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ADAPTIVE SYSTEM FOR REGULATING THE DRYING PROCESS OFCOTTON IN DRUM DRYERS

Isamiddin Siddikov[1, a)], Davronbek Khalmatov[2], Sayyora Yunusova[1]

[1]Tashkent State Technical University, Tashkent, Uzbekistan
[2]Tashkent Institute of Textile and Light Industry, Tashkent, Uzbekistan

[a)]Corresponding author: rajabovjakhongir6338@gmail.com

Abstract: The issues of creating an adaptive system for automatic maintenance of technological parameters of the raw cotton drying process are considered. The main factors affecting the drying process are determined and the mathematical dependence of these variables in the form of a discrete transfer function is revealed. The functional scheme of the adaptive control system for cotton drying has been developed, which includes a block for automatic adjustment of the regulator parameters and provides compensation for the mutual influence of technological parameters. An algorithm for estimating the parameters of the object model is proposed based on the application of the recurrent stochastic approximation method, which allows taking into account the additive random noise that is sent at the measured output. The object parameters are determined based on the thermal and material balance at the nominal operating mode of the drying drum. A method for constructing an adaptive mathematical model of the cotton drying process is developed, which provides predicting the behavior of a complex process that has a probabilistic nature. The parameters are corrected by recalculating the new estimates of the model parameters.

INTRODUCTION

For a number of modern industries, such as the textile industry, when building automatic control systems for this process, a special role is played by studying vibrations when pulling a tape with a certain amplitude and frequency [1, 2].

The process of drying raw cotton, the purpose of which is to maintain stable final moisture content of the cotton, quite is difficult to manage. Related to the following reasons:

- First, the low variable of the dried cotton on the drying drum, which causes a significant inertia of the process.
- Second, the drying drum is a pronounced distribution of parameters along the length in the drum.
- Third, the drying of cotton at a constant speed causes a nonlinear dependence of the output parameters on the input ones.
- Fourth, the process of drying cotton is stochastic, since it is influenced by a significant number of factors that are random variables.
- Fifth, the drying drum as a control object is a multi-dimensional one associated with the interconnectedness of variables [1, 3].

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About the authors：Isamiddin Siddikov

Email: rajabovjakhongir6338@gmail.com

SOLUTION METHOD

Based on the analysis of the drying process, the block diagram of the drum dryer is determined (fig.1):

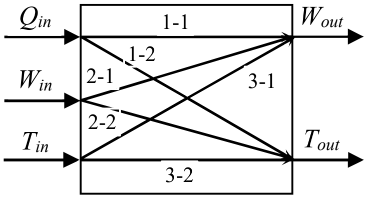

FIGURE 2. Block diagram of the drum dryer.

where is the Q_{in} - consumption of cotton, (kg/s); W_{in}- initial humidity of cotton, (%); T_{in} - temperature at the drum inlet, (°C); W_{out} - final moisture content of cotton,(%); T_{out} - the temperature of the drying agent at the outlet of the drum (°C).

For each of the control channels, the transfer functions are an a periodic link with a delay in the form of:

$$W_{ij}(p) = \frac{K_{ij}}{T_{ij}p+1}\cdot e^{-\tau_{ij}p}$$

Where is the input sequence number, - output serial number. For the experimental SBO-10 drying drum, the dynamic characteristics of each channel were obtained [1, 2].

Parameters of the transfer function of the control channels.

	1-1	1-2	2-1	2-2	3-1	3-2
Channel / Parameter	Q-W	Q-T	W-W	W-T	T-W	T-T
K	3	40	0,1	1	0,025	0,015
T, seconds	420	300	500	280	240	150
τ, seconds	240	90	480	80	120	30

K – gain factor; *T*, seconds – time constant; τ, seconds – transport delay.

When selecting the main control channel, the dynamic characteristics are evaluated, in which preference is given to the channel with the lowest constant delay. If the values of these parameters are the same, the channel that has the following parameters is selected τ/T has the lowest value.

In addition, in such cases, the technical realizations of the possibility of influencing the regulatory channel are also taken into account.

For the object under consideration, the main control channel is the input temperature of the drying agent and the output temperature: "T_{in} - T_{out}".

The block diagram of the control system is shown in **FIGURE 2**.

