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PREDICATION DIGITAL CONTROL SYSTEM FOR A DRYING APPARATUS

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Abstract
The paper describes method of solving the optimal control problems of the drying process, i.e. method of compensating for delay in the system, with the purpose of conserving energy resources and maintaining the quality of dried products. There has been developed the structural scheme of the predication control system for a drying apparatus and flow chart of the computer model. The computer-aided experimental studies of system were carried out with and without predicator, by means of Simulink and Control System Toolbox software packages intended for dynamic systems modeling. The results of studies are presented in the form of dynamic responses, and the results of comparative analysis of dynamic response are given in Table.

Keywords: *Drying apparatus, optimal control system, digital control system, Smith's predicator, quality of regulation*

1. Introduction

30 percent of the energy spent in a number of enterprises is consumed in the technological drying process. Therefore, the solution of the optimal control problems of the drying process is of great importance for improving energy efficiency and product quality. The quality of the dried material, i.e. the quality of product, is determined by the value of residual humidity. The existing software and hardware applications of drying apparatus cannot provide the optimal conduct of the drying process, i.e. the minimum specific energy consumption and maximum performance, while maintaining the standard level of residual humidity [1].

The current value of residual humidity of the material depends not only on the temperature of a hot surface and the speed of movement of the drying material, but also on a number of factors that are changing randomly in time. At the same time, operational control of technological parameters of the material at the inlet to the drier cannot be carried out by modern technical aids. Therefore, information about the variations in the mentioned parameters cannot be applied for the operational impact on the value of residual humidity, with the purpose of maintaining its optimal value. Thus, the objective of residual humidity stabilization should be addressed by the closed automatic regulation system (ARS). At present, residual humidity stabilization is carried out by changing the amount of heat supplied to the material, by or the speed of movement of the material, which do not meet the stabilization essential requirements.

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2. Basic part

The paper dwells on possibilities for improving the quality of a single-channel ARS, particularly the quality of the transient responses, by changing the amount of heat supplied to the material. The possibility of improving the quality of regulation in the case under consideration, is determined as follows;

$$J_0 = \lim_{T\to\infty} J(T) = \int_0^\infty e^2(\tau)d\tau \quad (1)$$

with the criterion

$$M = \max_{\omega\geq 0}|\Phi(j\omega)| \leq 1{,}4 \quad (2)$$

with provision for the limit, where e(t) = w(t) – w_{opt}, Φ(jω) – is a Nyquist plot.

The poor quality of a thermal-channel ARS is associated with a slow response of the object, and accordingly with a great deal of delay. Taking into account information about the net value of delay of the object on a regulatory effect, by using the forecasting regulators of the object's response, under specific conditions, it is possible to substantially improve the quality of regulation. The most widespread forecasting regulator is the so-called Smith predicator [1], against which the thermal-channel ARS will have a structure that is shown in Fig. 1.

On a diagram in Fig. 1, Q(Z), W(Z), E(Z) - regulatory effect, residual humidity and regulation error, respectively; N(Z) – disturbance effect; $W_{set}(Z)$ – a given value of residual humidity of the material; $W_q(Z)$ – transient function of the apparatus by thermal channel; $W_{r2}(Z)$ – pH-regulator selected by certain methods.

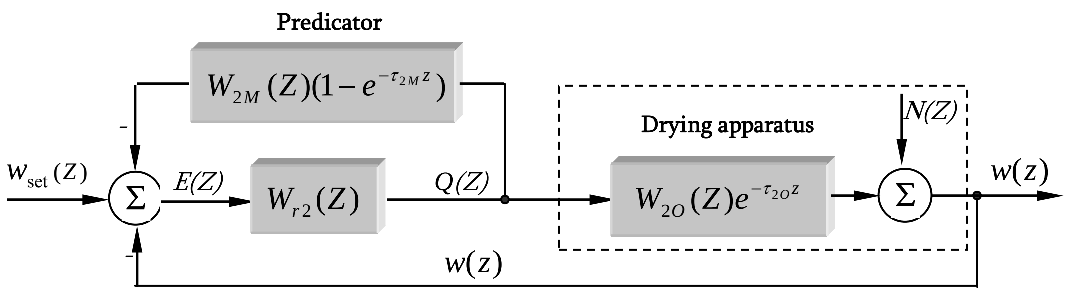

Fig. 1 Structural scheme of the predication control system for a drying apparatus

