Mathematical Modeling of Technological Processes on the Example of Glass Tare Production

Elena V. Morozova[1, 2]
[1]Saint Petersburg Electrotechnical University "LETI"
St. Petersburg, Russia
[2]Kamyshin Technological Institute (branch) of Volgograd State Technical University
Kamyshin, Russia
konvvert@yandex.ru

Mihail P. Belov
Saint Petersburg Electrotechnical University "LETI"
St. Petersburg, Russia
Milesa58@mail.ru

***Abstract*— Mathematical modeling of complex objects, systems and processes is currently one of the main tools for their design and study. Mathematical modeling of complex systems and devices not only saves money, but also shortens the time for conducting research. Often it allows you to conduct virtual experiments, while real experiments cannot be carried out or is not economically justified. In the article one of the approaches to mathematical modeling of complex stochastic systems is considered on the example of technological processes of glass tare production. A mathematical model of glass tare production is developed by the authors. The practical importance of the work is to create an imitation model, which is based on the developed mathematical models of the functioning of technological equipment. The obtained models allow optimizing the main parameters of technological processes of industrial production, ensuring the effectiveness of making managerial decisions.**

Keywords*— modeling; mathematical model; technological process; glass tare production

I. Introduction

The introduction of innovative technologies, the transition to the release of new products, the changing needs of the market and other regulations force the administration of enterprises to continuously improve the management of material, financial and human resources to maintain the competitiveness of their products and reduce the costs of its creation.

Creation of the developed programming-methodical support, which enables, if necessary, operatively to carry out the functional and structural modeling of production lines, technological complexes and aggregates, as complex production systems, will contribute to the optimization of production.

Mathematical modeling of production systems is one of the most effective tools for creating industrial applications. [1–6]

II. The Object and Methods of Research

In the general case, the mathematical model of a complex production system is a set of relationships (for example, equations, logical conditions, operators) that determine the characteristics of the process of functioning of this system, depending on its structure and parameters, and also the algorithms of the system's behavior, impact of the environment, initial conditions and the time on her.

The mathematical model is the result of the formalization of the technological process of the functioning of the production system under study. It is a formal (mathematical) description of the technological process with the degree of approximation to reality necessary in the framework of the study [5].

The existing variety of objects of complex production systems, the stochastic and dynamic nature of their functioning does not always allow to obtain adequate mathematical models for them, formulated in the form of familiar analytical relationships.

One of the solutions is the creation of mathematical models using computers based on probabilistic simulation models and the decomposition of the technological process into functional subsystems, based on the approach proposed by Buslenko N.P. [2]. The synthesis of algorithmic and software on the basis of the constructed mathematical models is subsequently carried out.

Technological processes of industrial production can be represented in the form of connected graphs. The nodes of the constructed graphs correspond to the functional states of the technological equipment used in manufacture. The orientation of graph edge reflects the direction of the operations and their interrelationship. Mathematical models and modeling algorithms are developed on the basis of the graphs of functional states of technological equipment.

Time is the main independent variable in mathematical models, which will be constructed using the described method. Other variables appearing in the developed models will be some time functions (dependent variables).

The experimental basis for creating models was the study of statistical regularities in the distribution of random quantities of the flow of basic and auxiliary production processes, the time between failures, and the time for eliminating

978-1-5386-5824-6/18/$31.00 ©2018 IEEE

technological and technical failures for various types of equipment.

Statistical studies of complex systems of technological equipment require a large amount of research to obtain, accumulate, process and analyze information, the most important stage of which are timekeeping of individual machines using technical means and instrumental measurement methods. In this case, the necessary number of repeated timekeeping is determined using the formula [3]:

$$n = (z \cdot \delta / \varepsilon)^2,$$

where σ is the standard deviation of the random variable (determined from a series of preliminary experiments); ε is accuracy of observations (in units of time); z is a tabular value equal to 1.96 (based on the reliability of observations, given by the probability $p = 0.95$).

III. Results of the research and their discussion

To illustrate the possibilities of the formalization method described, let us consider the process of functioning of the technological equipment of glass tare production.

On the basis of the analysis of the technological process for the production of glass tare and using the above-mentioned recommendations of Buslenko N.P., we introduce the following main technical and technological subsystems for the production of glass tare: T_1 is “Loading of charge and cullet into glass worked furnaces”, T_2 is “Glass-making”, T_3 is “Production of glass tare”, T_4 is “Annealing”, T_5 is “Sorting”, T6 is “Packing of glass products”. Each subsystem within the framework of the source systems corresponds to the technological process performed by the concrete equipment, while the interconnections that ensure their interaction are preserved.

Further decomposition of technical and technological subsystems allows us to single out subsystems of the lowest level, as well as the most important technological operations performed by the glass processing equipment within these subsystems. Each of the selected systems is represented in the form of connected graphs, on the basis of which mathematical models of technical and technological subsystems are developed.

