American Journal Of Applied Science And Technology
(ISSN – 2771-2745)
VOLUME 04 ISSUE 12 Pages: 47-56
OCLC – 1121105677

Publisher: Oscar Publishing Services

Journal Website:
https://theusajournals.com/index.php/ajast

Research Article

ADAPTIVE CONTROL SYSTEM FOR A FLUIDIZED BED DRYER

Submission Date: December 13, 2024, **Accepted Date:** December 18, 2024,
Published Date: December 23, 2024
Crossref doi: https://doi.org/10.37547/ajast/Volume04Issue12-09

Bekkulov Jakhongir Sherbaevich
Department of "Automation and Control of Technological Processes," Doctor of Philosophy in Technical Sciences, Karshi Institute of Engineering and Economics, Uzbekistan

Saidov Imam Hasan ugli
Master's student of the "Automation and Control of Technological Processes" Department, Karshi Institute of Engineering and Economics, Uzbekistan

Akhemoda Sitora Askar kizi
Student of the Department of "Automation and Control of Technological Processes", Karshi Institute of Engineering and Economics, Uzbekistan

Turaev Orzubek Amir ugli
Student of the Department of "Automation and Control of Technological Processes", Karshi Institute of Engineering and Economics, Uzbekistan

ABSTRACT

The advantages and disadvantages of numerous interconnected adaptive drying process control systems have been analyzed. An adaptive system for the process has been developed that enables the calculation of hydrodynamics and seed moisture content in a fluidized bed. This system is based on the separation of reactive zones, taking into account the fluidized bed and dynamic models of the drying process within the fluidized bed.

KEYWORDS

Intensity, dynamic, model, adaptive, object, optimal, algorithm, parameter, microprocessor, concentration, material, technology.

INTRODUCTION

The high intensity and instability of ongoing processes make the fluidized bed a complex control object, with process requirements becoming more stringent due to significant nonlinear and stationary characteristics. As a result, demands on the process control system are increasing. The process control system should be implemented at a modern level using means that ensure high speed and accuracy [1-3]. Complex control algorithms that differ from standard ones are being developed, and principles of adaptation and industrial algorithms are being utilized. The control system should manage the adaptive main technological parameters. Despite numerous theoretical and practical works, the development of adaptive control algorithms for interconnected objects remains a relevant task today. Adaptive control algorithms for fluidized bed objects are mainly used to control temperature regimes, but they are rarely applied to hydrodynamic regimes, which determine the efficiency of heat and mass transfer and energy consumption. It is necessary to ensure that the control system is implemented using standard devices.

The development of microprocessor technology has enabled its widespread use in improving the control of the drying process. High speed, accuracy, reliability, and compactness of microprocessor devices are among the advantages of digital control systems. Furthermore, digital control devices allow for the implementation of complex control algorithms. The use of mathematical models, optimal control algorithms, as well as their advantages such as flexibility and adaptability, are important factors. As a result of these factors' influence, the following methods are increasingly applied. The intensity of processes leads to technological regimes approaching the stability threshold. Ensuring such modes requires the use of control systems based on mathematical models. Extensive research in the field of adaptive control is being conducted both domestically and internationally[2]. Among the many adaptation methods, three main ones are distinguished: programmed control, adaptive control, and self-tuning controllers. If a system has auxiliary variables that can be measured and their relationship with the system's dynamic characteristics is known, then these variables can be used for programmed control of the regulator's coefficients. The block diagram of such a system is shown in Figure 1. When controlling technological processes, the load (operating mode) of the control object is chosen as such a variable.

