APEM journal **Advances in Production Engineering & Management** 3 (2008) 4, 161-170
ISSN 1854-6250 Scientific paper

FUNCTION SCHEDULING WITHIN A SYSTEM OF PRODUCTION CONTROL : STUDY OF A REAL CASE

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Abstract:
This article presents the function scheduling within the system of production control. It describes a library search concerning the scheduling problems. Then, it presents an algorithm of scheduling of a method really applied in industry. This method has the advantage of being simple and easy to implement: it can treat two types of planning : at the earliest and at the latest. It establishes the Gantt diagram and organizes the work in the factory by distributing the load on the various working stations.

Key Words: Production management - Scheduling - Planning - Gantt Diagram.

1. INTRODUCTION

Nowadays, the production function is one of the important company functions, its goal is to produce goods and services in order to achieve a return on capital employed which may or not be reassigned to new investments.

The improved performance of the company is dependent on organizational methods and exploitation of the available resources. Therefore, proper production management is now a necessity for the company to manage its production very well. It has to find a solution in order to reach its objectives in spite of many conflicts.

In order to satisfy the development of the market requirements, the industrialists have to diversify their manufactured products, reduce their delivery times and minimize their costs. It is undeniable that software assistance becomes necessary to confront the diversity of information, solve many problems and control these constraints.

Moreover, to cope with the globalization of the economic stakes, manufacturers must be competent and offer the lowest prices. A decrease in production costs is essential to achieve this goal. In this sense, a better distribution of work on the different machines and the implementation of cellular manufacturing systems for the optimization of intermediate stocks contribute certainly to reduce costs.

The computer provides a decision tool and helps us to make the production planning. This planning is even more efficient than the scheduling algorithm it uses is effective. The goal is to achieve an optimal scheduling, which divides the workload with the best manner and takes into account the various production constraints [1].

2. THE PRODUCTION SYSTEM

In a manufacturing company, the production system collects all the ways to add value to products or services. This transformation is controlled by a management system which must comply with a lot of constraints in order to achieve the defined goals [2].
Production systems can be classified according to the nature and volume of manufactured products.

2.1. The unit production

It consists on producing a single product at customer's request. There is no stock of finished product. Once manufactured, the product is directly delivered to the customer. In this production mode, products have to reply to the specific needs expressed by customers. The unit production mode is practiced in the production of certain products types:

- Very expensive (airplanes, locomotives, ships…)
- With certain characteristics that meet a specific need (furniture…)
- Complex (assembly of factory or workshop...).

In this structure type, the major problem is to carry out the work with a competitive cost and in the requested time limit.

2.2. The serial production

It consists on producing a large number of identical items whose design and features have already been definitively established. The manufacturing process is divided into elementary and repetitive operations to produce several times the same article. Serial production is a production for the stock. The series size depends on two factors: technology and demand.

There are two serial production types:

- **The production in great series:**

The quantities to produce are important and the products diversity is limited.
In this case, the use of production lines is very profitable. When the production line is balanced, the rate of resource use is high and the waiting time by the products being manufactured is generally low.

- **The production in small and medium series:**

This is the case of most of small and medium companies for which the diversity of products and the low level of applications don't permit a specialization of production ways. The scheduling, in this case, plays an important role in optimizing the use of resources and minimizing the waste of time.

2.3. The continuous production

The difference between serial production and continuous production also called mass production is about technology. In the first, the product passes during its manufacture with distinct operations separated from each other. But in the continuous production, the product circulates in a continuous flow and undergoes physical and / or chemical transformations. Such systems concern the industries whose production requires liquids or gases manipulation (petroleum product, semolina…).

The Production Management Assisted by Computer differs from one mode of production to another. Therefore, the choice of a production management software isn't so easy, it's a difficult task that must be properly done to choose the program that suits the needs and activities of the company.

3. SCHEDULING PROBLEMS

In the production system, the scheduling problem is to organize in time how to perform interdependent operations with the help of resources available in limited quantities in order to achieve a production plan [3].

Basing on the concepts of task, resource, constraint and objective, scheduling can be defined: "Scheduling some tasks: is to order their implementation by allocating the necessary resources and fixing their start date" [4].

The tasks are subject to some constraints. Scheduling, which is a solution to the defined problem, is evaluated against one or more objectives to reach. The most often encountered objective in the literature is to have a scheduling optimizing some criterions [5].

The determination of these objectives is often extremely difficult. Indeed, we are usually confronted with many goals more or less contradictory and whose relative importance is difficult to assess. Among these criterion, we can quote:

- The cost and duration of implementation.
- The respect for the time limit.
- The amount of needed resources.
- The amount of work waiting.
- The immobility duration of resources.

