

MACHINE LOAD BALANCING UNDER FINITE CAPACITY SETTINGS IN A JOBSHOP ENVIRONMENT

V.Mahesh*, A.Chennakesava Reddy** and C.S.P Rao***

ABSTRACT

Shop-floor control has long been recognized as an important tool in improving manufacturing performance. The performance of the shop depends on various parameters such as initial conditions of the machines, the load on the system, sequencing rule etc. This paper describes an approach in which capacity requirement planning and shop floor scheduling are integrated in order to achieve a unified manufacturing aim. The integration of capacity planning and scheduling makes way for the effective use of production resources and creation of realistic process plans that can be readily executed with less modifications in a computer integrated manufacturing system.

KEYWORDS: Job shop, Capacity Requirement Planning, Priority, Machine Utilization.

1.0 INTRODUCTION

The elements of job shop scheduling problem are a set of machines and a collection of jobs to be scheduled. Although it is possible to allow any number of operations in a given job, the most common formulation of the job shop problem specifies that each job has exactly m operations, one on each machine. It is conceptually no more difficult to deal with general cases in its operation sequence. Because the workflow in a job shop is not unidirectional, each machine in the shop can be characterized by the input and output flows of work. There is no initial machine that performs only the last operation of a job, nor is there a terminal machine that performs only the last operation of a job.

In a multi-project environment, projects typically share common resources. Adequate management of these scarce resources is therefore of crucial importance. The capacity utilization that can be realized strongly depends on the mix of production orders (jobs). In order to set reliable due dates, it is important for planners to accurately estimate what workload and mix of jobs can be completed in a specific period. If planners can accurately estimate the workload and mix that can be completed, they can obtain achievable production plans. One of the difficulties of scheduling is that, many often-conflicting objectives are present. Some of the most common objectives of scheduling are to

1. Meet due dates
2. Minimize average flow time through the system
3. Minimize the total number of tardy jobs
4. Minimize the average tardiness of the jobs
5. Minimize the maximum tardiness of the jobs
6. Minimize work-in-process (WIP) inventory
7. Provide for high machine / worker time utilization (Minimize machine /worker idle time), and
8. Minimize production costs.

In these objectives, (1) to (5) are aimed primarily at providing a high level of customer service, and (6) to (8) are aimed mainly at providing a high level of plant efficiency.

2.0 RELEVANT LITERATURE

A large number of approaches to the modeling and solution of these scheduling problems have been reported in the Operations Research (OR) literature, with varying degrees of success. Nabil Nasr and E.A.Elsayed [6] investigated the problem of minimizing the mean flow-time in a general job shop machining system with alternative machine tool routings. An efficient algorithm based on a mixed integer programming formulation is developed to solve the problem by decomposing it into sub problems that are easier to solve. Kumar & Rajotia [4], discuss upon integrating the process planning and the job-shop scheduling problem.

*Dept. of Mechanical Engg, S.R Engineering College, Warangal, Email: maheshuutukuru@rediffmail.com

**Dept. of Mechanical Engg, JNTU, Ananthapur, email: dr_areddy@yahoo.com

***Dept. of Mechanical Engg, NIT, Warangal, email: csp_rao@rediffmail.com

Capacity outsourcing has become an integral part of capacity investment decisions [5]. Atamturk and Hochbaum [1], propose a four-way tradeoff among capacity, production, subcontracting, and inventory levels over a finite horizon. Kouvelis and Milner [2] consider two-stage supply chains and analyze the impact of supply/demand uncertainty on capacity and outsourcing decisions. In contrast, outsourcing becomes more attractive as uncertainty in demand increases. Pindyck [7] shows that demand uncertainty can discourage firms from capacity expansion when there is perfect competition; while Kulatilaka and Perotti [3] show that higher uncertainty may increase the firm's incentive to invest when there is imperfect competition. Van Mieghem [10] studies the trade off among capacity investment, production and subcontracting in a two-stage, two-player, two-market setting. He models the interactions of a manufacturer's and a subcontractor's decisions. He observes that the manufacturer subcontracts more (invests less on his own capacity) as the demand uncertainty increases, which induces the subcontractor to invest more. Under a similar setting, Tan [8] investigates capacity investment and pricing decisions for a manufacturer and a subcontractor with guaranteed availability.

3.0 PROBLEM DEFINITION

The Production Planning and Control (PPC) department of the user industry has to prepare scheduling of jobs on the high cost/critical equipment available on the shop floor under various constraints. From the time a customer places an order for a particular product, the order is uniquely identified and all the parts of it are also identified. The shop floors and machines are also uniquely identified. The industry may have thousands of parts to be processed on various machines in a given time horizon and a part may *recirculate* a machine more than once for an operation. Then it is very difficult to schedule them on the available finite resources. The distribution of loads on machines may not be uniform, which leads to under loads and overloads on the machines.

