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SYNTHESIS OF SYNTHETIC REGULATORS FOR SUGAR PRODUCTION AUTOMATED CONTROL SYSTEM

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Abstract. To solve the problem of sugar plant technological complex efficient control basing upon the method of analytical construction of aggregate regulators it is necessary to determine the optimal parameters values. As input data time series of technological variables of sugar production are used. To investigate the efficiency of the developed automated synergistic control system, simulation modeling was performed by comparing the functioning of the developed system with the traditional schemes.

Key words: synergetic regulator, automated system, mathematical model, sugar plant.

Introduction

At the modern stage of control systems development increasing of production efficiency is possible due to the development and implementation of automated technological systems. Sugar production includes a set of different subsystems to be interconnected by processes of intensive interaction, the exchange of energy, substance and information. These subsystems are non-linear, multidimensional and complicated in linkage [1].

Formulation of problem

Taking into account the features of the synergetic approach it is necessary to tend to its practical usage which will allow the application of efficient methods to solve actual problems concerning optimal control of the sugar plant technological complex material flows. The task of optimal control is in need to determine the methods to influence the system and the parameters to provide the best phase transition basing upon certain criteria.

The synergetic principle to control complex systems allows you to change the structure of the system or to give another level of self-organization by changing the order parameters. The ability to change such parameters and the limits in which they may be changed are determined by means of a synergistic regulator. In information systems the synergetic controller is represented as a software tool [2, 3].

The application of a synergistic approach to manage the sugar plant technological complex will provide increasing of the work efficiency. Taking into account that the diffusion, juice-cleaning and evaporative departments are the main subsystems of the technological complex of a sugar plant [4] it will lead to the general increasing of the productivity and energy efficiency of the plant.

In the conditions of sugar producing enterprises capacity increasing it is the urgent need to elabore efficient systems for resource-saving management of technological objects using modern information technologies including knowledge engineering [5]. The application of the synergetic principle of control is increasingly applied to various objects but in automated control systems for complicated technological complexes such methods are only started to be used. Therefore, the synergetic approach to the automated control of the sugar plant technological complex is based on the method of aggregate regulators analytical design.

Analysis of recent research results

In paper [3] it is represented a synergetic approach to manage complicated technological objects as well as to define and describe abstractor attractive fields as the centers to form dissipative space-time structures. This method allows us to assess the behavior of a complicated system viewing self-organization in the case of chaotic influences either external or internal ones.

It should be noted that in the case of synergetic control of complicated systems particular attention should not be paid on the force power of the system itself but on the accuracy and the nature of information management [2, 6] because precisely the information management determines the efficient organizational and technical structure.

In order to synthesize efficient control strategies for nonlinear systems there were the papers devoting to the methods of passification [7], back stepping [8], robust [9, 10] and synergistic [6, 11] control to be observed. Among them the most promising for complicated technological objects are synergistic control methods to be observed in papers [11-13]. Application of this approach makes it possible to take into account the physical and chemical characteristics of technological processes, reflecting the phenomena of natural self-organization to provide resource-saving operating modes being characterized by resistance to external perturbations as well as to structural and parametric changes and allowing to organize efficient search of target states in different conditions, differ in necessary flexibility while changing goals and tasks variations, have high reliability and ability to prevent the occurrence of critical situations [6, 14].

In paper [11] there are modern approaches to object management methods to be described basing on the synergistic approach. If control is done by changing the order parameters we observe instability, symmetry violation and boundaries of a complex nonlinear system as a result of such actions. Thus, we have several possible scenarios of the system's behavior after the phase transition. In the case of control by changing the initial conditions there is the possibility of developing the system in several directions including chaotic behavior to be observed. The difficulty of this approach is in no everlasting possibility to change the initial conditions. Sometimes they are rigidly fixed. Each of these methods is used when the another one is impossible for application. So, if there is a perspective to determine the set of parameters of order from the set of system characteristics and parameters exactly and there is no possibility to change the input conditions the first approach is used. If the set of parameters is too large or may not be determined due to complicated interconnections within the system a second approach should be applied.

Moreover, in paper [3] it was shown that these methods give satisfactory results for models of real idealized systems. These factors required new approaches to manage complicated non-linear technological complexes.

The questions about analytical design of aggregate regulators for separate subsystems of the sugar plant technological complex have not been studied enough deeply too.