These objectives can be quantitative requirements (values to be achieved or not to be exceeded) and take the form of constraints to be respected, or to qualitative requirements presented as a criterion to be optimized. Among the criterion used to evaluate the quality of an obtained scheduling, there are [6]:

• **Total length (Makespan):** The total duration of the scheduling is equal to the difference between the completion date of the most belated task and the beginning date of the first task. Minimization of this period is the most often met, since it inevitably leads to an efficient use of resources.

• **Respect of dates at the latest:** In several real problems, best compliance with delays is obtained by minimizing the largest delay or the delays sum.

• **Minimizing the costs:** This kind of criterion can be expressed in a wide variety of forms such as, for example, the minimization of outstanding stocks.

For the case study presented in this paper, we will mainly select as a scheduling criterion the minimization of the total length, this requires a better balance of different machines that guarantee a high occupancy rate while reducing queues.

There are two scheduling types:

• **Forecast scheduling:** It aims to generate an optimal scheduling minimizing a given criterion or a combination of several criterions. The defined scheduling problems are combinatorial optimization problems. They are difficult to solve using a polynomial algorithm [7]. The solution can be obtained either by accurate methods (Linear programming [8] or dynamic programming [9], [10] used to deal with very small problems (for example, problem with one machine), or by heuristics [11] based on approached algorithms often polynomial, which can solve complex problems. Heuristics do not guarantee the achievement of the optimal solution, but provide, within a reasonable time and with an acceptable cost, a solution which has generally quite good performances and a scheduling for which the found value is near the optimum value.

• **Reactive scheduling:** It is a scheduling system that includes a method for reacting in real time to hazards [12], [13]. These uncertainties may be internal: occurring inside the workshop (resources breakdowns, staff absence…) or external: caused by its environment (supply delay, unexpected arrival of a manufacturing order…).

4. STUDY OF A SCHEDULING REAL CASE

We shall now describe a scheduling method which was implemented in a company specialized in mechanical cutting. This method has shown excellent results because its simplicity and its efficiency.

The production of this company is small and medium series. The scheduling problem is a 'job-shop' [14]: the order of passage through the machines is not necessarily the same for all the components.

However, it is necessary to note that the problem must comply with the following hypothesis: For a given task, all pieces must be done in full and uninterrupted time in order to limit the adjustment time.

We propose, in what follows, the basic elements of the used scheduling algorithm. There are two types of sequencing: at the earliest and at the latest.

4.1. First type: Sequencing at the earliest

Planning for the production program is started on the date of machines availability. The Gantt diagram is elaborated by the first task on the first machine, and then the next task and so forth. It is filled from left to right according to the chronological order of processing (Fig. 1 & 2).

We suppose that the task (i) begins on the machine M_i at the time t_i, the problem is to know the timing that the next task (i +1) will start on the machine M_{i+1}. In order to treat this problem, we will define some parameters:

- N_j : Number of items to be produced during the task (j).
- R_j : Rate (or speed performance of the task (j) on the machine).
- t_j : starting instant of the task (j).
- tc_j : Period of machine change (from machine M_j to machine M_{j+1}).
- Rav(j) : Availability instant of machine M_j just after the carrying out of all its earlier tasks (right availability).
- Lav(j) : Availability instant of machine M_j just before the carrying out of all its latest tasks (left availability).

Two scenarios may arise:

4.1.1. The machine M_i is faster than the machine M_{i+1} : ($R_i > R_{i+1}$)

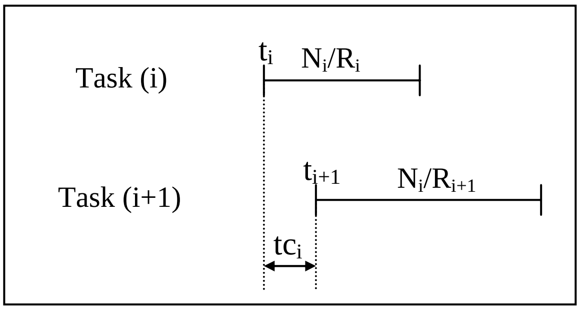

Figure 1: Gap between the tasks beginning (Case of sequencing at the earliest).

In this case, the starting instant of the task (i +1) will be:

$$t_{i+1} = \max(t_i + tc_i , Rav(i+1)) \quad (1)$$

This means that we should respect two constraints.

