Effect of Scheduling rules on performance of Semi Automated Flexible Manufacturing System

Durgesh Sharma
IMS Engineering College, Ghaziabad
durgeshrsharma@gmail.com

Suresh Garg
Delhi Technical University, Delhi
skgarg63@yahoo.co.in

Chitra Sharma
IGIT, IP University, Delhi
chitrabist@rediffmail.com

ABSTRACT

This work presents a impact of commonly used scheduling rules on performance of Semi Automated Flexible Manufacturing System. A semi automated Flexible Manufacturing system is low cost alternative to FMS, which provide most of features of Flexible Manufacturing System at an affordable cost. The performance of such system is highly dependent upon the efficient allocation of the limited resources available to the tasks and hence it is strongly affected by the effective choice of scheduling rules. Out of the many scheduling rules and processes, paper examines the most commonly used scheduling rules at different levels of Automation.

KEYWORDS

Flexibility	Flexible Manufacturing System (FMS)
Semi automated	Scheduling rules
Dispatching rules	

INTRODUCTION

The increasing demand for low cost, low-to-medium volume production of modular goods with many different variations creates the need for production systems that are flexible and that allow for small product delivery times. This leads to production systems working on small batches, having low setup times and mainly characterized by many degrees of freedom in the decision making process. This type of system is known as flexible manufacturing systems (FMS). Even though there is no single universally accepted definition of FMS, we are referring to the ones given by (Viswanadham & Narahari, 1992) and (Tempelmeier & Kuhn, 1993) as a production system consisting of identical multipurpose numerically controlled machines (workstations), automated material and tools handling system, load and unload stations, inspection stations, storage areas and a hierarchical control system. Considering the real-world circumstances and more practical approaches (i.e., number of workstations, different parts, variability, customization etc.), the definition of FMS can be referred to the literature study of (Young-On, 1994) on FMS performance

Flexible manufacturing systems (FMS) are production systems consisting of identical multipurpose numerically controlled machines (workstations), automated material handling system, tools and load and unload stations, inspection stations, storage areas and a hierarchical control system. The latter has the task of coordinating and integrating all the components of the whole system for automatic operations. A particular characteristic of FMSs is their complexity along with the difficulties in building analytical models that capture the system in all its important aspects. Thus optimal control strategies, or at least good ones, are hard to find and the full potential of manufacturing systems is not completely exploited.

SEMI AUTOMATED FLEXIBLE MANUFACTURING SYSTEM

In developing countries like India, it is often difficult to justify the high initial cost of Flexible Manufacturing System. It is therefore desirable, to look for low cost FMS versions that render most of its expected features, but at an affordable price. One-way to achieve this is by substituting the fully automated Flexible Manufacturing System with less expensive alternatives. These alternatives may result in some deterioration in performance and the same may be quantified. If the resulting investment cost reduction offsets the loss in performance then the low cost alternative may be preferred. Caprihan and Wadhwa (Caprihan and Wadhwa, 1993) termed this type of systems as Semi Automated Flexible Manufacturing System (SAFMS). The lack of computer based integration and automation in SAFMS are represented by different levels of delays present in the system in taking scheduling and dispatching decisions.

APPROACHES TO SCHEDULING IN FMS

The different approaches available to solve the problem of FMS scheduling can be divided into the following categories:

- **The heuristic approach.**
- **The simulation-based approach.**
- **The artificial intelligence-based approach**

This section deals with the above mentioned approaches one by one.

A very common approach to scheduling is to use heuristic rules. This approach offers the advantage of good results with low effort but is very limited since it fails to capture the dynamics of the system. The performance of these rules depends on the state the system is in at each moment, and no single rule exists that is better than the rest in all the possible states that the system may be in. Moreover, there is no established set of rules that is optimal for every FMS since the success of these rules obviously depends on the particular FMS at hand. Thus, it is known that some set of rules gives good results, but deciding which particular rules are the best for a particular configuration has to be done by trial and error. But the performance of these rules depends on the state the system is in at each moment, and no single rule exists that is better than the rest in all the possible states that the system may be in. It would therefore be interesting to use the most appropriate dispatching rule at each moment.

The other method of scheduling is Simulation .It is used extensively in the manufacturing industry as a means of modeling the impact of variability on manufacturing system behaviour and to explore various ways of coping with change and uncertainty.

Simulation helps find optimal solutions to a number of problems at both design and application stages of Flexible Manufacturing Systems (FMS's) serving to improve the "flexibility" level.

At an advanced stage, scheduling is also done by the intelligent systems which employ expert knowledge. In practice, human experts are the ones that, by using practical rules, make an FMS work to the desired objective.

