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SYSTEM OF ADAPTIVE CONTROL OF TECHNOLOGICAL PARAMETERS OF PRODUCTION OF SODA

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Annotation. *A systematic analysis of the existing system of analytical control of technological parameters for the production of soda ash is made. It is investigated as an adaptive control object, which operatively changes its parameters depending on the real state of the controlled technological process. A technique is proposed for determining the frequency of the removal of technological parameters, based on methods of mathematical statistics and based on the analysis of experimental data of a particular process.*

Key words: *calcined soda, analytical control, frequency of data collection, mathematical expectation, intensity, frequency spectrum, algorithm, adaptation, probability.*

Introduction. One way to improve production efficiency is to obtain reliable, accurate and operational data for management purposes. In connection with this, an important role is played by the analytical control of technological processes in industries covering the whole of its life cycle in the production stage, i.e. from the raw material to the final product.

In the existing production of soda ash, about 90% of the total number of measurements is carried out to control current technological parameters, while the analytical control system is tightly regulated and the frequency of monitoring technological parameters is set on the basis of technological regulations. On the other hand, the technological processes taking place at different stages of production are both fleeting and slow-moving. In addition, information on technological parameters can be both excessive and inadequate, and these factors affect the quality of the management process and this ultimately affects the quality of the output and economic production until then. These and other factors determine the creation of an effective control system, taking into account the features of the current state of the technological process. In this regard, there is a need to find solutions that allow ensuring lower costs for the analytical control of technological parameters of the carbonization process while maintaining the necessary reliability, reliability and accuracy of the information obtained.

For this purpose, it is proposed to determine the frequency of data collection on the state of the technological process on the basis of the most effective experimental studies, the variability of the actual process, as a result of which it is possible to develop an adaptive management aporia for this system.

Formulation of the problem. It is known that changes in the parameters of the composition and properties of process flows that need to be controlled in a real case have a probabilistic character.

The existing methods of reflecting ch-c objects under the influence of interference require not only information about their static and dynamic properties, but also complete information about their static x-like, therefore, in our case, it is necessary to create control monitoring systems that ensure high quality processes controlling the control of the technological process in conditions of incomplete information of statistical x-like signals and interference.

Solution method. To solve this problem, we will investigate the systems of analytical control of the production of soda ash as an object of management. It should take into account the fact that the quality control of material flows of the technological process depends on the operating modes of technological equipment. At the same time for all monitored parameters the following conditions are normal and emergency states. The emergency state has two varieties:

- "withdrawal" from the normal state;
- "return" from emergency to the zone of normal state.

1. -the character of changes in the controlled parameter of the technological parameter is shown in Figure 1.

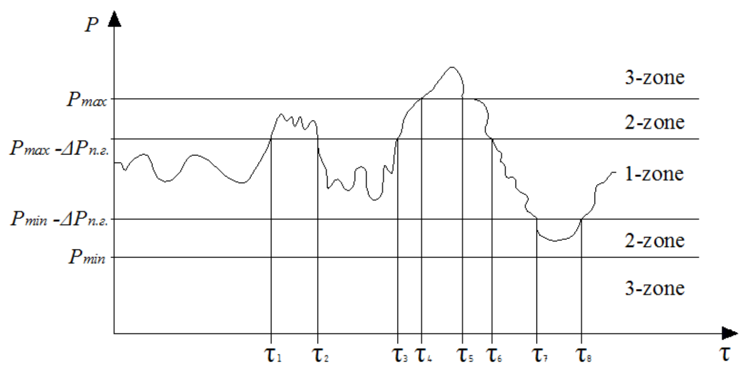

Figure 1. ***Nature of changes in the controlled process parameter***

The marked states of the monitored parameters are characterized by the following features (see Figure 1). normal state (observed in the time intervals $\tau < \tau_1, \tau_2 < \tau < \tau_3, \tau_6 < \tau < \tau_5, \tau > \tau_8$ and $\tau < \tau_8,$) - the parameter values are in the central part of the zone of its regulated (permissible) changes (zone 1):

$$P_{\min} + \Delta P_{n.г.} \leq P_{\max} - \Delta P_{n.г.} \qquad (1)$$

where P is the current value of the monitored parameter;

$P_{\max} - \Delta P_{n.г.} = P_{в.n.г.}$ are $P_{\min} + \Delta P_{n.г.} = P_{н.n.г.}$ - the values of the upper and lower warning limits [2] of regulation (representing the lowered and accepted value of the control margin $\Delta P_{n.г.}$ (as of the upper and lower limits of the admissible parameter values).

