MES, shop floor scheduling (assigning, sequencing, simulation), alternative routes, parallel machining, constraint, due date, decisions on shop floor level

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SHOP FLOOR CONTROL DECISION SUPPORTING AND MES FUNCTIONS IN CUSTOMIZED MASS PRODUCTION

Abstract. This paper deals with the production control problems of customized mass production, which can be described as a coupling of make to stock and make to order type production at the same time. In order to solve scheduling and resources allocation issues, different production models for mass production will be presented and evaluated. Some deterministic and stochastic properties of the models will be discussed for investigating the use of behaviour based control policy. This paper overviews the definition and the common functions of Manufacturing Execution Systems (MES). Some possible extensions of MES systems for mass production is also described. Research and development work has been carried out in the field of process management function of MES at the University of Miskolc, Department of Information Engineering. The focus has been set to determine alternative routings, materials, human work forces and machines allocation for optimal scheduling. The shop floor level evaluation process of production output will be presented. The dispatcher policies at production line and shop floor level will be also discussed. The result of this work will be summarized in this paper. Some future research activities will be also outlined.

1. INTRODUCTION

The modern production information engineering systems highly utilize computer aided application systems. As a result of research and development activities three large application systems have been developed which offer “turnkey” solutions for the management to support decision making. They are as follows:

- Enterprise Resources Systems (ERP),
- Computer Aided Design and Computer Aided Manufacturing (CAD/CAM) and
- Manufacturing Execution Systems (MES).

This paper focuses on MESs In order to solve scheduling and resources allocation issues, different production models for mass production.

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2. MANUFACTURING EXECUTION SYSTEM

2.1. MES DEFINITION, SCOPE AND FUNCTIONALITY

A Manufacturing Execution System (MES) is a collection of hardware/software components that enables the management to control production activities from order launch to finished goods. While maintaining current and accurate data an MES guides, initiates responds to and reports on plant activities as they occur. MES provides mission-critical information about production activities to decision support processes across the shop floor level of manufacturing management [1].

MESs are intended to provide plant-wide insight into the production process, informing about the state of production, production performance, and emergence and allocation of production costs to products. MES may improve better resources planning and allocation, allows supervising the process execution, thus it is possible to promptly identify and react to abnormal events. Product tracking, as the core functionality of a MES system has the main objective to accompany and supervise the manufacturing process. Based on requests from the production manager or upper Enterprise Resources Planning (ERP) system, the feedback information from low level Supervisory Control and Data Acquisition (SCADA) systems, and inputs from the user/operator it has to be in the position not only to know the current state of production and state of all products, but also to recognize abnormal, deviant or critical states in the production process [3].

It brings together data from a wide range of sources into one integrated whole, it can:

- download the job schedule from your ERP,
- allow inventory to be allocated as used,
- generate labels for inventory created,
- follow the quality control plan and prompt operators to record checks,
- provide real-time SPC alarms for those responsible for the process,
- connect direct to plant equipment and sensors (PLCs) to monitor when machines are running, count production and spoilage,
- upload actual performance back to the ERP,
- providing real-time alarms and exception reports,
- analyse historic data and perform trend reporting.

2.2. REQUIRED EXTENSION OF MES FOR SUPPORTING DECISION MAKING

The Product Tracking function of a MES system can be extended to implement supervisory activities. This function should compute qualitative and quantitative descriptors of the output of production and utilization of the resources so that they could be compared to the original production plans. This function should take cumulative behaviour of the production into account, i.e. it should aggregate certain manufacturing data.

Due to the special properties of each kind of Production Information System, manufacturing, enterprises it is almost impossible to implement a generic solution for supporting this kind of decision making process. Manufacturers may need so called "satellite systems" which can extend the MES functionality as described above.

3. CUSTOMIZED MASS PRODUCTION

The phrase "customized mass production" is generated as a variant of "mass customization". It was originally coined in 1987 by Stan Davis. He described mass customization as the result when "the same large number of customers can be reached as in mass markets of the industrial economy, and simultaneously they can be treated individually as in the customized markets of pre-industrial economies". Customization is a production activity when a firm produces goods or services to meet demands of individual customer or customer's group or shopping centers with near mass production efficiency and cost.

