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A coordinated scheduling system for customer orders scheduling problem in job shop environments

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ABSTRACT

In this study a coordinated scheduling of customer orders (CSCO) system, with the purpose of improving customer order flow time, is proposed for the order-based production system in which several jobs make up a given customer order and nothing is delivered to the customer until the order is complete. The customer order flow time, which elapses between the release of the first job and the completion of the last job of an order, is crucial because it shows how long the order is in the shop and in the finished goods warehouse. Shorter customer order flow time results in less work-in-process (WIP) and finished good inventory (FGI). The CSCO includes two main decisions: (i) release the jobs and (ii) dispatch the jobs at the station level. Extensive simulation experiments were performed to compare the proposed scheduling system with the benchmark mechanisms presented in previous studies. They led to the conclusion that CSCO significantly dominates the others in two order-based job shops.

1. Introduction

Over the last decades many research results have been published about the effects of dispatching rules on the performance of job shop production systems. The performance effectiveness of a job shop has long been measured relative to the job flow time. The results of these studies cannot be extrapolated to a shop where several jobs make up a particular customer order and where nothing is delivered to the customer until the order is complete (Blocher, Chhajed, & Leung, 1998). Work jobs within a customer order have different routing length. This type of scheduling problems is usually referred to as customer orders scheduling (COS) problems. The research literatures on COS problems are scarce. Ahmadi and Bagchi (1992) considered the COS problem in a multi-machine, focused factory environment, with performance based on the order flow times and due dates. Gupta, Ho, and van de Veen (1997) studied a bi-criteria COS problem involving both flow time and makespan on a single machine environment. Blocher and Chhajed (1998) focused on minimizing the order flow time in a parallel machine environment. Blocher et al. (1998) examined the performance of order-based dispatch rules in a general job shop, where the environmental factors were shop utilization and due-date tightness and the performance measures were order flow time, order tardiness and proportion of tardy orders. Ahmadi, Bagchi, and Roemer (2005) showed that the problem of minimizing the weighted sum of customer order delivery time is unary NP-hard, and proposed several heuristic solutions for solving special cases of the problem. Yang (2005) established the complexity of several customer order scheduling problems on parallel machines with different types of objectives, job restrictions, and machine environments. Erel and Ghosh (2007) showed that the customer order scheduling problem on a single machine is strongly NP-hard.

Based on the above descriptions, most of the research use order flow time as an objective. In this study, we first introduce a new class of customer order scheduling problem of minimizing the customer order flow time. The customer order flow time, which elapses between the release of the first job and the completion of the last job of an order, is considered a crucial measure in this kind of shop environment. Shorter customer order flow time results in less work-in-process (WIP) and finished good inventory (FGI). The WIP and FGI tie up capital and costs interest. Reducing the customer order flow time can therefore contribute in two ways to an increase in the return on investment. In addition to the WIP and FGI levels, shorter customer order flow times result in a higher product yield and better capacity given tool inventory and facility constraints. Therefore, we think that minimizing the customer order flow time in order-based production system is a promising area of research. Furthermore, because of the complexity of the COS problem, the existing studies focused primarily on developing and comparing dispatching rules and due date setting mechanisms, not on proposing an order releasing policy. The primary objective of the present study is to develop a scheduling system, which we call the coordinated scheduling of customer orders (CSCO), involving an order releasing policy and a dispatching rule

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for the COS problem in dynamic job shop environments, in order to improve the customer order flow time. The results of our experiments indicate that the CSCO performs better than the conventional scheduling combinations of order releasing policies and dispatching rules.

The rest of the paper is organized as follows. A description of the order releasing policy and dispatching rule follows in the next section. In Section 3, our proposed framework is described in detail. Then, in the fourth section the simulation model and the experimental design used to study the performance of the scheduling system are discussed. We present some general observations of the results in the fifth section. In the final section we provide a summary of the results and make some suggestions for future work.

2. Related work

In order to describe the process of developing two decision-making schemes that are included in our proposed CSCO for improving the customer order flow time, it will be helpful to first discuss the following two areas as background: order releasing policy and dispatching rule.

