practical effect.

2 Statement of the problem

The goal of setting up a regulation system is to make the regulated quantity $y(t)$ (the output of the object) equal to the task $g(t)$. In real conditions, this equality is satisfied within a certain error δ:

$$y(t) = g(t) \pm \delta. \tag{1}$$

δ is an avoidable tuning error. Its price is $2 \div 5$, of the task.

The fulfillment of condition (1) is difficult mainly for two reasons:

1. In real conditions, the existence of an exciting effect $f(t)$ that affects the object and deviates it from the task state.
2. Since the control object is a dynamic object, the transition process occurs when any input g or f changes. The main goal, equality $y(t) = g \pm \delta$, is fulfilled only after the transition process is completed.

So, the ACS should mainly perform two functions.

1. Compensating (balancing) excitatory effects.
2. Improve the transition process (for example, provide quickness, reduce oscillation). $\varepsilon = g - y$

Error C is raised when any change occurs in the system. At this time, the regulator affects the object to reduce error.

Figure 2 shows the sequence of operations in a closed system working on the principle of feedback.

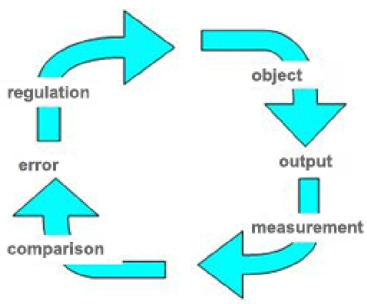

Figure 2: sequence of operations in a closed system working on the principle of feedback

The positive aspect of systems based on the principle of feedback:

1. The exciter can compensate for the effect of $f(t)$ without measuring it.
2. It senses any changes that occur in the system.

Negative aspects:

1. Full compensation is performed late (theoretically at the $t = \infty$ point).

2. High frequency cannot be obtained.

3. The sensitivity is high.

3 The solution of the problem

P, PI, PID (proportional-integral-differential), which has proven itself in practice as a controller ,controllers are used. The PID-controller consists of P, I and D-accumulators, is written with the following equation [6,8]:

$$U = K_T\varepsilon + K_i\int_0^t \varepsilon dt + K_D\frac{d\varepsilon}{dt} \quad .U = K_T\varepsilon + K_i\int_0^t \varepsilon dt + K_D\frac{d\varepsilon}{dt} \quad .$$

Here, $\varepsilon(t) = g(t) - y(t)$-dynamic error , KT, Ki , KD- are tuning parameters.

If we take the Laplace transform of each side of this expression under zero initial conditions, we can find the appropriate transfer function: $W_T(s) = \frac{U(s)}{E(s)} = K_T + \frac{K_i}{s} + K_D s = \frac{K_D s^2 + K_T s + K_i}{s}$

To get P- or PI-regulators, it is necessary to take tuning parameters $K_i = K_D = 0$ or $K_D = 0$.

The internal structure of the regulator is shown in Figure 3.

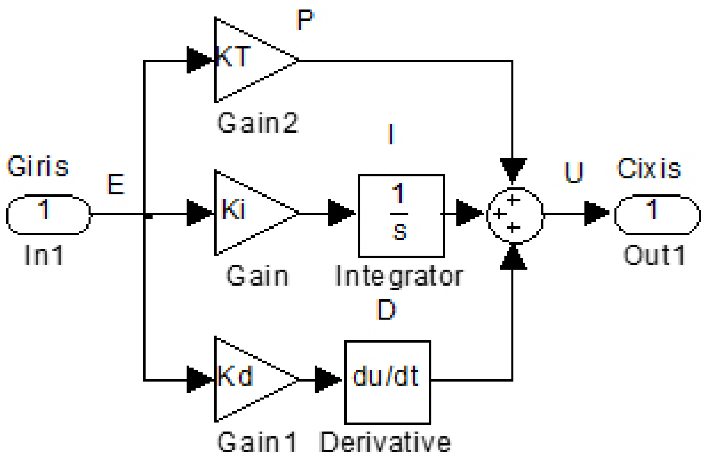

Figure 3: The internal structure of the regulator

In Simulink, the PID controller is located in the Simulink Extras/Additional Linear bunker. The quality indicators of the system depend on the value of the error parameters.

Usually, the quality of ACS is studied in the case of task $g = 1(t)$ single impulse signal. The quality indicators are determined based on the changing nature of the transition characteristic $y(t)$ in the simple case. In this work, we will consider the characteristic $y(t)$ of high quality, which has low oscillation and settling (static) error and settles quickly.

The model of the object is given as a transfer function. Picture 4 shows the implementation scheme of ACS in Simulink.

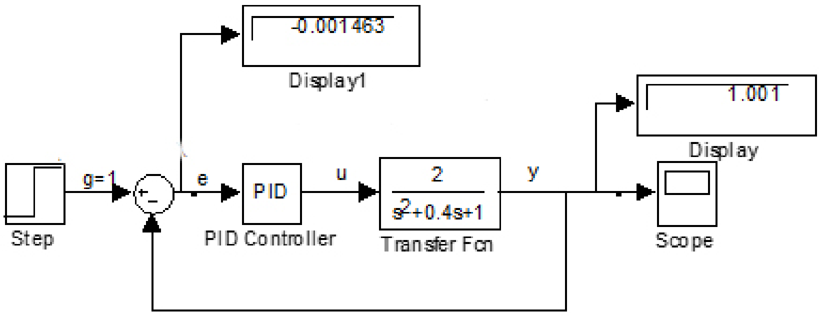

Figure 4: The implementation scheme of ACS in Simulink

The object's transfer function - $W_{ob} = \frac{2}{s^2+0.4s+1}$.
The controller is a PID controller.
Figure 5 shows the settings window of the PID controller.