Mass production is one of the great production or industry paradigms born in the 20th century. The base of the mass production is the stable market demand and the high volume. As it is well known, Henry Ford and his famous T model were the first important actors in this industrial stage. Today mass production is very common all over the world for a lot of customers goods. Mass production technology has automated manufacturing and/or assembly lines, specialized skilled workers, big lot size, automated quality checking, automated packing operations, and relatively high material stock level.

In the original mass production paradigm, the firms forecasts the future market demand and this forecast drove the MRP (Manufacturing Resources Planning) type Production Planning systems to order the required parts and materials for the Manufacturing Execution System.

A very efficient approach to customization is when the enterprise proactively develops families of products with modular product architecture, modular components, various packing form and graphic and so on. The operations are implemented in flow shop type manufacturing and assembly line. The lot size generally as high as possible. There is a stable supply chain system for materials and product components.

In customized mass production paradigm the firms plan their production partially for external direct orders, arriving from logistic or shopping centers but to reach better delivery dates they must make forecast for manufacturing semi finished products and buying materials with long external lead time.

The efficiency of automated manufacturing or assembly lines depend on the batch size, the set up frequency, the utilization rate and the size of queues. In the real manufacturing practice there is a lot of uncertainty, which has a complicated affect on realization of predicted schedule in shop floor level. If any material or components do not arrive in time, machine line or lines break down, skilled workforce is missing, specification or volume of market demand has been changed then the original schedule will not be achievable and the warehouse stock level will be too high or too low.

Basically there are two kind of manufacturing: make to order (MTO) and make to stock (MTS). The production of unique or too complex goods falls into the first category. MTO production can be characterized by individual product (machine) usually designed from a set of firm level components, and small batch production on universal CNC machines at job-shop environment. In this environment there are lots of uncertainties in incoming orders and availability of machines, equipment or human resources. For this reason, up-to-date engineering data and fast real time information management are the most important tools to achieve production goals. Make to stock manufacturing can be used in mass production, where the products are delivered from a warehouse when customer requests them. Certain manufacturers may use both types: beside satisfying their accepted orders they can utilize their manufacturing resources as producing some goods for stock.

At present, satisfying customer demands from inventory is becoming more and more expensive. Having free resources to quickly deliver the goods may meet customer needs but holding reserve manufacturing capacities causes long return of invested money. Therefore the importance of flexible and integrated software tools supporting decisions on planning and control level is very high.

4. SCHEDULING PROBLEMS IN CUSTOMISED MASS PRODUCTION

4.1. CLASSIFICATION OF SHOP FLOOR SCHEDULING MODELS

Scheduling is the allocation of a set of well defined resources to a set of well defined tasks subject to some well defined constraints, in order to satisfy a specific objective. In order to formulate a scheduling problem, the format N/M/A/B is typically used:

where:

N: number of jobs,

M: number of machines,

A: the job flow pattern and

B: the performance measure (e.g. tardiness).

Usually, we are interested in N-jobs problems and therefore we may specify only the last three of these in the problem, i.e. M/A/B specification. This is usually called as $\alpha/\beta/\gamma$ specification [2], where:

- α machine environment,
- β processing characteristics/constraints and
- γ objective functions.

Production of parts is carried out in batches. The batch size may vary from one part (manufactured in job shops) to millions of parts (manufactured in assembly lines). Depending on how the jobs are executed in the shop floor (i.e. the sequence in which jobs visit machines) we can classify manufacturing systems as one of:

- serial systems (also called flow shops) or
- non-serial systems (job shops).

The following figures (Fig. 1. and Fig. 2.) summarize some typical flow types.

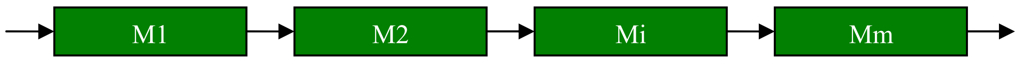


Fig. 1. Flow Shop Schematic

In flow shop structure, there are *m* machines in sequence. There are usually unlimited intermediate storages between two successive machines. All jobs have the same routing. Each job has to be processed on each one of the *m* machines. Permutation flow shop means that the queues in front of each machine operate according to FIFO (First In First Out discipline).

