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Performance analysis of dispatching rules in a stochastic dynamic job shop manufacturing system with sequence-dependent setup times: Simulation approach

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ABSTRACT

Stochastic dynamic job shop scheduling problem with consideration of sequence-dependent setup times are among the most difficult classes of scheduling problems. This paper assesses the performance of nine dispatching rules in such shop from makespan, mean flow time, maximum flow time, mean tardiness, maximum tardiness, number of tardy jobs, total setups and mean setup time performance measures viewpoint. A discrete event simulation model of a stochastic dynamic job shop manufacturing system is developed for investigation purpose. Nine dispatching rules identified from literature are incorporated in the simulation model. The simulation experiments are conducted under different levels of shop utilization and setup time. The important aspects of the results of the simulation investigation are also discussed in detail.

Introduction

Production scheduling in a manufacturing system is associated with allocation of set of jobs on a set of production resources over time to achieve some objectives. In a job shop manufacturing system, a set of jobs are processed on a set of machines and each job has specific operation order. The job shop scheduling problem is a combinatorial optimization problem as well as NP-hard and it is one of the most typical and complex among various production scheduling problems [1,2]. In dynamic job shop scheduling problems jobs arrive continuously over time in job shop manufacturing systems. Further, in a stochastic dynamic job shop (SDJS) manufacturing system at least one parameter of the job (release time, processing time/setup time) is probabilistic.

In traditional approaches, in order to reduce the complexity of solving job shop scheduling problems, setup time is either neglected or included in the processing time of a job. But this effort does not represent the realistic picture of a manufacturing system. Setup time is a time that is required to prepare the necessary resources such as machines to perform an operation [3]. In many real-life situations, a setup operation often occurs while shifting from one operation type to another. Sequence-dependent setup time depends on both current and immediately previous operation [3]. Sequence-dependent setup time encounters in many industries such as textile industry, printing industry, paper industry, auto industry, chemical processing and plastic manufacturing industry. In textile industry, during dyeing operation, a very little setup time is required for job changing when dyeing from pale shade to deep shade products. On the contrary, much more setup time is required to clean the dyeing vessel, if otherwise. Even in some cases, setup time becomes equal to or more than operation time. Scheduling problems with sequence-dependent setup times are among the most difficult classes of scheduling problems [4]. It has been pointed out by Manikas and Chang [5] and Fantahun and Mingyuan [6] that limited research on job shop scheduling problems considering sequence-dependent setup times is available.

A dispatching rule is used to select the next job to be processed from the set of jobs awaiting processing in the input queue of a machine. Dispatching rules are also termed as sequencing rules or scheduling rules. These rules are classified into broad four categories namely as process time based rules, due date based rules, combination rules and rules that are neither process time

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based nor due date based [7]. In a manufacturing system, dispatching rule is one of the methods that can be used to carry out scheduling. Better the dispatching rule, better will be scheduling of the manufacturing system. Scheduling is a part of production planning. Thus, selecting a better dispatching rule for scheduling helps in carrying out a better production planning. This paper assesses the performance of nine dispatching rules identified from the literature.

The remainder of the paper is organized as follows. The review of relevant literature is introduced in the section "Literature review". The section "Job shop configuration" describes salient aspects of configuration of the SDJS scheduling problem. The outline for development of simulation model is explained in the section "Structure of simulation model". The section "Experimental design for simulation study" presents details of simulation experimentations. The section "Results and discussion" provides analysis of experimental results. Finally, the section "conclusions" gives concluding remarks and directions for future research.

Literature review

Ramasesh [8] provided a review of simulation research in dynamic job shop scheduling problems. Allahverdi et al. [9] provided a comprehensive survey of literature on scheduling problems with setup times (costs). Panwalkar et al. [10] provided a survey of scheduling rules used in manufacturing systems. Blackstone et al. [11] presented a state-of-the-art review of scheduling rules used in job shop scheduling problems. Holthaus and Rajendran [12] proposed two new dispatching rules for dynamic job shop scheduling problems to minimize mean flow time, mean tardiness and percentage of tardy jobs performance measures. These rules combine Process Time and Work Content in Queue for the next operation on a job by making use of additive (Rule 1) and alternative approaches (Rule 2). The authors concluded that Rule1 is quite superior in minimizing mean flow time performance measure. Jayamohan and Rajendran [13] proposed seven dispatching rules for minimization of mean flow time, maximum flow time, variance of flow time and tardiness performance measures in dynamic shops. The proposed rules are found to be very much effective in minimizing different performance measures. Jain et al. [14] proposed and assessed the performance of four new dispatching rules for makespan, mean flow time, maximum flow time and variance of flow time measures in a flexible manufacturing system. The authors found that the proposed dispatching rules provide better performance than the existing rules. Dominic et al. [15] developed two better scheduling rules viz. longest sum of Work Remaining and Arrival Time of a job (MWRK_FIFO) and shortest sum of Total Work and Processing Time of a job (TWKR_SPT) for dynamic job shop scheduling problems. These rules are tested against six existing scheduling rules i.e. First-in-First-out (FIFO), Last-in-First-out (LIFO), Shortest Processing Time (SPT), Longest Processing Time (LPT), Most Work Remaining (MWRK) and Total Work (TWKR) for mean flow time, maximum flow time, mean tardiness, tardiness variance and number of tardy jobs performance measures.

