Modeling of industrial stream and resources of machine-building enterpriser complex of wood preparation

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Abstract. Theoretical bases of linkage of material streams of the machine-building enterprise and the automated system of decision-making are developed. The process of machine-building manufacture is submitted by the existential system. The equation of preservation of movement is based on calculation of volume of manufacture. The basis of resource variables includes capacities and operators of the equipment. Indignations such as a defect and failure are investigated in the existential basis. The equation of a stream of details on a manufacturing route is made. The received analytical expression expresses a condition of a stream of movement of details in view of influence of work of the equipment and traumatism of the personnel.

1. Introduction

During preparation of wood, it is required to carry out a set of works: cutting down trees, skidding, loading. The enterprises engaged in preparation of wood require equipment of high-efficiency machines. Modeling of an industrial stream and resources of manufacture of machines for preparation of a wood is necessary and a challenge.

1.1. The classical models describing material streams of resources of the enterprise.

Some forms of models are known: balance; mass, continuous and stationary; the theory of schedules; discrete-logic and network models.

1.2. The brief characteristic of models

The balance model of manufacture is one of the simplest models. The theory of balance models has been formulated by V Leontjev in the middle of the 30s. The model is put in a basis of a continuous stationary model of a stream which realization guarantees performance of the set volumetric parameters during the stipulated period [1]. Models of the theory of schedules directly result in statement of a problem of schedules formation of sequence performance of the operations making a technological route. The models considered above are widely used in practice of construction of the automated control systems. These models concern the class «Just in time» [2].

In models of distributed dynamics, the task of the accounting the inertial delay in performance of
production targets on technological operations is put by approximation of the process by equivalent inertial parts. The models of discrete-logic are used for small-scale types of manufactures and characterized by the combinatorial approach for the solution of tasks of resources distribution of. During formation of planned daily tasks, a plenty of combinations of resources become known. The given approach cannot provide the decision of a task in the view at a level above a site of the shop [3].

Network models are used in the distributive system and submitted as graphs, which tops are technological operations and arches are submitted moving details. The character of formalization of the object of modeling has two approaches of creation of models: discrete and continuous. Occurrence of the continuous approach to construction of imitating models is connected with the advent of analog computers and their use for the decision of the differential equations. The continuous approach was originally applied to modeling continuous real objects which were described by the differential equations [4].

Continuous models can be divided into analytical, discrete-continuous and stochastic. Analytical models include dynamic models of processes: on the basis of the ordinary differential equations; on the basis of the differential equations. There are algebraic models of conditions, which are subdivided into: models of linear algebra; network; systems of mass service. The discrete-continuous form is the complicated updating of the analytical model, which is taking into account the fact that the object of management is observed and copies during the certain discrete moments of time. Stochastic models are a more complex variant, but closer to real processes. The model of algebra of logic is the fundamental mathematical device of the description of discrete-logic processes. They are used for the description of rather simple technical devices. Algorithmic models are the form of imitation of a wide class of mathematical and physical objects on the digital automatic device. Situational and semantic approaches are used in construction of expert systems. Models of indistinct representations are used in systems of an artificial intellect and expert systems.

2. Methods of the research
When justifying the methods and algorithms of the management of the machine-building enterpriser, the methods of system analysis, the general theory of systems, the theory of automatic control, the methods of mathematical and simulation modeling were used.

3. The results of the study and their discussion

3.1. The description of an industrial stream and resources of the machine-building enterprise
The description of environment is ordered moving particles. Let us consider movement of details along axis $x$. On a piece $[x, x+\Delta x]$, there are $\Delta n$ details in time $\Delta t$.

\[ A discrete system shall be replaced on the continuous model [5]. The law of movement of details will be determined by function $n=n(x, t)$ from two variables $x, t$. Let us consider this dependence at $x=\text{const}$, $t=\text{const}$ and $x, t=\text{const}$. At $x=\text{const}$, let us pass to concept of a stream, what quantity of details will pass in time $\Delta t$ through the fixed point on axis $x$: \]

\[ q = \lim_{\Delta t \to 0} \frac{\Delta n}{\Delta t} = \frac{dn}{dt} \bigg|_x, \quad dn = q(t)dt \]

\[ n = \int_{t_i}^{t_f} q(t)dt \bigg|_x. \]
At \( t = \text{const} \), let us pass to the concept of density, what quantity of details is on piece \( \Delta x \) at the moment of time \( t \):

\[
\rho = \lim_{\Delta t \to 0} \frac{\Delta n}{\Delta x} = \frac{dn}{dx}
\]

\[
n = \int_{x_i}^{x_f} \rho(x)dx
\]

At \( x, t = \text{const} \), let us pass to the concept of speed, what distance \( \Delta x \) will be passed with details in time \( \Delta t \):

\[
v = \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t} = \frac{dx}{dt}
\]

3.2. Statement of management problem by processing details on manufacturing route

Infringement of uniformity of distribution of details on a manufacturing route can be of two types: a defect and halting. In case of a defect, the part of details descends, and in case of halting there is infringement of distribution of density (Figure 2). Updating a material stream consists in change of speed \( v \) or intensity of stream \( q \).

