EXTENDED FLEXIBLE FLOW SHOP SCHEDULING PROBLEM WITH LIMITED MACHINE AVAILABILITY

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Abstract. This paper discusses the extended flexible flow shop scheduling problem. In order to solve scheduling and resources allocation issues, a new computer model for customized mass production will be presented. We have developed a computer framework to check different approximate heuristic algorithms. The focus has been set to determine alternative routings and machines allocation for feasible scheduling. 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.

Keywords: shop floor scheduling, alternative routes, parallel machining, constraint, due date, setup, heuristic method

1. INTRODUCTION

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.

The problem is inspired by a real case study concerning a Hungarian firm specialized in lighting products. It is a customized mass production approach 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.

2. EXTENDED FLEXIBLE FLOW SHOP SCHEDULING PROBLEM

The machine environment can be seen on the Figure 1. The scheduling model can be described as follows.

In the system, there are different final products which may be produced. There are an order book for a given time period. It has production orders. Each production order includes the type of the final product, the required quantity and the defined due date. At the shop floor, pallets can be moved. Each pallet consists of a pre-decided number of the finished products. Each production order is identified to be consisting of a particular number of pallets. We schedule pallets, one pallet means one job. Each job has four attributes: the type of the final product, the quantity of the products, the constrained start time (the earliest time when all of the required material available in the needed quantity) and the defined due date.

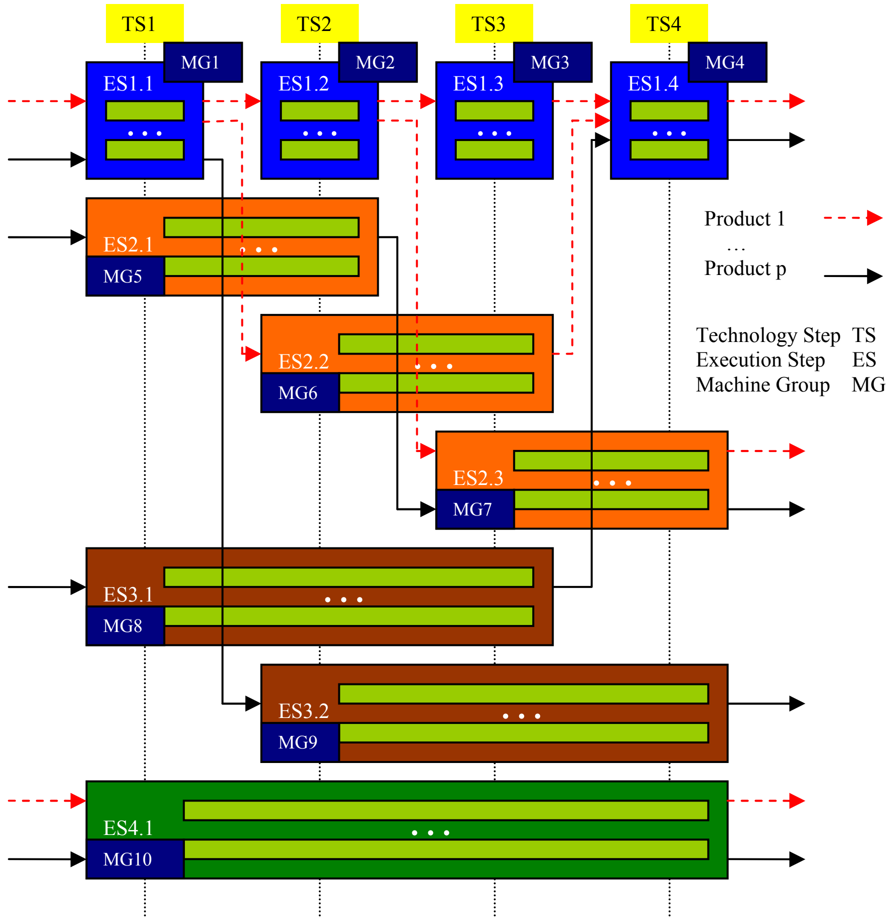

Figure 1. Extended Flexible Flow Show Scheme

Each job has to visit four technology steps in the same sequence. A technology step may include some operations, but no pre-emption is allowed at the level of the technology steps.

The workshop contains ten possible machine groups connected to each others in a given configuration (Figure 1.). Each machine group contains a pre-defined number of machines. In a given machine group, each machine can process the same execution step which is a well-defined set and sequence of technology steps.

In our model the machines are not continually available for processing, they have more one non-availability intervals. In addition, each machine may have different production rates (quantities producible per time unit) for different products. Similarly, each machine may have different setup times (time delay to changeover from one product type to another product type) for different products.

A given final product can be produced differently, because there are different execution routes on which the required components are taken through becoming the final product. These alternative routes differ in the execution steps. In our model, a dynamic list describes the available execution routes at a given time period for each final product.

The shop floor has already been loaded, the actual state of the system is known. It means that the effect of the last confirmed schedule can be obtained from an array which shows the earliest time of each machine when the machine is available.

