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ABOUT SIMULATION OF PRODUCTION WITH USE OF LEVELS OF SUBJECTS AND TECHNOLOGICAL AND FLOW LEVELS OF THE DESCRIPTION

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Using statistical approach, which is widespread in natural sciences, the model of production of technological system with a continuous method of the organization of production is provided. The status of flow parameters of production of technological system is set by a set of statuses of subjects of the labor. A point in phase technological space sets the status of a separate subject of the labor. It is entered a distribution function of subjects of the labor on a status and the kinetic equation for a distribution function of subjects of the labor on statuses of technological processing is written. The closed system of the dynamic equations (the balance equations) describing behavior in time of values of the first moments of a distribution function characterizing frequency curve of in-process backlogs on technological AND operations the rate of processing of subjects of the labor on technological operations is written.

Keywords: production line, subject of the labor, product line, parameters of a status of the product line, technological line item, the transition period, production management systems, kinetic equation, mass production, work in progress, production PDE-model

Introduction. Variety and complexity of manufacturing technologies of a product creating premises to simulation of the technological process of production-technical system based on idea of it as a complex of the subjects of labor, which are in different stages of technological processing [1-4]. However, it is almost impossible to trace a behavior of the separately taken subject of the labor because of quality and the probable nature of influence on the subject of the labor of a technology equipment [4, 5]. Effective approach to simulation of big systems is the statistical approach [6-9], considering technological process at two levels of the description on the subject-technological level [10] and flow level [11]. At the subject-technological level patterns of behavior of separate elements of a system, on a flow level – their aggregated characteristics and communications between these characteristics are researched. Interconnection between levels is carried out through the kinetic equation [12-14]. This article is devoted to features of application of statistical approach to simulation of technological systems.

Main part. *1. Subject-Technological Level of The Description of Technological Process.* During execution of technological operation regarding work, the cost of technological resources by purposeful influence of a technology equipment is transferred [2,5,8,15]. On each operation, inevitably there are oscillations of geometrical characteristics, physicomechanical properties of materials, which are caused by a complex of arbitrary and systematic production factors. Thus, technological process is accidental process of transition of subjects of the labor of one status in another because of influence of a technology equipment. Its status is defined as a status of number of subjects of the labor [5-9]. Coordinates in phase technological space to time point can provide the status of an subject of the labor (t, S, μ) [2,6]: cost amount S_j ($\$$) and intensity of transfer of expenses in unit of time μ_j ($\$$/hour) from a technology equipment on j subject of the labor, $0 < j < N$. Coordinates S_j and μ_j also define technological paths of subjects of the labor in phase technological space $S_j = S_j(t)$. Intensity of transmission of expenses $\Delta S = \Delta S(t)$ from means of labor on j subject of the labor for runtime of technological operation Δt is accidental process [4,7,8,15], which value in the fixed time point is defined by a random variable [6]

$$\mu = \frac{\Delta S}{\Delta t}. \qquad (1)$$

The system status in some time point will be defined if micro parameters are determined S_j and μ_j , and in any other time point, it is found from equations of state of parameters of an subject of the labor [16]:

$$\frac{dS_j}{dt} = \mu_j, \frac{d\mu_j}{dt} = f_j(t, S), \qquad (2)$$

$f_j(t, S)$ - production function for a technology equipment [17]. If the quantity of subjects of the labor are much more than unit, then to solve system (2) from 2N - the equations are almost impossible. Instead of reviewing of a status of subject of the labor of technological process with parameters S_j and μ_j, we will enter the normalized function of distribution of subject of the labor on statuses. Each point in this space will set a status of an subject of the labor [6,14,18]. It is reasonable to expect that in case of big N this function will be well approximated by the continuous function of distribution of subject of the labor on statuses $\chi(t, S, \mu)$.

