14th International Research/Expert Conference
"Trends in the Development of Machinery and Associated Technology"
TMT 2010, Mediterranean Cruise, 11-18 September 2010

GRAPHICAL DEPICTING OF PROCESSING CYCLE IN MULTIPRODUCT PRODUCTION SYSTEM

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ABSTRACT
Duration of the processing cycle is related to the wide range of problems and requires knowledge of the set of variables: the order processing, the spatial arrangement of equipment and schedule of production quantity. The planning of production cycle includes a number of interdependent variables which includes all activities: technological and transport operations. With graphical depiction of the production cycle it is possible to simulate the material flow in production systems, and the value of this way of planning is most obvious in cases of multi products production systems.
Keywords: production system, processing cycle, graphical method

1. INTRODUCTION

During the manufacturing process, subject is experiencing a series of transformations that occur in a sequence, continuous, with one or more delays. In addition to these activities, there is related consumption of time which is dependent on a number of technological, organizational and production factors. All these activities are part of the processing cycle. Selaković gave a definition of terminology that separates the concepts of components of processing cycles (operation, transport, lag) [1]. According to [2], total production cycle time is time that is spent for the implementation of all activities and events since leaving the intermediate goods from the warehouse until entering the finished product in the exit warehouse. Main groups of times in processing cycle are [3]:

$$t_{cj} = t_{kj} + t_{tj} + t_{sj} \qquad (1)$$

Symbols:

f_r – operative unit factor of terminated period, table 1.,	q_{jf} – operative quantity of each *j-work* piece,
k_i – time of i-activity or delay during processing cycle,	t_{kj} – technological processing time of *j-work* piece,
M_{ijf} – matrix of equipment load during processing of operative quantities of *j-work pieces,*	t_{tj} – total time of transport of *j-work* piece,
M_{ir} – load matrix of *i-equip.* for processing of *r-oper.,*	t_{rijf} – load time of *i-equipment* for processing of r-operation of *j-work* piece and *qf-quantities,*
M_q – matrix of annual processed quantities of above work pieces,	t_{sj} – total standstill time of *j-work* piece,
M_{qf} – matrix for j =1…n work pieces processed within terminating period T_r,	t_{ifb} – available time in the operating period,
M_{sj} – lowest common multiple of the work pieces launched together,	t_{ifmax} – max. processing time for each capacity,
	η_{imax} – max. rate of utilization of a certain equipment,
	η_t – rate of utilization of time available for production system.

Most of the factors affecting the processing cycle time for a given production program has the source in the selected model of manufacturing system. Our desire is to establish a planned duration of the processing cycle for the planning and production management before processing begins. Mikac shows that it is possible to perform analytical and graphical method of determining processing cycle [2].

2. CALCULATING THE PROCESSING CYCLE

In manufacturing systems that are based on material flow line model it can be no difficulty in numerical-analytical method to calculate the processing cycle. In other models, due to difficulties in determining the number and time of some pause in the manufacturing process, it is very difficult to calculate the cycle time in advance with numerical-analytical method. Waiting times are determined specifically the situations that will arise in production systems, depending on:

- work pieces range launched in the operating schedule
- amount of individual work pieces in the operating schedule
- disposal time for one operational period
- sequence and duration of individual operations for a particular work piece.

Generally, the operational range and quantity of production for an operating period can be defined with relation (pieces/year):

$$M_{qf} = \frac{|M_q|}{f_r} = |q_{1f} \quad q_{2f} \quad \dots \quad q_{jf} \quad \dots \quad q_{nf}|. \tag{2}$$

For such a range of manufacturing and operational software it is important to calculate a single operative equipment load:

$$M_{ijf} = |M_{ir}| \times |q_{if}| = \begin{array}{c|ccccc|c|} & 1 & \dots & j & \dots & n & \\ 1 & t_{r11f} & \dots & \dots & \dots & \dots & t_{1f} \\ \dots & \dots & \dots & \dots & \dots & \dots & \\ i & \dots & \dots & t_{rijf} & \dots & \dots & t_{if} \\ \dots & \dots & \dots & \dots & \dots & \dots & \\ m & \dots & \dots & \dots & \dots & t_{rmnf} & t_{mf} \end{array}. \tag{3}$$

Table 1. Operative factor unit, depending on T_r

Terminating unit T_r	year	quarter	month	week	day	hour	set
Operative unit factor f_r	1	4	12	52	260	k_i	M_{sj}

