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# INFORMATICS DEVELOPMENT OF TECHNOLOGIES IN MACHINE BUILDING

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***Abstract*****—**The complexity of operative fabrication planning, especially in the case of series production, requires a high volume of calculation. The frequent changes of batches requires the recalculation of the fabrication cycles with time consuming operations. In this paper we developed a new algorithm which allows the calculation of the fabrication cycles directly on a component level without the necessity of operation level calculations. In order for this to work it is crucial to memorize on a component level information about the component's technology. Like this the fabrication cycle can be calculated online for any type of fabrication batch.

The algorithms can be used in the contractual phase in order to estimate the delivery timeline, in the fabrication preparation phase in order to estimate the required capacity and workforce, as well as in the fabrication programming and reprogramming phase when different simulation can be made with different priority variants, different capacity allocations with variance efficiency analysis.

Through the definition of specific data structures for the presented relations, we demonstrate that the computer assisted operative programming approach is possible in the machine building industry, even on an enterprise level. With these conditions it is ensured a superior quality of the decision system, the accumulated experience is suggesting the realization of a methodological framework in this field.

***Keywords*****—**manufacturing, machine building, informatics

## I. INTRODUCTION

The two major objectives of manufacturing engineering are efficiency and manufacturing time. The importance of these elements is even greater in the case of serial production.

During the design of the technology, a production batch (quantity) is taken into consideration, which later cannot be adhered to during consequent batches. Thus a disturbance occurs in the loading of the machines and work-groups, interruptions and lags occur between operations, additional time losses appear during the replacement of newer tools and instruments. At the same time, along with the change of batches between operations, the transportation and storage in these periods becomes inefficient. The batches between operations should be recalculated (a new schedule), but in the case of mass production (a large number of components and operations), this is very time-consuming. In the case of a new customer, the final production time is hard to estimate, even though the recalculation methods are known.

## II. GOAL OF THE DEVELOPMENT

For the disturbances mentioned, we have developed a new calculation model for the calculation of the production cycle, the elements (data) of which do not depend on the scale of the production batch and can be fixed (memorized) during the design stage of the technology, on component level. In the production stage, the recalculation according to a new batch, can be solved instantly with adding the new batch (saving a significant amount of time), because the calculations do not need to be taken to the operation level. In case of computer applications, we can achieve almost on-line results [1], [2]. The high-speed algorithms are developments of an international level.

## III. IMPLEMENTATION

For each component, the preparation time, unit production time, transport time, the machine and tool type, etc. corresponding to the internal operations are known. During the design of the technology, from these data, so-called partial results can be fixed on the component level, which do not depend on the size of the batch. With the help of these, later, during the production processes, the full production time can be calculated instantly for any order, by entering the order batch, saving a significant amount of time.

The cycle calculation method minimizes idle time, increases the loading of machines and work-groups, decreases the number of interruptions and ensures the appropriate change of temporary tools. At the same time the size of batches between operations is also regulated, decreasing storage costs.

### *A. Calculation of the component-level production time*

Legend:
L – production batch (quantity)
PTi – the preparation time of operation i
TTi – the transport and waiting time after operation i
UTi – the processing time after operation i (1 piece)

UTn – operation n, the unit processing time of the last operation for the component

C1 – the first part sum on component level

C2 – the second part sum on component level

C3 – the time delay between the components to be fitted

TCT – the total production time of L pieces of components

ETJ-1– the earliest start time of the j-1 level component in function of level j connected components.

Accordingly, we can calculate and memorize the following values on a component level [1]-[2]:

$$\mathbf{Ti = UTi + PTi} \qquad (1)$$

$$\mathbf{C1 = PT1 + \underset{T1>T2}{TT1} + \underset{T1<T2}{UT1} + \sum_{\substack{i=2 \\ Ti>Ti\text{-}1;\,Ti<Ti+1}}^{n-1}(PTi + UTi) + \sum_{\substack{i=2 \\ Ti>Ti\text{-}1;\,Ti>Ti+1}}^{n-1}(PTi + TTi) + \sum_{\substack{i=2 \\ Ti<Ti\text{-}1;\,Ti>Ti+1}}^{n-1}(UTi + TTi) + \underset{Tn>Tn\text{-}1}{(UTn + TTn)} + \underset{Tn>Tn\text{-}1}{(PTn + TTn)}} \qquad (2)$$