Purpose of research

The purpose of the paper is to use synergetic regulators for sugar plant complicated technological complex to give the necessary opportunities of the practical results application for the object and to elaborate the efficient resource-saving strategies to control the diffusion, juice-cleaning and evaporation department of the sugar plant technological complex.

To achieve this goal, the following tasks, need to be solved:

- to carry out synthesis of synergetic management systems for sugar production;
- to determine the optimum values of the control parameters for the diffusion, juice-cleaning and evaporation departments of the sugar plant technological complex by the method of analytical construction of the aggregate regulators;
- to carry out simulation modeling of the sugar production technological complex.

Results of research

The core of the synergistic method to manage complex dynamic systems is the principle of resonant information influence on the order parameters within which the system is sensitive and its internal features are preserved. Resonant impact does not predict influence by action forcing itself but by properly organized, i.e. consistent with internal properties, weakly powerful actions leading the system to move in a given direction [11].

Having evaluated the behavior of the studied system [4], we can conclude that it has a nonlinear character. To study such systems and to determine optimal control it is necessary to apply the method of analytical construction of aggregate regulators. In accordance with this method it is necessary to determine the laws of management u_i to provide optimal control of the main technological processes of sugar production. Synthesis of synergistic control systems for diffusion, juice-cleaning and evaporation compartments is carried out.

The mathematical model (1) describes the process of extraction of sugar from beetroot chips:

$$\frac{dF_{cm}}{d\tau} = -a_1 \cdot F_{cm} + a_2 \cdot F_{\partial c} \cdot R + a_3 \cdot \frac{F_{\partial c}^2 \cdot B}{D \cdot T} + a_4 \cdot \frac{D \cdot B}{T} + a_5 \cdot T\,,$$

$$\frac{dF_{\partial c}}{d\tau} = -a_6 \cdot \frac{F_{\partial c}}{T} - a_7 \cdot F_{cm} \cdot R - a_8 \cdot \frac{F_{\partial c} \cdot F_{cm} \cdot B}{D \cdot T} - \,, \qquad (1)$$

$$- a_9 \cdot D \cdot B \cdot R + a_{10} \cdot T$$

$$\frac{dD}{d\tau} = a_{11} \cdot \frac{F_{cm} \cdot B}{T} - a_{12} \cdot \frac{D}{T}, \;\; \frac{dR}{d\tau} = a_{13} \cdot \frac{F_{\partial c} \cdot B \cdot D}{T} - a_{14}\,,$$

where: F_{cm} - consumption of beetroot chips, m^3/h; $F_{\partial c}$ - consumption of diffusion juice, m^3/h; R - goodness, %; B - digestion, %; D - loss of sugar with pulp, %; T - temperature, °C; $a_1 - a_{14}$ - the model parameters to be determined by identifying of multidimensional time series using the Vector ODE software environment [15].

As a control tool u_1 we select the value of the expense of beetroot chips F_{cm}, as a control u_2 we select the value of diffusion juice loss $F_{\partial c}$.

According to the method of analytical construction of aggregate regulators, the control laws depend on:

$$u_1(R,B,T)\,;\; u_2(R,D,T)\,. \qquad (2)$$

In accordance with the method of analytical design of aggregate regulators control actions are defined. For further research it is necessary to observe invariant manifolds:

$$\psi_1(R,B,T) = 0\,;\; \psi_2(R,D,T) = 0\,. \qquad (3)$$

In parallel, the consistent observation of invariant manifolds allows us to consider invariants to be attractors with attractive zones while applying control laws $u_1(R,B,T)\,;\; u_2(R,D,T)$.

There is a movement of the system in the phase space up to the intersection of the manifold $\psi_1 = 0$, $\psi_2 = 0$. Goodness and temperature cannot directly affect management u_1, u_2, - thus it is necessary to ensure such linkage through ψ_i:

$$\psi_1 = R + T + \nu(B)\,,\ \psi_2 = R + T + \nu(D)\,, \quad (4)$$

where: ν – certain function of the dependence of real technological parameters.

