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THE METHODOLOGY AND MODEL FOR IN-PROCESS INVENTORIES CALCULATION IN THE CONDITIONS OF METALLURGY PRODUCTION

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In the paper a methodology and model for "In-process inventories calculation" in the metallurgy production conditions is described. The model was designed based on the factors affecting the in-process inventories levels. The in-process inventories levels have to respect different efficiency of the aggregates in sequence, idle times, technological safety and the production continuity. For the calculation of the in-production inventories levels a dynamic model was designed. In the paper the results are compared from the analyses of real metallurgical production division and this model too.

Key words: metallurgical production, rolling optimalization, matematical dynamic model.

INTRODUCTION

The task of production management in a factory is to provide optimum amount of inventories necessary for the work of individual machines and devices.

Several authors give relations for the norms of inventories entering the production process based on the norm of daily consumption of specific material, on the basis of EOQ - economic order quantity model, method of stable size of order, method of stable cycle of ordering [1, 2] and relations for the calculation of sales inventories, also based on formatives of sales inventories [3].

A basic method of determining the optimum amount of inventories of in-process and unfinished production is also norming. A normative represents average amount of financial capital that is locked up in this inventories [4]. The determination of the amount of inventories on the basis of this normative, however, is not sufficient during operation since it is necessary to determine the amount of inventories not in the form of expenses, but in the form of the amount of inventories, e.g. in tons, m^{-3} and other measurement units.

The calculation of the inventories of in-process production is given by the sequence of the technological operations. In practice the choice of methodology is important for their determination. They are very specific in the case of metallurgical industry (technological inventories), where it is not possible at any time to turn off and on the production devices, e.g. stove aggregate [5].

Individual stores differ in their function and the role they play in the storing. Some of the stores are characterized by not only storing raw materials and materials, but they also include the function of technological operations. Because of this the calculation of these inventories requires specific approach and methodology.

Special aspects of metallurgical production are also the heat and chemical processes that are realized continually and cannot be interrupted, therefore the dimensioning of stores must provide also for this requirement [6].

METHODOLOGY OF DETERMINING IN-PROCESS INVENTORIES

The current softwares provide many tools which enable planners to do correct planning, scheduling, coordination, and control of the production, and provide them through feedback with the possibility to recognize consequences of their decisions. Some softwares provide identification of in-process production in individual buffer stores, however, they do not exhibit the function of determining the optimum amount of these inventories for the subsequent production operations. This led to the idea of creating a methodology and the model itself for the mentioned function.

Conditions for the creation of in-process inventories model calculation

A model for the calculation of optimum level of inventories of in-process production is created for in-process storage located between two successive aggregates according to Figure 1.

The calculation of optimum inventories in the designed model was performed on the basis of these parameters:

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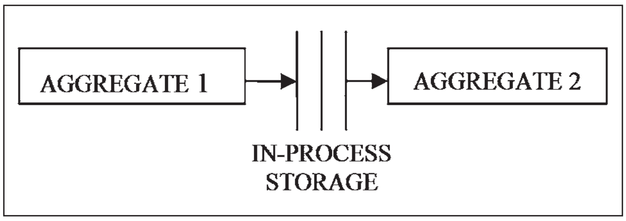

Figure 1 Diagram of material flow via the in- process storage between aggregates

1. Ratio of performances of two successive aggregates μ in given planning period $\mathbf{T_{PP}}$ – of the performance of preceding $\mathbf{\mu_1}$ and of the performance of subsequent aggregate $\mathbf{\mu_2}$.
2. Size of planning period $\mathbf{T_{PP}}$.
3. Technological time of storing $\mathbf{T_{TECH}}$ – time statistically measured from operation, in-process inventories waits in the in-process storage for processing in the next aggregate (both quantitative and qualitative characteristics of inventories do not change).
4. Idle time of aggregates 1 and 2 ($\mathbf{I_1}$, $\mathbf{I_2}$) in planning period $\mathbf{T_{PP}}$.
5. Uniformity of production **maxDIF** – ratio of maximum of planned volume of production per day and average volume of production in the planning period.