This leads to the idea of a scheduling approach that mimics the behaviour of human experts, that is the emerging field of intelligent manufacturing (Parsaei & Jamshidi Eds, 1995). The literature offers different intelligent techniques for the scheduling of manufacturing systems. Namely, fuzzy logic systems (FLS), artificial neural networks (ANN) and artificial intelligence (AI) used in scheduling. AI based systems (i.e., more precisely expert systems) are useful in scheduling because of their ease in using rules captured from human experts.

HEURISTIC RULE-BASED SYSTEM FOR SCHEDULING

Heuristic approaches are the scheduling and dispatching rules that are generally used to schedule the jobs in a manufacturing system dynamically. Different rules use different priority schemes to priorities the different jobs competing for the use of a given machine. Each job is assigned a priority index and the one with the lowest index is selected first.

Many researchers (Panwalker & Iskander, 1977); (Blackstone, Phillips, & Hogg, 1982); (Baker, 1984); (Russel, Dar-El, & Taylor, 1987); (Vaspalainen & Mortan, 1987); (Ramasesh, 1990) have evaluated the performance of these dispatching rules on manufacturing systems using simulation.

The conclusion to be drawn from such studies is that their performance depends on many factors, such as the criteria that are selected, the system's configuration, the work load, and so on (Cho & Wysk, 1993). With the advent of FMS's came many studies analysing the performance of dispatching rules in these systems (Stecke & Solberg, 1981); (Egbelu & Tanchoco, 1984); (Denzler & Boe, 1987); (Choi & Malstrom, 1988); (Henneke & Choi, 1990); (Tang, Yih, & Liu, 1993);(Nof & Solberg, 1979) carried out a study of different aspects of planning and scheduling of FMS.

They explore the part mix problem, part ratio problem, and process selection problem. In the scheduling context, they report on three part sequencing situations:

- **Initial entry of parts into an empty system**
- **General entry of parts into a loaded system**
- **Allocation of parts to machines within the system**

They examined three initial entry control rules, two general entry rules, and four dispatching rules. Their conclusion was that all these issues were interrelated: performance of a policy in one problem is affected by choices for other problems. (Stecke & Solberg, Loading and control policies for a flexible manufacturing system, 1981) investigated the performance of dispatching rules in an FMS context.

They experimented with five loading policies in conjunction with sixteen dispatching rules in the simulated operation of an actual FMS.

Under broad criteria, the shortest processing time (SPT) rule has been found to perform well in a job shop environment (Conway, 1965). Stecke and Solberg, however, found that another heuristic - SPT/TOT, in which the shortest processing time for the operation is divided by the total processing time for the job - gave a significantly higher production rate compared to all the other fifteen rules evaluated.

Another surprising result of their simulation study was that extremely unbalanced loading of the machines caused by the part movement minimization objective gave consistently better performance than balanced loading. (Iwata, Murotsu, Oba, & Yasuda, 1982) report on a set of decision rules to control FMS. Their scheme selects machine tools, cutting tools, and transport devices in a hierarchical framework.

These selections are based on three rules which specifically consider the alternate resources. (Montazeri & Nan Wassenhove, 1990) have also reported on simulation studies of dispatching rules.

(Buzzacot & Shanthikumar, 1980) consider the control of FMS as a hierarchical problem:

- Pre-release phase, where the parts which are to be manufactured are decided
- Input or release control, where the sequence and timing of the release of jobs to the system is decided, and
- Operational control level, where the movement of parts between the machines is decided.

Their relatively simple models stress the importance of balancing the machine loads, and the advantage of diversity in job routing. (Buzzacott, 1982) further stresses the point that operational sequence should not be determined at the pre-release level.
His simulation results showed that best results are obtained when:

For input control, the least total processing time is used as soon as space is available

For operational control, the shortest operation times rule is used.

In the study of (Shanker & Tzen, 1985), the formulation of the part selection problem is mathematical; but its evaluation was carried out in conjunction with dispatching rules for scheduling the parts in the FMS. Further, on account of the computational difficulty in the mathematical formulation, they suggested heuristics to solve the part selection problems too.

On the average, SPT performed the best. Moreno and Ding (1989) take up further work on heuristics (for part selection) as mentioned above, and present two heuristics which reportedly give better objective values than the heuristics in this (Shanker & Tzen, 1985), however, they are able to do by increasing the complexity of the heuristics.

Their heuristic is 'goal oriented' in each iteration, they evaluate the alternate routes of the selected job to see which route will contribute most to the improvement of the objective. Otherwise, their heuristic is the same as that of Shanker and Tzen.