There have been a few attempts to address dynamic job shop scheduling problems with sequence-dependent setup times. To the best of authors' knowledge, Wilbrecht and Presscott [16] were first among researchers to study the influence of setup times on dynamic job shop manufacturing systems performance. The authors proposed and tested a setup oriented scheduling rule, job with Shortest Setup Time (SIMSET). The authors concluded that SIMSET rule outperforms other six existing scheduling rules i.e. Random, Earliest Due Date, Shortest Run, Longest Run, Shortest Process and Longest Process for value of work-in-progress, number of processes completed in a week, number of jobs sent out of the shop in one week, number of processes completed late in one week, distribution of completion times, queue wait time of a job in a shop, number of jobs waiting in a shop, shop capacity utilized, number of jobs waiting in a queue for more than one week and size of jobs waiting in a queue for more than one week performance measures. Kim and Bobrowski [17] studied impact of sequence-dependent setup times on a dynamic job shop manufacturing system performance. The authors concluded that setup oriented scheduling rules i.e. Shortest Setup Time (SIMSET) and Job with Similar Setup and Critical Ratio (JCR) outperforms ordinary scheduling rules i.e. Shortest Processing Time (SPT) and Critical Ratio (CR) for mean flow time, mean work-in-process inventory, mean finished good inventory, mean tardiness, proportion of tardy jobs, mean machine utilization, mean setup time per job, mean number of setups per job and mean total cost per day performance measures when a manufacturing system with sequence-dependent setup times is considered. Kim and Bobrowski [18] extended their earlier research [17] to investigate impact of setup times variation on sequencing decisions with normally distributed setup times. The authors concluded that setup times variation has a negative impact on a manufacturing system performance. Recently, Vinod and Sridharan [19] proposed and assessed performance of five setup oriented scheduling rules viz. Shortest Sum of Setup Time and Processing Time (SSPT), Job With Similar Setup and Shortest Processing Time (JSPT), Job with Similar Setup and Earliest Due Date (JEDD), Job with Similar Setup and Modified Earliest Due Date (JMEDD) and Job with Similar Setup and Shortest Sum of Setup Time and Processing Time (JSSPT) for dynamic job shop scheduling problems with sequence-dependent setup times. The authors concluded that proposed rules provides better performance than the existing scheduling rules i.e. First-in-First-out (FIFO), Shortest Processing Time (SPT), Earliest Due Date (EDD), Modified Earliest Due Date (MEDD), Critical Ratio (CR), Smallest Setup Time (SIMSET) and job with similar setup and Critical Ratio (JCR) for mean flow time, mean tardiness, mean setup time and mean number of setups performance measures.

Literature review clearly reveals that there is a need to evaluate the performance of dispatching rules in a SDJS manufacturing system with sequence-dependent setup times. The present paper is an attempt in this direction. It assesses performance of existing nine best performing dispatching rules identified from literature using simulation modeling for makespan, mean flow time, maximum flow time, mean tardiness, maximum tardiness, number of tardy jobs, total setups and mean setup time performance measures in such shop. Further, the effect of change in setup time and shop utilization levels on system performance is also assessed.

Job shop configuration

In the present study, a job shop manufacturing system with ten machines is selected. The configuration of the manufacturing system is determined based on configuration of job shop considered by previous researchers [12,19]. It has been pointed out by researchers that six machines are sufficient to represent the complex structure of a job shop manufacturing system [16,20] and variations in job shop size don't significantly affect the relative performance of dispatching rules [12,20]. For the same reason, most of the researchers addressed a job shop scheduling problem with less than ten machines [15,21,22].

Job data

Six different types of jobs i.e. job type A, job type B, job type C, job type D, job type E, and job type F arrive at the manufacturing system. All the job types have equal probability of arrival. Job types A, B, C, D, E, and F require 5, 4, 4, 5, 4, and 5 operations respectively.