

# An Adapted Partial Method for Schedule Preparation for the Start and Finish of the Mechanical Machining of Lots in a Virtual Cellular Manufacturing System

Ivan Dakov and Aneliya Petkova,  
Faculty of Management, Technical University, Sofia, Bulgaria  
idakov@tu-sofia.bg, anel\_kost@yahoo.com

**Abstract** - This paper presents a method for schedule preparation for the start (prolongation) and finish of lots machining which is adapted to the conditions of the Virtual Cellular Manufacturing Systems for mechanical machining. The aim of the schedule is to show which lots will be machined in the VCMS during the next plan periods and to specify the terms (times) for the start and finish of lot machining within each one of them. The schedules are to be formed consecutively – at the end of each plan period for a horizon from three to five plan periods. The plan period could be from one day until six days (a workweek). It depends on the prevalent prolongation of the machining of lots in the VCMS and the workweek duration. By means of the elaborated algorithm the sequence of the schedule development was specified.

**Index terms** – Virtual Cellular Manufacturing System, Schedule, Terms for start and finish of lots machining in VCMS.

## I. INTRODUCTION

The elaboration of the schedules for the start (prolongation) and finish of the mechanical machining (processing) of the lots (jobs) in the VCMS is an important stage of production planning.

The specific conditions of the VCMS, namely, a wide-stock list of machined lots, which could not be repeated rhythmically or periodically, require the use of a “partial method”, which binds the work of VCMS with other links in the enterprise. VCMS is a medium link where parts will be processed. Therefore the required data for the creation of schedules for the start and finish of lots machining are: the planned times for beginning of assembly of the parts, the required quantities of each part types, operation times and the set ups for each operation of the part’s mechanical machining in the VCMS. The scheduling norms are: a lot (batch) size, the flow times, calculated in a parallel-serial operation combining and the lead times for start and finish the mechanical machining of the lots in the VCMS according to the beginning of assembly.

The terms for the end of machining of each lot and the term of its beginning in relation to the start of their assembly are to be calculated on the base of the scheduling norms. For each job which will be processed in the VCMS, the availability of the materials, needed instruments, facilities and the management programs for the automated technological modules (ATM) are to be checked. Hence,

according to the elaborated schedules virtual cells will be formed and the schedules for machining of each lot will be developed.

## II. GENERAL POSITIONS

The task of the schedules in the VCMS is to show which lots will be machined during the next plan periods and to specify the terms (times) for the start (prolongation) and finish of their machining within each planned period. The schedule preparation requires that the lot size is known, which is different for each of them, also the set of assembly of the respective series of products has to be ensured.

The machining of each lot is carried out in one virtual cell which exists until all parts are processed. It is accepted for the movement of the parts in the VC to be done in transfer lots (several parts of the whole lot that move together). Concerning the combining of operations in the respective virtual cell, according to the publications of Abedzadeh [4], Abdunour [5], Drolet [6] and Rheault [7] it was not accepted to be parallel, i.e. without overlapping of the sequent operations couples. This is the reason to have a longer processing time.

To make it shorter, it is necessary for the operations to be combined in a parallel-serial way (with operations overlapping), only in some cases when there is a considerable reserve of time (remaining time) and the lot size is very small, as an exception, unparallel operation combining could be used. The scheduling norms, required for the schedules preparation are: the flow time in the VCMS and the lead times for the start (prolongation) and finish of the machining of each lot according to the beginning of assembly. The development of schedules for mechanical machining of the lots in the VCMS includes their assignment in plan periods depending on the calculated periods for their processing and the calculations for the correspondence between the available time and the planned volume of work of each automated technological module (ATM) type.

This activity of the production planning could be done by means of the “partial method” – “by lot anticipation” [1], which must adapt itself to the specific conditions of the VCMS.

ATM are located in an “equally dispersed” manner in the VCMS as each ATM type is surrounded by other ATM types.

Figure 1 shows the ATM layout in the VCMS. The layout of ATM consists of four different types (A, B, C and D), and each type has three numbers (A<sub>1</sub>, A<sub>2</sub> and A<sub>3</sub>) [3].

The ATMs are located on a rectangular manufacturing floor in three rows, each row contains four of them.

A <sub>1</sub>	D <sub>1</sub>	C <sub>1</sub>	B <sub>1</sub>
C <sub>2</sub>	B <sub>2</sub>	A <sub>2</sub>	D <sub>2</sub>
A <sub>3</sub>	D <sub>3</sub>	C <sub>3</sub>	B <sub>3</sub>

Figure 1. Layout of the ATM in the VCMS [3].