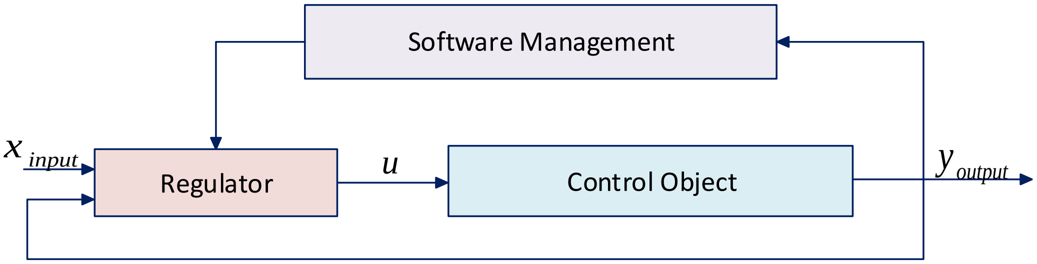

Figure 1. Program control of an adaptive system.

This method is used when a load is present, but it does not always correspond to real conditions. This adaptive control method is considered important; however, it requires considerable time for modes associated with complex processes. The adaptive system with a guiding model is shown in Figure 2.

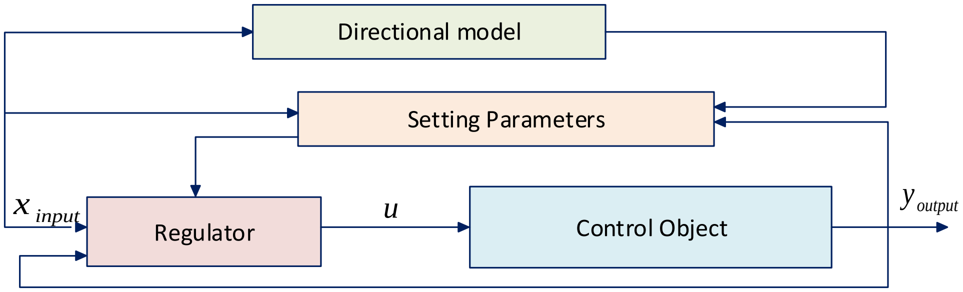

Figure 2. Adaptive system with a guiding model.

The principle is that the system characteristics are established in accordance with a guiding model, which determines the exact response of the process to the control signal. The scheme consists of two loops: an internal loop, which includes the object and control, and an external loop for adjusting control parameters, which minimizes the difference between the output data of the object and the model.

The guiding models used are generalized into multidimensional systems. The self-tuning controller does not directly update parameters that differ from the aforementioned schemes; instead, this occurs as a result of calculations. The structural diagram of the self-regulation controller is shown in Figure 3.

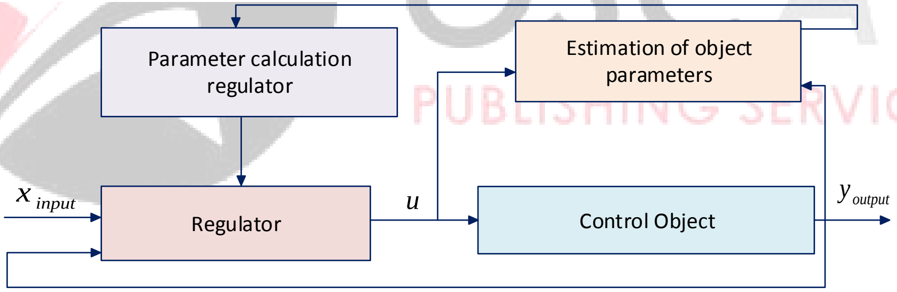

Figure 3. Self-tuning regulator of the adaptive system.

It can be considered that the self-tuning regulator consists of two loops: an internal one, which includes the object and the controller, and an external one, comprising a parameter estimation device and a computational regulator. The system can be viewed as a device with automatic process modeling, where the process model and control mode are continuously updated. For periodic evaluation of process parameters, various methods can be employed, such as stochastic approximation[3-5].

The scope of application for adaptive methods is very wide; however, when selecting an adaptation method, it is necessary to consider the actual characteristics of the control object. The hydrodynamics of the fluidized bed does not provide previously considered models of fluidized bed pulsations, and the understanding of macroscopic patterns does not allow for their use in the design and operation of real devices for controlling fluidized bed processes.