3. OBJECTIVE FUNCTIONS

A scheduling objective is a measure to evaluate the quality of certain schedule. In real-life situations, there are many (delivery capability, machine utilization rate, stock or WIP level, they are usually conflicting) objectives. For delivery capability, 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 jobs J_i $(i=1,\ldots,N_J)$. 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 unavailability of components from the beginning. We denote the completion time of job J_i by C_i. The following definitions may be defined for each job:

Lateness of a job: $L_i = C_i - d_i$. (1)

Tardiness of a job: $T_i = \max(0, L_i)$. (2)

Earliness of a job: $E_i = \max(0, -L_i)$. (3)

With each of these functions F_i we get some possible objectives. So the most important objectives may be as follows:

Maximum: $\gamma = \max(F_i)$. (4)

Total: $\gamma = \sum_i F_i$. (5)

Average: $\gamma = \frac{\sum_i F_i}{n}$. (6)

Number of late jobs: $\gamma = |\{i \mid T_i > 0\}|$. (7)

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: $\gamma = \max(w_i F_i)$. (8)

Weighted total: $\gamma = \sum_i w_i F_i$. (9)

Weighted average: $\gamma = \frac{\sum_i w_i F_i}{n}$. (10)

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

Makespan: $\gamma = \max(C_i)$. (12)

Total flow time: $\gamma = \sum_i C_i$. (13)

Weighted total flow time: $\gamma = \sum_i w_i C_i$. (14)

It is well known, that the solution can be quite different if the chosen objective 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.

4. HEURISTIC SOLUTIONS

Our scheduling problem is difficult to solve because of its combinatorial nature. In order to define a schedule for the production of each job, it is necessary for each job *i* $(i = 1,\dots,N_J)$:

1. to assign to one of the possible route,
2. to assign to one of the possible machine at each possible machine group according to selected route,
3. to fix its position in the queue of each selected machine,
4. to fix its starting time on each selected machine.

Using indexed arrays, we can define the input entities of the scheduling model. These are as follows:

- final products,
- jobs with attributes,
- machine groups,
- machines with setup times, production rates and calendar,
- execution routes,
- availabilities of execution routes and machines, and
- the effects of the last confirmed schedule.

Output arrays have been defined to store the result of the scheduling. These are as follows:

- array *J_A* which includes the route and machines assigned to jobs,
- array MWLOAD which shows the sequence of jobs to be processed on machines,
- array MSTET which stores the calculated times (start time, setup time, process time and end time) of the jobs on machines.

We have developed a production simulator model which represents the machine environment with unlimited buffers between machines. The simulation means numerical simulation of the production to calculate the time data of the operations. Inputs are the jobs, the machines, their assignments *J_A*, the sequences of jobs on machines *MWLOAD*, the abilities of machines (production rates, setup times) and availabilities of machines.

The simulator has two kinds of working methods. These are as follows:

- Independent setup: It means that the setup of a given machine can start before the job arrives at the machine.
- Dependent setup: It means that the setup of a given machine can be considered as the part of the process, so the setup can not start before the job arrives at the machine.

The outputs of the time calculation are *MSTET* array, which includes fixed times, and *OBJ_VALUE*, which stores the evaluated value of the chosen objective function.

The most important tasks are assigning routes and machines to jobs and sequencing the jobs on machines. Different heuristic approximate procedures have been developed to solve the problem. These procedures are integrated into the scheduling engine (SE). At present, SE includes four kinds of classes of heuristic algorithms, which are as follows:

- Basic Workload Balancing Algorithms (BWBA),
- Heuristic Easy-priority&FIFO Combination Algorithms (HEFCA),
- Heuristic Inserting Algorithms (HIA).
- Extended Heuristic Inserting Algorithms (EHIA)

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. Simulation: SE calculates the MSTET.

The algorithms differ from each others in the decision making in issues of assigning and sequencing and the integration degree of steps.

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 to each allowable routes and machines particularly, then it orders the jobs using chosen priority rule on each first machine. Finally, the jobs flow through the system in order of arrival. After simulation it selects the best solution according to the chosen objective function. The priority rules adapted for the extended flexible flow shop scheduling problem are as follows:

- Earliest Due Date (EDD),
- Shortest Processing Time (SPT),
- Longest Processing Time (LPT),
- Smallest Static Slack (SSS),
- Critical Ratio (CR).

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

EHIA orders the jobs using chosen priority rule and then it calls HIA to schedule the jobs. After simulation it selects the best solution according to the chosen objective function.

5. COMPUTER APPLICATION

We developed a computer application which consists of a problem generator, production simulator, scheduling engine and a database system. The main goal of this framework is that it can be an extremely useful tool supporting studies of alternative scheduling algorithms.

The application uses sample data sets created by 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 directly change certain data.

4. CONCLUSIONS

The conventional flow shop model has to be extended to a new model which supports alternative technological routes, parallel machines and where setup and job characteristics are also considered. In this paper, some possible extensions of flow shop model have been described. A new scheduling approach based on heuristic methods to solve extended flexible flow shop scheduling problems has been introduced. A computer program developed for this problem has been outlined.

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