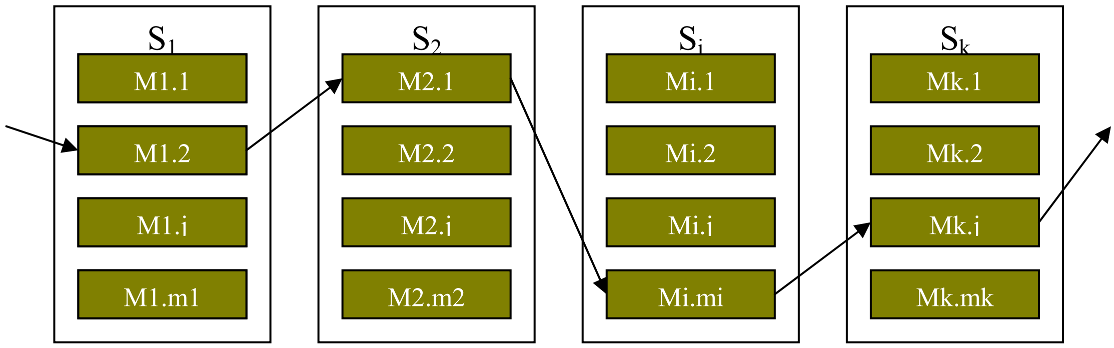


Fig. 2. Flexible Flow Shop Schematic

The flexible flow shop environment has *k* stages, at stage S_i $(i=1, \ldots, k)$ there are m_i identical machines in parallel. There is usually unlimited intermediate storage between two successive stages. Each job has to be processed at each stage on any of the machines.

In this paper, we are focusing on studying extended flexible flow shop machine environment with alternative routes, parallel machines and unlimited intermediate storages. The following sections will deal with an extended flow shop environment with four stages (see Fig. 3).

4.2. THE SCHEDULING PROBLEM

The problem is inspired by a real case study concerning a Hungarian firm specialized in consumers goods (lighting-products). It is a customized mass production so that an order-book for a given time period corresponds to different products to be produced in required quantity. The main goal is that the short term (daily, weekly) production schedules of the manufacturing processes at the production facilities of the firm to be automatically generated.

This section covers the scheduling problem in detail, the related entities of the system, and how they relate to each other. The whole scheduling model can be described as follows. We present the machine environment (α), the processing characteristics and constraints (β) and the objective functions (γ).