Basing on the dependences (3) and (4) we'll obtain:

$$R + T + \nu(B) = 0\,,\ R + T + \nu(D) = 0\,. \quad (5)$$

Changing the macro-variables ψ_1 and ψ_2 obey the functional:

$$T_i\,\dot{\psi}_i(\tau) + \psi_i(\tau) = 0 \quad (6)$$

On the basis of the equation of the model and equation (6) we'll obtain:

$$T_1\left[\frac{dR}{dt} + \frac{dT}{dt} + \frac{\partial \nu}{\partial B}\cdot\frac{dB}{dt}\right] + R + T + \nu(B) = 0\,,$$

$$T_2\left[\frac{dR}{dt} + \frac{dT}{dt} + \frac{\partial \nu}{\partial D}\cdot\frac{dD}{dt}\right] + R + T + \nu(D) = 0\,, \quad (7)$$

and the laws of interconnecting controlling the technological processes of the sugar plant diffusion department:

$$u_1 = -\frac{R+\nu}{T\cdot T_1} - \frac{T-B^2}{T}\cdot R\cdot F_{\partial c} - \frac{T-B^2}{T}\cdot\frac{B}{T}\cdot\frac{F_{\partial c}^2}{D} +$$

$$+\left(\frac{B+T}{T} - \frac{T-B^2}{T}\right)\cdot F_{бc} +$$

$$+\left(\frac{\frac{T-B^2}{T}}{R} - \frac{\frac{T-B^2}{T}}{\frac{B}{T}} - R\cdot\frac{B}{T}\cdot\left(\frac{B}{T}\right)^2\right)\cdot D +$$

$$+\frac{\frac{T-B^2}{T}}{\frac{B}{T}},$$

$$u_2 = -\frac{D+\nu}{T\cdot T_2} - \frac{B}{T}\cdot D\cdot R\cdot\frac{T\cdot B^2}{T}\cdot\frac{B}{T}\cdot\frac{F_{бc}\cdot F_{\partial c}}{D} +$$

$$+\frac{T\cdot B^2}{T}\cdot R\cdot F_{бc} - \left(B + \frac{B}{T}\right)\cdot\frac{R}{D} +$$

$$+\left(\frac{B^2+T^2}{T^2}\frac{T-B^2}{T}\right)\cdot F_{\partial c} + \frac{T\cdot B^2}{T}\cdot\frac{F_{\partial c}\cdot R}{D^2} - \quad (8)$$

$$-\left(\frac{T-B^2}{T} + \frac{T-B^2}{T}\right)\cdot\frac{F_{\partial c}}{D^2} + \frac{T\cdot B^2}{T}\cdot D,$$

where: *T1, T2* are the parameters of the synergetic regulator.

Parameters of setting control laws to affect the quality of process dynamics to cause efficient self-organization of the system, there are time parameters - T1, T2 time constants. The conducted researches of the synthesized system of synergistic control allowed to determine the optimal values of T1 and T2 parameters according to the criteria of duration and resource consumption (Fig. 1).

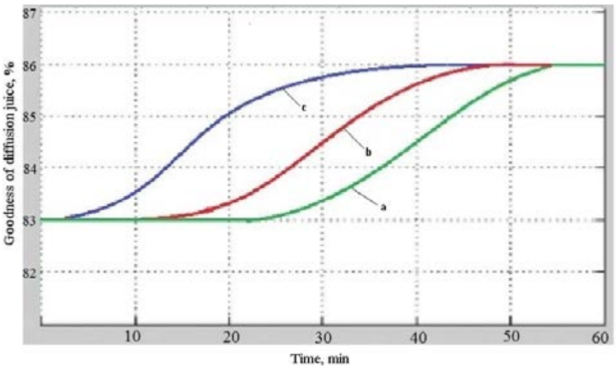

Fig. 1. Transitional process to regulate the goodness of diffusion juice: a) at T1 = 160 sec; T2 = 180 sec; b) at T1 = 80 sec; T2 = 100 sec; c) at T1 = 10 sec; T2 = = 20 seconds.

The parameters of the setting of the laws of control adjust the regulation time *T1, T2*. The condition of system stability predicts the values: *T1> 0, T2> 0*.