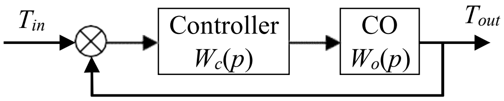

Fig.2. Block diagram of the automatic temperature control system of the drying drum.

The existing system of automatic control of the drying process does not give the desired effect, due to the lack of consideration of the interaction of variables, as well as the stochastic of external factors [4-7].

In this regard, the most promising is the creation of an adaptive control system, which is built on the basis of this system with control over the deviation of the main adjustable value T_{out} and with compensation for disturbances in the initial humidity of the cotton W_{in}, cotton consumption Q_{in}.

To ensure that these requirements are met, the controller parameter settings block is added to the control system (Fig. 3).

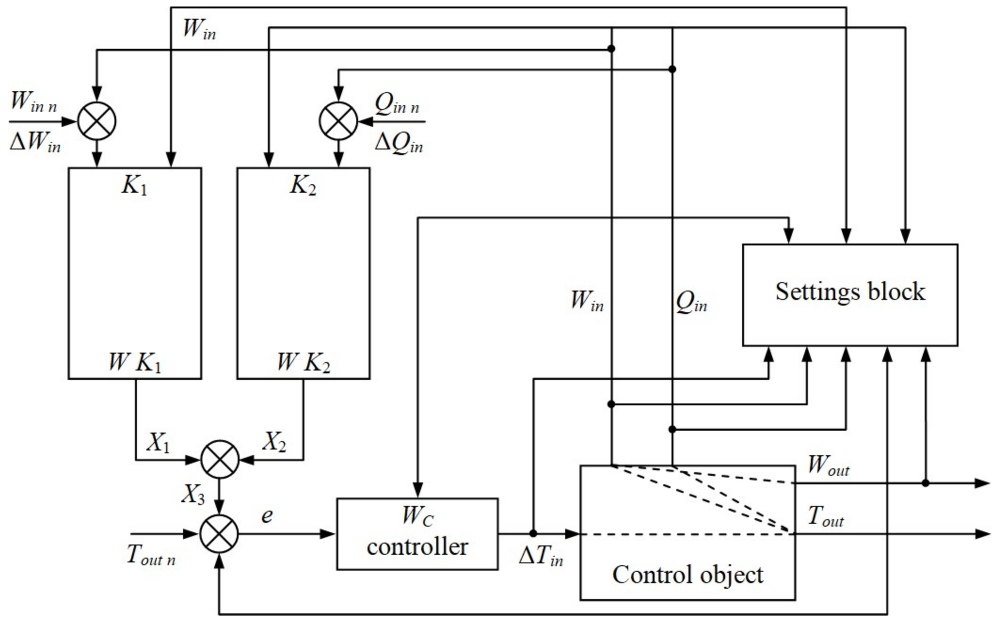

FIGURE 3. Functional diagram of the adaptive control system for cotton drying.

The model parameters are estimated using recurrent stochastic approximation (RSA) based on the a priori values of the input and output data of the object [8-10].

The correction of the model parameters is provided by recalculating the parameters taking into account the new estimates of its parameters. The dynamic characteristic of the object is taken as the model parameters (T_{10}, K_0, τ_0) and regulators (K_p, T_i, T_g).

In this case, the dynamics of the drum dryer can be described by a linear zed model in the form of a linear control difference:

$$\begin{cases} y(k)\cdot u(k)+a_1 y(k-1)\cdot u(k-1)+\ldots\ldots.+a_m\, y(k_m)\cdot u(k-m)= \\ =b_1\cdot u(k-d-1)+\ldots\ldots.+b_m\cdot u(k-d-m), \\ \\ u(k)=U\ (k)\cdot U_{oo}\ , \\ y(k)=Y(k)\cdot Y_{oo}\ , \end{cases} \tag{1}$$

where d - stored parameters, m - number of quantization cycles, $u(k)$, $y(k)$ - deviations, $U(k)$, $Y(k)$ - value changes, U_{00}, Y_{00}- set values.

