USING OF MATHEMATICAL APARAT FOR ALGORITHMIZATION OF MECHANICAL PRODUCTION AT SCHEDULLING AND MANAGING PRODUCTION WITH DETERMINISTICALY GIVEN INPUTS IN PRODUCTION LOGISTICS

prof. Ing. Dušan Šebo, PhD.
Ing. Róbert Jurčišin
Faculty of Mechanical Engineering
Department of Management and Economics
Nemcovej 32, 040 01 Košice, Slovakia
Tel.: (+421) 55 602 3232
Fax: (+421) 55 602 3234
e-mail: dusan.sebo@tuke.sk
e-mail: robert.jurcisin@tuke.sk

Abstract

The main idea of the article is the assignment of components to machines by mathematical algorithm. Algorithm is able to calculate each queue which is arranged to production and calculate continuous period of production of each component. Mentioned algorithm is able to determine structure of machining time needs for fulfilled order according to individual components and machines or separately for each component. There are also other given information for farther technical – economic analyses, examination of external cooperation in global aspect.

Key words: algorithm, production, management, machines, component

1. INTRODUCTION

Following article deals with problems of engineering and production scheduling in conventional machine-industry production. For filling of production was used method FIFO (First in First Out) which is suitable for conventional machine-industry production. In this algorithm, we were looking for an optimal solution with the shortest technological times of production. This thesis has also wide possibilities to use in technical-economic analysis and also pricing of machinery products, technical preparation of production using expert methods and so on.

2. THE ALGORITHM OF MECHANICAL PRODUCTION MANAGEMENT

In this article the problematic of production scheduling of component basis by FIFO method is solved which is suitable for conventional mechanical production. However, problematic of production scheduling is solved by the other methods too, such as network analysis where we can use methods for example CPM, PERT, GERT, MPM. These methods with increasing number of components are non-transparent. Our aim is to outline the problematic of solving conventional mechanical production, where the solution is completely deterministic and component base is variable.

We will not concern with these methods in the companies such as KIA, PSA, and GETRAG FORD where the production is controlled by computers for big series and machines are controlled by NC or CNC. The production in these companies is on the basis of line flow manufacturing where we can use balancing of lines with heuristic approach.

There is a case study in application part of this article which concerns with production scheduling for conventional mechanical production with deterministic approach.

2.1 Methods of nework analysis

These methods refer to single-use production process and are suitable for time coordination of big amount of related operations sharing on realization of production processes. These methods are not suitable for periodic processes. They come out of the idea that production process will be projected in oriented network graph of relevant type with which realize time capacity analysis and cost analysis with the aim to find minimum time of production processes and consequences arising from that such as critical activities, the probability of realization in calculated time and so on.

In term of logistic we try to coordinate production operations, find the time of their start, finish and make detail time planning according to which production process will be run.

Methods are divided by the type of network graph:

- according to edge (edge is operation)
- according to corner (corner is operation)

According to duration of activity:

- deterministic
- stochastic

According to number of activities between two corners:

- methods for monographs
- methods for multigraphs

Methods:

CPM (Critical Path of Method) – is suitable for deterministic production processes which we can design by edge graph.
MPM (Metra Potencial Method) – is suitable for deterministic production processes with parallel running of processes and feed-backs.
PERT (Program Evolution and Review Technique) – is suitable for non-deterministic production processes where the operations can we evaluated by the time defined by normal distribution of probability and we can design them by edges - oriented graph.

GERT – is suitable for production processes of probability character which we design as a general flowchart (multigraphs) such as type GAN (General Activity Network).

2. 2 Utilization managing (BOA)

BOA (Belastungsorientierete Auftragsfreigabe) is a procedure which comes from the fact that production order can be unloaded to production only when it can be machined. It can not increase the number of components in front of production equipments. We can name this stage of production orders as the unloading of production orders to production.

The main aim of this method is a continual removal of fronts in front of production equipments. The key to control of the length of the continuous times in production is in system BOA the regulation of entry of production tasks to production system.