The mathematical model of the process of preliminary bowel movements has the form:

$$\frac{dF_{CaO}}{d\tau} = b_1\cdot\frac{F_{CaO}\cdot C_{CaO}}{T} - b_2\cdot F_{\partial c} - b_3\cdot\frac{F_{пов}\cdot F_{\partial c}}{T}\cdot b_4\cdot F_{CaO}\,,$$

$$\frac{dF_{\partial c}}{d\tau} = -b_5\cdot\frac{F_{\partial c}\cdot C_{CaO} + F_{пов}\cdot C_{CaO}}{T} - b_6\cdot F_{CaO}\,, \quad (9)$$

$$\frac{dpH}{d\tau} = b_7\cdot\frac{F_{\partial c}\cdot pH}{T} + b_8\cdot F_{CaO} - b_9\cdot\frac{F_{\partial c}\cdot F_{пов}\cdot pH}{T}\,,$$

$$\frac{dC_{cp}}{d\tau} = b_{10}\cdot F_{CaO} - b_{11}\frac{C_{cp}\cdot(F_{пов} + F_{\partial c})}{T}\cdot b_{12}\cdot C_{CaO}\,.$$

where F_{CaO} - consumption of lime milk, m^3/h; $F_{\partial c}$ - consumption of diffusion juice, m^3/h; *pH* - pH of diffusion juice; C_{cp} - dry matter content,%; $F_{пов}$ - flow of diffusion juice return, m^3/h; T - temperature, ºC; C_{CaO} - concentration of lime milk,%; $b_1 - a_{12}$ - the model parameters to be determined by identifying multidimensional time series using the Vector ODE software environment [15].

As a control tool u_1 we select the value of the expense of beetroot chips F_{CaO}, as a control tool u_2 we select the value of diffusion juice consumption $F_{\partial c}$.

According to the method of analytical construction of aggregate regulators, the control laws depend on:

$$u_1(C_{CaO}, pH, T)\,;\ u_2(C_{cp}, F_{пов}, T)\,. \quad (10)$$

According to the method of analytical design of aggregate regulators the control actions are defined. For further research it is necessary to observe invariant manifolds:

$$\psi_1(C_{CaO}, pH, T) = 0\,;$$

$$\psi_2(C_{cp}, F_{пов}, T) = 0\,. \quad (11)$$

In parallel, the consistent consideration of invariant manifolds allows us to consider invariants as attractors with attractive zones while applying control laws

$$u_1(C_{CaO}, pH, T)\,;\ u_2(C_{cp}, F_{пов}, T)\,.$$

There is a movement of the system in the phase space up to the intersection of the manifold $\psi_1 = 0$, $\psi_2 = 0$. Goodness and temperature cannot directly affect control u_1, u_2, thus it is necessary to ensure such linkage through ψ_i:

$$\psi_1 = pH + T + \nu(C_{CaO}),$$
$$\psi_2 = F_{\text{пов}} + T + \nu(C_{\text{ср}}), \qquad (12)$$

where ν - a certain function of the dependence of real technological parameters.

Proceeding from the dependences (11) and (12) we'll obtain:

$$pH + T + \nu(C_{CaO}) = 0,$$
$$F_{\text{пов}} + T + \nu(C_{\text{ср}}) = 0. \qquad (13)$$

Changing the macro-variables ψ_1 and ψ_2 obey the functional:

$$T_i \dot{\psi}_i(\tau) + \psi_i(\tau) = 0. \qquad (14)$$

Basing on the equation of the model and equation (14) we'll obtain:

$$T_1\left[\frac{dpH}{dt} + \frac{dT}{dt} + \frac{\partial \nu}{\partial C_{CaO}} \cdot \frac{dC_{CaO}}{dt}\right] + pH + T +$$
$$+ \nu(C_{CaO}) = 0,$$
$$T_2\left[\frac{dF_{\text{пов}}}{dt} + \frac{dT}{dt} + \frac{\partial \nu}{\partial C_{\text{ср}}} \cdot \frac{dC_{\text{ср}}}{dt}\right] + F_{\text{пов}} + T +$$
$$+ \nu(C_{\text{ср}}) = 0.$$

And the laws of interconnecting the technological processes of sugar plant defecation:

$$u_1 = \frac{(F_{\text{дс}} \cdot C_{CaO} + F_{\text{пов}} \cdot C_{CaO}) \cdot C_{CaO}}{pH} -$$
$$- \frac{(F_{\text{дс}} + F_{\text{пов}} + F_{CaO}) \cdot pH}{pH} + \frac{C_{CaO}}{pH \cdot T_1},$$
$$u_2 = \frac{\dfrac{F_{CaO} \cdot F_{\text{дс}}}{C_{CaO}} - T \cdot C_{CaO} - F_{\text{дс}} + F_{\text{пов.}} \cdot C_{CaO}}{C_{\text{ср}}} - \qquad (16)$$
$$- \frac{F_{CaO} \cdot T + F_{\text{дс}} \cdot T + F_{\text{пов}} \cdot T_.}{C_{\text{ср}}} +$$
$$+ F_{CaO} - T_. \cdot (F_{\text{дс}} + F_{\text{пов}}) \cdot T -$$
$$- \frac{F_{CaO} + F_{\text{дс}} + F_{\text{пов}}}{C_{\text{ср}} \cdot T_2} \cdot T,$$

where *T₁, T₂* are the parameters of the synergetic regulator.