$$\mathbf{C2 = \underset{T1>T2}{UT1} + \sum_{\substack{i=2 \\ Ti>Ti\text{-}1;\,Ti>Ti+1}}^{n-1} UTi + \underset{Tn>Tn\text{-}1}{UTn}} \qquad (3)$$

$$\mathbf{C3 = \sum_{\substack{i=2 \\ Ti<Ti+1;\,Ti<Ti\text{-}1}}^{n-1} UTi} \qquad (4)$$

$$\mathbf{C4 = (UTn, j * j\,level\ quantity - UT1, j - 1) > 0} \qquad (5)$$

If we memorize the C1, C2, C3, C4 part sums in the stage of technological preparation by component, by adding the L production batch at the start of production, we can calculate the total production time and the earliest start time on a component level:

$$\mathbf{TCT = C1 + L * C2 - (L - 2) * C3} \qquad (6)$$

$$\mathbf{ETj\text{-}1 = \max_{r\in j}\ (ETj + IVj) \quad j > 1,} \qquad (7)$$

r is the set of the components connected to level j-1

$$\mathbf{IVj = C1, j + Lj * C2, j - (Lj - 2) * (C3, j + C4, j - 1)} \qquad (8)$$

In the manufacturing phase [2], the total TCT production time can be calculated on the component level, and also the start time by component, and at the end we obtain the production time of the ordered product. In case of a technology implemented on computers the loading data can be calculated ulterior per work location, and in a next phase, at the analysis of the overloads, the start times can be modified (delay or capacity increase, etc.). Without the need for operation level calculations (they are done on component level) saving of calculation time is significant in the production phase, and the control of production can be executed in real time, with accurate calculations according to the formulas above.

To minimize waiting times, the results take into account the international experience, that if after a longer duration operation, a shorter one follows and the start of the next operation is delayed, so that the production of the L quantity batch can be ensured in real time. As examples, let us present the following two cases [1], [3]:

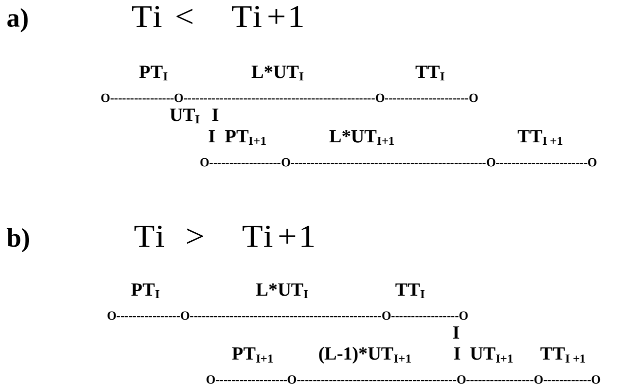


**Fig. 1.** Shifting the starting time of operations

$$\mathbf{ET1 = 0;} \qquad (9)$$

$$\mathbf{ETi = \max_{j,\,i>1}(\ ETi\text{-}1 + PTi\text{-}1 + UTi\text{-}1 + TTi\text{-}1;\ ETi\text{-}1 + PTi\text{-}1 + L * UTi\text{-}1 + TTi\text{-}1 - (L - 1) * UTi - PTi\ )} \qquad (10)$$

We act similarly between the first operation of the component and the connected next level component's last operation. (see the formula for C4).

