UTILIZING SIMULATION MODEL IN LARGE-SCALE PRODUCTION MANAGEMENT

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Abstract: *Main aim of this paper is to present the simulation model for large-scale production process, where usage of the model helps to simulate the course of production for different dynamic characteristics of workplaces' operations. This model can be used for both the preparation process of the production and also in the realization process, it means within the framework of operative production management and this way it can contribute to its efficiency. The structure of the model is created by functional blocks and their linkages considering organizational and chronological hierarchy of the actions which are presented as the model's structure. The theoretical knowledge of regulation, hierarchical system and optimization are the base for the simulation model creation.*

Keywords: *Dynamic behavior, Functional blocks, Mass production, Production Process, Simulation model.*

JEL Classification: *C610, L230, M11.*

Introduction

One of the issues of changes aimed at the increasing production and business activities efficiency is intensifying and rationalizing production process (system) by application of flexible management system that would be adequate to these changed requests [6].

In the production process these requirements are concerned primarily with achieving higher levels of labour productivity, increasing time and performance utilization of equipment, staff economy, relative savings of physical work, determination of optimum parameters of workplaces in the connection with economic decisions' criteria (cost optimization, expenses, profit etc.).

Model considerations presented in this paper relate to large-scale production process with parallel linkage of workplaces.

1 Basic Preconditions of the Presented Simulation Model

When forming dynamic characteristics of the large-scale production process including its modeling projection, the following characteristics are considered:

a) functional characteristics of elements, which form the process' dynamics of the production process and are presented by special functions of sub-blocks and blocks modeling dynamic characteristics of production process (blocks labeled "RS", "PSI", "PSII", "MAX", "PR" and "NS");

b) structure of its linkage and behavior, i.e. its dynamic characteristics which are determined by the character of transformation of the value and change its inputs to its outputs.

Individual functional blocks and sub-blocks model dynamic characteristics are based on discrete linear transformation, further on the basis of non-linearity in the form of time delays and limitation of output change of individual blocks and sub-blocks of the model when changing its inputs and then by limitation given by transformation output sign [4]. Functional blocks, its sub-blocks and its linkage are functionally determined in a way that it is possible to, by the modeling of its application, express criteria condition for evaluation of effectiveness of existing dynamic characteristics of large-scale production process, analyze it and execute simulation evaluation of the changes' impact [9].

Criteria condition of assessing required level of dynamic characteristics of workplaces is based on theoretical knowledge verified in practice, namely, that dynamic characteristics must be such, so that it is possible in case of the existence of unproductive states at a workplace to fulfill production tasks in the remaining time, i.e. from certain time to the end of given period. This requires, apart from securing the production of required production's remaining amount by the period end, also balancing already existing undesirable deviation in the production tasks fulfillment [1]. The time duration of unproductive state at a workplace influences productive time in shift (the time, in which product is produced). If the projected time t_m is fulfilled, the shift is considered, from the viewpoint of possibility to fulfill production tasks as normal, if the projection time t_m is not fulfilled, the shift is considered as pessimistic, and if it comes to extension of time t_m, the shift is considered as optimistic.

Criteria condition for evaluation of required level of dynamic process' characteristics of large-scale production process is possible to write in formula:

$$Q_{pT}^{max}(T-\tau) = Q_{pT}(T-\tau) + \sum_{t=0}^{t=\tau} \Delta Q(t), \quad (1)$$

where:

$Q_{pT}^{max}(T-\tau)$ – maximum amount of production, which is possible to produce in time,

$(T-\tau)$ – while respecting necessary or limiting conditions (dynamic characteristics) of workplace's operation in the production process, such as: productivity of equipment, productivity of conveying equipment, level of requirements for safety conditions at a workplace, admissible level of cost effectiveness of workplace operation, etc.,

$Q_{pT}(T-\tau)$ – required amount of production, which should be produced in time $(T-\tau)$,

$\sum_{t=0}^{t=\tau} \Delta Q(t)$ – sum of undesirable regulation deviations in the fulfillment of required amount of production in the time interval $t = 0$ to $t = \tau$,

$(T-\tau)$ – the time when it should come to balancing of arisen deviation at the latest,

τ – time, in which it comes to finding out the amount of incepted deviation from time $t = 0$, i.e. from the time determined by us as the beginning of monitoring the production progress and deviation in production.

Criteria condition is determined from the empiric operation management of production organizations and from the logic of management based on deviation method (application of regulation principles, management with a closed structure), which is the base of a large-scale production's management process and therefore also forms required dynamic characteristics of production system [7].

2 Methods

In order to create such a management system it is necessary to have knowledge of a dynamic behavior and characteristics of production system and its management [9]. Under the term of dynamic behavior we consider reactions, i.e. with what changes of output levels in time does the production system react to changes of the values of its inputs, while the dynamic behavior of the system is dependent on its dynamic characteristics [1]. One of the possibilities how to solve the problematic of analysis and creation of systems with required dynamic behavior is its exploration with the use of simulation models [8, 10].