This paper focuses on capacity requirement planning (CRP), which is used to normalize the loading on machines so that the machine utilization improves.

4.0 SCHEDULE GENERATION

The scheduling system is developed as per the requirements specified by the User industry. It is a Priority based dynamic scheduling with resource optimization. The clash between the work orders waiting to be processed on the same machine is resolved based on the Priorities of the Work Orders. The scheduling program takes care of the following constraints while generating activity schedule for a given number of work orders:

- The sequence of operations for manufacturing a product is fixed.
- The part or job may visit the same machine several times.
- An operation may not begin until its predecessors are completed.
- The priority of a work order is not fixed.
- The efficiencies of the work places may vary with time and there is possibility of breakdown.
- The influence of the labour is ignored.
- The industry works for two shifts in a day.
- Change in Material Availability Dates.

5.0 CAPACITY REQUIREMENTS PLANNING (CRP)

A capacity requirement planning (CRP) is computerized system that projects the load from a given material plan onto the capacity of a system and identifies under loads and overloads. It is then up to the MRP planner to level the load, - that is, smooth out the resource requirements so that capacity constraints are not violated. Load profiles can also be displayed graphically, as shown in figure 1. The dashed line represents the normal capacity. We can see that the machine is under loaded in periods 1, 5 and 6 and overloaded in periods 2, 3, and 4.

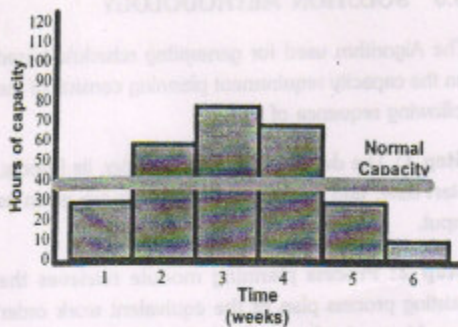


Figure 1: Load Profile

Underloaded conditions can be leveled by

1. Acquiring more work
2. Pulling work ahead that is scheduled for later time periods or
3. Reducing normal capacity.

Additional work can be acquired by transferring similar work from other machines in the same shop that are near or over capacity, by making components in house that are normally purchased from outside suppliers, or by seeking work from outside sources. Pulling work ahead seems like a quick and easy alternative to alleviate both underloads and overloads. However, we must remember that the MRP plan was devised based on an interrelated product structure, so the feasibility of scheduling work in an earlier time period is contingent on the availability of required materials or components. In addition, work completed prior to its due date must be stored in inventory and thus incurs a holding cost. When work is shifted to other time periods, the MRP plan should be rerun to check the feasibility of the proposed schedule.

If an underloaded condition continues for sometime, reducing the size of the workforce may be a viable alternative. Smaller underloads can be handled by reducing the length of the working day or workweek, by scheduling idled workers for training sessions or vacations, or by transferring workers to other positions

at machine centers or departments where overloads are occurring. Overloaded conditions are the primary concern of the MRP planner because an overloaded schedule, left unchecked, cannot possibly be completed as planned.

Overloads can be reduced by

1. Eliminating unnecessary requirements
2. Rerouting jobs to alternative machines or workcenters
3. Splitting lots between two or more machines
4. Increasing normal capacity
5. Subcontracting
6. Increasing the efficiency of the operation
7. Pushing work back to later time periods or
8. Revising the master schedule.

With CRP, load profiles are determined with jobs assigned to the preferred machine first, but when capacity problems occur, jobs can certainly be reassigned to alternate machines.

In addition, if two or more similar machines are available at the same time, it may be possible to split a batch – that is, assign part of an order to one machine and the remainder to another machine.

Normal capacity can be increased by adding extra hours to the day, extra days to the week, or extra shifts. Temporary overloads are usually handled with overtime. More extensive overloads may require hiring additional workers. Work can also be subcontracted out. In the present paper, load normalization is achieved by assigning the overloads on a machine to another similar machine and also an under loaded machine acquires additional load from the other similar machines by pulling the work ahead.

For example, one of the approaches followed in this paper is, the utilization of each machine in the shop is deduced from the generated schedule and the machines that are over-loaded and under-loaded are identified. From the group of over-loaded machines, the most over-loaded machine is taken and the jobs on this machine are listed. The time taken for

processing of each job on the machine is found out. The job, which is processed on the machine for the maximum time is identified. This job is chosen for modification and a specific constraint is fired, e.g., an alternate machine should be found for performing the operation of the job in place of machine selected earlier. Thus a suggestion is given to the process-planning module that the operation of the job is to be performed on some other machine if an alternative with the similar capabilities is available. Process planning module takes these constraints into consideration and regenerate the process plan for the affected jobs. These modified process plans are input to the scheduling module and the reschedule is carried out.