*B. Case study*

For example, starting from the data of 10 operations of a component we calculate the mentioned part sums, then directly on component level, the total production time for a quantity of L=10 in minutes:

TABLE I
INITIAL DATA AND THE CALCULATED RESULTS

| ***Number of Operations*** | ***10*** | ***20*** | ***30*** | ***40*** | ***50*** | ***60*** | ***70*** | ***80*** | ***90*** | ***100*** |
|---|---|---|---|---|---|---|---|---|---|---|
| **PT** | 5 | 3 | 4 | 2 | 3 | 4 | 5 | 3 | 4 | 5 |
| **UT** | 7 | 4 | 8 | 3 | 7 | 4 | 6 | 3 | 7 | 4 |
| **TT** | 3 | 2 | 4 | 3 | 2 | 4 | 3 | 2 | 4 | 3 |

**$C_1$ = (5+3+4+4+3+2+5+3+4+4+4+3) = 44**
**$C_2$ = 7+8+7+6+7 = 35**
**$C_3$ = 4+3+4+3 = 14**
**$_{TCT}$ = $C_1$ + L* $C_2$ - ( L – 2)*$C_3$ = 44 + 10* 35 - 8* 14 = 282 min**

If we return to the algorithm described in A with another L – production batch, with the help of a memorized technology which contains C1, C2, C3, C4 part sums, we can recalculate operatively, with high speed, the start time of the components, and also the production time of the products.

According to the data above we have plotted the graph over time (in minutes) [3]-[4]:

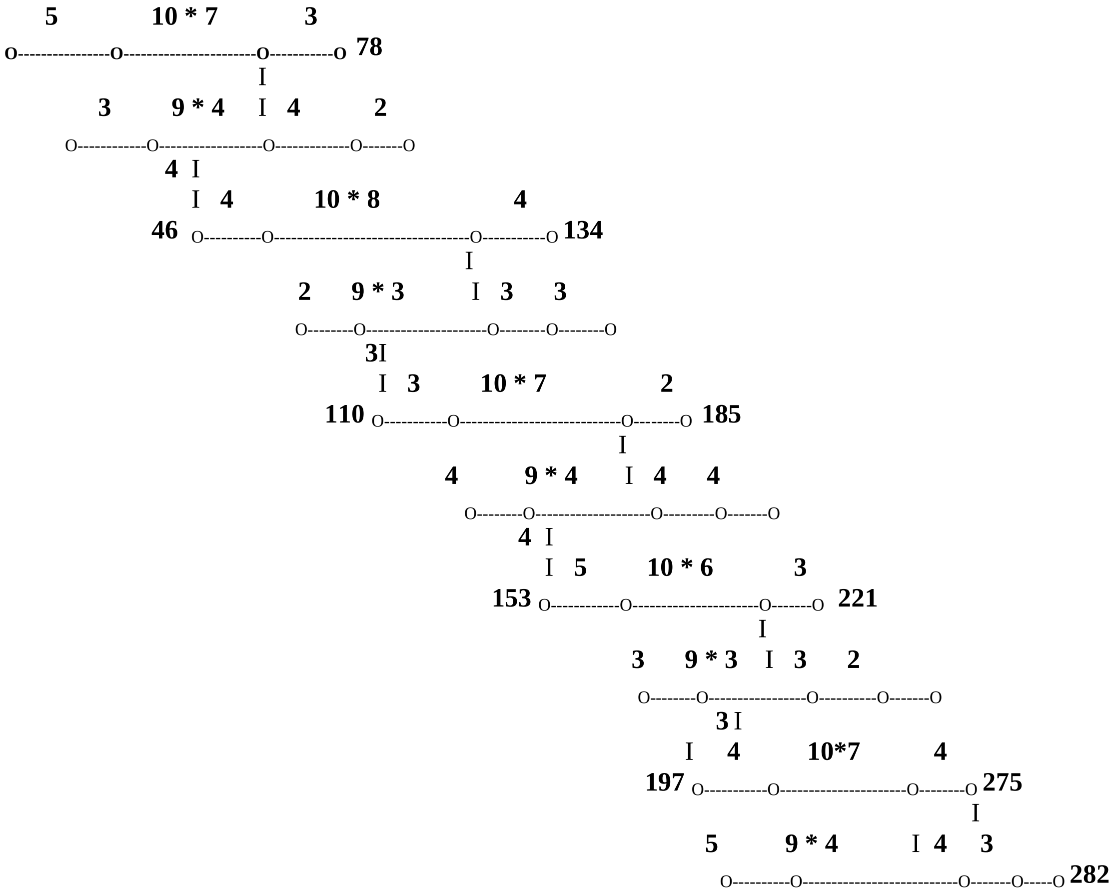


Fig. 2. Timely scheduling of operations

## IV. Conclusions. Possibility for further development of the research

The solution can be applied to any discrete technology (machinery, light industry, food industry, electrical appliances, etc.) but we can achieve a serious advantage in the case of multi-operation or the series production of products with multiple parts [4].