When calculating the optimum volume of inventories it is necessary to monitor the measure of influence of individual parameters on this volume. The measure of influence of a given parameter on the volume of inventories will be expressed in percentages. The storage will be dimensioned based on the parameter which affects the most the volume of inventories it is the dominant parameter and will provide the overlap of the measure of influence of all the other parameters.

In the creation of the model it is necessary to take into account also the variability of the volume of production which depends on the composition of the order which changes depending on the market development. The volume of in-process inventories therefore changes depending on the volume of production in the planning period. For this reason we chose the dynamic model of calculation.

Model for the calculation of optimum in-process inventories volume (OIV)

The model for the calculation of optimum inventories volume of in-process production is given by the calculation of individual parameters according to the model, Figure 2.

CALCULATION OF PARAMETERS:

1. Calculation of the parameter – ratio of performances of preceding and subsequent aggregate **„μ“** according to the relation

$$\text{if } \mu 1 > \mu 2 \qquad \mu = \left(\frac{\mu_1}{\mu_2} - 1 \right) \cdot 100 \qquad / \% \qquad (1)$$

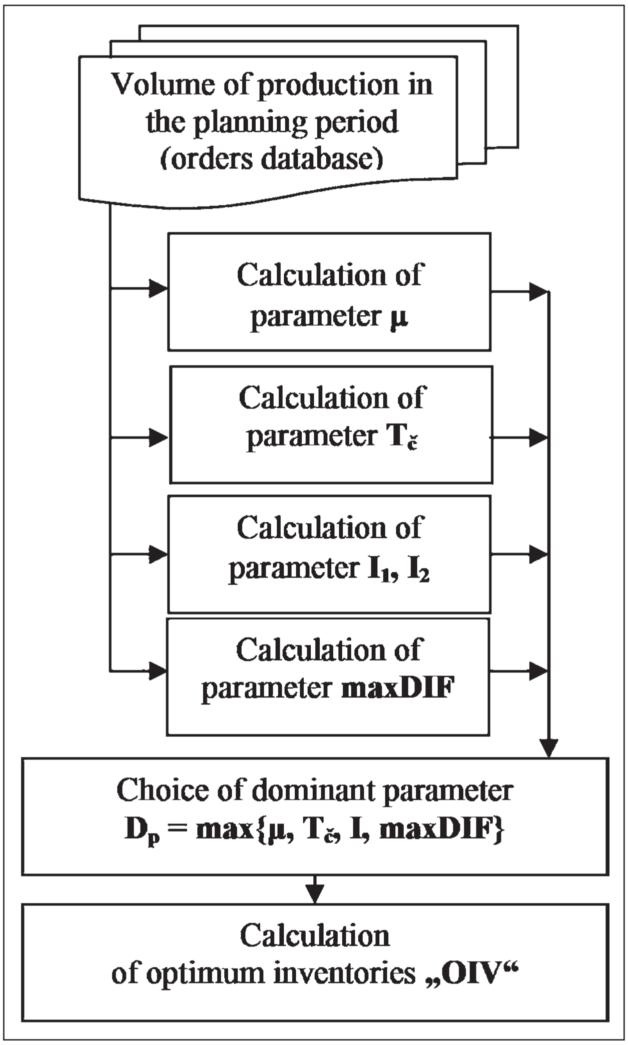

Figure 2 Model for calculation of optimum inventories steel rolling mills

$$\text{if } \mu 1 < \mu 2 \qquad \mu = \left(1 - \frac{\mu_1}{\mu_2} \right) \cdot 100 \ / \ \%$$

where:

μ_1 - output of the first (delivering) aggregate /tons/day.

μ_2 - output of the second (receiving) aggregate /tons/ day.

2. Calculation of the parameter waiting time of the in-process production **„$\mathbf{T_w}$“** according to the relation

$$T_w = \frac{T_{TECH}}{T_{PP}} \cdot 100 \ / \ \% \qquad (2)$$

where

T_{TECH} – average technological time gained from operation /h.