![Figure 2. Infringement of uniformity of distribution of details on manufacturing route](image)

3.3. Formal model of manufacture process in a models class of mathematical physics

Movement of details shall be considered in a three-dimensional Cartesian system of coordinates. Let us allocate an interval, with the ends on which there is a portion of a material. Axis \( x \) is used for the description of a condition of a material stream of details from a defect, axis \( y \) - for the description of a condition of a stream from the failure connected to work of the equipment and axis \( z \) for the description of a condition of a stream from the work of the personnel.

Let us designate:

\[
X = (x, y, z), \quad \Xi = (\xi, \eta, \zeta), \quad d^3\Xi = d\xi d\eta d\zeta
\]

It is possible to offer the following analytical forms of laws of management of movement of a material. The integrated law on time concerning a stream:

\[
v(x, y, z, t) = -k_{11}(x)k_{12}(y)k_{13}(z)\int_{t}^{t} q(x, y, z, t)dt
\]

The integrated law on a route concerning density:
Practically (6) the law of smoothing functions \( q, \rho \) and \( v \), approaches actual production to desirable. If \( \int q_i(x, y, t) dt \neq 0 \), it means that \( Q \neq q \), i.e. there are underproduction products, it is necessary to change speed that is a deviation\{rejection\} from stream \( \int q_i(x, y, z, t) dt \to 0 \).

Finally let us have a system of the partial differential equations from the set mode and management of the object with the help of speed \( v \) or intensity of stream \( q \):

\[
\begin{align*}
\frac{\partial q}{\partial t} &= -\frac{\partial (q(x, y, z, t))}{\partial x} - \frac{\partial (q(x, y, z, t))}{\partial y} - \frac{\partial (q(x, y, z, t))}{\partial z} + b(X, t) \quad \text{Object} \\
v(x, y, z, t) &= -k_{11}(x)k_{12}(y)k_{13}(z)\int q(x, y, z, t) dt \quad \text{Management}
\end{align*}
\]

\( x_0 \leq x \leq x_k, y_0 \leq y \leq y_k, z_0 \leq z \leq z_k, t \geq t_0, q(x_0, y_0, z_0, t) = q_0(t) \),

\[
q(x_k, y_k, z_k, t) = q_k(t), \rho(x, y, z, t_0) = \rho_0(x, y, z),
\]

\[
\rho_s = uq_s, \rho_y = vq_y, \rho_z = wq_z.
\]

The system of the equations has the analytical decision under known initial and regional conditions which can be received on the basis of the Dirac delta function [6, 7]. Green's function is the decision of the equation for a considered regional task at:

\[
G(x, y, z, t, \xi, \eta, \zeta, \tau) = \delta(x-\xi)\delta(y-\eta)\delta(z-\zeta)\delta(t-\tau).
\]

For a dot source of loss of quantity of details \( N_0 \), the function of a defect will be described as:

\[
b(x, y, z, t) = N_0\delta(t)\delta(x-\xi)\delta(y-\eta)\delta(z-\zeta)\delta(t-\tau).
\]

The decision for \( q \) looks like:

\[
q(x, t) = q_0 + \frac{N_0}{16\pi\sqrt{K_xK_yK_z}} \exp\left[\frac{-(x-x_0)^2}{4K_xt}\right] + \exp\left[\frac{-(y-y_0)^2}{4K_yt}\right] + \exp\left[\frac{-(z-z_0)^2}{4K_zt}\right].
\]

After integration, one can receive

\[
q(x, t) \approx q_0 + \frac{N_0}{16\pi\sqrt{K_xK_yK_z}} \left[ \exp(2a\sqrt{b}) \text{erfc}\left(\frac{a\sqrt{b}}{\sqrt{t}}\right) + \exp(-2a\sqrt{b}) \text{erfc}\left(\frac{a\sqrt{b}}{\sqrt{t}}\right) \right] +
\]

\[
+ \frac{1}{a_x} \left[ \exp(2a\sqrt{b}) \text{erfc}\left(\frac{a\sqrt{b}}{\sqrt{t}}\right) + \exp(-2a\sqrt{b}) \text{erfc}\left(\frac{a\sqrt{b}}{\sqrt{t}}\right) \right],
\]

where

\[
a_x = \sqrt{\frac{(x-x_0)^2}{4K_x} + \frac{(y-y_0)^2}{4K_y} + \frac{(z-z_0)^2}{4K_z}},
\]

\[
b = \frac{u(x-x_0)}{2\sqrt{K_x}},
\]

\[
c = \frac{u(x-x_0)}{2K_x},
\]

\[
\text{erfc}(x) = \frac{2}{\sqrt{\pi}} \int_{x}^{\infty} \exp(-u^2) du.
\]

The received analytical expression expresses a stream condition of movement of details in view of the influence of work of the equipment and traumatism of the personnel.
Conclusions
Use of the model, using methods of mathematical physics, has allowed establishing communication between continuous movement of details and discrete-nomenclature operations. Thus, parameters of output and work in progress are continuous functions, time-dependent and coordinated. The process of moving of details on a manufacturing line is formalized by the system of the partial differential equations.

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