2. Kinetic Description of Technological Process. We will break phase space into such number of cells that the cell sizes $\Delta\Omega = \Delta S \cdot \Delta\mu$ there were much less values of characteristic (1) parameters of technological system and at the same time contained in themselves a large number of subjects of the labor. Instead of fixing exact parameter values of subjects of the labor, we will characterize approximately a status of technological system by number of subjects of the labor in each cell $\Delta\Omega$ [6,8,13]. If the sizes of a cell are rather small, then the approximate description will bear in itself almost so detailed information, as exact. That value $\chi(t, S, \mu) \cdot d\Omega$ represents number of subjects of the labor in an infinitesimal cell $\Delta\Omega$ phase technological space; we can on change of phase coordinate S and phase velocity μ, to judge also change of the function $\chi(t, S, \mu)$:

$$\frac{\partial \chi(t, S, \mu)}{\partial t} + \frac{\partial \chi(t, S, \mu)}{\partial S} \cdot \mu + \frac{\partial \chi(t, S, \mu)}{\partial \mu} \cdot f(S) =$$
$$= J(t, S, \mu), \frac{dS}{dt} = \mu; \frac{d\mu}{dt} = f(S). \qquad (3)$$

The equation (3) describes change averaged on an infinitesimal cell of phase technological space $\Delta\Omega$ characteristics of subjects of the labor S_j, μ_j. We will read function $\chi(t, S, \mu)$ the normalized

$$\int_0^\infty dS \cdot \int_0^\infty d\mu \cdot \chi(t, S, \mu) = N. \qquad (4)$$

Production function $f(t, S)$ is defined from the given method of production. In case of relocation along technological regarding work, impact from the equipment of the route located with a density is made $\lambda(S)$. We can speak only about probability that after such influence the subject of the labor will be in this or that status. This probable nature of

influence can be considered; having set function $\psi(t, S, \mu)$, defining probability that after influence the subject of the labor will consume technological resources with intensity μ. Function $\psi(t, S, \mu)$ it is possible to set, analyzing passport data of a technology equipment:

$$\int_0^\infty \psi(t, S, \mu) \cdot d\mu = 1, \int_0^\infty \mu^k \cdot \psi(t, S, \mu) \cdot d\mu = [\psi]_k, \ k = 1, 2.....$$ (5)

Quantity of the subjects of the labor, which were affected in unit of time from a technology equipment in a cell $dS \cdot d\mu$ with coordinates (S, μ) and moved as a result of influence to a cell $dS \cdot d\tilde{\mu}$ with coordinates $(S, \tilde{\mu})$, in proportion to the work of a flow of subjects of the labor $\chi(t, S, \mu) \cdot \mu$ on transition probability $\psi(t, S, \tilde{\mu}) \cdot d\tilde{\mu}$. Number of the subjects of the labor, which were affected in unit of time from a technology equipment and the accepted values in limits $(\tilde{\mu}; \tilde{\mu} + d\tilde{\mu})$ there is a value $\psi(\tilde{\mu}) \cdot \lambda(S) \cdot \mu \cdot \chi(t, S, \mu) \cdot d\tilde{\mu} \cdot dS \cdot d\mu$. Along with it in a volume, element $dS \cdot d\mu$ subjects of the labor from volume arrive $dS \cdot d\tilde{\mu}$ by the reverse transition in quantity $\psi(\mu) \cdot \lambda(S) \cdot \tilde{\mu} \cdot \chi(t, S, \tilde{\mu}) \cdot d\tilde{\mu} \cdot dS \cdot d\mu$, and the total number of subjects of the labor in a volume element changes in unit of time on value $dS \cdot d\mu \cdot J$

$$J = \lambda(S) \cdot \int_0^\infty \{\psi(\mu) \cdot \tilde{\mu} \cdot \chi(t, S, \tilde{\mu}) - \psi(\tilde{\mu}) \cdot \mu \cdot \chi(t, S, \mu)\} d\tilde{\mu}.$$ (6)

From where the kinetic equation (3)–(6) can be presented in the form [12]

$$\frac{\partial \chi(t, S, \mu)}{\partial t} + \frac{\partial \chi(t, S, \mu)}{\partial S} \cdot \mu + \frac{\partial \chi(t, S, \mu)}{\partial \mu} \cdot f =$$
$$= \lambda \cdot \left\{ \int_0^\infty \psi(\mu) \cdot \tilde{\mu} \cdot \chi(t, S, \tilde{\mu}) d\tilde{\mu} - \mu \cdot \chi(t, S, \mu) \right\}.$$ (7)