#### A. Distribution of the lots in the plan periods

The distribution of the lots in the plan periods is to be realized depending on the terms for the start (prolongation) and finish of their machining in the VCMS, which are linked with the planned time for the beginning of the assembly of the parts (fig.2).

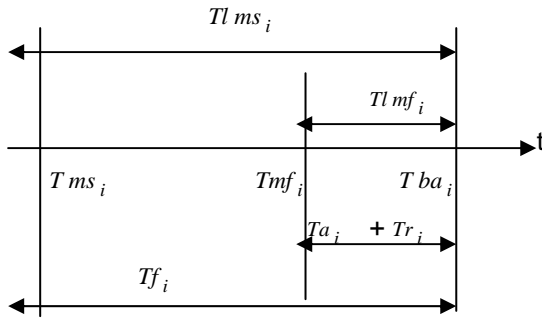


Figure 2. Planned terms for lot i.

For this purpose we use:

- 1) the flow time of the machining of each lot in the VCMS ;
- 2) the lead times for the finish and start of the machining of each lot, according to the planned time for assembly beginning.

The flow time for machining of lot *i* in the VCMS ( $Tf_i$ ) is to be calculated in work days with overlapping of the pairs of sequential operations, realized in the virtual cell.

The lead time of the completion of the machining of the *i* lot in VCMS ( $Tl mf_i$ ) will be calculated in work days with the formula:

$$Tl mf_i = Ta_i + Tr_i \quad (1)$$

where:  $Ta_i$  is the time for machining the *i* lot in other manufacturing links (thermal processing) after VCMS, in work days.

The lead time for the start of machining the *i* lot ( $Tl ms_i$ ) is to be calculated in work days in the formula:

$$Tl ms_i = Tf_i + Ta_i + Tr_i \quad (2)$$

By the means of the calculated flow time for machining of the lot ( $Tf_i$ ) in the VCMS, the lead time for the completion of the machining of the lot ( $Tl mf_i$ ) in VCMS and the lead time for its start ( $Tl ms_i$ ) in the VCMS, the respective terms for the completion and start of the lot machining in VCMS, are to be determined.

The term for the finish of machining of *i* lot in the VCMS ( $Tmf_i$ ) in relation to the planned time for its assembly beginning ( $Tba_i$ ) is to be calculated in the following formula:

$$Tmf_i = Tba_i - Tl mf_i \quad (3)$$

The calculated term shows the planned period, the work day in it and the hour of its beginning, when the machining of lot *i* in the VCMS must finish at latest. The beginning of work day is determined by the start of first shift. The calculations for the machining start of the lots in the VCMS ( $Tms_i$ ) are to be done in following formula:

$$Tms_i = Tba_i - Tl ms_i = Tmf_i - Tf_i \quad (4)$$

The calculated term shows the plan period, the work day in it and the hour of its beginning, when the machining of lot *i* in the VCMS must start at latest.

If for an example lot, the flow time for its machining in the VCMS is 4,19 work days, the time for its machining after VCMS is 3 work days and the remaining (reserve) time before its assembly beginning – 3 work days and the time for its assembly beginning is planned to be at the beginning of the first work day from 25<sup>th</sup> plan period (a five day week) – 25/1/1, then the respective terms for the end of its machining in VCMS is the end of 11<sup>th</sup> hour of 6<sup>th</sup> day from 23<sup>th</sup> plan period – 23/6/11. The machining start of the example lot in VCMS is the beginning of 15<sup>th</sup> hour of the second day from 23<sup>th</sup> plan period – 23/2/15.

After the two type of terms are calculated, the lots are to be arranged in terms of the increase of their machining start (prolongation) and then - in terms of the increase of their machining finish.

Since the VCMS is a medium link, through the terms in the first case, the work of VCMS will be bound with the preceding link (the link of row materials). By means of the terms in the second case the work of the VCMS will be bound with the assembly link, i.e. two schedules types will be created.

The schedules for binding the VCMS's work are to be made for the chosen plan horizon, the hour of beginning

(prolongation) and finish of its machining are to be specified for each lot respectively.

By the means of the flow time of each lot in the VCMS and the calculated terms for the start and finish of its machining, the operations will be distributed in each plan period.