This approach was used for the analysis and projection of dynamic behavior of mass production system. The principles of logistics [5] and the principles of feedback control [2] cannot be overlooked. Formed simulation model was elaborated based on theoretical findings of regulation, hierarchical systems, empiric research, and optimization and was systematically tested by software.

3 Simulation Model Structure

The base of simulation model structure is formed on the basis of regulation circumference, since by the regulation process application it is possible to simulate large-scale production's fulfillment of the criteria condition.

Individual functional blocks of the model labeled "PR", "MAX", "RS", "PSI", "PSII", and "NS" and its functional linkage and behavior in given hierarchical structure (functional, time and organizational decomposition) are set in the analogy of process management with a feedback, on which base we are able to test the level of required dynamic characteristics of large-scale production process.

Functional block "PR" is a block determining controlling quantity, block "NS" is a block of failure state impact simulation (unproductive states), blocks "RS", "PSI" and "PSII" model are regulating system connected with regulated one, including feedback loops.

Time decomposition is based on the fact that partial sub-systems of a given system are activated in different time levels. In the case of simulation model, meaning that the model's blocks and sub-blocks are activated during shifts and within the framework of given period (e.g. month) the fulfillment of the production tasks are given by market, (they are based on demand).

The activities of blocks "RS", "PSI", "PSII" and "MAX", possibly block "PR" are activated by internal shifts and in the framework of time level the period activates the activity of blocks "PSII" and "PR".

Organizational decomposition of a complex system, which production system is, is realized considering organization structure of its creation purpose [3]. In a case of the model it is a structure of parallel linkage of workplaces from the view of its possible production representation and its grouping into hierarchically higher controlling and organization levels.

From the view of functional decomposition, we decompose the system into four levels, namely:

- Stabilizing: regulation with balancing undesirable deviation – activity of block "RS";
- optimizing: optimization of controlling quantity (quantities) – activity of block "PR";
- adaptation: adaptation of regulation process, including optimization of controlling quantity considering newly arisen condition of system's activity – activity of block "PR";

- self-organizing: system's structure change, if it is not able to fulfill target behavior with given limitations (it is not applied in the model).

Functional block "PR"

This block is modeling optimal determination of controlling quantity, such as market required amount of production ($T^{(i)}$) from individual workplaces for the time periods while respecting conditions determining maximum of possible dynamics of production at the workplace considering the limitation of its possible operation: technological, safety and transportation. Simultaneously both, the minimum of operation's cost effectiveness at the workplace and fulfillment of required level of production qualitative parameters are respected.

Functional block "MAX"

This block is modeling the outcome of criteria condition required dynamic characteristics of production process, i.e. such situation in evaluating the possibility to fulfill tasks at the workplace, when the given time for the whole period is fully used for production together with maximal possible production dynamics in the shift.

Functional block "MAX" is model's "signalization" of a operation's state , which warns of a situation that it does not have to come to the fulfillment of required task in the production for a given period and that it is necessary to think about transfer of tasks among workplaces (if it is possible).

Functional block "NS"

This block is modeling systems of unproductive states (failure/malfunction) in the production process in workplaces on the base of generating and by the usage of random number system or deterministic implementation into process of its simulation, when the unproductive states make a system, which is a relative system in the connection to shift's real time, both from the view of time duration and inception moment of these unproductive states. In model it comes to generating a group of unproductive states expressed by time of inception, time duration and characteristics of its influence on production process in the sense that it is state of stopping or limiting production at a workplace.

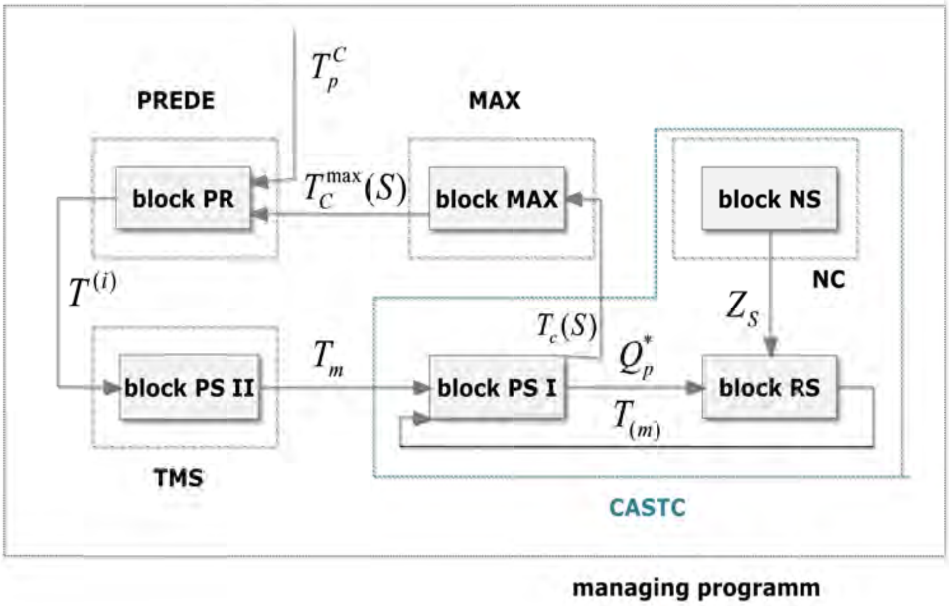
Stochastically determined combination of unproductive states at workplace in shift is considered in model as one of possibly really existing situations at a workplace, from the view of influence of unproductive states in the connection to the length of its duration and amount of failures of production resulting from this.