T_{PP} – size of planned period /h.

3. Calculation of parameter maximum idle time **„I“** according to relation

$$I = \frac{\max\{I_1, I_2\}}{T_{PP}} \cdot 100 \ / \ \% \qquad (3)$$

where:

I_1 - period of idle time of the first aggregate during planned period T_{PP} /h.

I_2 - period of idle time of the second aggregate during planned period T_{PP} /h.

4. Calculation of parameter uniformity of production **„max DIF“** according to relation

$$\max DIF = \left[\max\left\{ \frac{V_2^i}{\overline{V_2}} \right\} - 1 \right] \cdot 100 \ / \ \% \qquad (4)$$

where:

V_2^i - planned production on the second aggregate during planned period T_{PP} /tons/day.

i - days during planned period T_{PP}.

$\overline{V_2}$ - average volume of production on aggregate 2 during planned period T_{PP} /tons/day.

5. Choice of dominant parameter **„D_p“**

$$D_p = \max \{ \mu, T_č, I, \max DIF \}$$

6. Calculation of optimum volume of inventories according to maximum value D_p **„OIV“** according to relation

$$OIV = \frac{D_p \cdot V_2}{100} \ / \ t \qquad (5)$$

APPLICATION OF MODEL "OIV" FOR THE METALLURGY MANUFACTURY DEPARTMENT

The model is applied for the rolls storage which is located between aggregates „leaching lines“ and „rolling tracks“. In it are stored leached rolls which are inputs for the rolling tracks where the sheet metals are cold rolled. The current capacity of the storage is 15 000 t per day. The input values needed for the calculation of in-process inventories according to the above model are given in Table 1 and the calculated values in Table 2. The calculation was realized for the planning period of one week, 168 hours.

It follows from the input data that aggregate 1 – leaching lines has daily production higher than aggregate 2 – rolling tracks, namely by 7,69 % which implies that during normal operation aggregate 1 is able to cover the consumption of aggregate 2.

Based on the technological procedure the inventories must be located in the in-process storage 24 hours on average (on the basis of monitoring during operation {16-34}). Parameter 2 from the proposed model – the average technological waiting time of the in-process inventories before aggregate 2 represents 14,28 % of the time of planning period TPP.

The parameter „maximum idle time“ is 9,52 % of the planning period, it represents the idle time of aggregates 1 and 2. This parameter represents the time when given aggregate is not working which, on average, represents decrease in the output of aggregate 1 by 666,4 t/day and of aggregate 2 by 618,8 t/day. If there are no more unexpected downtimes of aggregate 1 then under these conditions aggregate 1 is capable of covering the consumption of aggregate 2.

Table 1 **Input values for the calculation of parameters**

Parameter			Value
Output of aggregate 1 - leaching lines, (t/day)	μ_1		7 000
Output of aggregate 2 - steel rolling mills, (t/day)	μ_2		6 500
Average technological time of storing, (h)	T_{TECH}		24
Size of planning period, (h)	T_{PP}		168
Time of idle time of aggregate 1 in planning period T_{PP}, (h)	I_1		16
Time of idle time of aggregate 2 in planning period T_{PP}, (h)	I_2		16
Total volume of production on aggregate 2 in planning period T_{PP}, (t)	V_2		35 964
Planned volume of production on aggregate 2 in individual days of planning periods T_{PP} (t/day):			
V_2^1	V_2^2	V_2^3	V_2^4
4 270	5 152	5 223	5 274
V_2^5	V_2^6	V_2^7	
5 571	5 290	5 184	
Average volume of production on aggregate „2“ in planning period T_{PP} (t/day)			5 138

Table 2 **Calculated values**

Parameter	Value %
1. Ratio of outputs of aggregates μ	7,69
2. Waiting time of products $\mathbf{T_w}$	14,28
3. Idle time **I**	9,52
4. Uniformity of production **maxDIF**	8,42
$\mathbf{D_p}$ **= { μ, $\mathbf{T_w}$, I, maxDIF }** = {7,69;14,28; 9,52; 8,42}	
Optimum volume of inventories „OIV“ (t/day) **$\mathbf{D_{pmax}}$ = 14,28 %**	**5 136**

Parameter 4 representing the "uniformity of production" was calculated on the basis of maximum value of planned volume of production for individual days in given planning period, max: V_2^5 = 5 571 t/day. To this volume corresponds maxDIF = 8,42 %.