2) *emergency state of "leaving" parameter values* (observed in time intervals $\tau_1 < \tau < \tau_2, \tau_3 < \tau < \tau_4$) and $\tau_5 < \tau < \tau_6, \tau_7 < \tau < \tau_8$ parameter values are located within the zone of regulated limits of its permissible changes, but near one of its boundaries (2nd zone):

$$P_{\min} < P < P_{\min} + \Delta P_{n.г.} \qquad \text{or}$$

$$P_{\max} - \Delta P_{n.г.} < P < P_{\max} \qquad (2)$$

3) *emergency state of "return" of indicator values* (in the figure is observed in the time interval $\tau_4 < \tau < \tau_5$) - parameter values are outside the zone of regulated limits of its permissible changes (zone 3):

$$P > P_{\max} \quad \text{or} \quad P > P_{\min} \qquad (3)$$

Determination of the optimal control frequency for each of the states considered above is possible on the basis of the information obtained on the characteristics of the variability of the controlled parameters of the technological process in a form that allows us to develop a reasoned approach to determining the reasonable time for their subsequent monitoring. To obtain such information it is necessary to conduct several series of purposeful experimental studies of the characteristics of the real variability of the technological process and its parameters.

Determination of the required control frequency (control interval - $\Delta\tau$) of technological parameters consists of the following stages:

1. Several series (experiments) of inspection of the current production are carried out in the characteristic modes of operation described above, during which it is necessary to determine the parameter value at regular intervals X.

$$X_{iz}^{T} = X_{iz} \qquad (4)$$

where *i* is the number of the point in the given experiment (*i = 1,2, ..., k*); *z* is the number of the experiment (*z = 1,2, ..., m*); X_{iz}^{T} is the current value of the parameter at the *i*-th point of the *z*-th experiment.

2. Based on the results of each of the *z* experiments, it is necessary to determine the estimate of the mathematical expectation on the *z*-th realization of the random process

where $$\hat{M}(X_z) = \frac{\sum_{i=1}^{k} X_{iz}}{K} \qquad (5)$$

K is the total number of points obtained in this experiment.

3. For each of the *z* experiments, it is necessary to construct the corresponding graphs of the parameter change (see the example in Fig. 2), also applying lines corresponding to:

- estimation of mathematical expectation $\hat{M}(X_z)$;
- the boundaries of the zone of regulated values of the parameter they correspond to any of the $j_{(+)}$ and $j_{(-)}$ levels, respectively;
- the actual boundaries of the zones of increased risk of monitoring parameters are experiments of $X_{\text{мах}}^{\text{рег}}$ and $X_{\text{мin}}^{\text{рег}}$.

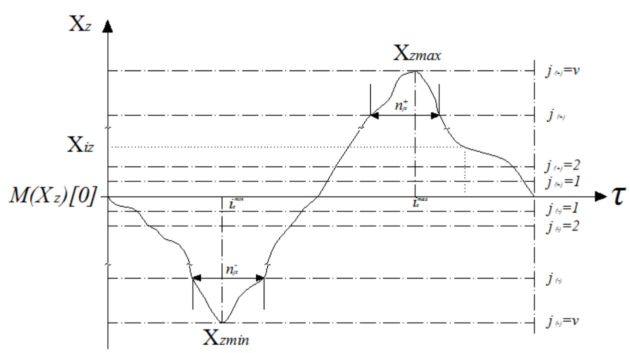

Figure 2. ***An example of an experimental study of the variability characteristics of a controlled process parameter.***

In each of the experiments it is necessary to determine the values of the levels of variation in the intensity of the parameter control:

$$\Delta X_z^{\text{var}+} = \frac{\Delta X_{z,\max}}{\nu}$$

$$\text{at } \Delta X_{z,\max} = X_{z,\max} - \hat{M}(X_z) > 0 \qquad (6)$$

$$\Delta X_z^{\text{var}-} = \frac{\Delta X_{z,\min}}{\nu}$$

$$\text{at } \Delta X_{z,\min} = X_{z,\min} - \hat{M}(X_z) < 0 \qquad (7)$$

where $\Delta X_{я}^{\text{var}+}, \Delta X_{я}^{\text{var}-}$, - steps of varying levels of control intensity respectively, for cases where the current value of the parameter is greater or less than $\hat{M}(X_z)$ — the mathematical expectation of the variable in this experiment; ν — the number of selected levels of variation in the intensity of the parameter control (chosen depending on the requirements for the accuracy of processing experimental data).

Further, the value of the intensity levels of the parameter control is calculated by the equations:

$$X^{+}_{jz} = \Delta X^{\text{var}+}_{jz} \cdot j_{(+)} \quad (8)$$

$$X^{-}_{jz} = \Delta X^{\text{var}-}_{jz} \cdot j_{(-)} \quad (9)$$

Where j is the number of the intensity level of the parameter control (*j = 0,1,2, ..., v*).
For each of the levels of control intensity of the parameter, relative control intensity factors are determined. For this, X^{T}_{iz} — the current values in each experiment are compared with X^{+}_{jz} and X^{-}_{jz} the corresponding values and n^{+}_{jz} and n^{-}_{jz} the number of points in the experiment and by inequalities

$$n^{+}_{jz} \text{ at } X^{T}_{iz} \geq X^{+}_{jz} \quad (10)$$

$$n^{-}_{jz} \text{ at } X^{T}_{iz} \leq X^{-}_{jz} \quad (11)$$

The relative coefficients of the intensity of the parameter control are determined from the equations:

$$A^{+}_{jz} = \frac{n^{+}_{jz}}{K} \quad (12)$$

$$A^{-}_{jz} = \frac{n^{-}_{jz}}{K} \quad (13)$$

where A^{+}_{jz} — the relative intensity factor of the parameter control at $X^{T}_{iz} \geq \hat{M}(X_z)$;
A^{-}_{jz} — the relative coefficient of intensity of the parameter control at $X^{T}_{iz} \leq \hat{M}(X_z)$;

