PHYSICS AND MATHEMATICS

AUTOMATIC CONTROL SYSTEM FOR THE DRUM DRYER

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Abstract

The article deals with the issue of automation of the drum, taking into account the disturbing effects on the drying process. A block diagram of the automatic control system of the drum dryer is presented.

Keywords: drying, infrared radiation, automation.

In automatic control systems, the feedback principle is often used, which ensures the minimization of deviations of the controlled value from the set value, regardless of the reasons that caused these deviations [1].

Analysis of the operation of drum dryers and the results of our prospecting studies show that the degree of their automation does not allow to optimize the mode of the drying process [2,3]. This is explained by the fact that most installations are equipped with local automatic control systems that stabilize only one parameter, as a rule, the temperature of the drying agent. Such systems do not always make it possible to stabilize even the quality indicators of the dried material - grass cutting, since there is no functional connection between the optimized and controlled parameters.

Research on the drum dryer with infrared heat source shows that it is a multidimensional control object. The interaction of the controlled and control parameters is determined by the properties of the installation and the drying material. As controlled influences, based on the efficiency of control and simplicity of technical implementation, it is advisable to use the sup-

ply of source material and power consumption. Controlled quantities should characterize the quality indicators of the finished product, i.e. temperature and humidity of plant material. However, the industry has not yet produced sensors capable of measuring the temperature of the stem material in the flow. In addition, it was found that there is a lag in the temperature and humidity control channels, which practically excludes the possibility of stable accurate control of the dryer by these parameters.

There is no such delay in the control channels of the drying agent temperature, which correlates well with the temperature of the material at the outlet of the drying drum.

Thus, high quality indicators of the resulting feed additives can be ensured by stabilizing its moisture content (the main quality indicator) and the temperature of the drying agent at the outlet, which will also create a stable control system

Based on the results of studies of the statistical and dynamic characteristics of the drum dryer, it is possible to draw up the structure of its control system (Figure 1).

Figure 1. Block diagram of the automatic control system of the drum dryer

The diagram uses the following designations: $m_1(p) - m_6(p)$ - transfer functions of the control object; $\Lambda_1(p)$ and $\Lambda_2(p)$ - transfer functions of sensors; $Z_1(p)$ and $Z_2(p)$ - transfer functions of executive mechanisms; $K_1(p)$ and $K_2(p)$ - transfer functions of actuator control devices; X_1' and X_2' -

output coordinates of control devices; $R_1(p)$ and $R_2(p)$ - transfer functions of regulators; X_1 and X_2 - their output coordinates; ε_1 and ε_2 - input actions of regulators; W_{MO} and S_{CA}^0 - setting influences; S_{CA}^2 -

outlet temperature of the drying agent; W_{M2} - Humidity of the finished product of drying; G_3 - electricity consumption; G_M - the amount of raw material supplied for drying; F - disturbing effect (initial moisture content of the dried material).

for executive mechanisms:

$$G_M = X_1' \cdot Z_1(p), G_3 = X_2' \cdot Z_2(p), \quad (1)$$

for control devices, executive mechanisms

$$X_1' = X_1 \cdot K_1(p), X_2' = X_2 \cdot K_2(p), \quad (2)$$

for regulators:

$$X_1 = \varepsilon_1 \cdot R_1(p), X_2 = \varepsilon_2 \cdot R_2(p), \quad (3)$$

For control object

$$W_{M2} = G_M \cdot m_1(p) + G_3 \cdot m_2(p) + F \cdot m_3(p), \quad (4)$$

$$S_{CA}^O = G_M \cdot m_4(p) + G_3 \cdot m_5(p) + F \cdot m_6(p), \quad (5)$$

In matrix form, equations (1) - (5) can be written as follows

$$U = S \cdot X'$$

$$X' = KX$$

$$X = RE$$

$$Y = MU + HF \quad (6)$$

it follows

$$X' = \begin{Bmatrix} X_1' \\ X_2' \end{Bmatrix}; \text{ and } Z = \begin{Bmatrix} Z_1 & 0 \\ 0 & Z_2 \end{Bmatrix};$$

$$X = \begin{Bmatrix} X_1 \\ X_2 \end{Bmatrix}; \text{ and } K = \begin{Bmatrix} K_1 & 0 \\ 0 & K_2 \end{Bmatrix};$$

$$E = \begin{Bmatrix} \varepsilon_1 \\ \varepsilon_2 \end{Bmatrix}; \text{ and } M = \begin{Bmatrix} m_1 & m_2 \\ m_4 & m_5 \end{Bmatrix};$$

$$Y = \begin{Bmatrix} W_{M2} \\ S_{CA} \end{Bmatrix}; \text{ and } R = \begin{Bmatrix} r_1 & 0 \\ 0 & r_2 \end{Bmatrix};$$

$$U = \begin{Bmatrix} G_{M1} \\ G_F \end{Bmatrix}; \text{ and } H = \begin{Bmatrix} m_3 \\ m_6 \end{Bmatrix};$$

The error of discord can be expressed in terms of set points and feedback signals:

$$E = Y_0 - \Lambda Y \quad (7)$$

$$\text{где } Y_0 = \begin{Bmatrix} W_{M0} \\ S_{CA}^0 \end{Bmatrix}; \Lambda = \begin{Bmatrix} \Lambda_1 & 0 \\ 0 & \Lambda_2 \end{Bmatrix}$$

Having solved the joint equation (6) and (7), we obtain a separate expression describing the closed-loop control system:

$$Y = Y_0 \cdot \frac{MSKR}{E + LMSKR} + F \cdot \frac{H}{E + LMSKR^*} \quad (8)$$

Based on expression (7), one can analyze the system as a whole and synthesize its regulators. To do this, determine the requirements that the system must satisfy.

