METABK 59(2) 187-190 (2020)
UDC – UDK 658.16.008:338.91:339.4:669.1:669.162.2=111

APPLICATION OF BALANCE MODELS IN METALLURGY

Received – Primljeno: 2019-09-20
Accepted – Prihvaćeno: 2019-11-10
Original Scientific Paper – Izvorni znanstveni rad

In general, management is the planning and coordination of all processes and their elements in enterprises in order to achieve the objectives with the highest efficiency. The basic management tools, especially in companies with complex production processes with high inertia and long production time, include balance models. The paper points out the methodology, principles and importance of balance models in metallurgy and describes the methodology for material-energy, capacity and economic balance of this process.

Key words: management, production process, balance model, metallurgy, blast furnace

INTRODUCTION

Production processes (PP) in metallurgy are chains of a large number of production operations of a continuous-discrete nature, characterized by high inertia where feed-forward control system (Figure 1) is applied, which in theory creates conditions for the "invariance" of the production process - fault minimization and their impact on quantitative, qualitative time parameters of output products [1 - 5].

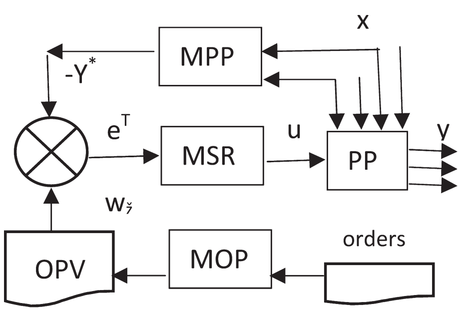

Figure 1 Principle of application of "feed forward" to control production processes [2].

where:

X - vector of main input quantities,

Y - vector of main output quantities,

W_z - goals of the production process, parameters of operational production plan,

e^T - vector of deviations from the operational plan in planning period T,

u - management and control vector,

Y^* - vector of simulated outputs,

OPV - operational production plan.

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In order to digitize and automate the management of metallurgical production processes (Figure 1), it is necessary to create three types of models [6 - 8]:

- Model of production processes (MPP)
- Operative production planning models (MOP)
- Management models (MSR).

In order to create models of production processes it is necessary to create their balance models. Balance models are the first step for the analysis, modelling and management of complex production processes - logistics chains, as well as production processes in metallurgy.

The balance model carries out the transformation of the physical production process (represented by the production operations into active elements of the production process, such as aggregates, equipment, warehouses, vehicles, transport routes, etc., on the material flow represented by raw materials, materials, energies, products - passive elements of the production process) into a graphical model, a block diagram that depicts (in normative marks) a functional model of the production process.

Graphical model - block schemas of the production process the designer of the logistics system creates an abstract tool for realization of balances:

- **material and energy balance**, which calculates the need for raw materials, materials, semi-finished products, energy for individual production operations and at the same time their need from the beginning of the production process to the respective operation for the respective production plan or order filling for the respective planning period,

- **capacity balance** to calculate operational time - capacity requirements for individual active elements of the production process,

- **economic balance**, which calculates the costs of individual production, transport, storage and management operations.

METODOLOGY AND PRINCIPLES OF BALANCE MODELS DESIGN

Material energy balance (MEB)

For the implementation of the MEB, the following applies:

- the law of conservation of matter and energy
- the principle of continuity
- principle of balance triads
- the deductively inductive or abductively inductive principle.

a) Law of conservation of matter and energy

The production process (PP) is defined as a system of production operations (PO), which are involved in the processing of a product in a self-managed section [2, 6, 8]

$$PP \equiv \{PO\}$$

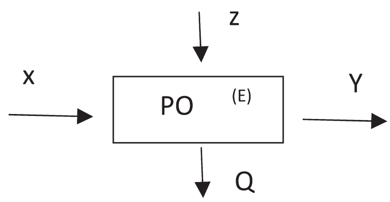
The production operation can be understood as a relatively separate closed system, to which the law of conservation of matter and energy (M. V. Lomonosov 1748, and L. Lavisier 1774) applies, “the sum of the material and energy inputs of the production operation PO_i equals the sum of its outputs and energy consumed its implementation” (Figure 2).