For each of the *z* experiments, the data obtained in the form

$A^{+}_{jz} = \varphi'(X^{+}_{jz})$;

$A^{-}_{jz} = F'(X^{-}_{jz})$;

represent two generalized variational series of the form

$$A^{+} = \varphi'(X^{+}); \quad (14)$$

$$A^{-} = F'(X^{-}); \quad (15)$$

The values of the arguments of the variational series (14) and (15) are divided into equal intervals, the values of which are assumed to be equal to the maximum values of the steps of variation of the relative strengths of the control intensity $\Delta X^{\text{var}+}_{я}$ and $X^{\text{var}-}_{я}$. To determine the value of the functions A^{+} and A^{-} at each interval, one should follow the recommendations of the "theory of pessimism" [3]. According to this theory, when assessing the case of stochastic uncertainty of conditions when the probability distribution for the parameters either does not exist or can not be obtained, it is always necessary to be guided by the worst conditions. Therefore, out of several values of the functions that appear inside the interval, a value corresponding to the lowest relative control intensity factor is chosen and is taken as the value of the function in the given interval.

After fulfilling these calculations, two curves are plotted in all intervals [4], characterizing the value of the relative intensity of the control as a function of the deviation of the parameter from its mathematical expectation of the species,

$$A^{+}_{\min} = \alpha'(X^{+}) \quad (16)$$

$$A^{-}_{\min} = \alpha'(X^{-}) \quad (17)$$

5. Accept, the time interval between the measurements:

- for parameter values in the zone of its mathematical expectation (zone 1 in Fig. 1), $\Delta\tau = \Delta\tau_{M(X)}$;

at values of the parameter close to the boundary values of the regulated zone (zone 2 in Fig. 1) $\Delta\tau = \Delta\tau^{рег}_{\min)}$ and $\Delta\tau = \Delta\tau^{рег}_{\max}$;

- for values of the parameter equal to the boundary values in the zones of increased risk (zone 2 in Fig. 1), the time interval between the measurements will be determined on the basis of Kotel'nikov's theorem [5]. According to which:

$$\Delta\tau = \frac{\pi}{\omega_c} \quad (18)$$

where $\Delta\tau$ is the time between measurements; ω_c is the maximum frequency of the spectrum of the variable under study.

Therefore, in our case $\Delta\tau_{\max} = \Delta\tau = \dfrac{\pi}{\omega_c}$

6. Based on the dependencies obtained above, we can construct the desired resultant

dependencies of time intervals between measurements on the deviation of the measured parameter from its mathematical expectation in the form of X^+

$$\Delta\tau^+ = \Delta\tau_{\max}^{M[X]} - A_{\min}^+ \cdot B^+ \left\{X^+ - M[X]\right\} \text{at } X^-$$

$$\Delta\tau^- = \Delta\tau_{\max}^{M[X]} - A_{\min}^- \cdot B^- \left\{X^- - M[X]\right\}$$

It is obvious that the above-described experimental studies of the characteristics of the actual variability of the parameters of analytical control in their normal and emergency states are expedient for the following three characteristic states of the regime of the entire technological process in the production of soda as a whole:

1) when the process parameters for a sufficiently long time is in normal mode;

2) when the indicators (or at least one indicator) of the quality of the product obtained are within the limits of norms, but in the immediate vicinity of their regulated defective boundary (the risk of production of poor-quality products);

3) when the indicators (or at least one indicator) of the quality of the product obtained are located outside the defective boundary (the area of the marriage).

To carry out the experimental research it is necessary to perform the following stages of work:

- collection and analysis of initial data on the statics and dynamics of changes in controlled parameters;
- formalization (description) of possible changes in the values of these parameters by the appropriate separation of their states (into quasi-stationary and transitional, in the areas of output of quality products, risk and marriage);
- the ranking of the monitored parameters of analytical control in terms of the magnitude of their resulting influence on the management of the technological process (based both on their frequency (autocorrelation) characteristics and on the cost implications).

conclusions

Thus, our analysis of the analytical control system for the production of soda ash as a control object, the determination of the requirement for experimental studies of the variability of the parameters of analytical control in the development of the adaptive control algorithm for the analytical control system is a prerequisite for the creation of a system for adaptive analytical control of the soda ash production process.

The nature of the functioning of this system largely depends on the completeness of the reflection of the state of the technological process and the effectiveness of decisions taken by the management personnel. In this regard, the use of the algorithm for adaptive control of the analytical control system (which allows to quickly determine the moments of the occurrence of violations and quantify changes in the parameters of the process technology) is of great importance for improving the production economy and raising the level of technological discipline.

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