Thus, increasing porosity leads to a decrease in the melting rate between particles, disrupting the established equilibrium. However, if the layer is compressed due to destruction, i.e., concentration, then during its dissolution, the gas velocity between particles increases, and the attraction force grows, which also contributes to the layer returning to its equilibrium state. In both cases, the layer moves while possessing kinetic energy. The energy and resulting inertia pass through the equilibrium position, after which the motion occurs again in the opposite direction. This model represents continuity equations for solid matter and gas. The model assumes that when disturbances or changes occur in the drying agent reactant, the amount of material in the layer transitions to a state of directed motion in the solid phase[5-8].

Furthermore, the dependence of the output parameter on the input parameter is nonlinear, as the moist concentrate is dried in a fluidized bed dryer at a constant or decreasing rate (the degree of characteristic equations can be two or more), and the process under consideration has a stochastic mathematical description. This is due to the fact that it is continuously affected by external disturbing factors. Figure 4 presents a functional diagram of the relationship between the regulation of the potassium chloride drying process in a fluidized bed dryer and the technological parameters influencing moisture content.

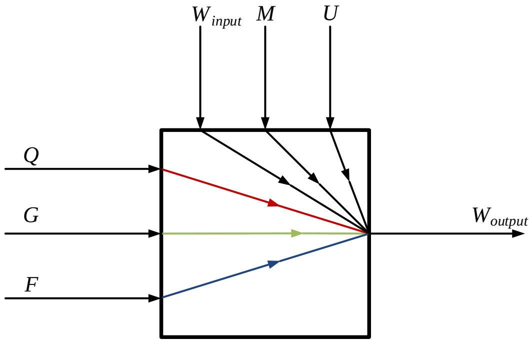

Figure 4. Functional diagram of the relationship between product drying process regulation and technological parameters affecting moisture content: Q - drying agent flow rate [m3/hour]; G - primary air flow rate [m3/hour]; F - secondary air flow rate [m3/hour]; Winput - input material moisture content [%]; M - material flow rate [m3/hour]; U - incoming air humidity [%]; Woutput - output material moisture content [%].

To simplify our reasoning, let's consider only two channels; a more detailed scheme can then be presented as shown in Figure 5. Here, $x_1^{вых}(t)$ and $x_2^{вых}(t)$ are the control signals, while y_1 and y_2 are the actual values of the controlled variables. In a well-designed system, the channels $x_1^{вых}(t)$ and $x_2^{вых}(t)$ are independent, meaning that the output $y_1(t) \to x_1^{вых}(t)$ is controlled only by the signal $x_1^{вых}(t)$, and $y_2(t) \to x_2^{вых}(t)$ is controlled only by the signal $x_2^{вых}(t)$ (the signal $x_1^{вых}(t)$ does not affect y_2, and $x_2^{вых}(t)$ does not affect y_1).

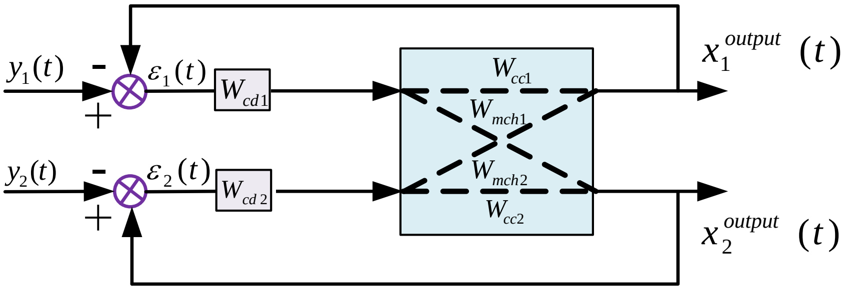

Fig. 5. Structural diagram of the two-dimensional system

In real systems (alongside the main channels W_{mch1} and W_{mch2}), cross-connections W_{cc1} (where signal $x_1^{output}(t)$ affects output $y_2(t)$) and W_{cc2} (where signal $x_2^{output}(t)$ affects output $y_1(t)$) often occur. When investigating such systems, as well as when synthesizing regulators (correcting devices W_{cd1} and W_{cd2}), it is necessary to take these cross-connections W_{cc1} and W_{cc2} into account. An object is considered autonomous if, through the application of additional connections, the mutual influence between channels is eliminated (i.e., W_{cc1} and W_{cc2} are absent) [4].