We can imagine the machine, group of machines, equipments, whole work-room or production system as a "funnel" to which enter production tasks which have necessary time for realization. After machining production orders leave the group of production machines and equipments. Exit from funnel symbolizes possible available capacity and volume of funnel means existing stage of waiting production tasks. Provided that we cannot change capacity of production machines and equipment in a short term it is possible to control their stock only through the entering of the production tasks to system.

We can imagine this "funnel" like this:

The narrower is the hub, the more is the system automatically prolonging and fronts are prolonging too, what is an impassable stage which have to crash automatically. Therefore the aim is to enlarge the hub and transmissivity of this hub will be controlled by FIFO method and we will be able to control fronts by this method.

Production tasks are unloaded to system in three steps:

1. Determination of urgent production orders. Starting terms are determined coming out of the latest term of finishing of production orders.

2. Specification of capacity utilization of production machines and equipments. In this step it is necessary to think about very important decision parameters such as bounds of utilization and percentage of utilization. Bounds of utilization = planned exit of order in planned period + planned average stock. Percentage of utilization is possible to determine as relation bounds of capacity to planned output

3. Unloading of production orders. Production order can be unloaded only if its expected capacity demands are not exceeding bounds of utilization by any production equipment during planned period.

2.3 The structure of mechanical production process

Formal concept of structure of mechanical production process is based on transformation analysis which is there by production of mechanical products in one production system, where it is necessary to notice first dominant position of components as well as procedure of their production. The shape of components and their construction – technological elements predestine genesis of their production, sometimes variantly but always deterministic. The structure of production objects in mechanical production system is illustrated in picture number 1. It is obvious from this structure that with special logistic configuration of components will be created the product and we will make components by adding or removing of construction – technological element.

Manufactured:

Products $a_1, a_2, a_3, \ldots a_v \ldots a_{v-1}, a_v$

s-a structure ↖↗

Components $s_1, s_2, s_3, \ldots s_i \ldots s_{i-1}, s_i$

s-p structure ↙↓↘

Primitives $p_1, p_2, p_3, \ldots p_p \ldots p_{p-1}, p_p$

Figure 1 Formal structure of mechanical products

Formal description of elementary structure of products and relations between components and its construction – technological elements is the basis of logistic process net for mechanical production systems and relative industrial production systems.

2.4 Simulation and optimalization of charging of conventioanal mechanical production

For the simplest algorithm of calendar charging of mechanical production system by components we can use as an entrance series of components Si, $_{1\to i \to m}$ according to the order they come to production system and on which machine VZ_j, $_{1\to j \to n}$ are assigned (its priority in system is assigned by FIFO from table of assigning and for calculation is obliged – working with the waiting list of components is an external operation and serves for finding optimal solution of continuous time of production of components).

The entrance for simulation algorithm is a matrix of assignment tij, which sets how much time is needed for realizing the operations of i –part of component on j – part of machine.

The second entrance for initialization formula of algorithm is the matrix ${}^{i}B_{iv}$, which determines how many components of the kind of i – part is in v – part of product (number of components is taken over from bill of material of composition drawing of product).

The third entrance is matrix ${}^{u}B_{uv}$ (number of components of product $A_{1\ldots v}$, which is necessary to produce for the certain order D_{vQ}).

We will still following interval of time jump of finishing work T_k find from initialization formula,

$$T_k = t_{ij}\sum_{v} {}^{v}B_{uv}\,{}^{i}B_{iv} - \sum_{\int \epsilon k \forall S_i \approx VZ_j} T_{k-1} \rightarrow \min,$$

where for minus item hold the rule of counting off for f k $\forall$ $k_{si} \approx VZ_j$, if in the last step the component was on the same machine and where [1]:

- (i) sequence of the components
- (j) sequence of production equipment
- $S_{1\ldots i}$ component
- $VZ_{1\ldots j}$ production equipment
- (v) sequence of the product
- $A_{1\ldots v}$ product
- ${}^{i}B_{iv}$ matrix determines, how many components of i-type is in the v-type of the product, (countability of piece list of composition drawing)
- ${}^{(u)}$ sequence of batch
- $Q_{1\ldots u}$ order, (u-type of batch in countable expression in v-type of the product)
- D_{vQ} batch
- ${}^{u}B_{uv}$ (numbers of pieces of the product $A_{1\ldots v}$ which we want to produce in given order)
- t_{ij} operation time i-type of the component on j- type of the machine