For the example lot, all operations of its mechanical machining are planned to be done only during the 23<sup>th</sup> plan period from the 15<sup>th</sup> hour of its second day till the end of the 11<sup>th</sup> hour of its sixth day. The schedules are to be specified at the end of each plan period. Thus a rolling production planning in the VCMS is to be realized.

### B. Calculation of the planned loading of each ATM type for each plan period

The calculations determine the correspondence between the planned loading and the production possibilities of each ATM type within each planned period.

The volume calculations are to be made first for the incoming plan period and then for next ones.

The specific particularities of the VCMS, according to which the virtual cell was equipped with a given number of ATMs, which perform the machining of a given lot, require that the moment loading of the respective modules is considered. To this purpose, calculations for the available time (time fund) of the s-ATM type for plan period  $q$  ( $Fe_{sq}$ ) and the volume of work during the same period are to be made. The available time is calculated in hours, in following formula:

$$Fe_{sq} = Dw_{sq} \cdot Ksh \cdot Tsh \cdot M_{sq} - Tm_{sq} \quad [h] \quad (5)$$

where:  $Dw_{sq}$  are the number of work days at plan period  $q$ ;

$Ksh$  is the shift coefficient, defining the shift number;

$Tsh$  is the duration of one shift;

$M_{sq}$  is the ATM number of s-type, at plan period  $q$ .

$Tm_{sq}$  is the time for plan maintenance, and repairs for ATM of type  $s$ , at plan period  $q$ .

In order to calculate the volume of work for machining of  $i$ -lot when it performs the  $j$ -operation at ATM of  $s$ -type, during  $q$ -plan period ( $Wij_{sq}$ ) the following formula is used:

$$Wij_{sq} = \frac{n_{iq} \cdot top_{ijs}}{60 \cdot d_{ijs}} + \frac{Tsu_{ijs}}{60} \quad [h] \quad (6)$$

where:  $n_{iq}$  is the lot size of type  $i$ , which will be machined at plan period  $q$ , items;

$top_{ijs}$  - the operation time of operation  $j$ , performing at  $s$ -ATM type, which processes the operation  $j$ ;

$d_{ijs}$  - the number of parts of type  $i$ , processed at the same time, at ATM of type  $s$ , performing the operation of type  $j$ ;

$Tsu_{ijs}$  - the set up time for operation of type  $j$ , at ATM of type  $s$ , which machines the lot of type  $i$ , min.

The calculations for the correspondence between the available time and planned volume of work are to be done for each ATM type.

In the VCMS which has been presented there are four ATM types, each type has three numbers.

The next calculations to be made are for the percentage loading ( $Lp_{sq}$ ) of each one ATM in  $q$ -plan period in the formula:

$$Lp_{sq} = \frac{Wij_{sq}}{Fe_{sq}} \cdot 100 \% \quad (5)$$

The admissible overloading is + 5%, otherwise corrections of the terms of lot machining will be done.

Finally, the deficit or surplus of available time for each  $s$ -type ATM during the plan period  $q$  ( $D_{sq}$ ) will be calculated. The following formula will be used:

$$D_{sq} = Fe_{sq} - Wij_{sq} \quad [h] \quad (6)$$

When there is a difference with a positive sign there is a surplus of available time and if the sign is negative – a deficit (overloading more than 5%). Then it is required to do a re-assignment of the work in the plan periods and eventually, a correction of the terms for beginning and finish of the lot machining in VCMS.

### III. PRESENTATION OF THE ALGORITHM FOR SCHEDULE PREPARATION FOR THE START AND FINISH OF THE MACHINING OF LOTS IN VCMS

The algorithm for schedule preparation for the start and finish of the lot machining in VCMS is presented in figure 3 and includes the following blocks, describing the work sequence:

Block 1. In this block the times for the beginning of the assembly of the respective lots are to be introduced;

Block 2. Introduction of the data and the scheduling norms for each lot, machined in the VCMS, namely:

- 1) lot size;
- 2) operation times;
- 3) set up times;
- 4) flow time, realized in the VCMS;

Block 3. Determining the terms for the start and finish the machining of each lot, by means of the lead times and the flow time, which will be realized in the VCMS.

Block 4. Distribution of the lot-operations for each lot during the planned periods in relation to the planned terms for their machining in the VCMS.

Block 5. includes the calculations for the correspondence between the available time and the volume of work of each ATM type for each plan period.