2.1. Order releasing policy

After arrival, orders may be released to the shop floor at any time. The order releasing policy determines when and what job in the pre-shop pool (PSP) should be released. To date, several policies have been studied and proposed in the literatures, ranging in complexity from simple to complicated. In this study, we test three order releasing policies that are most frequently used in previous studies and have different characteristics from one another: immediate release (IMR), constant work-in-process (CONWIP), and predicted release date (PRD).

In IMR, an order is released to the shop floor as soon as it is accepted, regardless of the shop status or the characteristics of the order being released. Melnyk and Ragatz (1989) indicated that IMR, which corresponds to the no-order-review/release policy, showed better delivery and mean job flow time performance. Bertrand and van de Wakker (2002) concluded that all jobs of an order are best to be released immediately upon the arrival of the order for assembly job shop: it results in the shorter assembly order flow time.

The CONWIP policy was proposed by Spearman, Woodruff, and Hopp (1990). It has drawn the attention of many researchers because it has substantial advantages of being able to directly control WIP using cards, and can be applied to a wider variety of manufacturing environments. The CONWIP policy states that when a job is in its final processing stage, a new job must be released into the shop. Limiting the amount of WIP reduces storage, costs, allows the quick identification of quality problems, and permits a rapid response to machine breakdown, material shortage or worker unavailability (Ryan, Baynat, & Choobineh, 2000).

The PRD policy determines the release date of each job through a prediction technique. A job is released whenever it reaches its release date. PRD mechanisms are like backward infinite loading (BIL) and the modified infinite loading (MIL) (Ragatz & Mabert, 1988), determining the job release date through a regression model based on a number of predictive factors. Moreira and Alves (2006) showed that the time period an order spends in the warehouse of finished goods waiting to be delivered, can be reduced if PRD is used.

The central idea of the proposed order releasing policy is to present a hybrid architecture combining the concepts of CONWIP and PRD to result in performance improvements over traditional one-representation architectures. It inherits the advantages of both policies, in order to support CSCO for reducing WIP and order waiting time in the warehouse, so as to improve the customer order flow time.

2.2. Dispatching rule

A variety of dispatching rules were tested in Blocher et al. (1998) in the order-based production system, divided into five classes: arrival oriented, due date oriented, processing time oriented, job complexity oriented, and ratio oriented. Among them, the simple rules, EDD, SPT, and FCFS performed well in this kind of production system. EDD seems to be the most robust of the rules. Deciding which rule to use must be determined not only by the desired performance measure, but also by due-date tightness and shop utilization. In this study, five dispatching rules were investigated in order of the increasing sophistication in their use of information for determining the next job to be processed on an available machine: first come first served (FCFS), earliest due date (EDD), and shortest processing time (SPT), Shortest remaining processing time (SRT), and critical ratio (CR). We chose those rules, because they do not need parameter estimation, are most frequently used in previous studies, and each has different characteristics. Among these rules, EDD is a due date oriented rule, SRT and SPT are processing time oriented rules, FCFS is a arrival oriented rule, and CR is a ratio oriented rule.

In this study, we not only test the above five dispatching rules in the order-based production systems, but we also propose a dispatching rule as an assistant to support CSCO in coordinating the completion time of the jobs within a customer order to plan them being completed at about the same time. It is anticipated that reducing the order waiting time in the warehouse will improve the customer order flow time.

3. The structure of the coordinated scheduling of customer orders system

This section discusses in detail the proposed coordinated scheduling of customer orders (CSCO) system for improving the customer order flow time. The section is divided into three subsections, namely, the CSCO concept, order releasing control and dispatching control.

3.1. The CSCO concept

The basic idea of CSCO is to reduce the time period an order spends in the shop floor and in the warehouse of finished goods waiting to be delivered, so as to improve the customer order flow time. How CSCO works can best be explained by the following rules.

- Rule 1: consider the fact that different jobs in an order may have different completion times when releasing a job onto the shop floor.
- Rule 2: synchronize the progress of jobs in the shop that belong to the same order.
- Rule 3: give priority to those jobs that might increase the final customer order throughput time when a work centre becomes idle.

Among these rules, Rule 1 is needed in case of development of an order releasing control. Rules 2 and 3 are needed in case of development of a dispatching control. The underlying manufacturing control philosophy of CSCO will be briefly discussed in the next