- First constraint: $\mathbf{t_{i+1} \geq t_i + tc_i}$ is linked to the relationship between task (i) and task (i+1).
- Second constraint: $\mathbf{t_{i+1}} \geq \mathbf{Rav(i+1)}$ is linked to the availability of machine M_{i+1} to carry out the task (i+1).

4.1.2. The machine M_i is slower than the machine M_{i+1} : ($R_i < R_{i+1}$)

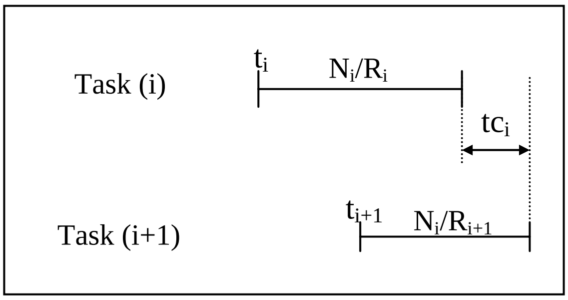

Figure 2: Gap between the tasks end (Case of sequencing at the earliest).

In this case, the start of the next task (i +1) must take into consideration the delays sum of machine M_i. The machine M_{i+1} must begin later in order to be able to operate continuously and without interruption. So, we have:

$$t_{i+1} = \max (t_i + tc_i + N_i/R_i - N_i/R_{i+1},\ Rav(i+1)) \qquad (2)$$

The ratio $\mathbf{D_i = N_i / C_i}$ represents the length of the effective job of machine M_i in order to do the task (i).

We suppose that the number of items to be produced N_{i+1} is almost equal to N_i because the waste rate is practically negligible between the two machines.

4.2. Second type: Sequencing at the latest

In this type, the planning for the production program is done from the hoped date of delivery of the item or its stocking date as a finished product. The Gantt diagram is based on the latter task on the last machine (test-bed or assembly post), then the task which precedes it and so on. It is filled from right to left in the opposite direction in chronological order (Fig. 3 & 4).

The knowledge of the start moment t_i of the task (i) on the machine M_i allows to calculate the start moment t_{i-1} of the task (i-1) that precedes it on machine M_{i-1}.

Two scenarios could also arise:

4.2.1. The machine M_i is slower than the machine M_{i-1} : ($R_i < R_{i-1}$)

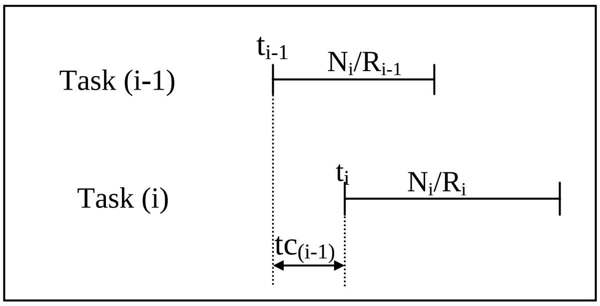

Figure 3: Gap between the tasks beginning (Case of sequencing at the latest).

In this case, the start moment of the task (i-1) that precedes the task (i) will be:

$$t_{i-1} = \min (t_i - tc_{(i-1)} , Lav(i-1) - N_i /R_{i-1}) \quad (3)$$

This means that we should here respect two constraints.

- First constraint: $\mathbf{t_{i-1} \leq t_i - tc_{(i-1)}}$ is linked to the relationship between task (i-1) and task (i).
- Second constraint: $\mathbf{t_{i-1} \leq Lav(i-1) - N_i / R_{i-1}}$ is linked to the availability of machine M_{i-1} to carry out the task (i-1).

4.2.2. The machine M_i is faster than the machine M_{i-1} : ($R_i > R_{i-1}$)

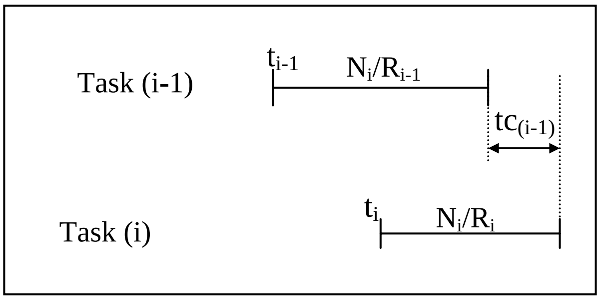

Figure 4: Gap between the tasks end (Case of sequencing at the latest).

