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A Model of the Multiple Process in Biogas Devices

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Abstract. This article provides a model of multistage processes in biogas plants. In developing a mathematical model of the process in biogas plants, the relationship between the elements of interdependence is given separately. A quantitative level of generalization of each working part of a biogas plant has been developed, a clear formula has been developed to describe the number of parts in the system, and several similar innovations have been developed.

INTRODUCTION

The systematic nature of the anaerobic process in biogas plants [1-4] modeling indicates the complexity of showing that it has not been seen in biogas production [5-7]. This process should be continued until small and precise systems are obtained that are not difficult to model. Such other indivisible subsystems are called elements of a complex system.

In the mathematical modeling of the above process, the interrelationships between the interrelated elements play an important role, i.e., the temperature depends on the rate of biomass loading or the duration of the process.

The mathematical model of a complex multilevel system consists of mathematical models of elements, systematic analysis, and the relationship between them in terms of element speed or process duration.

The division into subsystems continues until simple subsystems are obtained. That is, the mathematical representation of these systems should not be complicated. This part of the system, which has no other divisibility, is called the elements of a complex system. When choosing a mathematical apparatus for modeling such elements, it is important to consider the elements of a given system class and their relationships.

It can be seen that the creation of mathematical models of optimization of multistage process control is also complicated by the fact that there are control systems in which optimal models operate. Multi-level system processes are continuous and discrete.

In general, the diversity of management problems requires the construction of a multi-level system that requires the parent system's configuration. The formation of the component of the optimal model of the problem depends on the periodicity of control and the frequency of correction of the models [8-10].

MATERIALS AND METHODS

In the form of a hierarchical model, we can say that a multi-state technological process includes models designed for all control system states.

The composition of this system model depends on the degree of integration of technological areas and the subsystems in each part of the system [9,11,12,13]. The quantitative degree of aggregation of each working part of a biogas plant describes the number of parts in the system. In this case, the degree of concentration is determined by the following expression:

$$S = k_s * m^{-1},$$

Here m is the number of component systems involved in the construction of the integrated macromodel; k_s is the coefficient representing the structural properties of the system.

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RESULTS AND DISCUSSION

The mathematical model of the anaerobic process in biogas plants consists of a system of equations for a separate local part system and contours, which includes mathematical expressions of technological processes that represent the relationships between them [14-16].

For each contour of this system, depending on the raw material to be processed and its quality, the material balance law is fulfilled concerning the total product and its components.

From a mathematical point of view, the balance calculation of the scheme is brought to the solution of a system of algebraic equations [16-21]. The following balance equations can be constructed for the contour of each circuit according to the mass of the product:

$$\sum_{s=1}^{k_{i1}} \gamma_{is}^{bx} = \sum_{s=k_{i2+1}}^{k_{i2}} \gamma_{is}^{\text{вых}}, \qquad i = \overline{1,n} \;;\; s = \overline{1, n_{\iota 1} + n_{\iota 2}} \tag{1}$$

and by mass of components:

$$\sum_{s=1}^{k_{i1}} \gamma_{is}^{bx} d_{ijs}^{bx} = \sum_{s=k_{i2+1}}^{k_{i2}} \gamma_{is}^{\text{вых}} \, d_{ijs}^{\text{вых}} \,, \qquad j = \overline{1,m}\,. \tag{2}$$

Here i is the contour number, k is the number of contours, m is the number of components, s is the contour product number, and $k_{i1}k_{i2}$ is the number of inputs and outputs.

It should be noted that the solution of the array of balance equations has several computational difficulties: the size of the system measurements, poor substantiation, uncertainty, inconsistency, and flammability of ore beneficiation schemes. The modern technological scheme of processing raw materials does not work without the return of circulating products. The product from the following circuits must be sent to the beginning of the scheme for processing [22, 23]. However, when calculating the balance of the contour of the scheme, it is necessary to consider the product's full characteristics. In this case, it is necessary to use balance equations and more complex equations.

In the second stage, mathematical models are constructed for each separated contour, taking into account the constraints and limitations based on the first stage results.

Let's look at the process of creating an integrated macromodel of an anaerobic multistage process in biogas plants. The following material balance equations are appropriate for the u-contour of a multistage process in biogas plants:

$$\begin{aligned} \alpha_i \gamma_{\alpha_i} &= \beta\gamma_i + \theta_i \gamma_{\theta_i} \,, \\ \gamma_{\alpha_i} &= \gamma_{\beta_i} + \gamma_{\theta_i} \,, \end{aligned} \tag{3}$$

Here α_i , β_i , θ_i are the amount of useful metal in the concentrate and u is the amount of useful metal in the waste products of the contour; γ_{α_i} γ_{β_i} γ_{θ_i} is the amount of solids in the concentrate and waste products consumed by the contour.