Using the obtained relationships, it is possible to synthesize regulatory influences for the technological operations of the 1st and 2nd carbonation, as well as for intermediate bowel movements.

The parameters of the control laws setting regulate T_1, T_2. regulation time. The condition of system stability involves the values: $T_1>0$, $T_2>0$.

While simulation the averaged technological indicators of the technological parameters on the equipment with a productivity of 3000 t / day were used.

As a result of the research, it was found that the system is resistant to perturbations, and the time of regulation depends only on the T_1, T_2values. Moreover, the nature of the transient processes does not change while changing the time of regulation and accordingly does not depend on it.

On the basis of the abovementioned, one can synthesize the laws of mutual control for the mathematical model of the saturator (17):

$$\frac{dF_{C\text{г}}}{d\tau} = c_1 \cdot \frac{F_{C\text{г}} \cdot C_{C\text{г}}}{T} - c_2 \cdot F_{\text{дс}} - c_3 \cdot \frac{F_{\text{пов}} \cdot F_{\text{дс}}}{T} \cdot c_4 \cdot F_{C\text{г}},$$
$$\frac{dF_{\text{дс}}}{d\tau} = -c_5 \cdot \frac{F_{\text{дс}} \cdot C_{C\text{г}}}{T} - c_6 \cdot F_{C\text{г}}, \qquad (17)$$
$$\frac{dpH}{d\tau} = c_7 \cdot \frac{F_{\text{дс}} \cdot pH}{T} + c_8 \cdot F_{C\text{г}} - c_9 \cdot \frac{F_{\text{дс}} \cdot pH}{T}$$
$$\frac{dC_{\text{ср}}}{d\tau} = c_{10} \cdot F_{C\text{г}} - c_{11} \frac{C_{\text{ср}} \cdot F_{\text{дс}}}{T} \cdot c_{12} \cdot C_{C\text{г}}$$

where $F_{C\text{г}}$ - the saturation gas consumption, m³/h; $F_{\text{дс}}$ - consumption of diffusion juice, m³/h; pH - pH of diffusion juice; $C_{\text{ср}}$ - dry matter content, %; T - temperature, °C; $C_{C\text{г}}$ - concentration of carbonation gas,%; $c_1 - c_{12}$ - the model parameters are determined by identifying multidimensional time series using the Vector ODE software environment [15].

The mathematical model (18) describes the process to get syrup:

$$\frac{dF_{\text{дс}}}{d\tau} = -p_1 \cdot F_{\text{дс}} + p_2 \cdot F_c \cdot R + p_3 \cdot \frac{F_c^2 \cdot C_{\text{ср}}}{h \cdot T} +$$
$$+ p_4 \cdot \frac{h \cdot C_{\text{ср}}}{T} + p_5 \cdot T, \qquad (18)$$
$$\frac{dF_c}{d\tau} = -p_6 \cdot \frac{F_c}{T} - p_7 \cdot F_{\text{дс}} \cdot R - p_8 \cdot \frac{F_c \cdot F_{\text{дс}} \cdot C_{\text{ср}}}{h \cdot T} -,$$
$$- p_9 \cdot h \cdot C_{\text{ср}} \cdot R + p_{10} \cdot T$$
$$\frac{dh}{d\tau} = p_{11} \cdot \frac{F_{\text{дс}} \cdot C_{\text{ср}}}{T} - p_{12} \cdot \frac{h}{T}, \quad \frac{dR}{d\tau} = p_{13} \cdot \frac{F_c \cdot C_{\text{ср}} \cdot h}{T} - p_{14},$$

where $F_{\text{дс}}$ - the flow of diffusion juice, m³/h; F_c - consumption of syrup, m³/year; R - goodness,%; $C_{\text{ср}}$ - dry matter content,%; h - level in the evaporation plant, m; T - temperature, °C; $p_1 - p_{14}$ - the model parameters to be determined by identifying multidimensional time series using the Vector ODE software environment [15].