In this case, the previous task (i-1) must start early so that the machine M_i can carry out the task (i) by operating continuously and without interruption. So, we have:

$$t_{i-1} = \min (t_i - tc_{(i-1)} + N_i/R_i - N_i/R_{i-1}, Lav(i-1) - N_i/R_{i-1}) \quad (4)$$

4.3. Application example

To illustrate the algorithmic model proposed above, we intend to treat a simple example of scheduling (2 components and 7 machines).

We will plan the manufacture and the assembly of 1500 units of a finished product compound of two parts A and B according to the manufacture ranges showed on the table below (Table I).

We will present the Gantt Diagrams corresponding to the two types of sequencing: at the earliest (Fig. 5) and at the latest (Fig. 6). To treat this case, we take the following hypothesis:

- We suppose that the company works eight hours per day.
- Item A has a priority over item B.
- The setting times are included in the rates.
- The change times are all identical and equal to one hour.
- The length of the effective job of a machine, defined as the ratio between the quantity to be produced and the machine rate, must be an integer, and if this is not the case, it is rounded to an integer value by excess.

Table I: Manufacture ranges.

Component	Order of carrying out	Operation	Machine	Rate (items per hour)	Job length (hours)
1500 items A	1°	Cutting up	CUT	220 i/h	7 h
	2°	Forge	FOR	110 i/h	14 h
	3°	Cleaning	CLN	200 i/h	8 h
	4°	Manufacturing	MAN1	130 i/h	12 h
1500 items B	1°	Cutting up	CUT	150 i/h	10 h
	2°	Forge	FOR	260 i/h	6 h
	3°	Grain throwing	GRN	140 i/h	11 h
	4°	Manufacturing	MAN2	200 i/h	8 h
A + B	-	Assembly	ASM	150 i/h	10 h

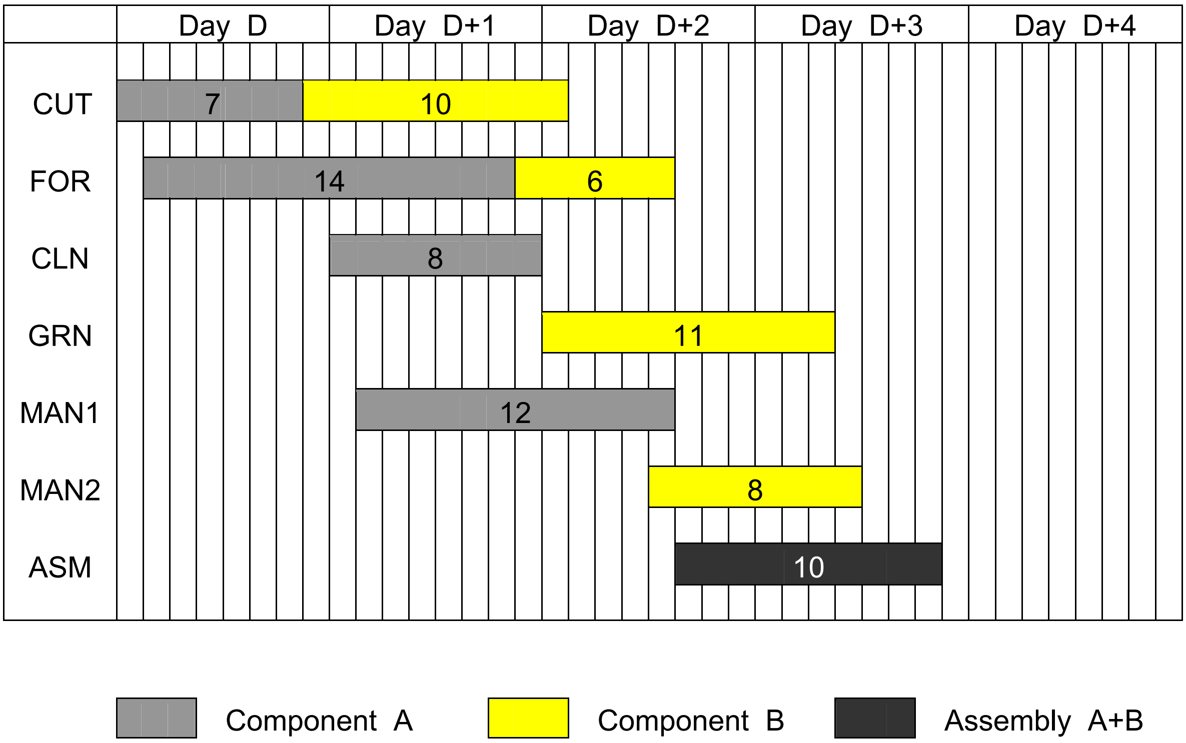

Figure 5: GANTT diagram obtained from sequencing at the earliest.