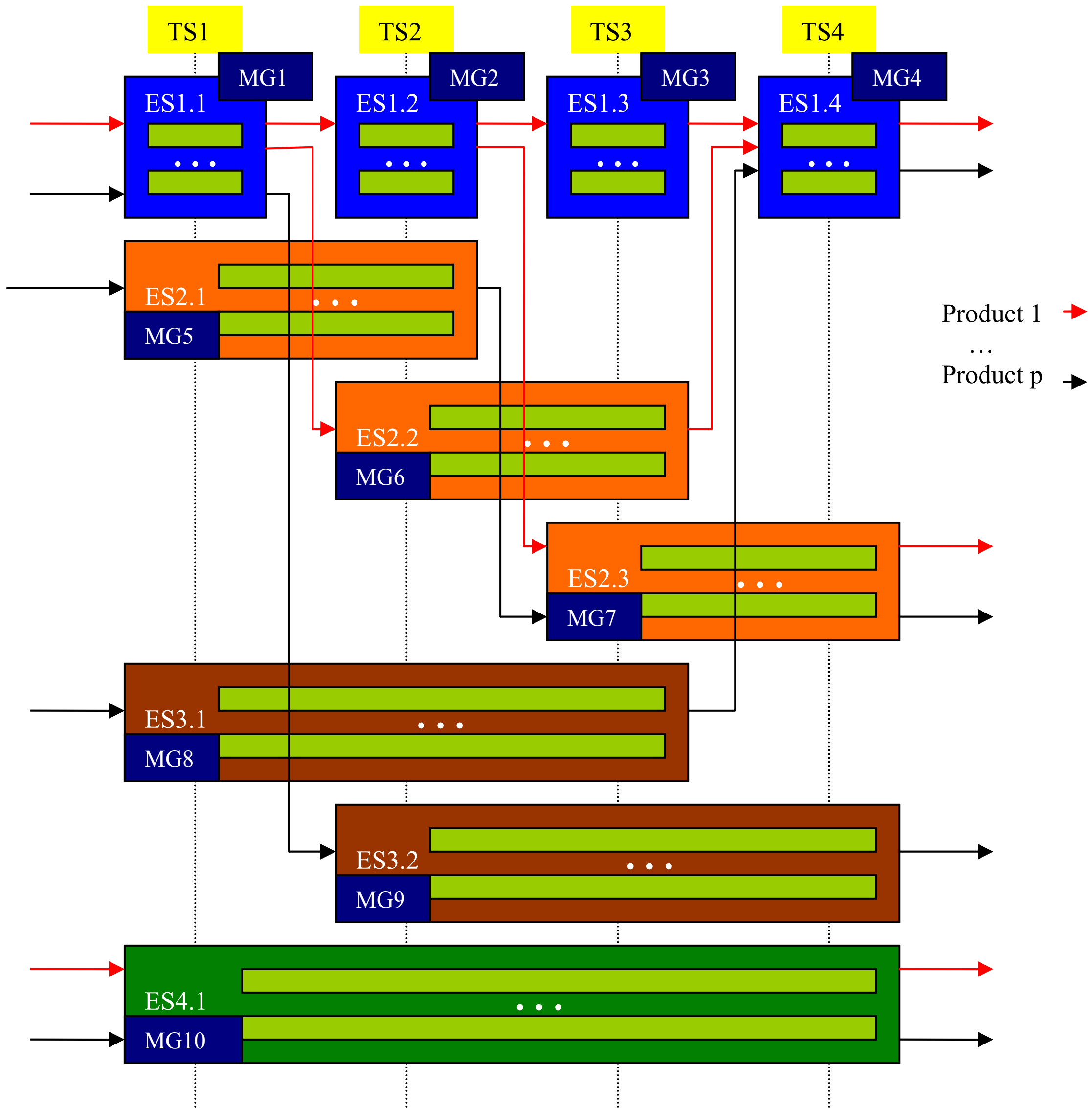


Fig. 3. Flexible Flow Shop Schematic

The customized mass production has the following properties:

Product Type: The product type can be defined as the combination of components that a machine is capable of handling. The combination uses the AND operator and the OR operator to combine various lists of components, these are defined in BOM (Bill of Materials).

Production Orders: There are production orders. A production order includes the type of the final product must be manufactured, the required quantity and the defined due date. In order to satisfy a production order, the components are taken through various processes before finally becoming the final product. Manufacturing, as the name indicates, includes a set of steps that involve the actual production of the final product.

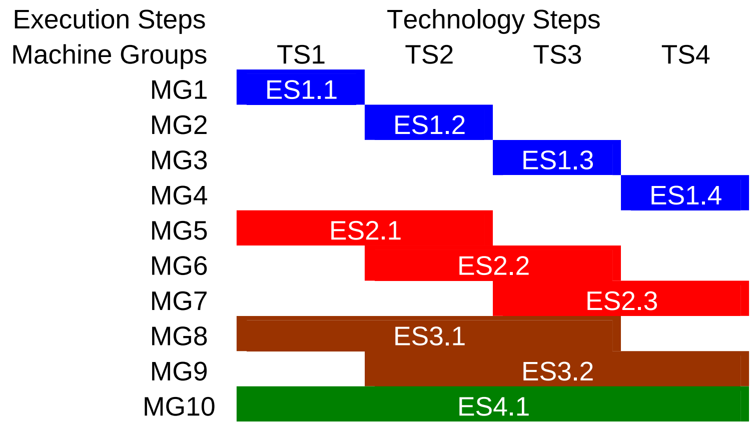


Fig. 4. Execution Steps

Technology Steps: The steps under the technology processes are termed as technology steps. Typically, in manufacturing we have four technology steps like preparation, assembly, quality checking and packaging. Preparation is the first step of the technology processes when defined properties of certain components have to be modified. Assembly is the technology step in which the components are assembled together, quality checking has two parts: a forced wait time when the quality of the product is observed and ascertained before going through packaging finally. A technology step may include some operations, but we suppose that no pre-emption is allowed at the level of the technology steps.