Functional blocks "RS", "PS" and "PSII"

They model dynamics of fulfillment task progress in production from the view of time hierarchy, namely: internal shifts (block RS), shift (block PSI) and shift with the linkage to determined period (block PSII) for individual workplaces. The outcome of blocks "PSI" and "PSII" is the determination of controlling quantity (expected production) for time level of shift and internal shift and its possible change.

Blocks "RS", "PSI" and "PSII" model represent regulating and regulated system according to the analogy of regulation circumference. More detailed characteristics of purpose functions and linkage of individual blocks in simulation model are mentioned in another paper. Linkage of model's individual blocks is shown in Fig. 1.

Fig. 1: Simulation model structure



Source: Authors

Legend of individual quantities (information) used in Fig. 1 is following:

T_p^c - marker's required production amount (demand) from workplace for given period (t. period $^{-1}$)

$T^{(i)}$ - optimal amount of required production determined by calculation for *i-th* workplace for given period (t. period $^{-1}$)

T_m - required production amount from workplace per shift (shift expectation) (t. sm^{-1})

$T_c^{max}(S)$ – maximum amount of production from workplace given by simulation for given period (t period^{-1})

$T_{(m)}$ - shift expectation of workplace production after having done the correction as the consequence of undesirable deviation inception in production (t. sm^{-1})

T_cS - determined production amount from workplaces, given by simulation, after finishing S-th shift from the period beginning (for given time) (t. time^{-1})

ZS – unproductive state with maximum amount of its influence in workplace towards lowering possible production from workplace (t. min^{-1})

As fundamental input quantities, when change of their level will, in the process of simulation, influence the level of process dynamics of possible workplace task fulfillment in given period, are considered following quantities: amount of workplace shifts in given period, effectiveness of controlling influence, capacity limitation of production from workplace considering applied technological system, limitation in safety and manipulation, productive time in shift for production by production equipment, amount of reserves in workplace productive activity and in the amount of productive time in shift, required revenue from utility products from refining process, cost effectiveness of operation and occurrence frequency of so called unproductive states in workplace, information delay and delays in possible realization of given measures in workplace operation.

4 Discussion

By applying the simulation model it is possible:

- To simulate the course of large-scale production and results in the process of production for different, in simulation determined, dynamic characteristics of workplaces operations;
- to determine, in advance, the situations and times when it would not come to fulfillment of workplaces' tasks with the necessity to adapt the whole process of production which is lying in the redistribution of required workplace's production tasks with the possibility to fulfill these tasks within the organization or reorganization of workplace structure (e.g. by operating another workplace or other workplaces), possibly there is a signal for the necessity of its preparation etc.;
- to optimally (sub-optimal) divide the distribution of required production to individual workplaces with regards to determined objective criteria and considered limiting conditions of mass production process realization;
- to create a database of production results achieved for certain technologies operated in certain conditions and objective requirements on the production process within different time, hierarchical levels with the possibility to its utilization for strategic, tactic and operative production management.

Conclusion

The next step of presented research will be focused on simulating model behavior. Simulation model behavior is formed by purpose functional activity of its blocks and sub-blocks and its linkage considering organization and time hierarchy of their influence within the framework of determined feedback loops and defined linkage. Simulation process from in terms of time hierarchy will begin from the highest hierarchical time level of simulation, i.e. with the activity of the function block "PR" which is impacting in the time level, meaning period towards to functional blocks impacting in lower time levels.

In terms of organization hierarchy the simulation will take place at every workplace. After finishing simulation of fulfilling required task in production of given workplace, this amount will be added to production of other workplaces with the objective to determine final amount of production for all workplaces of given organizational unit in shifts and after period ending. This simulation can help in capacity planning and also in strategic management of the organization.

Dynamics' simulation model of large-scale production process at given hierarchical organization level can be used in both the process of preparation of this production and also during the process of realization, i.e. within the framework of operative production management and therefore contribute to its efficiency.

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