Journal of Materials Processing Technology 138 (2003) 325–331

Journal of Materials Processing Technology

www.elsevier.com/locate/jmatprotec

Analysis of dynamic dispatching rules for a flexible manufacturing system

F.T.S. Chan[a,*], H.K. Chan[a], H.C.W. Lau[b], R.W.L. Ip[c]

[a]Department of Industrial and Manufacturing Systems Engineering, University of Hong Kong, Pokfulam Road, Hong Kong, PR China
[b]Department of Industrial and Systems Engineering, The Hong Kong Polytechnic University, Hong Kong, PR China
[c]Department of Manufacturing Engineering and Engineering Management, City University of Hong Kong, Hong Kong, PR China

Abstract

This paper presents a simulation model of a flexible manufacturing system (FMS) which subjects to minimization three performance criteria simultaneously such as *mean flow time*, *mean tardiness*, and *mean earliness*. The dispatching rule will be changed at a frequency that is varied by the number of outputs produced by the system. Therefore, the dynamic nature is *event-triggered* rather than changing the rule at a regular time interval, which is passive. Three indexes are calculated to represent the three criteria under monitoring and the indexes are ranked in descending order: the greater the index, the worse is the situation of the criterion in the system. Thus, an appropriate rule will be selected for the next operation in order to tackle that criterion with the largest index. This mechanism is so called *pre-emptive method*. Furthermore, the indexes can be biased so that particular criterion can have a greater weighting as set by the decision-maker. Results show that a solution (range of frequency) can always be determined to change the dispatching rule so that the system is better than just using fixed FMS scheduling rule.

Keywords: Flexible manufacturing systems; Dynamic scheduling; Simulation; Pre-emptive; Dispatching

1. Introduction

Flexible manufacturing systems (FMSs) have received increasing attention in recent decades. The development in robot design over the past 20 years has enabled automation in more complicated electromechanical assembly. In addition, with the aids of new microprocessor technologies, the concept of flexibility in manufacturing has become a key consideration in the design, operation, and management of manufacturing systems.

An FMS is able to assemble a variety of product types in small-to-medium sized batches at the same time and at high rate comparable to that of traditional assembly lines designed for high volume/low variety manufacture. An FMS might be simply defined as follows: "A manufacturing system is flexible if it is able to process a number of different tasks automatically and in any order". In fact, an FMS is a computer directed collection of CNC machines linked by an automated material handling system. The automated material handling system usually refers to automated guided vehicles (AGVs), which use embedded floor wires to direct driverless vehicles to various locations in the plant, and delivering materials [1]. Since FMSs are designed to combine the efficiency of a mass production line and the flexibility of a job shop to best suit the batch production of a mid-volume and mid-variety of products, it requires more management to function efficiently and effectively [2].

The procedure for scheduling operations on the machines is executed whenever a station completes performing of its current operation and becomes available for the next task assignment. For each candidate product waiting for its next operation in the station's input buffer, the priority index is calculated. The priority index depends on the optimality criterion selected. For example, for makespan criterion, the index is a function of the remaining processing and transportation times; and for a due date related criterion, modified operation due date can be used as a substitute of the remaining processing and transportation times. After the priority index is calculated for each operation of each product, the product waiting for its next operation with the highest-priority index is loaded first.

In this paper, a real-time scheduling approach is proposed using pre-emptive method for machines dispatching rules in an FMS. The dispatching rule is changing dynamically, through a series of computation and evaluation on the

* Corresponding author.
E-mail address: ftschan@hkucc.hku.hk (F.T.S. Chan).

0924-0136/03/$ – see front matter © 2003 Elsevier Science B.V. All rights reserved.
doi:10.1016/S0924-0136(03)00093-1

system's performance criteria. Then the performance of the system that was found by using dynamic scheduling method is compared with the best one that found among the static scheduling methods. The idea is proved through computer simulation. Section 2 reviews the relevant literature on real-time FMS scheduling models. The FMS model is described in Section 3. Section 4 illustrates the implementation of the dynamic scheduling model through a simulation study. Conclusions and future research directions are given in Section 5.