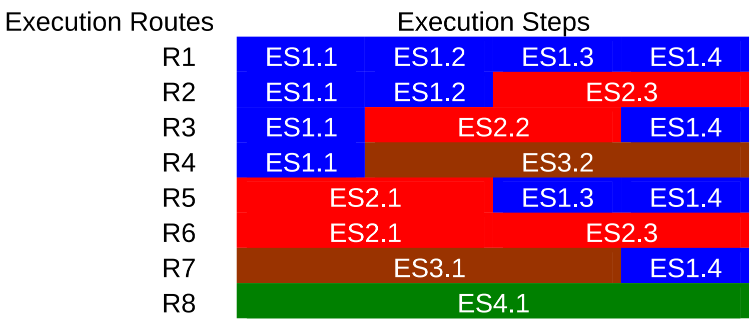


Fig. 5. Execution Routes

Execution Steps, Execution Routes: There is a very important concept namely execution step in this environment. The execution step is a well defined set and sequence of technology steps (Fig. 4.). It describes which technology steps to be processed on the same production line. If the execution step includes two technology steps (i.e.: TS1 and TS4), it has to include all technology steps which are between these two steps (TS1, TS2, TS3, TS4), as well. Moreover, the sequence of execution steps is called execution route. So each execution route includes all technology steps are required in order that the final product can be produced. An execution route can include one or more execution steps, but the common part of included execution steps, which is a set of technology steps, has to be an empty set.

Pallets: Each product is normally packaged in standard sized pallets, each pallet consists of a pre-decided number of the finished products. Even though the physical pallets come into existence only after packaging is over, for convenience reasons, we start looking at the logical pallets right from the beginning. Hence, we schedule pallets (job). A production order is first identified to be consisting of a particular number of pallets and the production order will be closed when all of these pallets have gone through all the technology steps.

Machines: In our scheduling model, a machine is a production line that consists of a group of workplaces, which are lined in a sequence; the output of the first workplace becomes the input of the second one and so on. Typically these production lines are inseparable unites. Hence when it comes to scheduling, then the production line should be considered as one unit and not the individual workplace.

Machine Capacity (speed) and Process Time: During manufacturing, we have to schedule units (pallets) on production lines (machines). In order to estimate the time taken by a pallet on a machine, we need to know the capacity of that machine to process that pallet. Capacity is normally specified as quantities producible per time unit on that machine. The capacity of a machine could vary based upon what is the final product it is producing.

If the efficiency of the machine is 100%, then the capacity will be equal to the theoretical speed. Normally, the efficiency is not 100%. There is another machine property named machine efficiency. Hence, the capacity of a machine should be treated as:

$$\text{Machine Capacity} = \text{Theoretical Speed} * \text{Machine Efficiency} \qquad (1)$$

The capacity of the machine is required while computing the process time of a pallet on the machine. Let's say, that the finished product of the pallet is P1 and using the above calculations, we find that the capacity of the machine is M1. This means that the M1 can produce C1 quantities of P1 per time unit. But currently M1 has to produce scheduled quantity, which might be different than C1. Hence,

$$\text{Process time in time unit a pallet on a machine} = \text{Scheduled Quantity} / \text{Machine Capacity} \qquad (2)$$

Setup time for machines: This is a very important property of the machine (production line). This does not affect the producibility of a final product directly. By definition, a setup time (changeover time) gives the time delay to changeover from one product type to another product type. In our current model, the setup is required if and only if the product type of last pallet different from the next one. We can say the setup time value depends on only the product type to be processed, so it is allowed to define multiple value setup time for one machine. Setup time is specified in time unit.

Machine Group: Each machine has an associated list. It shows all technology steps can be executed on a machine. In other words, a machine could be potentially capable of executing an execution step (which is a set of technology steps). A machine group is a set of machines can execute the same execution step (Fig. 4.). The machines in same group are parallel machines with different capacity and setup time.

Association execution routes to the final products: A given final product can be produced differently, because there are alternative execution routes on which the required components are taken through becoming the final product. These alternative routes differ in the execution steps. In addition, each execution route may include parallel machines assigned to one or more execution step. In our model, there is a dynamic list which describes the available execution routes at a given time period for each final product.

Availability of the components: In this issue we use a simplification of the original problem. It means that we do not focus on all components availability; instead we suppose all of the required material available in the needed quantity from the CST (Constrained Start Time) of the pallets on the machine. CST of the pallet specifies the earliest time when the first execution step of the pallet can start from the aspect of the component availability.

Objectives: A scheduling objective is a measure to evaluate the quality of certain schedule. In real-life situations, there are many (sometimes conflicting) objectives. In general, one can distinguish two types of objectives:

- due date related objectives and
- non due date related objectives.