From the matrix (3) it is easy to see the total load capacity of the individual equipment in the production system. It is a technological time for the execution of certain operations. That is the net time in total available time in a selected time interval T_r. The next step is determining the gross time available in the operating period in which all activities in the processing cycle has to be performed:

$$t_{ifb} = \frac{t_{if\max}}{\eta_{i\max} \times \eta_t}. \tag{4}$$

In such determined time, now it is needed to realize the total gross of the processing time, total time of transport and all standstill times in one production cycle. The difference of gross disposable time in the operating time and processing time depend on the size of the operating unit and the selected model of production system. This difference in time can provide different work pieces flow schedule through the production system. In that way it is possible to better use all of production capacities, or reduce the amount of pieces in the processing cycle. Numerical-analytical method allows the simulation of manufacturing processes, but it is very complicated and expensive. It requires a specific program for each chosen model of the production system, then additional programming for each choice of transport system and special training of users to use the software for the simulation of different manipulation of the work piece during the processing cycle.

3. GRAPHICAL DEPICTING OF PROCESSING CYCLE

Graphical-analytic method, on the contrary, allows to quickly and easily simulating the way of performance of the processing cycle. It gives a visual, graphical representation of starting, time consumption and finishing of processing cycle and standstill time within. For a graphical representation of the processing cycle, it is suitable some kind of time-line substrate, which enable the simulation of procedures in the production process, in the order they occur in production system in a given time interval. For example: Production program consists of four products, table 2. Quantities of the product B are big and medium for other products. Annual production is planned to take place continuously throughout the year, and the range will launch in the group sets.

Table 2. Production assortment

Serial. No.	Product	Product code	Annual quantity	Calculation code
1	Shaft	2379684 EC 1952-08	30 000	A
2	Shaft with gear	601542	50 000	B
3	Pulley	021 2849 EC 0150-05	20 000	C
4	Housing	TT-100.14.07.	20 000	D

According to the processing method [1], it is necessary to design a preliminary technological procedure, choose the production system model, choose the transportation system model, determine the order of processing, create the production line spatial spread and make the processing flowchart. According to this method, two groups were created: a three-subject group of products A, B and D and single-subject group of product C. As the benefits of the graphical-analytical method are more visible on multi-subject systems, this example will concentrate on the three-object group ABD. For this group, selected model is the multi-product flexible manufacturing system (MFPS) which consists of 9 production capacities, table 3.

Table 3. Known facts for three-subject group ABD

No. of pieces in group	Correlation factor	Critical equip.	Usability factors t – technical e – economical, l – one way transport r – returnable transport				Model	
q	k	$\Sigma\eta_{ij\max}$	η_{tl}	η_{el}	η_{tr}	η_{er}	Optimal	Possible
3	(-2) - (4)	1,41	0,57	0,75	0,63	0,77	**MFPS**	MSPS

Chosen T_r - operative factor unit (as in table 1) is week, then f_r = 52. Operative quantities for each work piece in this group are (all in pieces/week):

$$q_{\mathrm{A}f} = \frac{q_{\mathrm{A}}}{f_r} = \frac{30000}{52} = 577\,,\ q_{\mathrm{B}f} = \frac{q_{\mathrm{B}}}{f_r} = \frac{50000}{52} = 962\,,\ q_{\mathrm{D}f} = \frac{q_{\mathrm{D}}}{f_r} = \frac{20000}{52} = 385\,. \tag{5}$$

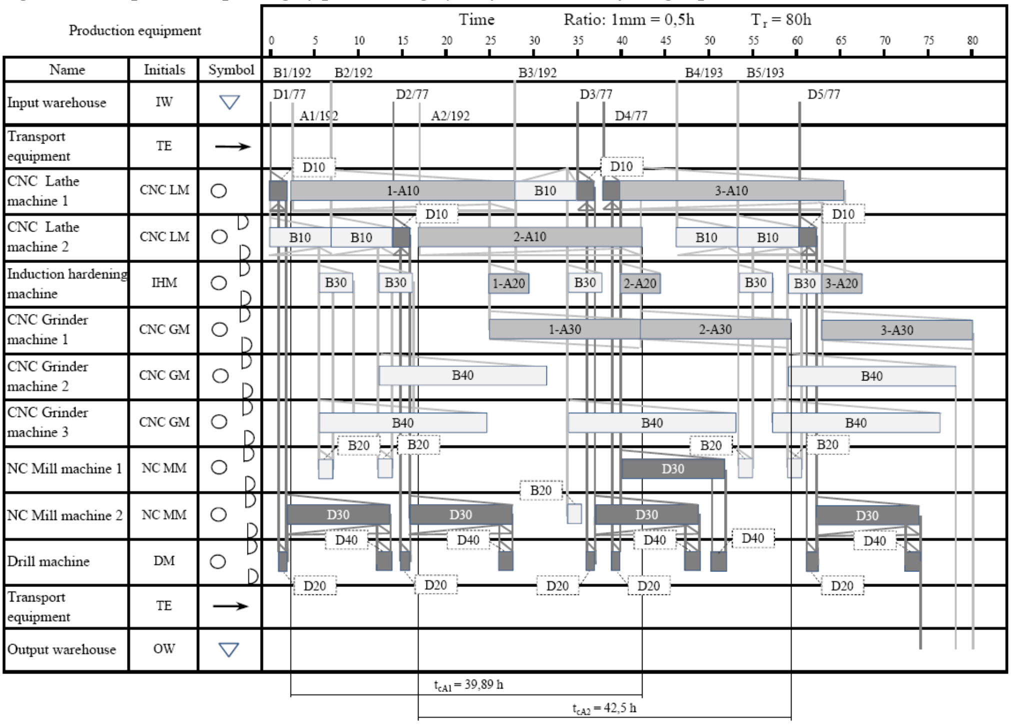
Matrix of equipment load during processing of operative quantities is:

$$M_{ijf} = \begin{array}{c|ccc|}
 & \multicolumn{3}{c}{\text{Operation No. - time}} \\
\text{i} & \text{A} & \text{B} & \text{D} \\
\text{CNC LM} & 10-0{,}14 & 10-0{,}04 & 10-0{,}025 \\
\text{IHM} & 20-0{,}02 & 30-0{,}02 & - \\
\text{NC MM} & - & 20-0{,}01 & 30-0{,}16 \\
\text{CNC GM} & 30-0{,}09 & 40-0{,}1 & - \\
\text{DM} & - & - & 20-0{,}017 \; 40-0{,}025
\end{array} \times \begin{array}{|c|c|c|}
\text{A} & \text{B} & \text{D} \\
577 & 962 & 385
\end{array} = \begin{array}{|ccc|c|}
\text{A} & \text{B} & \text{D} & \Sigma \\
78{,}47 & 35{,}59 & 9{,}625 & 123{,}69 \\
11{,}54 & 17{,}32 & - & 28{,}86 \\
- & 9{,}62 & 61{,}6 & 71{,}22 \\
51{,}93 & 96{,}2 & - & 148{,}13 \\
- & - & 6{,}55 \; 9{,}63 & 16{,}18
\end{array} \tag{6}$$

Total time t_{cj} under the processing cycle expended for the implementation of all activities and events during the manufacturing process of a work piece j is structured from a various operation times t_{kj}, time of transport t_{tj}, various delays and waiting t_{sj}:

$$t_{cj} = t_{kj} + t_{tj} + t_{sj} = \sum\nolimits_{r=1}^{n} t_{rij} + t_{uj} + \sum\nolimits_{m=1}^{n} t_{mj} + t_{ij} + \sum\nolimits_{r=1}^{n} t_{rij} \times (q_{mj} - 1) + \sum\nolimits_{z=1}^{l} t_{zj}\,. \tag{7}$$

Figure 1. Graphical depicting of processing cycle for three-subject goup ABD



Because all production equipment is flexible in this case, there is no preparation time for it. In this example, three lots of product A exist in production process. Since operation times t_{kj} and time of transport t_{tj} remain the same for all three lots, only difference in total time t_{cj} are caused by different delays and waiting time t_{sj} which can be modify easily with graphic-analytical method. Total cycle times for product A, lots 1 and 2 are then:

$$t_{cA1} = 39{,}89 \text{ h}, \; t_{cA2} = 42{,}5 \text{ h}. \tag{8}$$

As previously shown, the processing time and transportation can be easily calculated and are usually not be affected. The waiting time in turn, depends on the termination, and significantly affects the final time. Graphical method allows easy manipulation of time by changing the waiting time and number of lots, Figure 1.

4. CONCLUSIONS

A graphical representation of the processing cycle enables accurate determination of the structure and duration of all activities of the processing cycle. This method provides a simple way to simulate a manufacturing process. From the presented simulation it is relatively easy to determine the total time of processing cycle and its structure. For every work piece or series of work pieces is possible to show when each operation start, how time spend, when operation finished and more. This method give the possibility to visually simulate the process through adjustments of process with changing of number of pieces in group, changing the start time for each group, planning of delays or waiting's before and after the operations. This method give on this way the possibility to optimize the cycle of treatment and minimizing inventory and using of workforce.

5. REFERENCES

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