Equation (1) is a discrete transfer function:

$$W(z)=\frac{B(z)}{A(z)}=\frac{b_1 z+\ldots+b_m z^{+m}}{1+a_1 z+\ldots+a_m z^m}$$

$Q_j(k)=\left[a_{1j}(k), a_{2j}(k), a_{3j}(k), b_{1j}(k), b_{2j}(k), b_{3j}(k)\right]^T$ - values of the model parameters.

The estimation of the model parameters according to the RSA is carried out as follows:

1. based on the measured values $y_j(k)$ and $U_i(k)$, $(j=1,2\ ;\ i=1,3)$ the errors of the equations are calculated.

$$e_j(k)=y_j(k)-\psi_j^T\cdot Q_j(k-1),$$

where $e_j(k)$– equation error;

$y_j(k)$– new measurement values;

$\psi_j^T\cdot Q_j(k-1)$ – predicting parameter values;

$$\psi_j^T(k+1)=\left[-y_{1j}(k);-y_{2j}(k);-y_{3j}(k);u_1(k-d_{ij});u_2(k-d_{ij});u_3(k-d_{ij})\right].$$

2. New parameter values are calculated:

$$Q_j(k)=Q_j(k-1)\cdot\xi(k-1)\cdot e(k),$$

where $Q_j(k)$ - new parameter estimation;

$Q_j(k-1)$- old rating;

$\xi(k-1)$ - correction vector.

Measured output $y(k)$ contains additive random noise $n(K)$. The interference signal is considered as an autoregressive process with a moving average;

$$n(K)+C_1\cdot n(K-l)+...+C_p\cdot n(k-p)=V(K)+d_r\cdot V(K-l)+...+d_p\cdot V(K-p),$$

where $V(K)$- a sequence of nominally distributed static independent randomly distributed quantities.

3. Discrete noise filters transfer function:

$$G_\nu(p)=\frac{n(p)}{V(p)}=\frac{D(p^{-1})}{C(p^{-1})}=\frac{1+d_1\cdot p^{-1}+...+d_p\cdot p^{-m}}{1+c_1\cdot p^{-1}+...+c_p\cdot p^{-m}}$$

and so, we formulate a model of an object in which an external interference is involved:

$$y(p)=\frac{B(p^{-1})}{A(p^{-1})}\cdot p^{-d}\cdot u(p)+\frac{D(p^{-1})}{C(p^{-1})}\cdot V(p)$$

The task of parametric identification is to obtain estimates of the model parameters, i.e. the coefficients of the polynomials $A(p^{-1})$ and $B(p^{-1})$, and also $C(p^{-1})$ and $D(p^{-1})$.

4. The recurrent stochastic approximation (RSA) method involves the use of functions.

$$\bar{u}=\begin{bmatrix}u_1\\u_2\\u_3\end{bmatrix}=\begin{bmatrix}\Delta Q_{in}\\\Delta W_{in}\\\Delta T_{in}\end{bmatrix}=\begin{bmatrix}\Delta Q_{in}-\Delta Q_{in0}\\\Delta W_{in}-\Delta W_{in0}\\\Delta T_{in}-\Delta T_{in0}\end{bmatrix},\qquad \bar{y}=\begin{bmatrix}\Delta W_{in}\\\Delta T_{in}\end{bmatrix}=\begin{bmatrix}\Delta W_{in}-\Delta W_{out0}\\\Delta T_{in}-\Delta T_{out0}\end{bmatrix}$$

$$\Delta W_{out}(p)=\sum_{i=1}^{3}W_{i1}(p)\cdot u_i(p),\qquad \Delta T_{out}(p)=\sum_{i=1}^{3}W_{i2}(p)\cdot u_i(p)$$

$$y_i=\sum_{i=1}^{3}y_{i1};\qquad y_i=\sum_{i=1}^{3}y_{i2}$$

$$\frac{y_{ij}(p)}{u_i(p)}=W_{ij}(p)=\frac{k_{ij}}{T_{ij}\cdot p+1}\cdot e^{-p\phi_{ij}}$$