Currents from other circuits and the initial current may come to the input of the и - circuit. As a result, we get:

$$\alpha_i = \frac{\sum_{j=1}^{\pi} \left(\omega_{ij} \beta_i \gamma_{\beta_i} + \aleph_{ij} \theta_j \gamma_{\theta_j} \right) + \alpha_i^0 \gamma_{\alpha_i}^0}{\sum_{j=1}^{\pi} \left(\omega_{ij} \gamma_{\beta_j} + \aleph_{ij} \gamma_{\theta_j} \right) + \gamma_{\alpha_i}^0}, \tag{4}$$

$$\gamma_{\alpha_i} = \sum_{j=1}^{\pi} \left(\omega_{ij} \gamma_{\beta_i} + \aleph_{ij} \gamma_{\theta_j} \right) + \gamma_{\alpha_i}^0 \tag{5}$$

Here

$$\omega_{ij} = \begin{cases} I, \;\; if \;\; j - \text{contour concentrate} \\ i - \text{comes to the contour,} \\ 0, \;\; \text{for the rest,} \end{cases}$$

$$\aleph = \begin{cases} I, \qquad if \;\; j - discarded \; products \; of \; the \; contour \\ \\ i - \text{comes to the contour,} \\ 0, \qquad \text{for the rest;} \end{cases}$$

Where α_i^0 is the presence of a useful metal in the initial flow; $\gamma_{\alpha_i}^0$ is solid output in the initial current.

By changing i from 1 to n, we create a system of linear algebraic equations using equations (4), (5), and solve the system and find the functions:

$$\gamma_{\beta_i} = \gamma_{\beta_i}(\alpha_1^0, \alpha_2^0 \dots, \alpha_n^0, \gamma_{\alpha_1}^0, \gamma_{\alpha_2}^0, \dots, \gamma_{\alpha_n}^0, \beta_1, \beta_2, \dots, \beta_n, \theta_1, \theta_2, \dots, \theta_n),$$
$$\gamma_{\theta_i} = \gamma_{\theta_i}(\alpha_1^0, \alpha_2^0 \dots, \alpha_n^0, \gamma_{\alpha_1}^0, \gamma_{\alpha_2}^0, \dots, \gamma_{\alpha_n}^0, \beta_1, \beta_2, \dots, \beta_n, \theta_1, \theta_2, \dots, \theta_n),$$

In this case, i varies from *1 to n* *i=1,2,..,n* .

If β_π and γ_{β_π} represent the amount of useful metal in the finished product, then the system of equations is determined from the state of material balance according to the following technological scheme:

$$\sum_{i=1}^{\pi} \alpha_i^0 \gamma_{\alpha_i}^0 = \beta_n \gamma_{\beta_n} + \theta_{omb} \gamma_{\theta_{omb}} , \quad (6)$$

$$\sum_{i=1}^{\pi} \gamma_{\alpha_i}^0 = \gamma_{\beta_n} + \gamma_{\theta_{omb}} . \quad (7)$$

From this system, we create a macromodel to determine the amount of useful metal in the waste products:

$$\theta_{omb} = \beta_\pi - \frac{\beta_\pi \sum_{i=1}^{\pi} \gamma_{\alpha_i}^0 - \sum_{i=1}^{\pi} \alpha_i^0 \gamma_{\alpha_i}^0}{\sum_{i=1}^{\pi} \gamma_{\alpha_i}^0 - \gamma_{\beta_n}} . \quad (8)$$

In terms of the amount of useful metal in the finished concentrate, the macromodel looks like this:

$$\beta_\pi = \theta_{omb} - \frac{\theta_{omb} \gamma_{\theta_{omb}} - \sum_{i=1}^{\pi} \alpha_i^0 \gamma_{\alpha_i}^0}{\gamma_{\beta_\pi}} . \quad (9)$$

The extraction of a useful metal from a similar finished concentrate is determined as follows:

$$\varepsilon = \beta_\pi \gamma_{\beta_\pi} / \sum_{i-1}^{\pi} \alpha_i^0 \gamma_{\alpha_i}^0 . \quad (10)$$

Thus, in the initial stage of modeling, a macromodel is created for the whole process using only the input and output parameters of the contours.

So, in the second stage, a macromodel is created for the local part systems of a multi-state technological process.

CONCLUSIONS

The hierarchy of the system under study is represented by the first global mathematical model. Then, using the hierarchy structure, the micromodels of the local part systems are derived from the original macromodel. Thus, the problem leads to finding the optimal solution of the initial mathematical model. The results obtained using different methods are then compared, and the best method that meets the specified criteria is selected. In this case, the high-level model is built, considering the conditionally optimal solutions of low-level micromodels. In turn, a solution found using a high-level macromodel is sent to a lower-level model, and a detailed solution is sought in that model.

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