One of the features of drying herbs is the presence of significant disturbing influences. These influences include, first of all, the moisture content of the starting

The equation of communication between the input and output signals of the system elements in the operator form will have the following form:

material [4]. The lack of industrial sensors capable of measuring disturbances significantly complicates the automation of the process, since it is impossible to create a combined control system for deviation and disturbance. The systems of regulation only by deviation at large uncontrolled disturbances work unsatisfactorily.

Therefore, it is necessary to consider a system whose output parameters would not depend on uncontrolled disturbances, i.e. invariant system. Moreover, its structure must satisfy the two-channel condition, i.e. between the disturbance and the considered coordinate, there must be at least two channels for the signal to pass through.

Analysis of the scheme (Figure 1) from the point of view of satisfying the two-channel principle allows us to conclude that it is impossible to ensure the simultaneous invariance of all coordinates F from (the temperature of the drying agent at the outlet should remain dependent, since the moisture W_{M2} content of the material after drying is the main indicator of the quality of the process). In accordance with this and on the basis of expressions (6) and (7), we define the equations of the channels "disturbing influences - output coordinates" in matrix form:

$$Y = FH + E^*MSKR \quad (9)$$

$$\text{где: } E^* = -\Lambda_2 F m_6 / 1 + \Lambda_2 m_5 r_2 k_2 Z_2 = 0$$

Expression (8) allows you to write the equation of communication channels in a certain form. Substituting the corresponding values of the matrices and adding the right-hand side of the equation to zero, we obtain the invariance condition W_{M2} of F :

$$m_3(1 + m_5 r_2 Z_2 \Lambda_2) - m_5 m_2 r_2 k_2 Z_2 \Lambda_2 = 0 \quad (10)$$

Having solved (9) with respect to and substituting the values of the transfer functions of the system elements, obtained as a result of the search research of the dryer, we find the transfer function of the regulator that ensures the invariance of the final moisture content of the material from its initial moisture content (in this case, from the point of view of the technical feasibility of the controller, we will restrict ourselves to a second order polynomial):

$$r_2 = \frac{0,6(147p + 1)}{1226p^2 + 137p + 1} \quad (11)$$

The transfer function of the second regulator is determined based on the condition of ensuring the stability of the system. For this, it is advisable to use the D-diversity method. Suppose that to ensure stability it is necessary and sufficient to apply a proportional regulator. The analysis of the D-split curve showed that the system will be stable with a proportional controller having a gain in the range from -1.5 to + 1.5.

Finally, regulators are selected based on an analysis of the quality of management of the system as a whole. Since the control system of a drum dryer is nonlinear and has a high order, the traditional method for obtaining numerical solutions using PC programs is unsuitable (due to the large time spent on compiling and analyzing the results, and the use of programs is not effective). To solve the problem under consideration, it is advisable to use the tools available in modern automatic design systems.

The most convenient for designing a simulation model of a control system for a dryer and conducting

experiments is a complex of simulation programs for modeling and prospecting design of electromechanical systems. The complex of programs is designed to study the dynamic modes of automatic control systems based on their continuous nonlinear models, which are presented at the level of structural diagrams. The complex allows you to organize interaction with a PC at the level of structural or even functional diagrams of a dynamic system, simply describe, change the structure and parameters of the model during the experiment, automatically take the results in the form of tables, graphs, and complex quality indicators.

To use the complex, it is necessary to describe the structure of the system in a problem-oriented input language, which consists of modeling operators, control directives and changes in the model structure. To describe the model (Figure 1), the following were used: for modeling the reference and disturbing influences - elements of perturbation, for modeling control devices for actuators and sensors - inertless elements, for actuators - inertial elements and "lag" elements.

As a result of the simulation, the dynamic characteristics of the system were obtained for various variants of the transfer functions, which ensure invariance and for various values of the transfer coefficient.

To determine the degree of universality of the results obtained, the control system was investigated when the parameters of the transfer function of the control object were changed by $\pm 15\%$ (such a spread was obtained by analyzing the dryer and drying three different grass crops). Modeling showed that when using the same regulator settings, the nature of the dependencies did not change, in quantitative terms they differ from those given by no more than $\pm 5\%$.

Thus, it is more expedient to control the drum dryer using a multi-connected automatic control system that has negative feedbacks on the temperature of the drying agent at the outlet and the moisture content of the dried material. The use of the invariant principle of interconnected regulation ensures a high quality of drying, at which the error in stabilizing the moisture content of grass cutting does not exceed 0.1%.

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