As a control tool u_1 we select the value of the expense of beetroot chips $F_{\partial c}$, as a control tool u_2 we select the value of diffusion juice consumption F_c.

According to the method of analytical construction of aggregate regulators, the control laws depend on:

$$u_1(R, C_{cp}, T)\,;\; u_2(R, h, T) \qquad (19)$$

According to the method of analytical design of aggregate regulators, control actions are defined. For further research it is necessary to observe invariant manifolds:

$$\psi_1(R, C_{cp}, T) = 0\,;\; \psi_2(R, h, T) = 0 \qquad (20)$$

In parallel, the consistent observation of invariant manifolds allows us to consider invariants to be attractors with attractive zones while applying control laws $u_1(R, C_{cp}, T)\,; u_2(R, h, T)$.

There is a movement of the system in the phase space up to the intersection of the manifold, $\psi_1 = 0$, $\psi_2 = 0$. Goodness and temperature cannot directly affect control u_1, u_2, thus it is necessary to ensure such linkage through ψ_i:

$$\psi_1 = R + T + \nu(C_{cp}),\; \psi_2 = R + T + \nu(h), \qquad (21)$$

where ν - a certain function of the dependence of real technological parameters.

Basing on the dependences (20) and (21) we'll obtain:

$$R + T + \nu(C_{cp}) = 0,\; R + T + \nu(h) = 0 \qquad (22)$$

Changing the macro-variables ψ_1 and ψ_2 obey the functional:

$$T_i\,\dot{\psi}_i(\tau) + \psi_i(\tau) = 0\,. \qquad (23)$$

Basing on the equation of the model and equation (23) we'll obtain:

$$T_1\left[\frac{dR}{dt} + \frac{dT}{dt} + \frac{\partial\nu}{\partial C_{cp}}\cdot\frac{dC_{cp}}{dt}\right] + R + T + \nu(C_{cp}) = 0$$

$$T_2\left[\frac{dR}{dt} + \frac{dT}{dt} + \frac{\partial\nu}{\partial h}\cdot\frac{dh}{dt}\right] + R + T + \nu(h) = 0\,. \qquad (24)$$

and he laws of interconnecting control of the technological processes of the sugar plant diffusion department.

Basing on the developed control laws (u_1, u_2), recommendations are made in the form of determining the nature of the change in the (T_1, T_2) time regulation: "increase", "reduce", etc. To use these recommendations in the automated control system it is necessary to determine the quantitative characteristics of these recommendations.

In order to evaluate the carried research, we predicted the simulation to assume that the system operation process is reproduced using an algorithm to be implemented with the help of a computer.

$$\begin{aligned}
u_1 = &-\frac{R+\nu}{T\cdot T_1} - \frac{T - C_{cp}^{\,2}}{T}\cdot R\cdot F_c - \\
&-\frac{T - C_{cp}^{\,2}}{T}\cdot\frac{C_{cp}}{T}\cdot\frac{F_c^2}{h} + \\
&+\left(\frac{C_{cp}+T}{T} - \frac{T - C_{cp}^{\,2}}{T}\right)\cdot F_{\partial c} + \\
&+\left(\frac{\frac{T - C_{cp}^{\,2}}{T}}{R} - \frac{\frac{T - C_{cp}^{\,2}}{T}}{\frac{C_{cp}}{T}} - R\cdot\frac{C_{cp}}{T}\cdot\left(\frac{C_{cp}}{T}\right)^2\right)\cdot h + \\
&+\frac{\frac{T - C_{cp}^{\,2}}{T}}{\frac{C_{cp}}{T}}
\end{aligned}$$

$$\begin{aligned}
u_2 = &-\frac{h+\nu}{T\cdot T_2} - \frac{C_{cp}}{T}\cdot h\cdot R\cdot\frac{T\cdot C_{cp}^{\,2}}{T}\cdot\frac{C_{cp}}{T}\cdot\frac{F_{\partial c}\cdot F_c}{h} + \\
&+\frac{T\cdot C_{cp}^{\,2}}{T}\cdot R\cdot F_{\partial c} - \left(C_{cp} + \frac{C_{cp}}{T}\right)\cdot\frac{R}{h} + \\
&+\left(\frac{C_{cp}^{\,2} + T^2}{T^2}\,\frac{T - C_{cp}^{\,2}}{T}\right)\cdot F_c + \frac{T\cdot C_{cp}^{\,2}}{T}\cdot\frac{F_c\cdot R}{h^2} - \\
&-\left(\frac{T - B^2}{T} + \frac{T - B^2}{T}\right)\cdot\frac{F_{\partial c}}{D^2} + \frac{T\cdot B^2}{T}\cdot D
\end{aligned} \qquad , (25)$$

where T_1, T_2 – are the parameters of the synergetic regulator.