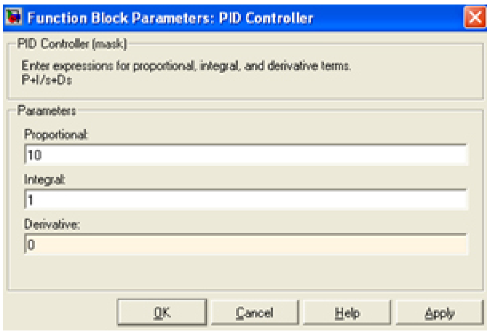

Figure 5: Settings window of the PID controller

$K_T = 10, K_i = 1, K_D = 0$ are included as starting initial values. By changing the parameter K_D, the switching characteristic $y(t)$ is improved. The goal is to obtain a transition characteristic with less oscillation and quick settling. Otherwise, the error must be $y(10) \approx 1$. The error should be observed on the display. Satisfactory switching characteristics were obtained at values of $K_T = 10, K_i = 1, K_D = 5$. The transition characteristic is non-oscillating and quickly settles to $(t \approx 3s)$.

Figure 6 shows the improved switching characteristics.

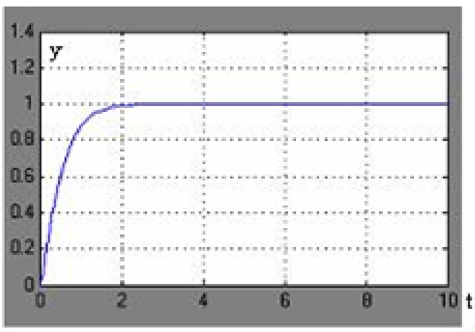

Figure 6: Improved switching characteristics

As can be seen from the display, since the static (decided) error is $\Delta_s \approx \varepsilon(10) = -0.00146$, the adjustment was made with high accuracy. The modeling time can be assumed to be $T = 10 \div 20\ s$.

The equation of the object given in the form of a situation model.

$$\overset{\mathbf{A}}{}\qquad\qquad \overset{\mathbf{B}}{}$$

$$\begin{pmatrix} \dot{x}_1 \\ \dot{x}_2 \end{pmatrix} = \begin{bmatrix} 0 & 1 \\ -2 & -1 \end{bmatrix} \begin{pmatrix} x_1 \\ x_2 \end{pmatrix} + \begin{pmatrix} 0 \\ 1.5 \end{pmatrix} u,$$

$$\overset{\mathbf{C}}{}\qquad\qquad \overset{\mathbf{D}}{}$$

$$y = (1 \quad 0) \begin{pmatrix} x_1 \\ x_2 \end{pmatrix} + 0 \cdot u \ .$$

Here are the starting conditions $x_1(0) = x_2(0) = 0$. x_1, x_2 -state variables, u-control, y-measured output quantity.

Figure 7 shows the Simulink scheme of the ACS.

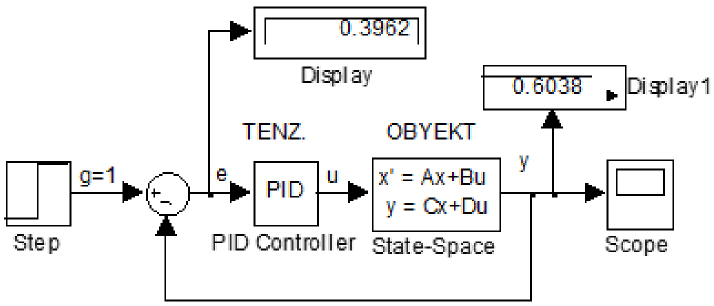

Figure 7: Simulink scheme of the ACS

Since there is only one KT parameter of the P-regulator (Ki=KD=0) , the transition characteristic $y(t)$ was improved by changing it each time from the parameters window. At the value KT=2, a satisfactory transition characteristic was obtained (Figure 8).

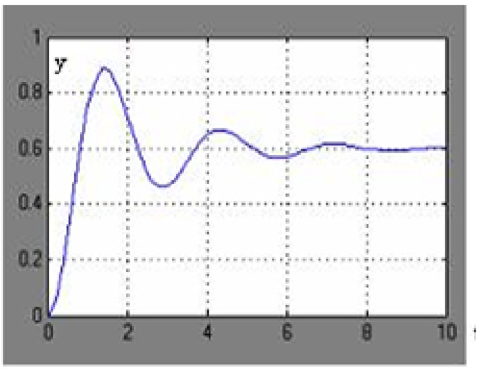

Figure 8

As can be seen from the picture and the display, the static (decided) error in the system is very large:$\Delta_s \approx \varepsilon(10) = -0.3962$. The reason why the static error exists is because the controller is a static P controller. As we increase KT , the static error decreases, but the oscillation increases sharply.

4 Conclusion

Since the main principle of regulation is feedback, the study focused on the construction and research of the closed CAP;

- the positive aspect of the systems based on the principle of feedback was shown;
- a particular attention was paid to the way in which the diagrams of individual links and graphs are obtained in Simulink;
- solving a specific problem using well-known theoretical techniques made it possible to obtain some results that have important applied significance;
- the work is focused on the use of control systems by designers, as well as their use in the educational process, even in the specialty "Fundamentals of Automatic Control Systems".

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