2. Relevant literature

Montazeri and Van Wassenhove [3] reviewed the performance of a number of dispatching rules for an FMS simulation model. They concluded that dispatching rules have a great impact on various system performance criteria, such as average machine utilization, average buffer utilization, and makespan, etc. However, general results are not available, as the performance of scheduling rules depends not only on the criterion chosen but also on the configuration of the production system at hand. Sabuncuoglu [4] conducted research to examine the effects of scheduling rules on the performance of FMSs. The objective was to measure the sensitivity of the rules to changes in processing time distributions, various levels of breakdown rates, and types of AGV priority schemes. Again, results show that the performance of FMSs can be improved to a certain extent by choosing proper scheduling/dispatching rules. Particularly under very lightly loaded system conditions, the differences between the rules are found to be statistically significant. Unfortunately, no general conclusion can be drawn in the paper for a general FMS.

Rau and Chetty [5] developed a dynamic programming algorithm to solve simultaneously the production planning problems of an FMS, namely, the selection of a set of part types, determining the production ratios, assigning the pallets and fixtures, and assigning operations and tools to machines. The dynamic programming developed was proven to solve the problem with the objective of minimizing the unbalanced workloads of the machines for a small-to-medium size system successfully. Langevin et al. [6] proposed an optimal dynamic programming approach to determine both the dispatching of the transportation tasks, and the routing and scheduling of the vehicles. Their method uses a state-space of partial transportation plans to obtain a solution to the dispatching/routing problem over a certain time horizon and reiterated on a rolling time horizon for real-time operation. The algorithm was proved to be very efficient in minimizing makespan or lateness.

In fact, FMSs are more sensitive to system disturbances and they require an immediate response to changes in system states, and this can only be achieved by real-time scheduling. A number of papers have investigated real-time scheduling by simulation using a fixed time interval to check the performance value of the system and then decide whether to change the current rule or not. Maimon and Gershwin [7] presented a method for the real-time scheduling and routing of material in a FMS whose machines occasionally fail. In the simulation model, a new schedule and a new routing scheme are calculated whenever a machine has failed or under repair (changes state). This is done by making use of a dynamic programming method, via a feedback control law, to optimize a cost function. Although the algorithm was proven by several examples, it is not sufficient to take action only when machine breakdown in an FMS system has occurred.

Kim and Kim [8] developed a scheduling mechanism in which the job dispatching rule varies dynamically and the best one is selected for a given criterion. The real-time control system periodically monitors the shop floor and checks the performance value of the system. Peng and Chen [9] using standard clock simulation to evaluate the performance of a set of scheduling policies for a short planning horizon and using ordinal optimization concepts to choose quickly the most desirable scheduling policy. However, the work of both Kim and Kim [8] and Peng and Chen [9] cannot always ensure the global "best" performance to drive the system. Moreover, although these authors worked with more than one performance criterion in the system (such as mean flow time, mean lateness), all the criteria are with equal weighting. In reality, decision-makers may not consider several performance criteria with the same priority. In this connection, one of the objectives of this paper is to investigate whether or not the developed algorithm can be worked equally well with biased performance criteria.

It can be said that most of the researchers did not investigate the importance of the time period to change the operational rule. They used to fix the time period to change the operational rules, which are not event-triggered. They also ignored the importance of biased performance criteria. In this paper, the pre-emptive approach is adopted to allow real-time machine dispatching in an FMS. The operational rules will be changed when certain number of outputs are produced by the system. The relationship between the frequency to change the rule and the improvement is investigated. In addition, the developed algorithm allows biased performance criteria to be under consideration. This is important because the majority of the decision-makers is not likely to consider several criteria as equally important.

3. The FMS model

3.1. System consideration

The FMS studied includes five general-purpose machine workstations and one loading/unloading station as depicted in Fig. 1. The system has a work in process (central buffer) area to hold all jobs to be processed. The central buffer has a