Times interval of jump will create time series which is in calendar expression at relevant shifts very quick and simple output which determines dominant time state of course of production. We can express production time of each components by loading data $\sum_f T_k$; $f \in k \forall k_{si} \approx VZ_j$ and by simple summing $\sum_f T_k > \max$; $f' \in k \forall k_{s''i}$ we can define the continuous production time of batch i.e. time horizon for verification and confirmation term of finishing its production. Optimalization of calendar plan of production charging will be accomplished by combinatory changes of sequence the components on entry to production system [1].

Production system in which 5 production equipments are situated has a right to manage and charge production by computer even if its processes are simply controlled and dispatching control does not exceed human abilities.

It would be more complicated if there were tenths of machines and equipments and thousands of components in production system and conventional small batch production for which mentioned algorithm is suitable for.

3. CASE STUDY OF SCHEDULING CONVENTIONAL MECHANICAL PRODUCTION

We will illustrate the case study of production scheduling in conventional mechanical production on virtual company in which there are situated four following machines:

VZ1: Centre lathe SV 18RA
VZ2: Table milling FC 50V with system NS 350
VZ3: Centre lathe SU 80A

VZ4: Grinding machine BP1/600

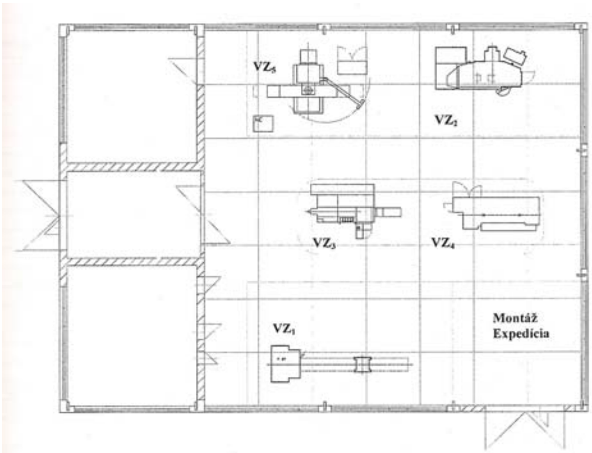

Figure 2 Disposition solution of production system

We are concerned with conventional mechanical production in which machines do not have NC or CNC control but controlled by human factor. Company runs at twelve hour shifts on principle of JIT (Just in Time). Running of the company is based on cooperating agreements with submitters who provide raw products in required quantity and quality in order to finalize the components according to drawing documentation.

Two orders were received in the company for cooperation. Submitter delivered drawing documentation, its production times that need to be accepted by cooperation company. Mathematically we try to find optimal solution with the shortest time of production. According to combinatory analysis we have n! possibilities for choosing the order of components. In our case we have exactly 120 possibilities. Therefore we showed the principle of algorithm only for illustration on three examples.

3.1 Table and calculations

Table 1 Table with input data of calculation matrix

Example¶

Si/VZj	Vz_1	Vz_2	Vz_3	Vz_4	A_1	A_2
S_1	38,6	6,9	3,6	3,8	16	16
S_2	77,6	16,3	8,3	14,3	8	8
S_3	27,5	5,3	-	-	20	20
S_4	10,3	-	3,4	5,3	70	70

S_5	6,7	-	5,7	-	10	10
					5	5
					Q1	Q2

$T_0 = 0$
$F_1 = S_2, S_3, S_4, S_5$ $Vz_1 = S_1$ $T_1S_1 = 38{,}6.\ (16.5+16.5) = \underline{6\ 176}$
$F_2 = 0$ $Vz_2 = 0$
$F_3 = 0$ $Vz_3 = 0$
$F_4 = 0$ $Vz_4 = 0$