For due date related objectives, we assume that there are n jobs J_i $(i=1,\ldots,n)$. Each job J_i has due date d_i and release date r_i. The due date represents the commitment of the company with a customer. The release date implies the non availability of components from the beginning. We denote the finishing time of job J_i by C_i. The following definitions may be defined for each job:

Lateness of a job: $L_i = C_i - d_i$ (3)

Tardiness of a job: $T_i = \max(0, L_i)$ (4)

Earliness of a job: $E_i = \max(0, -L_i)$ (5)

With each of these functions F_i we get some possible objectives.

So the most important objectives may be as follows:

Maximum: $\gamma = \max(F_i)$ (6)

Total: $\gamma = \sum_i F_i$ (7)

Average: $\gamma = \frac{\sum_i F_i}{n}$ (8)

Number of late jobs: $\gamma = |\{i \mid T_i > 0\}|$ (9)

Usually, not all of the jobs are equally important. Weights w_i can be assigned to each job representing the relative importance of the jobs. Some measures that take into account the different weight of the jobs are as follows:

Weighted maximum: $\gamma = \max(w_i F_i)$ (10)

Weighted total: $\gamma = \sum_i w_i F_i$ (11)

Weighted average: $\gamma = \frac{\sum_i w_i F_i}{n}$ (12)

The most common objective functions, which are non due date related, are as follows:

Makespan:	$\gamma = \max(C_i)$	(13)
Total flow time:	$\gamma = \sum_i C_i$	(14)
Weighted total flow time:	$\gamma = \sum_i w_i C_i$	(15)

It is well known, that the optimal solution can be quite different if the objective chosen changes. Depending on the fixed objectives, each decision maker wants to minimize a given criterion. On one hand, the commercial manager is interested in satisfying orders by minimizing the lateness. On the other hand the production manager wishes to minimize the work in process by minimizing the maximum flow time.

5. SOLUTION OF THE SHEDULING PROBLEM

In this section we outline our approach to solve problem described in section 4.2. We show the developed data model and the basic steps of our methods. Then we present a computer application of this solution.

5.1. SOFTWARE MODEL

In our model, we use indexed arrays in order to accelerate the calculation. In these arrays, there are no full length identifiers and attributes of entities (i.e.: jobs, machines, routes and so on), instead there are indexes, which are non-negative integer values assigned to the entities, to point to the position of the target object in the base array. Therefore, in any of indexes of a given array, we can use any value of the same array or another array. In order to indicate a vector element and a matrix element, we use the following formulations:

- ARRAY_NAME[ROW_INDEX]
- ARRAY_NAME[ROW_INDEX][COLLUMN_INDEX]

In case, an array element is a data structure made up of fields, we use the dot operator to refer to a specified data field by using the field name:

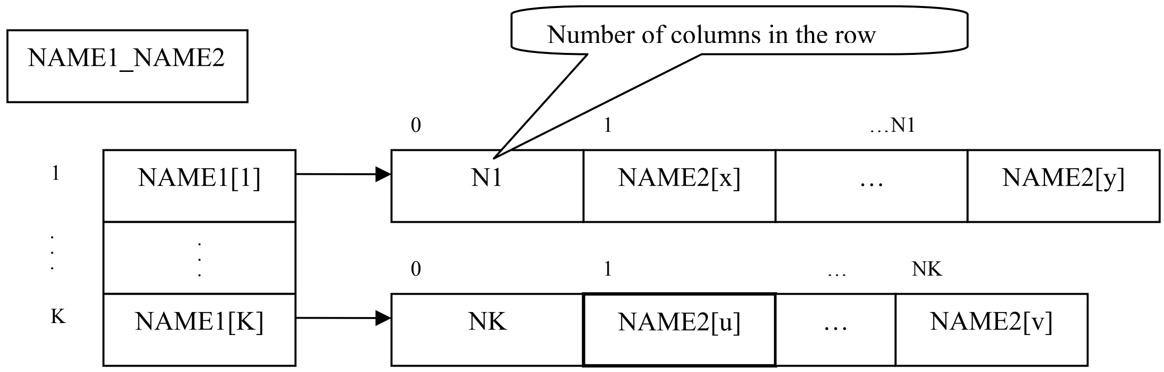
- ARRAY_NAME[ROW_INDEX].FIELD_NAME
- ARRAY_NAME[ROW_INDEX][COLUMN_INDEX].FIELD_NAME

Using the above formulations, we can describe the entities of the scheduling model detailed in section 4.2 as follows:

There are different final products p $(p = 1,\ldots, N_P)$ which may be produced. There are an order book for a given time period. It has production orders o $(o = 1,\ldots, N_O)$. Each production order o includes the type of the final product $O[o].P$, the required quantity $O[o].Q$ and the defined end time $O[o].ET$ (due date).