Block 6. Planning the terms for the start and finish of each machining of the lot in VCMS. If there is no correspondence between the available time and the volume of work of each s-type ATM, the required corrections are to be done. In such a situation we will be back to block 3. If the corrections are not necessary, block 6 will be performed.

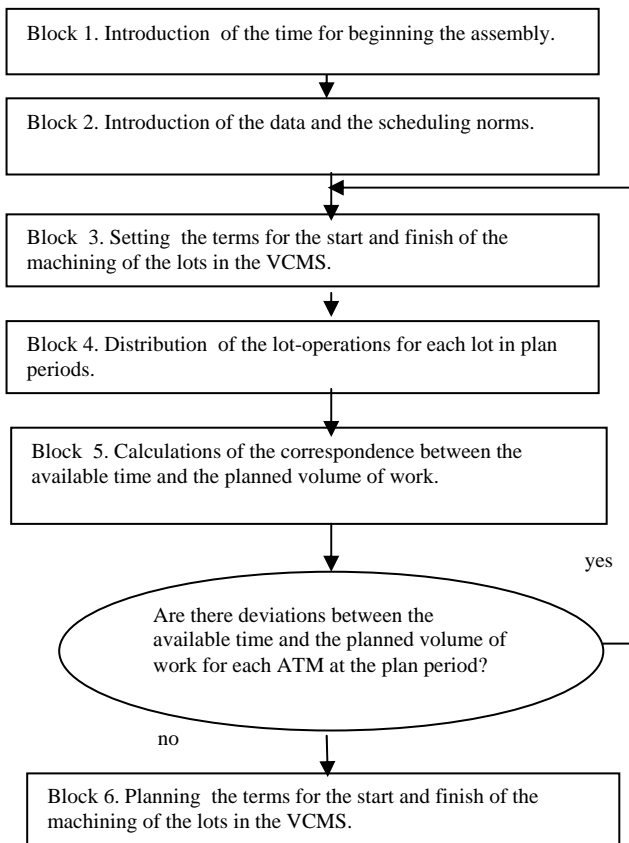


Figure 3. Block scheme of the algorithm.

#### IV. CONCLUSIONS

This paper presents an adapted “partial” method for schedule preparation for the start and finish of lot machining in the VCMS. Since in the VCMS conditions, a wide stock-list of parts are processed, the scheduling of each lot will be done separately.

On the basis of the planned times for the start of the assembly of the parts, the terms for the start and finish of

the lot machining are to be determined as for each of them data for their size, flow time and lead times are introduced. The schedules for several planned periods are prepared by means of these data. At the end of each period, the terms for lot machining during the next plan periods are to be specified.

The calculations for the correspondence between the available time and the volume of work are to be made for each ATM type.

An algorithm for presenting the sequence of work was elaborated.

The developed schedules for the start and finish of the machining of parts in the VCMS are a basis for the scheduling of each lot in the respective virtual cell.

#### REFERENCES

- [1] Dakov, I., A Market Oriented by Part Method for Coordination of the Manufacturing Links Work of the Industrial Enterprises with a Serial Production Type, “Machine Tooling”, it.7-8, 1994, Sofia
- [2] Dakov, I., S., Petkova, A., K., “Scheduling of the virtual cellular manufacturing systems for mechanical processing”, II-nd International conference – CADAM 04, Sibenik, Croatia, 09.2004
- [3] Dakov, I. S., Lefterova, T. K., Nedeva, C., “A method for location of workstations in virtual cellular manufacturing systems”, Applications of Mathematics, Engineering and Economics’ 27, D. Ivanchev and M.D. Todorov, Heron Press, Sofia, 2002
- [4] Abedzadeh M, Development of the virtual cellular concept in a reconfigurable manufacturing environment, PhD Thesis, UK, 1997
- [5] Abdunour, G , Drolet, J., M. Rheult., The Cellular Manufacturing Evolution, Computers & Industrial Engineering, Vol 31, No ½, 139-142, 1996.
- [6] Drolet, J., Scheduling of the Virtual Cellular Manufacturing System, Computers&Industrial Engineering, Vol. 1, Singapore, 1995
- [7] Rheult, M., J.R. Drolet, G. Abdunour, Physically Reconfigurable Virtual Cells: A Dynamic Model for a Highly Dynamic Environment, Computers & Industrial Engineering, Vol. 29, No 1 – 4, pp. 221- 225, 1995.