The transfer function of each link represents an aperiodic element with a delaying argument. Overall, this is the case:

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

where *i* is the sequential number of the input, *j* is the sequential number of the output.

The dynamic characteristics of each dryer unit are determined experimentally

Table 1

Channel designation	*1-1*	*1-2*	*2-1*	*2-2*	*3-1*	*3-2*
Channel/Parameter	*Q_{inp}- W_{out}*	*Q_{inp} – T_{out}*	*W_{inp}- W_{out}*	*W_{inp}- T_{out}*	*T_{inp}- W_{out}*	*T_{inp}- T_{out}*
K-gain coefficient	*3*	*40*	*0,1*	*1*	*0,025*	*0,015*
T-time constant	*320*	*300*	*400*	*280*	*240*	*150*

τ-transport delay	*240*	*90*	*380*	*80*	*120*	*30*

When selecting the main signal transmission channel, the dynamic characteristics of the object are evaluated. A channel with two parameters - T and τ - is preferred. In case these parameters are equal, a channel with a low τ/T ratio is selected, where the primary control channel is the temperature of the drying agent at the inlet - its temperature at the outlet (Fig. 6).

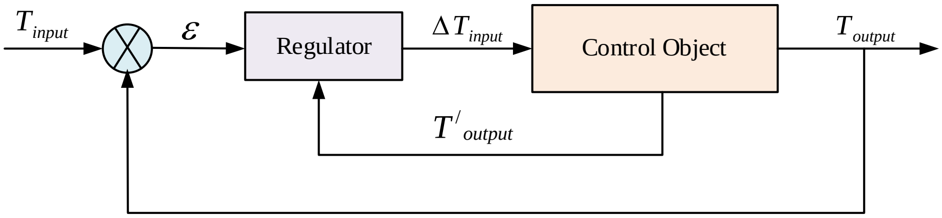

Fig. 6. Block diagram of an automatic control system

The adopted automatic control system does not provide the required drying quality. An adaptive control system is more preferable, the model of which is presented in Figure 7. It is built on the basis of a system that controls the main variable (T_{out}) depending on the deviation.

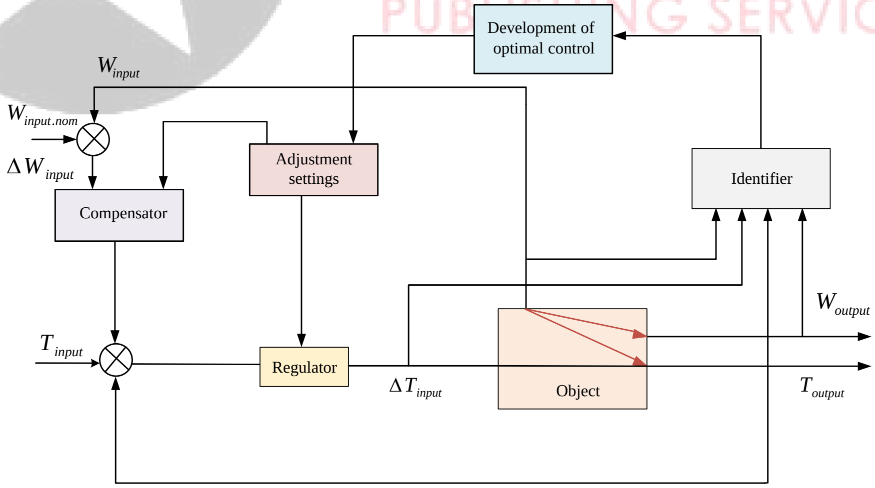

Figure 7. Model of an automatic control system for the drying process of mineral fertilizers.