If is marked:

Z - vector of secondary inputs,

Q - vector of secondary outputs,

E - vector of consumed energy.



$$X + Z = Y + Q + E$$

Figure 2 Balance model of the manufacturing operation [2].

b) The continuity principle

The principle of continuity is applied in the construction of balance models in such a way that the outputs from PO_i are inputs into the following consecutive operations PO_{i+1}, PO_{i+2}… (Figure 3).

c) Balance triads principle

The production process in metallurgy is created from a large number of production operations, and creates large chains and networks. We implement the balance model not at once for the entire production process. We divide the production process into “balance triads” by applying the continuity principle operations (PO_{i-1}, PO_i, PO_{i+1}), (PO_{i+1}, PO_{i+2}, PO_{i+3})... (Figure 4).

d) Deductively inductive and abductively inductive balance

For the realization of the material and energy balance, a deductive inductive approach is applied (from the beginning of the production process to its end) from the first production operation to the final one. When we have a certain amount of raw materials, materials, energy and we want to calculate how many of final products we can to gain. Material and energy standards are used for the calculation. The balance model is created for the unit quantity of product (tone, piece…) for all manufacturing operations as material and energy standard, and can be part of the production process management model [2]. The abductively - inductively approach is applied if they are known the necessary amount of products, eg. orders, sales plans, forecasts…, and is needed to calculate the necessary amount of inputs for each production operation. Then is proceed from the end of the production process, the last production operation, gradually to the first and the calculation of its inputs. In that case is proceed the principle of „Balancing triad“. The material balance is realized in annual planning, capacity planning, order acceptance, new product launches, or when changing material inputs for a traditional product.

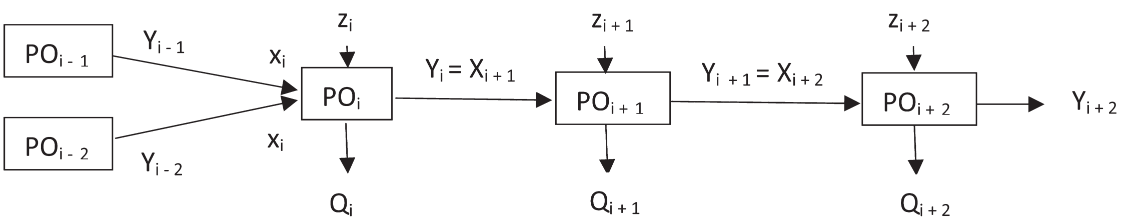


Figure 3 Principle of continuity in the creation of balance models [1, 2].