On a diagram: $W_{2O}(Z)e^{-\tau_{2O}z}$, $W_{r2}(Z)$ - the transient functions of the object and regulator, respectively; $W_{2M}(Z)(1-e^{-\tau_{2M}z}) = W_P(Z)$ - the transient function of Smith predicator, and it is determined by the object's model.

Fig. 1 illustrates the transient function of a closed system with disturbance channel (i.e. $N(Z) \to W(Z)$), which is equal to:

$$W_{cl}(Z) = 1 - \{W_{2O}(Z)W_{r2}(Z)[1 + W_{r2}(Z)(W_{2O}(Z) + W_P(Z))]^{-1}\} \quad (3)$$

If $W_{2O}(Z) = W_{2M}(Z)$ and $\tau_{2O} = \tau_{2M}$, then

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$$W_{cl}(Z) = 1 - \{W_{2O}(Z)W_{r2}(Z)[1 + W_{r2}(Z)(W_{2O}(Z)]^{-1}e^{-\tau_{2O}z}\}. \tag{4}$$

Viz, the equation characterizing the closed system, when the transient functions of predicator and model coincide, is written in the following form:

$$1 + W_{r2}(Z)W_{2O}(Z) = 0, \tag{5}$$

but without predicator

$$1 + W_{r2}(Z)W_{2O}(Z)e^{-\tau_{2O}z} = 0. \tag{6}$$

The comparison between the (5) and (6) expressions shows that under predetermined equal conditions, the reserve of stability of a system with predicator is far higher than of a system without predicator [1]. Frequently, the reserve of stability is higher by phase than $\omega_c\tau_0$, where ω_c - the crossing frequency of an open system, i.e. that frequency, for which

$$1 = |W_{r2}(e^{j\omega_c T_0})W_{2O}(e^{j\omega_c T_0})| > |W_{r2}(e^{j\omega T_0})W_{2O}(e^{j\omega T_0})|,$$

for all $\omega > \omega_c$ values, T_0 is time period of quantization.

By using PI regulator for ARS, Nyquist plot for the second summand of the (5) expression is determined according to the following ratio:

$$W_2(j\omega) = K_2K_{r2}(1 + T_{r2}(e^{j\omega T_0}))[(1 + T_{2O}(e^{j\omega T_0}))T_{r2}(e^{j\omega T_0})]^{-1}, \tag{7}$$

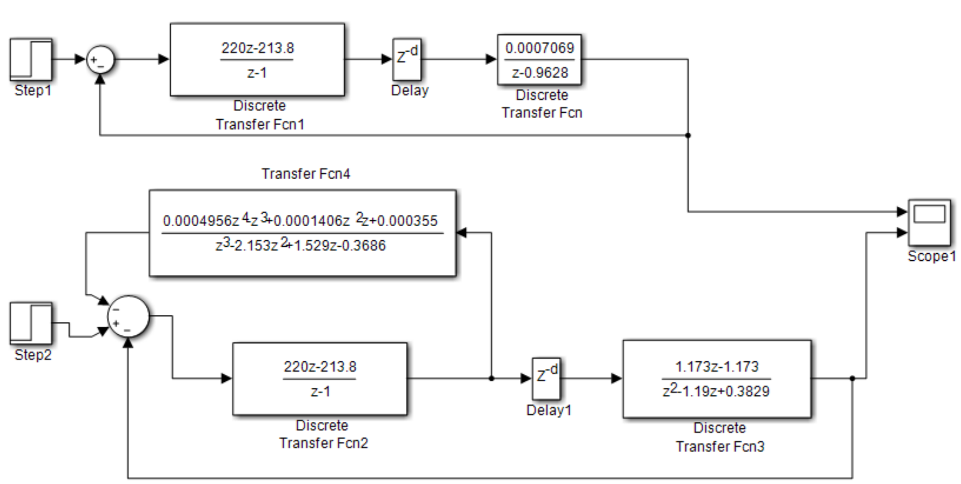
but Nyquist plot of the (7) expression is determined by the ratio