In the majority practical cases equation (7) does not depend from a state of subjects of the labor before test of influence from the equipment from where

$$\frac{\partial \chi(t, S, \mu)}{\partial t} + \frac{\partial \chi(t, S, \mu)}{\partial S} \cdot \mu + \frac{\partial \chi(t, S, \mu)}{\partial \mu} \cdot f = \lambda(S) \cdot \{\psi(\mu) \cdot [\chi]_1 - \mu \cdot \chi\}.$$ (8)

The solution of the equation (8) gives an opportunity to calculate values of flow parameters of technological process, is connected to great difficulties [6,13,19].

3. Flow Description of Technological Process. We will describe a status of technological process on a flow level the moments of a distribution function of subject of the labor on statuses $\chi(t, S, \mu)$

$$\int_0^\infty \mu^k \cdot \chi(t, S, \mu) d\mu = [\chi]_k, k = 0, 1, 2.....$$ (9)

It is known [1, 2, 7] that for the description of a status of production systems on a flow level use the two first the moment (9). The zero and first moments of a distribution function of subjects of the labor on statuses μ (9) have production interpretation: these are backlogs of subjects of the labor and their rate of movement along a technological chain [1,2,4]. Having increased the equation (8) on μ^k, $k=0,1,2....$ and having integrated on all range μ, we will receive not closed equations of balances of a status of flow parameters of technological system[6,20]:

$$\frac{\partial[\chi]_0}{\partial t}+\frac{\partial[\chi]_1}{\partial S}=\int_0^\infty d\mu \cdot J \, , \ \frac{\partial[\chi]_k}{\partial t}+\frac{\partial[\chi]_{k+1}}{\partial S}=$$

$$=k\cdot f(t,S)\cdot[\chi]_{k-1}+\int_0^\infty d\mu \cdot \mu^k \cdot J \, , \ k=1,2,3..... \tag{10}$$

If average cost of resources $\langle \Delta S\rangle$, postponed during execution of technological operation regarding work the prime cost of the final product is much less S_d, what is characteristic of the technological process consisting of a large number of technological operations, the balance equations (10) in zero approximation in small parameter $\langle \Delta S\rangle / S_d <<1$ will take a form:

$$\frac{\partial[\chi]_0}{\partial t}+\frac{\partial[\chi]_1}{\partial S}=0, \ \frac{[\chi]_k}{[\chi]_1}=[\psi]_{k-1}, \ \frac{\partial[\chi]_k}{\partial t}+\frac{\partial[\chi]_{k+1}}{\partial S}=$$

$$=k\cdot f(t,S)\cdot[\chi]_{k-1}, \ k=1,2,3..... \tag{11}$$

The system of the balance equations (11) is closed. For technological system, which macrostate is described by two parameters – a productions reserve of subject of the labor on technological and operation by their rate of movement, the system of the balance equations (12) can be written as:

$$\frac{\partial[\chi]_0}{\partial t}+\frac{\partial[\chi]_1}{\partial S}=0, \ \frac{[\chi]_2}{[\chi]_1}=[\psi]_1, \ \frac{\partial[\chi]_1}{\partial t}+\frac{\partial[\chi]_2}{\partial S}=f(t,S)\cdot[\chi]_1. \tag{12}$$

The equations (12) describe a status of technological process through parameters - backlogs of subjects of the labor and their rate of movement on a process flow.

Conclusion. It is at the first sight would be possible to conclude that with increasing of a number of elements unimaginably increase complexity of technological system and not to find in her behavior also traces of any regularity[21,22]. A research of the production-technical systems that consist of a very large number of the subjects of the labor, which are in technological process allowed to reveal important feature of such systems [4,22]. It is the behavior of similar technological systems is defined by the regularities of special type which received names of statistical regularities. The importance of application of statistical approach essence in giving «the simplified mechanism» for the description of macroscopic characteristics of production- technical systems [23-27]. In many ways, which shows practical interest, such description is quite enough.

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