The model parameters are estimated using a recurrent method of stochastic approximation based on the measured values of input and output variables. The identification of model parameters is carried out in the adjustment unit [5].

The model parameters consist of the object's dynamic characteristics (T, K, τ) and the controller's tuning coefficients (K_p, T_i, T_N)

The object under investigation - a drum dryer - can be described in a linear form as difference equations:

$$y_u(K)+a_1y_u(K-1)+...+a_my_u(K-m)=b_1u(K-d-1)+...+b_mu(K-d-m)\,, \tag{2}$$

where d and m are delay;

$$\left.\begin{array}{r} u(K)=U(K)-U_{00} \\ y(K)=Y(K)-Y_{00} \end{array}\right\}. \tag{3}$$

Here, K is the number of quantization cycles; $y(K)$ and $u(K)$ are variations, i.e., deviations; $U(K)$ and $Y(K)$ are current values; U_{oo} and Y_{oo} are predefined parameter values.

This linear differential equation corresponds to a discrete function.

Applying the time shift operator z, defined by the relation $y(k+i)=z^iy(k)$, to the finite-difference equation (2), one obtains the operator form of the discrete model:

$$(a_0+a_1z^{-1}+......a_nz^{-n})y(k)=(b_0+b_1z^{-1}+......b_mz^{-m})u(k) \tag{4}$$

From (4), under zero initial conditions, we can derive a discrete transfer function of the linear system, representing the ratio of z-transforms of the input signal to the output signal:

$$W(z)=\frac{y(z)}{u(z)}=\frac{b_0+b_1z^{-1}+......b_mz^{-m}}{a_0+a_1z^{-1}+......a_nz^{-n}}\,, \tag{5}$$

$$\Theta_j(k)=[a_{1j}(k);\ a_{2j}(k);\ a_{3j}(k);\ b_{1j}(k);\ b_{2j}(k);\ b_{3j}(k)]^{\tau}\,.$$

The proposed algorithm for evaluating model parameters:

1.$y_j(k)$ and $u_i(k)$, $j=1,2$; A measure $i=1,3$;

2. Calculate the equation error $e_j(k)=y_j(k)-\psi_j^T\,\Theta_j(k-1)$, where $e_j(k)$ is the equation error, $y_j(k)$ is the new measurement, and $\psi_j^T\,\Theta_j(k-1)$ is the predicted value;

3. Calculation of new parameter values

$$\Theta_j(k)=\Theta_j(k-l)-\xi_j(k-l)e_j(k)\,, \tag{6}$$

where: $\Theta_j(k)$ - new value; $\Theta_j(k-l)$ - previous value; $\xi_j(k-l)$ - correction vector; $e_j(k)$ - error.

4. New data vectors

$$\psi_j^T(k+1) = [-y_{1j}(k); -y_{2j}(k); -y_{3j}(k); u_1(k-d_{ij}); u_2(k-d_{ij}); u_3(k-d_{ij})], \quad (7)$$

$$P_j(k)\cdot\psi_j^T(k+1) = \begin{bmatrix} P_{11j}(k) & \dots & P_{16j}(k) \\ \vdots & \dots & \vdots \\ P_{61j}(k) & \dots & P_{66j}(k) \end{bmatrix} \cdot \begin{bmatrix} -y_{1j}(k) \\ \vdots \\ -y_{6j}(k) \end{bmatrix} = \begin{bmatrix} i_{1j} \\ \vdots \\ i_{6j} \end{bmatrix} = T. \quad (8)$$

5. Calculation

The measurable output *y*(*K*) contains an additive random noise *n*(*K*). The noise signal is considered an autoregressive process with a shifting mean value:

$$n(K) + C_1\, n(K-l) + \dots + C_p\, n(k-p) = V(K) + d_r\, V(K-l) + \dots + d_p\, V(K-p), \quad (9)$$

where *V*(*K*)is a sequence of statistically independent, randomly distributed values following a normal distribution.

