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A simulation analysis of part launching and order collection decisions for a flexible manufacturing system

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In a dynamic flexible manufacturing system (FMS) environment jobs arrive randomly, and in most of the existing studies the due date for a single part is set individually. However, when the due date is set for an order that consists of multiple parts, some completed parts may have to wait for the rest of the order to be completed. This paper studied the scheduling problem in the FMS in which orders require the completion of different parts in various quantities. The orders arrive randomly and continuously, and all have predetermined due dates. Two scheduling decisions were considered in this study: launching parts into the system for production, and determining the order sequence for collecting the completed parts. A new part-launching rule, named the Tardiness Estimating Method (TEM) was proposed. A discrete-event simulation model of the FMS was developed and used as a test-bed for experiments under various system conditions. The proposed part launch rule was capable of providing good performance regarding minimum mean tardiness and maximum service level, but provided only a moderate flow time when compared with the other five rules commonly used in the literature. In addition, three order collection rules were tested in the experiments. Collecting parts for the order with the earliest due date (EDD) was found better than the other rules for tardiness related measures.

1. Introduction

Given the increased level of global competition, the common challenge is that every modern manufacturing enterprise must be capable of making customized high-quality products with small lot sizes and short lead times in order to survive in today's competitive market. A flexible manufacturing system (FMS) is a computerized and highly automated production system that is designed to produce a mid-volume and a mid-variety of products at a high level of efficiency. This type of production system combines the efficiency of a mass production line with the flexibility of a job shop and is the best fit for modern manufacturing enterprises to boost their productivity and competitiveness [1]. Since the successful implementation of the first flexible manufacturing system (FMS) in the 1960s, an abundance of FMS issues have been studied. A FMS usually consists of a set of computer numerically controlled machines (CNCs) linked with an automated material handling system. One of the characteristics distinguishing the FMS from other manufacturing systems is that the FMS provides routing

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flexibility because of the capability of modern CNC machines, essentially allowing the design of alternative process plans for a job. This flexibility and level of automation make the FMS an extremely complex, large-scale modern production system.

A large amount of research has been conducted to solve problems such as loading, scheduling, automated guided vehicle (AGV) dispatching, or cutting tools management in FMSs. Most of the existing literature treats a job as a single order when released into the FMS, and each job in the shop normally represents a single type of part. The problem investigated in this study is that an order may require to complete different parts, each part in different quantities. Contrary to launching a part with a production due date, this problem involves two decisions as follows:

(1) Part launch: this refers to the selection of the parts to be loaded onto a pallet with at the loading/unloading end of the FMS for subsequent processing in the system.
(2) Order collection: since there may be many different parts that must be completed in the output buffer of FMS, they must be collected to form a completed order for shipment. This decision refers to deciding the order of collecting the completed parts and the subsequent shipment.

The purpose of this paper is to provide a simulation analysis by examining the above two decisions when operating a dynamic FMS. A discrete-event simulation model for a make-to-order FMS was developed and used as a test-bed for experiments under various system conditions. The remainder of this paper is organized as follows. Section 2 reviews the literature on scheduling as well as FMS control issues. Section 3 details the FMS simulation model used in the present research. Section 4 describes the order collection rules and the part launch rules as well as the experimental conditions in this study. Section 5 discusses the simulation results. Finally, in Section 6 conclusions are drawn and directions for future research are provided.

2. Literature review

A large amount of literature has been devoted on the examination of the effects of the planning and scheduling strategies of the FMS, both from an operational and a control point of view. To implement a FMS, the following issues must be taken into consideration [2]:

- Sequencing of the parts to be loaded into the system.
- Part routing.
- Sequence the parts waiting in each machine to be processed.
- Sequence those parts that require transportation.
- Allocate material handling devices to fulfill the transportation requirements of the parts.

These five issues can be further classified into eight scheduling problems. Table 1 provides a summary of the literature focusing on these eight problems. It is obvious that the top three are part launching (B), part routing (F), and part sequencing in the machine buffer (C).

2.1. Fixed part routing

In some studies, the part routes were determined in the FMS planning phase. In these studies the focus was on scheduling problems other than the dynamic part routing problem. For example, Sabuncuoglu and Hommertzheim [7] examined the effects of the dispatching rules used for prioritizing the jobs waiting for processing in the machine queue, and the rules to dispatch an automated guided vehicle (AGV) under various experimental conditions. They found that the smallest modified operation due-date (MOD) was the best rule for sequencing the jobs in the machine queue, and that the largest queue size (LQS) was the preferred rule for the dispatching an AGV for various due-date criteria. For different criteria, like minimizing the mean flow time, these researchers indicated that the shortest processing time (SPT) combined with any AGV rule tended to be suitable [8]. Among the AGV rules examined, LQS and STD (shortest travel distance) in combination with any machine rule proved to be the best rules. These authors also investigated the performance of the rules under various approaches of setting the internal due dates in a FMS [9]. They found that the ‘flow-allowance is proportional to the total work’ (TWK) rule outperformed other due-date setting rules by minimizing the mean tardiness for most of the conditions tested. Sabuncuoglu [11] extended their earlier work to measure the sensitivity of the machine and the AGV scheduling rules to the processing time distributions, loading levels, and machine and AGV breakdowns. The results of their study showed that the performance of scheduling rules is affected by the variances of the distribution of the operating time, the different system loading levels, as well as the machine downtime percentage.

Sabuncuoglu and Lahmar [16] compared two operation grouping policies: aggregation and disaggregation. In the aggregation case, all the operations required for making a part are performed at a single machine. The machine does not release a part until all the operations required are completed. Disaggregation is the process of assigning the operations required on a part to various machines. In short, aggregation is the case of a single-stage multi-machine FMS [26], while disaggregation is the case of a normal FMS. Their study concluded that although FMS managers may advocate the aggregation approach in order to reduce the number of setups, the aggregation approach is not always advantageous in a variety of FMS environments. They also concluded that the disaggregation approach is only suitable for FMSs composed of non-identical machines, and especially under heavy loading conditions.