When comes the real time scheduling of FMS, heuristic rules are often used. Practically, they can be used effectively, but they are short –sighted in nature. Due to the lack of any predictive and adaptive properties, their success depends on the particular plant that is under study and on the control objectives.

These rules refer only to some particular aspects of the scheduling problem, that is, to the ones of interest for the present study.

These rules are briefly presented here, for more precise descriptions the work of (Young-On, 1994); (Yao, 1994) and (Joshi & Smith, 1994) can be referred.

The heuristic rules are basically concerned with:

- Sequencing: that is, deciding the ordering of orders to be inserted into the system.
- Routing: that is, deciding where to send a job for an operation in case of multiple choices.
- Priority: setting for a job in a machine buffer: that is, deciding which will be the next job to be served by a machine.

Some sequencing rules are:

EDD (Earliest Due Date) : the first order that enters the system is the one with the earliest due date

- FIFO(First In First Out) : the first order that enters the system is the one that arrived first
- LPT(Longest Processing Time) : the first order that enters the system is the one with the longest processing time
- SPT(Shortest Processing Time) : the first order that enters the system is the one with the shortest processing time.

Some routing rules are:

- RAN (RANdom) : the next workstation is randomly chosen
- SQL (Shortest Queue Length) : the next workstation is the one with the shortest queue length
- SQW(Shortest Queue Workload) : the next workstation is the one with the shortest queue workload (the queue workload is defined as the sum of the processing times required by all thejobs waiting to be processed)

Finally, some priority setting rules for jobs in a machine buffer are:

- EDD (Earliest Due Date) : the first job to be processed is the one with the earliest due date
- Earliest FIFO (First In First Out) : the first job to be processed is the one that arrived first
- HPFS (Highest Profit First Served) : the first job to be processed is the one that gives the highest profit
- LIFO (Last In First Out) : the first job to be processed is the one that arrived last
- LS(Least Slack) : the first job to be processed is the one with the least slack
- MDD (Modified Job Due Date.) : it is a modified version of the EDD
- MODD (Modified Operation Due Date) : it is another modified version of the EDD
- SPT (Shortest Processing Time) : the first job to be processed is the one with the shortest processing time (on that operation)
- SPT/TPT (Shortest Processing Time/Total Processing Time) : the first job to be processed is the one with the lowest processing time (on that operation) to total processing time ratio

MOTIVATION FOR STUDY

The motivation for study is derived from the idea that most of the research work focuses on highly flexible and highly automated flexible Manufacturing system but very little work has been done on the kind of system that Small and medium industries are using. Most of these industries have partially automated flexible automation.

INDUSTRIAL IMPLICATIONS

Scheduling is the process of organizing, choosing and timing resource usage to carry out all the activities necessary to produce the desired outputs of activities and resources. In a manufacturing system the objective of scheduling is to optimize the use of resources so that the overall production goals are met. A heuristic based Scheduling Model for SAFM system is aims at making best use of available resources for SAFMS environments.

5.0 Operating environment and problem definition:
To study the performance of SAFM system , we have studied a number of automobile industries in and around Delhi and we have selected one industry from Northen India.

The industry supplies automobile components to many automobile industries like General motors, Maruti, Hero Honda etc. The machine shop set up includes 104 machines, which includes both CNC as well as conventional machines. We have taken a cell of 6 CNC machines for our study. These machines are connected by conveyor belt and decision are taken centrally. It takes some finite time to take decision and implement it.

THE SIMULATION SETUP

We have taken 6 parts for machining operation. Each part requires 4 to 6 operations. The processing time for machining of part varies from 40 minutes to 100 minutes.

Each machine is capable of performing different operations, but no machine can process more than one part at a time. Each part type has several alternative routings. Operations are not divided or interrupted when started. Set up times are independent of the job sequence and can be included in processing times. The scheduling problem is to decide on which rule should be selected for given amount of decision delay. The simulation model has been developed in Java. The results have been verified by hand simulation and comparison with WITNESS.