The various integrated modules shown in Figure 2 shall take care of the overall management of the software.

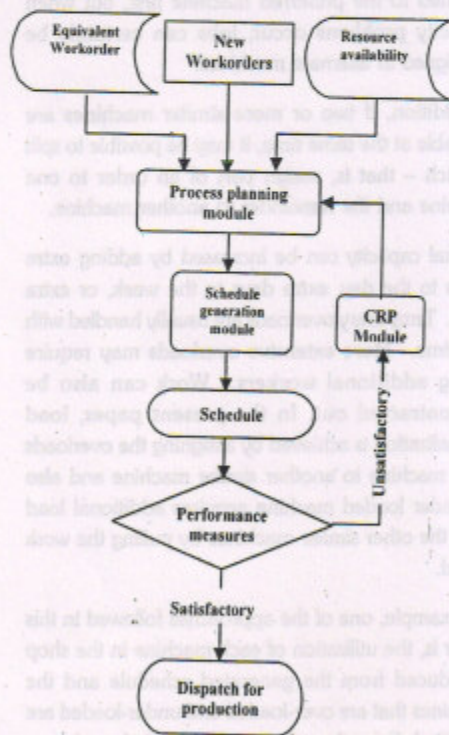


Figure 2: Integration of CRP module with scheduling

6.0 SOLUTION METHODOLOGY

The Algorithm used for generating schedule based on the capacity requirement planning consists of the following sequence of steps:

Step 1: The details of New Work order, its Priority, Start date, and equivalent Work order are given as input.

Step 2: Process planning module retrieves the existing process plan of the equivalent work order from Master database and add the entire data of New Work order to the Current database.

Step 3: The clash between the Work orders waiting to be processed on the same Work place is resolved initially based on the priorities of Work orders. If parts with same priority are contending for the same Work place then they are loaded on to the Work places based on longest processing time.

Step 4: The Capacity Requirement Planning Module generates the loads on each machine. The overloads and under loads are identified.

Step 5: The schedule performance measures like machine utilization and makespan are evaluated. If the performance is not satisfactory, the over-loaded work place and a job, which is taking maximum processing time on it, are identified.

Step 6: A constraint is fired by the CRP module, suggesting the process planning module to change the process plan of the job by identifying alternative work place. These modified process plans are input to the scheduling module and the reschedule is carried out followed by step 5. The constraints are fired till the results cannot be improved further.

7.0 RESULTS & DISCUSSION

It is observed that the utilization rate of most of the work places have been improved due to the integration of capacity requirement planning with scheduling. The utilization of all the work places in various work centers is evaluated from the generated schedule. For example, the Figure 2 shows the utilization rate of different work places in work center 3116, which is heavy machine shop of the user

industry. The CRP module now identifies, 9863 as over-utilized workplace and 9421 as under-utilized workplace. The CRP module feeds back a constraint that if an alternative work place is available for accomplishing the operations of the job, which is taking maximum time on 9863, then the alternative must be used. It also gives a suggestion that if work place 9421 (least utilized work place in the shop) is one of the alternatives for 9863, then 9421 could be used instead of 9863.

From Figure 6, it is found that after feedback, the utilization of work place 9863 is reduced, whereas the under utilized work place 9421 is better utilized. Similarly the utilization of other work places may also be normalized so as to achieve the performance measures.

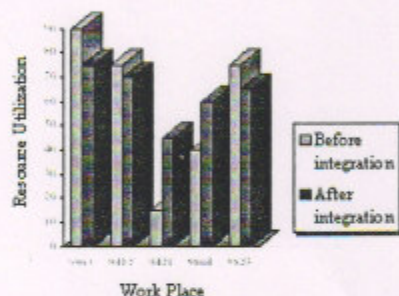


Figure 2: Work Place Utilization before and after integration

8.0 CONCLUSION

In the conventional approach where the scheduling function is isolated from capacity planning, the selection of process is an important decision making problem owing to the presence of multiple alternative plans. In this paper a new approach for the integration of CRP and scheduling was proposed by making use of the scheduling performance measures and the flexibility of in-house developed process planning module. In the proposed system, process planning and scheduling maintain their own identity but at the same time interact dynamically with each other for obtaining better results. By applying the proposed methodology in the industry, the resources can be better utilized, the bottleneck problems of the shop floor can be reduced and consequently the throughput of the parts significantly increases.

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