In the system, pallets can be moved. Each pallet consists of a pre-decided number $NP[p]$ $(p = 1,\ldots, N_P)$ of the finished products p. Each production order o is identified to be consisting of a particular number of pallets. We schedule pallets, one pallet means one job. So we have jobs j $(j = 1,\ldots, N_J)$ altogether. Each job has four attributes: $J[j].P$ means the final product *p*, *J[j].Q* means the quantity of the products, *J[j].CST* means the constrained start time and *J[j].CET* means the constrained end time.

Each job *j* has to visit four technology steps *TS[t] (t=1,…, 4)* in the same sequence. The workshop contains ten possible machine groups *mg (mg = 1,…, 10)* connected to each others in a given configuration (Fig. 3.). Each machine group *mg* contains a pre-defined number of machines. There is a two-dimensional array named *MG_M* which describes the list of machine groups with the machines which belong to them. The structure of *MG_M* is inherited from the general structure shown on Fig. 6. Machine group corresponds to NAME1 and machine corresponds to NAME2.



Reference to the value of a given element:
NAME1_NAME2[ROW_INDEX][COLUMN_INDEX]
where
ROW_INDEX = (1,…, K)
COLUMN_INDEX = (0,…, NAME1_NAME2[ROW_INDEX][0])

Fig. 6. General structure of two-dimensional arrays with variable number of row elements

In a given machine group *mg*, each machine can process the same execution step which is one of the well defined execution steps *es (es = 1,…, 10)*. It can be seen on Fig. 4.

We have machines *m* $(m=1,\dots, N_M)$ altogether. Each machine *m* may have N_P different capacity $M\_C[m][p]]$ $(m =1,\dots, N_M$ and $p = 1,\dots, N_P)$. Similarly, each machine *m* may have N_P different setup time $M\_ST[m][p]$ $(m =1,\dots, N_M$ and $p = 1,\dots, N_P)$, according to the definitions of the setup time and machine capacity in section 4.2.

There are eight possible execution routes *r (r = 1,…, 8)* (see Fig. 5.). Each route *r* includes a sequence of machine groups. These assignments are defined in an array named *R_MG*, which is a specialization of the structure shown on Fig. 6. Machine group corresponds to NAME1 and machine group corresponds to NAME2.

In our model, utilizing what has gone before, we can determine an array *P_R* which describe the available execution routes in the actual time period for each final product *p*. The array *P_R* can also be specialized from the general structure in such a way that final product corresponds to NAME1 and execution route corresponds to NAME2.

In order to define a schedule for the production of each job, it is necessary for each job j $(j = 1,\dots,N_J)$:

1. to assign to one of the possible route *P_R[J[j].P][pr] (pr = 1,…, P_R[J[j].P][0])*,
2. to assign to one of the possible machine *MG_M[pmg][pm] (pm = 1, …, MG_M[pmg][0]* at each machine group *pmg (pmg =1,…, R_MG[P_R[J[j].P][pr]][0])* according to selected route *P_R[J[j].P][pr]*,
3. to fix its position in the queue of each selected machine,
4. to fix its starting time on each selected machine.

We suppose the shop floor is has already been loaded, so the actual state of the system has to be known in order to calculate start time and end time of each job on each assigned machine. It means that the effect of last confirmed schedule has to be available. These data can be obtained from array *M_ENGAGED* which shows the earliest time of each machine when the machine is available, *M_ENGAGED[m]* $(m = 1,\ldots, N_M)$.

Additional arrays have been defined to store the result of the scheduling. There is a special array named *J_A* which includes the route and machines assigned to jobs in the following way: *J_A[J[j]][am]* $(j = 1,\ldots, N_J$ *and* $am = 0,\ldots,$ *R_MG[J_A[j][0]])*.
Where:

- *j* means a job,
- *J_A[j][0]* means the assigned route,
- *R_MG[J_A[j][0]]* means the number of machines in the assigned route,
- *J_A[j][am] (am=1,…, R_MG[J_A[j][0]])* means the sequence of assigned machines.