$\underline{T_1 = 6\ 176}$
$F_1 = S_3, S_4, S_5$ $Vz_1 = S_2$ $T_2S_2 = 77{,}6.\ (8.5+8.5) = 6\ 208$
$F_2 = 0$ $Vz_2 = S_1$ $T_2S_1 = 6,\ 9.\ (16.5+16.5) = \underline{1\ 104}$
$F_3 = 0$ $Vz_3 = 0$
$F_4 = 0$ $Vz_4 = 0$

$\underline{T_2 = 1\ 104}$
$F_1 = S_3, S_4, S_5$ $Vz_1 = S_2$ $T_3S_2 = 6\ 208 - 1\ 104 = 5\ 104$
$F_2 = 0$ $Vz_2 = 0$
$F_3 = 0$ $Vz_3 = S_1$ $T_3S_1 = 3,\ 6.\ (16.5+16.5) = \underline{576}$
$F_4 = 0$ $Vz_4 = 0$
…..,
$T = T_1+T_2+T_3+T_4+\ldots\ldots+T_{15} = 6\ 176 + 1\ 104 + 347{,}4 + 608 + 4\ 148{,}6 + 1\ 304 + 664 + 1\ 144 + 2\ 388 + 1\ 060 + 6\ 150 + 670 + 1\ 710 + 570 + 3140 =$ **<u>31 184 norm minute</u>**

Total machine time by setting of components from $S_1 - S_5$ is 31 184 norm minutes, what equal rounded is 520 norm hours.

4. DATA EQUATION

Table 2 Table with results of calculations

1.Example	31 184 norm min	520 norm hour
2. Example	**26 624 norm min**	**444 norm hour**
3. Example	28 052 norm min	467 norm hour

5. CONCLUSION

The combination of components in the second example is for our calculation more preferable then the other two. The company which ordered this cooperation for both orders has a big share on the mechanical companies market compared to our virtual company. But in other point of view the company wants to save own performance for other activities and decided for cooperation. Certainly the big company has much more machines for multi machine running, what reflected in cutting-down the time for machining the components. It is important to think on interoperable logistic, which was not calculated in main production time. One of the several problems of this company was logistic between operations. There was a problem sometimes to provide the car or people or a crane. The task to shift the components was carried out by incompetent people who were unable to read drawing documentation. Each problem in logistic causes is additional times and also loss for company. It is crucial to coordinate all the times which are important for technological calculations because it affect the price of our products. If we do not manage to do so, it may result in the loss for a company.

The following and the best combination by FIFO method requires 444 norm hours for machining both orders. Selected algorithms show how important it is for mechanical companies with conventional machines and also it can be a feedback for own technological preparation of production.

This work has additional possibility for using such as calculation of machine times for whole order for each machine or equipment and each component but also utilization of machines and it gives details for additional technical – economic analysis such as price making of mechanical products, technical preparation of production using expert method and so on.

This project will be programmed into integrated software package, where the whole program will be synergically built on three autonomous programs. The first program will ensure expert calculations of technological times for machining based on method of primitives. The second program will ensure managing of stocks from production point of view. The third and the most important program will ensure algorithm which on the basis of initialization formula calculates the shortest time for machining production batch or whole order. This software package will work with the help of interface such as autonomous universal system on existing systems and will be tested in real mechanical production.

6. REFERENCES

[1] Šebo, D.: Logistika ako nástroj manažérskej činnosti, Edícia vedeckej a odbornej literatúry – Strojnícka fakulta, ISBN 978-80-8073-776-4, Košice, 2007.

[2] Malindžák, D.: Výrobná logistika I., Vydavateľstvo ŠTROFFEK Košice, ISBN 80-967636-6-0, Košice, 1997.

[3] Leščišin, M, Stern, J, Dupaľ, A.: Manažment výroby, 1. Vydanie EU v Bratislave, ISBN 80-968881-0-2, Bratislava, 2002.

[4] Kavan,M.: Výrobní a provozní management, Grada Publishing, spol. s.r.o., ISBN 80-247-0199-5, Praha, 2002.

[5] Tomek, G, Vávrová, V.: *Řízení výroby a nákupu*, Grada Publishing, a.s., ISBN 978-80-247-1479-0, Praha, 2007.

This article is published under the project AV 4/0005/07.