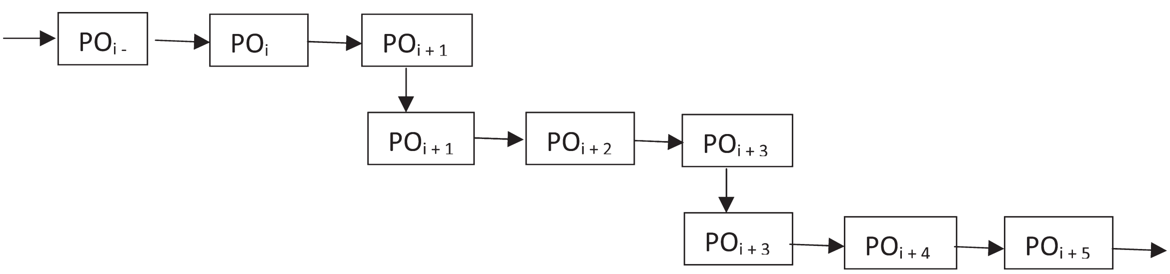


Figure 4 Example of balancing triad creation

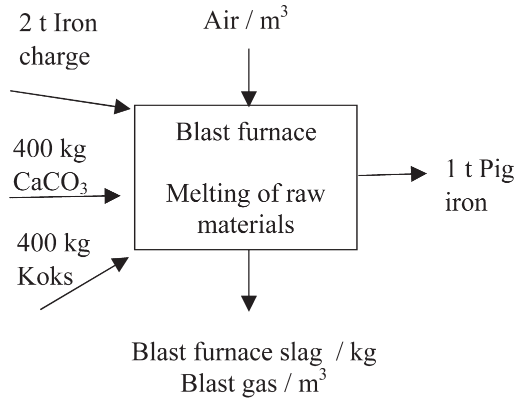


Figure 5 Example of application of "overweight" in pig iron production

Capacity balance

Each of the active elements of the production process has defined capacity options - KM_J (T) within a certain planning period "T". KM_J (T) is the available time pool of element "$_J$" for a given planning period, which it can devote to production, taking into account its downtime $I_{J.}$

$$KM_J (T) = PPD (T) * SM * DS\text{-}I_J$$

where:

PPD (T) - number of working days in period T

SM - number of shift per day

DS - shift length / hour /

I_J - Idle time / hour /

The capacity balance is the calculation of the capacity requirements KN_J (T) needed for implementation of the production plan on the individual active elements of the production in process in period T and their comparison with capacity options.

$$KN_J (T) = M_I * t_{I, J} \text{ for } _J = 1, 2,\dots n$$

where:

M_I - planned, ordered quantity of product I in period T

$t_{I, J}$ - processing time of product I on element $_J$

n - number of active elements

Does the balance sheet model also check the relationship between $KN_J(T)$ and $KM_J(T)$, possibly equilibrate them. A frequent goal of the capacity balance is to bring the bottleneck of the production process. The bottleneck is the active element that first restricts production by its capacity.

a) Absolutely bottleneck

$UM_J = \max KN_J(T)$ for $_J = 1, 2,\dots n$

b) Relatively bottleneck

$UM_J = \min (KM_J (T) – KN_J (T)) / KM_J (T)$ for $_J = 1, 2,\dots n$

c) Comparative bottleneck

$UM_J = \min (KM_J (T) / KN_J (T))$

for $_J = 1, 2,\dots n$

The capacity balance is similar to MEB in a deductive-inductive or abductive-inductive manner. Especially for annual and capacity planning.

Economic balance

The economic balance is realised especially in the annual production planning, custom logistics when receiving and confirming orders.

We calculate the economic balance for individual production operations from the prices of inputs (raw materials, materials, energy, products, labour, depreciation of buildings and machinery), and finally add a margin covering research, development, marketing, management, administration and other hard to quantify costs and profit.

The economic balance is based on the calculation of costs per unit of production. Generally, costs can be characterized as a monetary valuation of the consumption of production factors spent on achieving the required output sheets [8,9]. Cost calculation is based on the following formula:

direct material + direct labour + other direct costs + production overhead + administrative overhead + selling overhead = own cost of product + profit margin = selling price.

The basic inputs into the production process, which consists of direct material (raw materials, energy) and then in the operation item we included other costs, namely direct labour, production overhead - these are costs directly related to management and operation of the production process, depreciation of machines, production buildings, administrative overheads related to corporate governance (administration, management, research, development) and selling overheads related to packaging, distribution and marketing (advertising) costs. When placing a product on the market, it is necessary to set a selling price, in which the profit margin is added to the total cost of product.

CONCLUSION

Antošová et al. [10] point out in comparison of companies operating in metallurgy that in order to increase the efficiency of their production it is necessary to optimize economic and production processes. Production processes in metallurgy, petro-chemistry, chemical companies are among the processes with high inertia, especially in response to management interventions. They therefore apply a 'forward management system'. For its application (Figure 1) it is necessary to create production process models, planning models and management models.

The first step for creating these models is to create a balance model of the process that transforms the physical production process into a graphical model - a flow chart of the production process as the basis for realizing the balance. On this model the most frequent balances are realized - material and energy, capacity and economic. The article describes principles, rules, relations for their realization. The article defines in which cases we apply balance models in the company. This is always the case in the production process - changes in input prices, changes in suppliers, in order confirmation and acceptance, and in capacity and annual planning.

ACKNOWLEDGMENTS

Project VEGA 1/0317/19

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Note: The responsible translator for English language is Ladislav Pivka, Institut of Computer technics, Technical University of Košice, Slovakia