The implementation was supported by the research program of MTA DOMUS 2013, [1].

As practice and effective application of the research we are working now at the implementation of the method on the Flexible Manufacturing Cell, named UO-01-FMC (based on the horizontal milling center TMA AL 550, modernized on our own forces) existing into the Laboratory of Advanced Technologies of Oradea University, [5], [6].

This FMC has to work in different regimes as educational purpose, or as production and manufacturing of metallic parts, including here the automatic operation regime, which must be piloted from the hierarchic computer, and having this CAPP (Computer Aided Production Planning) function as base of simulation process [6].

The algorithms are useful from the unique manufacturing up to mass production. They may be included in the operational program known concepts of production, significantly improving their performance, making it possible to extend their applications with an acceptable response time at the company level. It will be appreciated that in particular for the production of the series, to calculate the duration of the manufacturing cycles and provides a reduction of computation time by at least 30% compared to conventional methods.

In such conditions can be developed operational planning options which can then be evaluated in terms of economic performance (load factor machines, batch fractionation, etc.) providing the information needs of the human decision maker. In addition to the above case study were specific testing was conducted by simulating a number of extreme cases.

For easy application of relations including the case with many components assembled in an assembly workshop in [1] presented a data structure and program specific query.

The above relations can be used to program the fabrication with limited capacity conditions. For a large series the algorithms can be generalized based on a transportation batch, safety stock, etc. [7]-[8].

Relations from (6)–(10) can be used to calculate the operation priorities of manufacturing. Thus beginning with the earliest starting times it is possible to calculate the latest starting times, beginning from the last operation to the first, resulting in the time reserve of each operation. In order not to produce many interruptions between the consecutive operations, sometimes priorities are calculated on a component level, reducing like this the unfinished production quantities. In the case of assembly operations, starting from the query of a structure file of the components [1], it is possible to calculate the time shifts between components which are assembled. (7)-(8)

In literature are described many ways and methods how to calculate priorities [5]. When applying the algorithms for the flexible manufacturing system area, it is necessary to correlate these with the specific storing methods, transporting and loading of pieces and tools [6].

In the preparation phase of the production in order to estimate deadlines simple relations can be used (C1, C2, C3, C4) with on-line high calculation speed answers, and in the operative programming phase we suggest the relations from the international practice presented in this paper.

Using the calculations of the earliest and latest starting dates of the component production, different formulas can be applied, even combinations of these for the priority order of the fabrication. By the use of the external priority on order level it is possible the forced speeding or the complete stopping of an order. For a better loading of the machines sometimes the priority of the current operation, successive operations, shorter operations or external operations can be applied. Priorities are only calculated for the unprecedented operations, forming a waiting queue on machine types, in descending order of the priorities. The list is updated dynamically, the programmed operations are deleted from the list and the following operations are introduced of which the priority is recalculated. The programming ends as the list becomes empty. The real start of the operation will be programmed to the starting time of the MAX (the earliest starting time of the operation; release time of the machine), modifying the starting time of the next operation and the release time of the machine.

The operative programming can be realized only if the available resources are established with their hourly schedule. In case of overload the possibilities are:

1) *increasing the capacity level*
2) *changing the work calendar (long week-ends, extended hours, etc.)*
3) *replacing the operation with an equivalent one*
4) *accepting the overload between some values on some resources*
5) *scheduling the programming for a later date than the latest start date*

Another development possibility of this work can be in the case of series production and mixed organization, in such a way that together with the registration of the unfinished production the remaining production times should also be calculated allowing to identify the degree of manufacturing advancement, the time to finish a batch assembly, etc.

It is necessary to have a database which ensures a good data security and makes restarting the programs from different calculation phases possible, allowing the realization and analysis of multiple manufacturing program variations, modifications of these, selecting the suitable option, restarting the manufacturing from a defined date. This paper provides elements for developing a methodology for operative programming of manufacturing, even on an enterprise level.

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