THE EXPERIMENTATION AND RESULTS

Three sets of data are entered as input to the model. Following assumptions are made

Case 1: Routing Flexibility : Part can be machined on 6 alternate machines

- Machine Flexibility : Very high
- No. of part processed : 1000 parts
- Dispatching rule : MinQ
- Parameter Varied : Review period delay and Sequencing rules

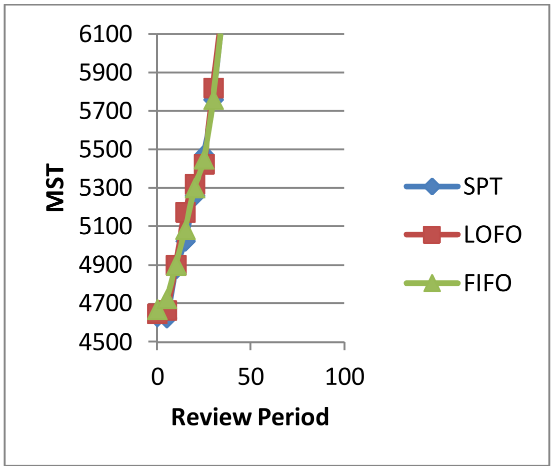

Figure- 1: MST vs Review Period at different Sequencing rules

Analysis of the result: From the fig-1, it can be seen among three rules SPT performs best at real time, but in case of review period delay beyond 20 min FIFO perform well as compare to other rules.

Case 2: Routing Flexibility: Part can be machined on three alternate machines (RF=3)	
•	Machine Flexibility: Very high
•	No. of part processed: 1000 parts
•	Parameter Varied: Review period delay and Sequencing rules
•	Dispatching rule: MinQ

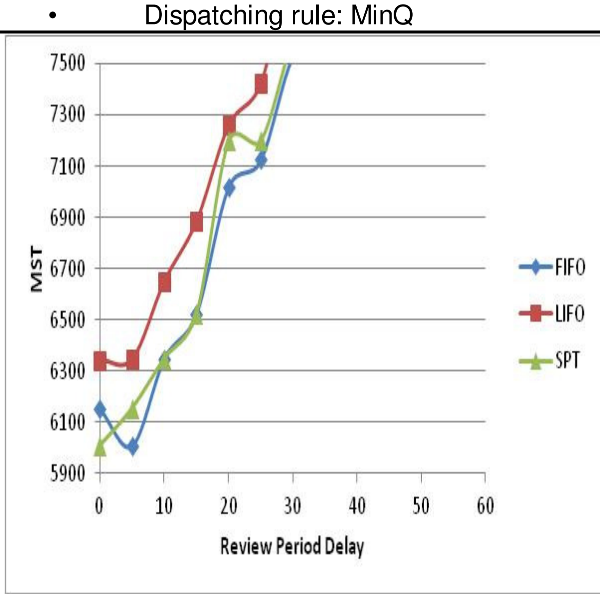

Figure- 2: MST vs Review Period at different Sequencing rules

Analysis of the result: From the fig-2, it can be seen among three rules SPT performs best at real time, but in case of review period delay beyond 5 min FIFO perform well as compare to other rules.

Case 3: Routing Flexibility : Part can be machined on two alternate machines (RF=2)	
•	Machine Flexibility : Very high
•	No. of part processed : 1000 parts
•	Parameter Varied : Review period delay and Sequencing rules
•	Dispatching rule : MinQ

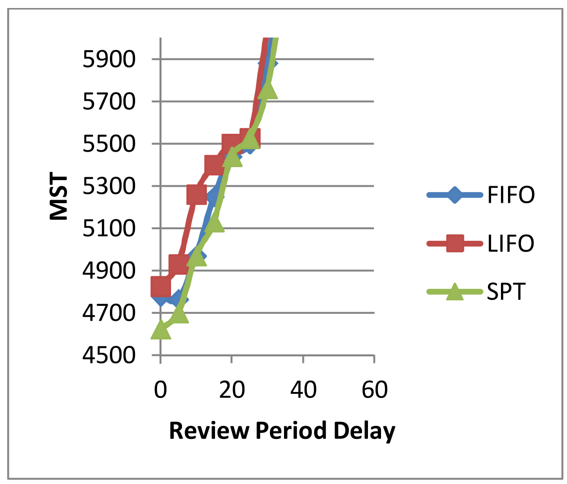

Figure- 3 : MST vs Review Period at different Sequencing rules

Analysis of the result: From the figure 3, it can be seen among three rules SPT performs best at all the levels of review period delays. However at higher levels of delay performance of FIFO and SPT are comparable.

CONCLUSION

In this paper, we have reviewed various approaches of scheduling FMS. We have taken special case of small and medium industries using Semi Automated flexible Manufacturing system. We have taken most commonly used heuristic scheduling rules for such system. From our simulation result at various levels of flexibility and automations, we find in most of the cases SPT performs the best at real time, but at higher levels of delays, performance of SPT and FIFO are comparable. The study also suggests that there is no particular rule, which performs best under all operating conditions.

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