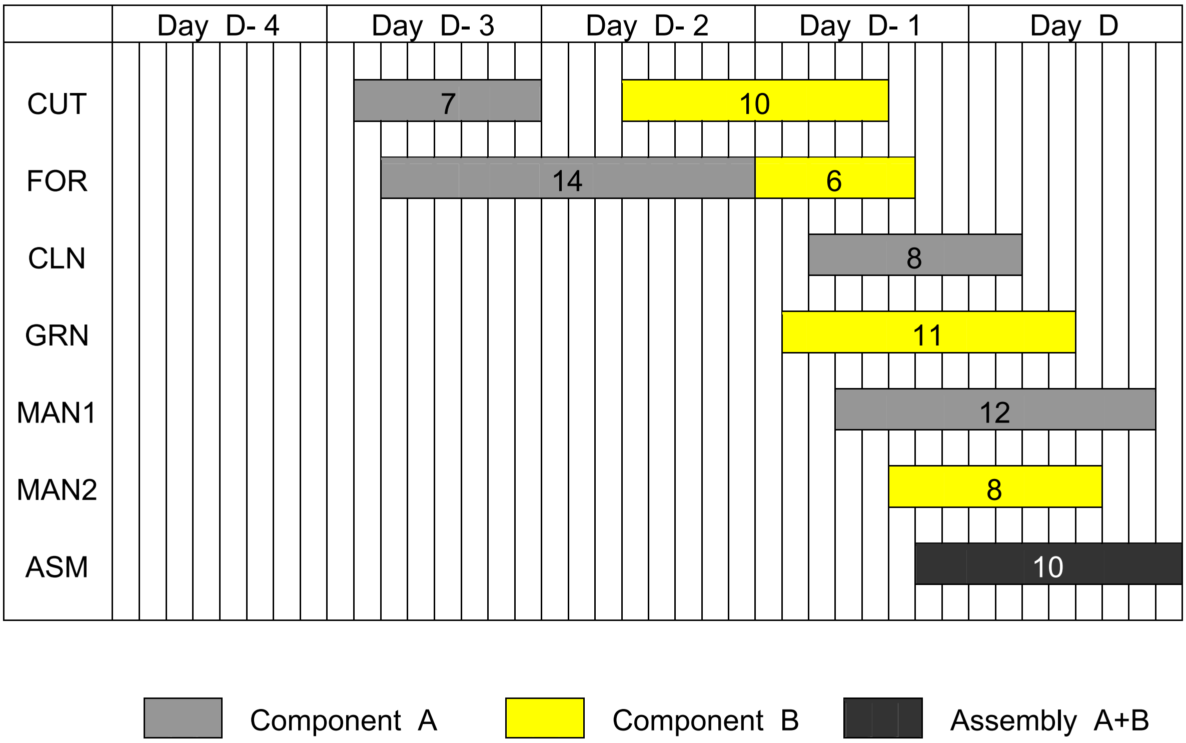

Figure 6: GANTT diagram obtained from sequencing at the latest.

4.4. Critics and improvements of the used method

The method detailed above is simplified. It ignores, for example, the setting time necessary at the beginning of each task or the production hazards (work stopping, breakdowns...) [15].

However, to remedy this problem we introduce into the model a corrective factor μ used to revise the rate of a given task. The rate R_i taken into account at calculations is equal to:

$$Ri = \mu * R'I \qquad (5)$$

With :

- $0 < \mu \leq 1$
- R'_i : Rate given by the machine manufacturer (theoretical rate)

This rate correction will absorb the differences due to unforeseen stops mentioned above. This factor μ will be chosen small when the stops at the workshop are frequent and the setting times are not controlled.

5. CONCLUSION

Based on a real experience spent in an industrial company, we can say that the practice of a Production Management Assisted by Computer is not an easy matter, because it requires a perfect organization and, above all, a great effort to integrate this tool in the workshop.

In this case, the selection of an ultra-sophisticated software, since the beginning, is not advisable. Its complexity will be a handicap for its use and its abandonment will be inevitable.

We can therefore begin managing the workshop production with a simple software based on the method described above, and thereafter, we will introduce in this software other parameters that can handle more complex situations [16].

The sequencing method presented in this paper is certainly simplistic, but it is very easy to implement and it doesn't require advanced abilities in production management to be able to use it. It is a first approach to the scheduling problem which is too complex and boring to set up. This difficulty scares away many small and medium companies who prefer driving their production on a daily basis and managing their time manually.

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