The structure of the simulation model of sugar plant technological complex consists of the following blocks: the immitter of input actions; model of microprocessor system of individual parameters local regulation; expert system of script control; unit for simulation results representation and interpretation.

The subsystem structure of the simulation modeling for the sugar plant technological complex is presented in Fig. 2.

Using the Matlab Toolbox Simulink environment it was constructed the simulation model (Fig. 3) of the research of the sugar plant technological complex.

To investigate the efficiency of the elaborated automated synergistic control system it was simulation being performed by comparing the functioning of the elaborated system with traditional schemes. The formation of incoming actions was carried out with the help of robust plans of the Taguchi's experiment. The results are shown in the table. 1.

According to Taguchi's approach, the design of processes and industries should be handled predicting that they are robust to the environment in relation to the variability of the components and to ensure that the dispersion of the indicators around the given value is as low as possible.

Simulation was conducted in accordance with the requirements of the technological process taking into account the diverse factors of sugar production.

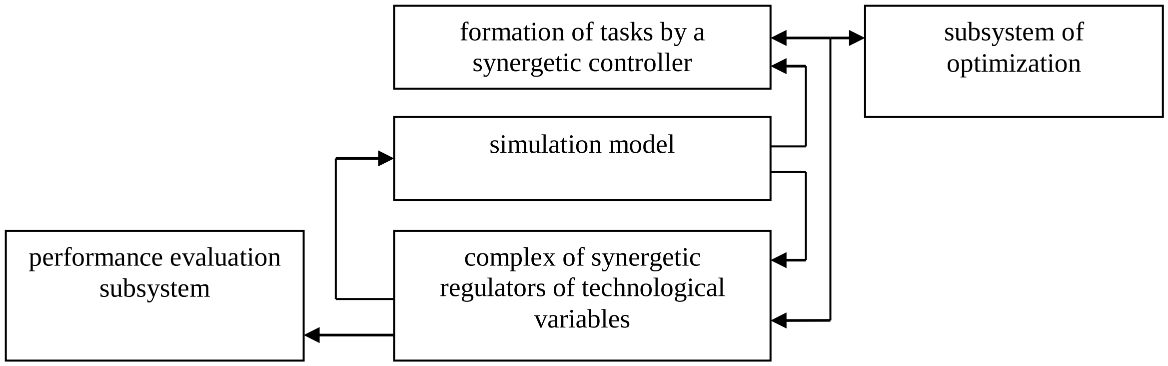

Fig. 2. Structure of the subsystem of the simulation modeling of the sugar plant technological complex.