Noise transfer function:

$$G_v(p) = \frac{n(p)}{V(p)} = \frac{D(p^{-1})}{C(p^{-1})} = \frac{1 + d_1 p^{-1} + \dots + d_p p^{-m}}{1 + c_1 p^{-1} + \dots + c_p p^{-m}}. \quad (10)$$

Thus, the model of the object involved in the external noise is:

$$y(p) = \frac{B(p^{-1})}{A(p^{-1})} \cdot p^{-d} \cdot u(p) + \frac{D(p^{-1})}{C(p^{-1})} \cdot V(p). \quad (11)$$

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

To implement such approaches, it is necessary to apply or identify special methods based on transient process calculations. For high-quality drying in the automatic control system, an adaptive control system is the most optimal solution. Adaptive control is built on a system that manages the main regulated parameter (W_{output}) based on deviations, adaptively compensating for the drying agent flow rate (*Q*), primary air flow rate (*G*), secondary air flow rate (*F*), and external disturbances related to the moisture content of the incoming wet concentrate, material flow rate, and incoming air humidity [6-8]. Figure 8 presents the structure of the adaptive control system for the drying process.

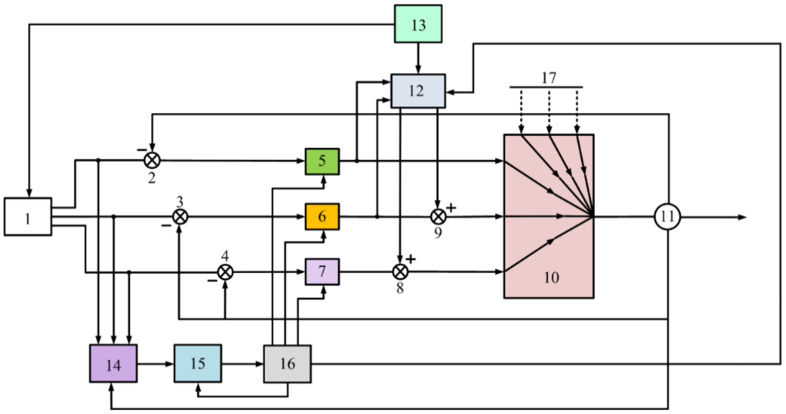

Figure 8. Structure of the improved adaptive control system for the drying process: 1 - task formation unit, 2, 3, 4 - comparative elements, 5, 6, 7 - flow sensors, 8, 9 - summing units, 10 - controlled object, 11 - moisture analyzer, 12 - compensator, 13 - functional unit, 14 - identification unit, 15 - parameter adjustment unit, 16 - adaptive control unit, 17 - external disturbances.

The drying process for the proposed moist product is characterized by an improved adaptive control method and the fact that during the operation of the control system, the regulated parameters remain unchanged and conform to the settings. During the operation of the improved adaptive control system, the time constant T of the compensating device [5-8] changes in response to variations in the parameters of the controlled object. This change occurs only when the result of altering the characteristics of the controlled object leads to a deterioration in the quality of regulation. This ensures the necessary stability margin for the system. The structural and functional diagram of the proposed improved drying drum control system is shown in Figure 9.