As an example, consider the construction of a mathematical model of the subsystem T_1 – “Loading of charge and cullet in glass worked furnaces”.

In the subsystem under consideration, subsystems of the lowest level were singled out: $T_{1.1}$ is “Feeding of cullet to the hopper feeder”; $T_{1.2}$ is “Feeding of charge and cullet to the hopper of charge loaders”; $T_{1.3}$ is “Feeding the mixture into the doghouse of the furnaces”.

Also, the main technological operations performed by the equipment within the framework of these subsystems were singled out: C_1 is the preparatory-final operation; C_2 is feeding of cullet into the feed hopper; C_3 is feeding of charge and cullet to the hopper of loaders; C_4 is feeding a mixture of charge and cullet into the doghouse of the furnaces; C_5 is failure for technical reasons; C_6 is simple equipment due to lack of work front.

The mathematical model (1) for the subsystem T_1 was developed on the basis of the constructed digraph (Fig. 1).

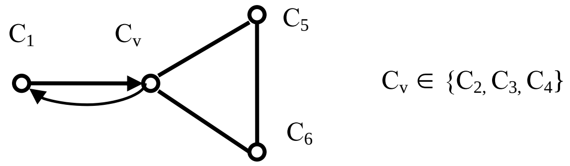

Fig. 1. The graph of the transition of the technological states of the equipment of the subsystem T1 – "Loading of charge and cullet into glass worked furnaces"

$$C(t+\Delta t) = \begin{cases} \mathrm{C}_1,\ if\ [(\mathrm{C(t)} = \mathrm{C}_1) \cup (\mathrm{C(t)} = \mathrm{C_v}) \cap \\ \cap (\mathrm{N_v(t)} > \mathrm{N_v})] \cap (\alpha(\mathrm{t}) = 1 \cap \beta(\mathrm{t}) = 0); \\ \mathrm{C}_2,\ if\ [(\mathrm{C(t)} = \mathrm{C_v}) \cap (\mathrm{N_v(t)} \le \mathrm{N_v}) \cup \\ \cup (\mathrm{C(t)} = \mathrm{C}_5) \cup (\mathrm{C(t)} = \mathrm{C}_6)] \cap \\ \quad \cap (\alpha(\mathrm{t}) = 1) \cap (\beta(\mathrm{t}) = 1) \cap \mathrm{N_v} > 0; \\ \mathrm{C}_5,\ if\ [(\mathrm{C(t)} = \mathrm{C}_5) \cup (\mathrm{C(t)} = \mathrm{C_v}) \cup \\ \cup (\mathrm{C(t)} = \mathrm{C}_6)] \cap (\alpha(\mathrm{t}) = 0); \\ \mathrm{C}_6,\ if\ [(\mathrm{C(t)} = \mathrm{C}_6) \cup (\mathrm{C(t)} = \mathrm{C_v}) \cup \\ \cup (\mathrm{C(t)} = \mathrm{C}_5)] \cap (\mathrm{N_v} = 0) \cap (\alpha(\mathrm{t}) = 1). \end{cases} \quad (1)$$

Where $C \in \{C_1, C_2, C_3, C_4, C_5, C_6\}$; $C_v \in (C_2, C_3, C_4)$; $v = 2, 3, 4$; t and Δt is an arbitrary moment and step of increment of the simulation time; $N_2(t)$ is a random function of the quantity of cullet fed into the hopper feeder; $N_3(t)$ is a random function of the number of fed charge and cullet in the feed hopper; $N_4(t)$ is a random function of the amount of the fed mixture into the doghouse of the furnaces; N_2 is the necessary amount of cullet for feeding into the hopper; N_3 is the required amount of charge and cullet for feeding into the hopper feeder; N_4 is the required amount of the mixture for feeding into the doghouse of the furnaces; $\alpha(t)$ is a random function characterizing the operability of the equipment (0 is does not work, 1 is works); $\beta(t)$ is a random function that characterizes the execution of a technological operation (0 is not performed, 1 is performed).

Similarly, mathematical models of other described subsystems are constructed.

The generalized mathematical model for the functioning of the mechanized line of glass tare production is constructed based on the graph of the transition of one technical-technological subsystem to another and the mathematical models of subsystems obtained. [4]

IV. Conclusion

Thus, as follows from the foregoing, when building algorithms for modeling the technological line of glass tare production, a unified ideology and a single methodological approach are used. All mathematical models are conceptually similar. And with their software implementation, small changes in the transition from one algorithm to another are enough. This makes it possible to greatly simplify the software implementation of the simulation model, including its encoding and debugging components.

The approach set forth in the article is an effective tool allowing simulating the technological processes not only of production of glass tare, but also of other industrial productions.

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