From the calculated values, the dominant parameter Dp = 14,28 was determined based on which the optimum inventories of 5 136 t/day was calculated, which represents almost 100 % of average volume on aggregate 2 (see Table 1).

CONCLUSION

For the comparison of results obtained by calculation an analysis was performed during operation in given planning period of the change of inventories in a specific storage. The storage capacity is 15 000 t of in-process inventories. The results of the analysis are shown in Table 3.

The values obtained through analysis and the calculated value of optimum inventories is depicted in Figure 3. In Figure 4 is shown the increase/decrease of inventories on stock during the monitored time period. During the period the level of inventories on stock decreased by 83 tons.

Table 3 **The results of the analysis / tons/day**

Day	Production from aggregate 1	Consumption of aggregate 2	Status of inventories
1	4 885	4 276	17 723
2	5 075	5 152	17 645
3	5 530	5 217	17 958
4	5 410	5 274	18 094
5	4 906	5 571	17 429
6	4 593	5 298	16 724
7	5 483	5 176	17 031

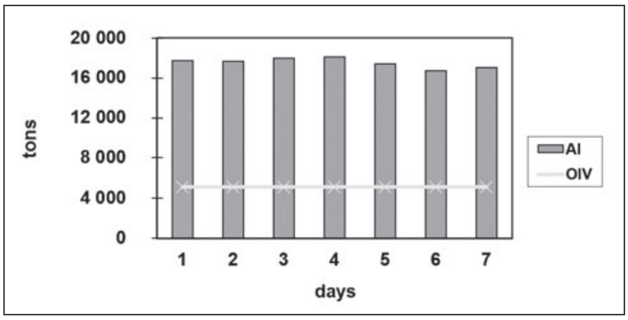

Figure 3 Diagram of calculated and current levels of inventories (AI – current level of inventories on stock, OIV – calculated optimum inventories volume)

It follows from the graph in Figure 3 that during the analyzed planning week the volume of in-process inventories was on average about 17 000 tons. According to the designed model for calculation of optimum level of inventories on stock before rolling tracks the optimum level of inventories is set at 5 136 t/day.

The high volume of inventories on stock for in-process production before rolling tracks was caused mainly by high level of inventories from previous time period. The output of aggregate 2 – leaching line, as we can see in Table 3, was used during the monitored period at most at 79 % and the output of aggregate 1 at 85 %. Another fact is that in the factory a higher volume of inventories is being handled also because of certain number of defective pieces. Eventually the remaining inventories are used for a more flexible adjustment to the market and to the customer requirements. They can have the character of speculative inventories.

From Table 3 also follows the fact that more than 15 000 t was stored in the given warehouse which is possible but eventually the manipulation with the inventories is more difficult.

Subsequently, the proposed model can be verified also by using a simulation [7, 8].

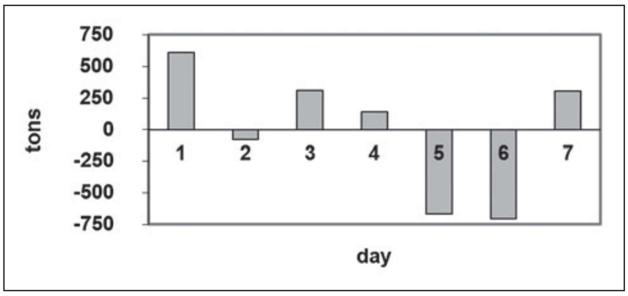

Figure 4 Increase and decrease of storage inventories

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Note: The English Language translation was done by L. Pivka, Kosice, Slovakia