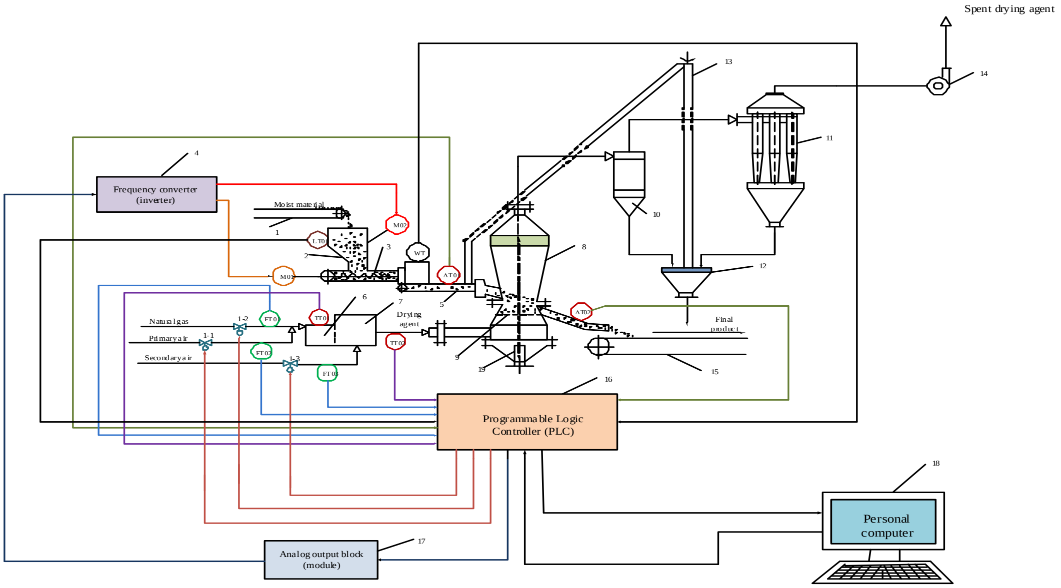

Figure 9. Structural and functional diagram of the improved fluidized bed dryer control system: 1 - wet material feed conveyor; 2 - wet material hopper; 3 - feeder; 4 - frequency regulator (frequency converter); 5 - feed conveyor; 6 - heater; 7 - mixer; 8 - dryer; 9, 10 - cyclones; 11 - dust collector; 12 - storage hopper; 13 - conveyor for feeding dried material to the cooler; 14 - programmable logic controller (PLC), 15 - analog input module and 16 - analog output modules; TT01, TT02 - temperature sensors; FT01 - gas flow sensor; FT02 - primary air flow sensor; FT03 - secondary air flow sensor; FT04 - drying agent flow rate sensor; FT05 - wet concentrate flow sensor; LT01 - level sensor; M01, M02 - electric motors.

CONCLUSION

The model accounts for the main parameters of the layer: gas velocity, solid phase velocity, and solid phase concentration. Based on the gravitational-vibrational model, it is possible to determine the final height of the layer and its pulsation. The technological process of seed drying in fluidized bed dryers and methods for modeling control objects have been analyzed. Shortcomings of existing control systems have been identified. When considering the technological process as a control object, reactive flows are defined, which enables the formulation of a control task that takes into account the identified monitoring requirements.

REFERENCES

1. Sherboevich, B. Z. (2023). Advanced control system for the drying process of potassium chloride in a drum dryer. PEDAGOGS, 46(2), 48-54.
2. Nurullaevich, K. S., & Sherboyevich, B. J. (2024). Abstract boiling on the example of an improved control system for the combustion of natural gas (potassium chloride) in the calorifier of the dryer. American Journal of Innovation in Science Research and Development, 1(7), 18-27.
3. Zhuraev, F. D., & Bekkulov, J. S. (2018). Analysis of membership functions and assessment of the condition of the management object. Scientific Knowledge of Modernity, (6), 31-35.
4. Zhuraev, F. D., & Bekkulov, J. S. (2018). Tasks Of Calculation And Design Of Automatic Control Systems. Scientific knowledge of Modernity, (6), 24-30.
5. Sherboyevich, B. J. (2022). Virtual analyzers used in determining the quality of Mineral fertilizers. Innovasionnie podhodi, problemi, predlojeniya I resheniya V nauke I obrazovanii, 1(1), 79-83.
6. Zhuraev, F. D., & Bekkulov, J. S. (2018). Identification of model parameters of a complex control object. Scientific knowledge of modernity, (6), 47-52.
7. Sherboyevich, B. J. (2024). Automatic Adjustment of Electromotor Speed. Miasto Przyszłości, 48, 1408-1412..
8. Sherboyevich, B. J., & Askarovna, A. S. (2024). The conceptual structure of the APC-an improved system for monitoring and controlling technological processes for the production of mineral (potash) fertilizers. American Journal of multifunctional publishing, 1(7), 26-35.