5. Moving on to the time formula:

$$T_{ij}\cdot\frac{dy_{ij}(t)}{dt}+y_{ij}(t)=k_{ij}\cdot u_i(t-\phi_{ij}).$$

At a point in time $t=k$:

$$\frac{T_{ij}}{\Delta t}\left(y_{ij}(k)-y_{ij}(k-1)\right)+y_{ij}(k)=k_{ij}\cdot u_i(k-d_{ij}-1),$$

where $d_{ij}=\frac{\tau_{ij}}{\Delta t}$

We guide you to the view:

$$y_{ij}(k)+a_{ij}\cdot(k-1)=b_{ij}\cdot u_i(k-d_{ij}-1),$$

$$y_{ij}(k)\cdot\left(T_{ij}+\Delta t\right)-T_{ij}\cdot y_{ij}(k-1)=k_{ij}\cdot\Delta t\cdot u_i\left(k-d_{ij}-1\right),$$

$$y_{ij}(k)-\frac{T_{ij}}{T_{ij}+\Delta t}\cdot y_{ij}(k-1)=\frac{\Delta t}{T_{ij}+\Delta t}\cdot k_{ij}\cdot u_i\left(k-d_{ij}-1\right).$$

It follows that:

$$a_{ij}=-\frac{T_{ij}}{T_{ij}+\Delta t};\qquad b_{ij}=-\frac{\Delta t+k_{ij}}{T_{ij}+\Delta t}.$$

6. To build identification algorithms, we write the model in the following form:

$$Y_{ij}(k)=\Psi_i^T\cdot\Theta_j(k)+e_j(k),$$

where

$$\Psi_j^T=\left[-y_{1j}(k-1);-y_{2j}(k-1);-y_{3j}(k-1);u_1\left(k-d_{1j}-1\right);u_2\left(k-d_{2j}-1\right);u_3\left(k-d_{3j}-1\right)\right]$$

$$\Psi_j^T\cdot(k+1)\cdot P_j(k)\cdot\Psi_j\cdot(k+1)=J$$

7. Correct vector:

$$\xi_o(k)=\frac{1}{J+\lambda_j}\cdot\begin{bmatrix} i_{1j} \\ \\ \\ i_{6j}\end{bmatrix}$$

Initial values:

$$\Theta_j(0)=\begin{bmatrix}0\\ \cdot\\ \cdot\\ 0\end{bmatrix}\qquad P_i(0)=\begin{bmatrix}\alpha......0\\ ....\\ \\ 0........\alpha\end{bmatrix}$$

where α - an arbitrary sufficiently large number.

After defining the parameters $\Theta_j(k)$ defining the parameters k_{ij} и T_{ij} models:

$$T_{ij}=\frac{\Delta t\cdot a_{ij}}{1+a_{ij}};\qquad k_{ij}=\frac{b_{ij}}{\Delta t}\cdot\left(T_{ij}+\Delta t\right).$$

Parameters for objects. k_{ij} and T_{ij} the corresponding routine conditions are determined on the basis of the heat and material balance of the drying drum. Comparing the heat balance equations, we get:

$$T_{out}=273-\frac{33}{0.163+\sqrt{10\ln\left[\dfrac{\dfrac{W_{out}}{10\cdot Q_{in}\left(W_{in}-W_{out}\right)}}{100-Q_{in}\left(W_{in}-W_{out}\right)}\right]}}$$

RESULTS OF THE STUDY

To automatically maintain the optimal value of the technological parameters of the cotton drying process, the functional that characterizes the performance of the drying drum is selected as the optimality criterion:

$$I = \frac{1}{T}\int_0^T (W_2 - W_1)\cdot G_1 \cdot dt\ ,$$

where W_1 and W_2 - humidity of the dried cotton at the inlet and outlet of the drying unit;

G_1 - Mass of dried cotton;

T - drying time.

When determining the optimal parameters of cotton drying, the transfer functions found by solving the identification problem are used as the initial data. A gradient method for solving the optimization problem is proposed. Recently, neural network and fuzzy logic methods have been used to solve the control problem [11-15]. At the same time, the deviations of the deviation temperature, fuel consumption and cotton, humidity of the dried cotton, and the performance of the drying drum are taken as fuzzy linguistic variables.

CONCLUSION

A method for constructing an adaptive mathematical model of the raw cotton drying process has been developed, which makes it possible to predict the behavior of a process that has a probabilistic nature with relatively slowly changing values of variables under conditions of uncertainty.

An algorithm for estimating and setting the object parameter based on the recurrent stochastic approximation method has been developed, which is easy to implement in real production.

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