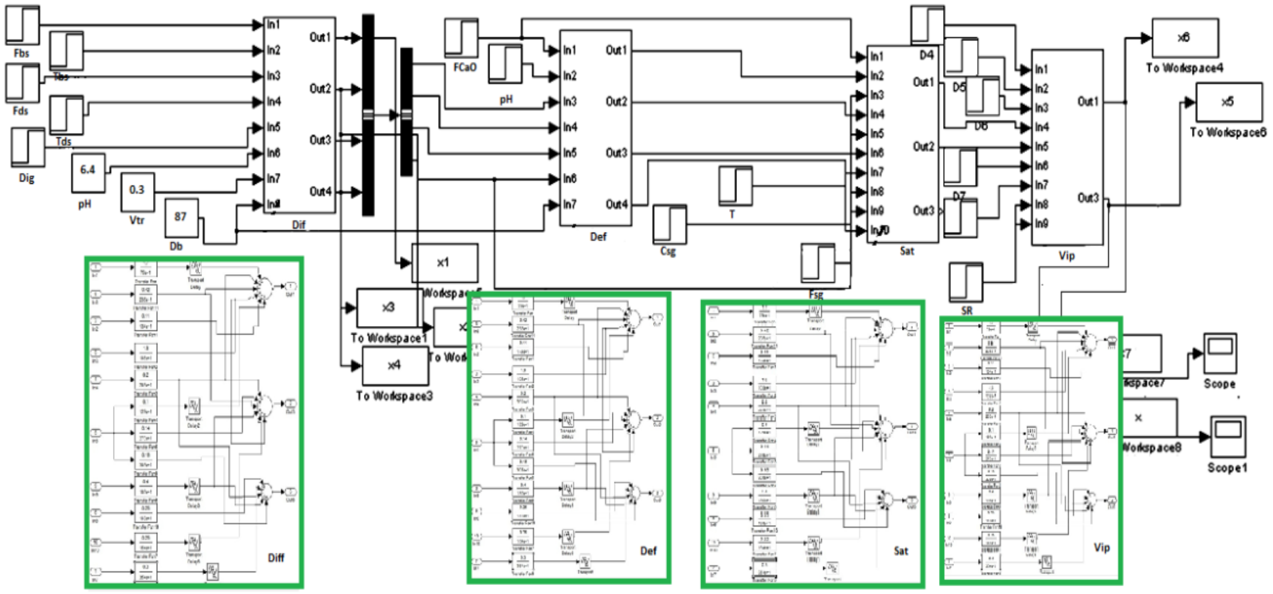

Fig. 3. Simulation model of the sugar plant technological complex in the Toolbox Simulink environment.

Table 1. Results of simulation modeling.

Dependence signal-noise, $(Eta_{less-good})$ i $(Eta_{more-good})$	Models of the existing control system			Imitation control models		
	Good -ness	Losses, %	Productivity, m^3/h	Goodness	Losses,%	Productivity, m^3/h
$Eta_{less-good} = -10*\log_{10}^{\frac{1}{n}*\sum_{i=1}^{n} y_i^2}$	-	0,4	-	-	0,33	-
$Eta_{more-good} = -10*\log_{10}(\frac{1}{n}*\sum_{i=1}^{n} 1/y_i^2)$	88,7	-	120	90,5	-	123,7

Conclusions

1. The synthesis of interconnected control systems of the diffusion, juice cleaning and evaporation departments of the sugar plant technological complex by the method of analytical construction of aggregate regulators is based on the ideology of the synergetic control theory.

2. In order to synthesize the laws of synergistic control of sugar production processes, invariant manifolds (attractors) are used, in which the natural properties of the object and the requirements of control tasks are properly coordinated. The control laws are defined u_i to provide optimal control of the main sugar production technological processes.

3. The simulated modeling of the proposed technical solutions showed the improved product quality, the increased productivity up to 1.8%, reduced energy consumption up to 3.7%, and a decrease of sugar losses up to 0.07%.

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СИНТЕЗ СИНТЕТИЧНИХ РЕГУЛЯТОРІВ АВТОМАТИЗОВАНОЇ СИСТЕМИ УПРАВЛІННЯ ДЛЯ ВИРОБНИЦТВА ЦУКРУ

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Анотація. Щоб вирішити проблему технологічного комплексу цукрового заводу ефективного управління на основі методу аналітичних робіт агрегованих регуляторів необхідно визначити оптимальні значення параметрів. В якості використовуваних вхідних часових рядів даних технологічних змінних у виробництві цукру. Для дослідження ефективності розробленої автоматизованої системи синергетичного управління і імітаційне моделювання було проведено шляхом порівняння функціонування розробленої системи з традиційними схемами.

Ключові слова: синергетичний регулятор, автоматизована система, математична модель, цукровий завод.

СИНТЕЗ СИНТЕТИЧЕСКИХ РЕГУЛЯТОРОВ АВТОМАТИЗИРОВАННОЙ СИСТЕМЫ УПРАВЛЕНИЯ ДЛЯ ПРОИЗВОДСТВА САХАРА

В. Ф. Лысенко, М. А. Сыч, Д. С. Комарчук

Аннотация. Чтобы решить проблему технологического комплекса сахарного завода эффективного управления на основе метода аналитических работ агрегированных регуляторов необходимо определить оптимальные значения параметров. В качестве используемых входных временных рядов данных технологических переменных в производстве сахара. Для исследования эффективности разработанной автоматизированной системы синергетического управления и имитационное моделирование было проведено путем сравнения функционирования разработанной системы с традиционными схемами.

Ключевые слова: синергетический регулятор, автоматизированная система, математическая модель, сахарный завод.