There is an array named *MWLOAD* which show the sequence of jobs on machines. This structure *MWLOAD[m][aj]* $(m= 1,\ldots,N_M$ *and* $aj = 1,\ldots,$*MWLOAD[m][0])* is a specialization of the general structure (Fig. 6.). In this case, machine corresponds to NAME1 and job corresponds to NAME2..

- *m* means a machine,
- *MWLOAD[m][0]* means the number of jobs which to be processed on machine *m*,
- *MWLOAD[m][aj] (aj = 1,…, MWLOAD[m][0])* means the sequence of jobs to be processed on machine *m*.

Finally there is an array named *MSTET* which stores the calculated times (*ST* start time, *SetT* setup time, *PT* process time and *ET* end time) of the jobs *MWLOAD[m][aj] (aj = 1,…, MWLOAD[m][0])*on each machine *m* $(m = 1,\ldots,N_M)$.

5.2. SCHEDULER ENGINE APPLICATION

A computer application has been developed which includes a problem generator, a time calculation model of the machine environment described above, the scheduling engine which can solve the problem, and the database system which contains the production data. The main goal of this prototype is that there should be a tool which allows future studies of alternative scheduling algorithms.

Original production data was not available, so the application utilizes sample data sets created by the problem generator. The generator produces random problem instances with sizes and characteristics specified by user and then it writes them into the database. The generated data are well defined random values, but the user can even directly change certain data.

Our scheduling problem is notoriously difficult to solve because of their combinatorial nature (Non-polynomial, NP hard). Some different heuristic approximate procedures have been developed to solve the problem. These procedures are integrated into the scheduling engine (SE). Our application has three kinds of classes of heuristic algorithms, which are as follows:

- Basic Workload Balancing Algorithms (BWBA),
- Heuristic EDD&FIFO Combination Algorithms (HEFCA),
- Heuristic Inserting Algorithms (HIA).

The basic approach of our heuristic algorithms consists of tree steps:

1. Assigning : SE creates the *J_A*.
2. Sequencing: SE creates the *MWLOAD*.
3. Time calculation: SE calculates the *MSTET*.

The time calculation model represents the machine environment with unlimited buffers between machines. The time calculation means the numerical simulation of the production. Its inputs are jobs j, machines m, their assignments *J_A*, sequences of jobs on machines *MWLOAD*, abilities of machines *M_C*, *M_ST* and *M_ENGAGED*. Time calculation of job j on an intermediate machine requires, among other things, the end time of job j on the previous machine and the shop floor environment has lots of junctions of the possible routes. So we have to define the machine group sequence in which the calculation can be performed. This sequence is fixed in *PRI_MG* array which includes the priority of each machine group. The priorities are as follows:

- Priority: {1, 2, 3, 4, 5, 6, 7, 8, 9, 10}
- Machine Group: {4, 3, 7, 2, 6, 9, 1, 5, 8, 10}

The calculation method goes in non-increasing priority order of the machine group, and it calculates times of each job on each machine which is in the machine group. The outputs of the time calculation are *MSTET* array, which includes fixed times, and *OBJ_VALUE* array, which stores the evaluated value of the chosen objective functions.

BWBA selects the least loaded route and machines for jobs, then it orders the jobs using EDD (Earliest Due Date) rule on each first machine. Finally, the jobs flow through the system in order of arrival (Fist In First Out, FIFO).

HEFCA assigns the jobs, which arrive in order EDD, to each allowable routes and machines particularly. In each case it uses sequencing algorithm of BWBA. After time calculations it selects the best solution according to the chosen objective function.

HIA integrates the assigning and sequencing problem. **HIA** tries to insert each job to each available position of each allowable machine. After time calculations it selects the best solution according to the chosen objective function.

At present, we have been working on improving our methods by implementing Taboo Search (TS) algorithm. TS has been proven to work well on other problems. This fact motivates our usage of TS for solving problem.

6. CONCLUSIONS AND FUTURE WORK

In this paper, the definition and the common functions of Manufacturing Execution Systems have been overviewed. Some possible extensions of MES systems for customized mass production has also been described. A new scheduling approach to solve extended flexible flow shop scheduling problem in customized mass production has been introduced. Future research work will be carried on investigating some heuristic procedures which can be applied to our scheduling problem and studying effect of change in the machine environment. Further research should also focus on combination of make to order and make to stock manufacturing.

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