$$\varphi_2(\omega) = arctg\, T_{r2}\omega - arctg\, T_2\omega - \pi/2, \tag{8}$$

for all values. And that means that the (7) hodograph will not cross the negative real semi-axis at none of K_{r2}, T_{r2} parameters of the installation of the regulator. Consequently, the theoretically closed system remains stable, with an unlimited rise of K_{r2}. Thus, the unit step excitation on a closed system produced an ideal form of response, which is close to rectangular pulse of the unit amplitude, as well as to the duration of τ_2 [4]. The above stated considerations are completely confirmed by the practical studies, which were carried out by means of Simulink and Control System Toolbox software packages intended for dynamic systems modeling.

Fig.2, a illustrates flow chart of computer modeling of a thermal-channel ARS for regulation of residual humidity of the material with predicator, but the results of modeling are presented in the form of curves in Fig. 2,b. The indicators of the quality of system with and without predicator, to see clear which system takes precedence, are shown in Table 1.

a)



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b)

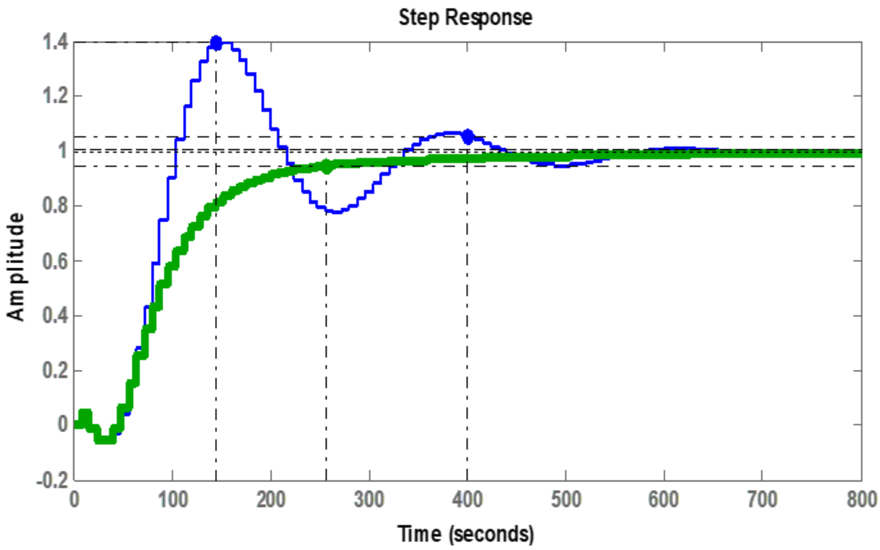

Fig. 2. Predication digital control system for a drying apparatus:
a) Flowchart model; b) Transient responses:
without predicator; with predicator.

Thus and so, it is clear from the transient responses shown in Fig. 2, b and data presented in Table 1 that the quality of the system's transient responses is higher with predicator than without it – the amplitude of the transient responses drops substantially and the time or regulation decreases.

Table 1

ARS	Quality indicators	
	T_s, sec.	σ, %
Without predicator thermal channel	400	39,7
With predicator thermal channel	257	—

The developed digital control system allows us for developing the microcontroller management system for drying apparatus.

3. Summary

The paper dwells on developing flow chart of the computer model of the predication digital control system for a drying apparatus. Analysis of the stability of system was carried out and the transient responses with and without predicator were constructed. The computer-aided experimental studies of system were carried out with and without predicator, by means of Simulink and Control System Toolbox software packages intended for dynamic systems modeling.

It is clear from the proposed transient responses and table data that that the quality of system is higher with predicator than without it.

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