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Analysis of dynamic control strategies of an FMS under different scenarios

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Abstract

This paper presents a simulation study aimed at evaluating the performances of a flexible manufacturing system (FMS) in terms of makespan, average flow time, average delay time at local buffers and average machine utilization, subject to different control strategies which include routing flexibilities and dispatching rules. The routing strategies under evaluation are 'no alternative routings'; 'alternative routings dynamic'; and 'alternative routings planned'. Above routing strategies are combined with seven dispatching rules, and studied in different production volume which varies from 50 to 500 parts. In addition, impacts of both infinite and finite local buffer capacities are analyzed. Since an FMS usually deals with a variety of products, effects of changing the part mix ratio are also discussed. Finally, machine failure is also introduced in this research to study the effects of machine reliability on the system. Simulation results indicate that the 'alternative routings planned' strategy outperforms other routing strategies if the local buffer size is infinity. However, there is no particular dispatching rule that performs well in all buffer size settings but infinity buffer size is not the best choice with respect to the four performance measures. In addition, the four performance measures, except machine utilization, under different control strategies seem quite insensitive to the variation in part mix ratios.

Keywords: Flexible manufacturing systems; Routing flexibility; Control strategies; Simulation

1. Introduction

Flexible Manufacturing System (FMS) is an integrated computer controlled system that consists of, but not restricted to, computer numerical controlled (CNC) machine tools, and automated material and tool handling devices. An FMS is capable of simultaneously handling a variety of product types in small to medium-sized batches and at a high rate comparable to that of traditional assembly lines which is designed for high-volume or low-variety manufacturing system. This system can process any products that belong to a certain number of families within its stated capacity according to a predetermined schedule. Usually, the system is designed such that manual intervention and change over time are minimized. Over the past years, increase in customer expectation affected mainly the assembly phrase of production, which assembles mass-produced parts into various end-products. However, customer's expectation now requires suppliers to produce quality individual parts that make up the end-products. In order to stay competitive; it is becoming more imperative to fulfill their expectations by adapting FMSs.

In general, there are two types of problem that need to be addressed in an FMS, namely design problems and operational problems [1]. The former deals with selection of FMS components while the latter concerns the utilization aspects of FMSs. The focus of this paper is on the operational problems—more specifically production planning and scheduling problems. Stecke [2] found that production planning in an FMS is more difficult than in assembly lines or job shop since each machine is versatile and is capable of performing different operations. In addition, the system can process several different part types simultaneously, and each part may have more than one route in the system.

Flexibility in FMSs is important to its success. Browne et al. [3] defined eight different types of

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flexibilities in the context of FMSs. These are machine flexibility, process flexibility, product flexibility, routing flexibility, volume flexibility, expansion flexibility, operation flexibility, and production flexibility. In this paper, routing flexibility with different dispatching rules will be examined against product flexibility and volume flexibility in a simulation study.

More specifically, the main purpose of this paper is to study the effects of different combinations of routing and dispatching strategies on the performances of an FMS under different scenarios. There are three routing strategies, No Alternate Routings (NAR), Alternate Routings Dynamic (ARD), and Alternate Routings Planned (ARP). These three routing policies are combined with seven dispatching rules in a simulation study under different production volume. Effects of changing the part mix ratio, local buffers sizes and machine failure have also been investigated. Four different performance measures, namely, makespan, average machine utilization, average flow time, and average delay at local input buffers, are recorded for evaluation. Results indicate that the ARP strategy outperforms other routing strategies if the local buffer size is infinity. There is no single dispatching rule that performs well in all buffer size settings, but infinity buffer size is not the best choice with respect to the four performance measures. In addition, the four performance measures, except machine utilization, under different control strategies seem quite insensitive to the variation in part mix ratios.

The rest of this paper is organized as follows: In Section 2, literature review is presented. In Section 3, the FMS model is presented. In Section 4, discussion of the simulation results are presented. Finally, conclusions of the research are given in Section 5.

2. Literature review

Alternate operations play an important role in the performances of FMSs. Wilhelm and Shin [4] investigated the influence that alternate operations might have on the performances of an FMS. The results showed that alternate operations could reduce flow time and increase machine utilization.

Due to high investment cost in FMSs, it is important to use computer simulation to support and analyze process operation and prediction of the performances of an FMS. Goyal et al. [5] highlighted the advantages of using simulation methodology for modeling FMSs. Simulation was employed to examine the effects of scheduling rules. Various performance measures such as throughput, utilization, etc. had been examined. Caprihan and Wadhwa [6] also made use of simulation methodology to find out the impacts of routing flexibility on the performances of an FMS.

The size of local buffers in FMSs may be restricted by limited physical space and high investment in real life applications. Therefore it is important to investigate the impacts of limited buffer capacity on the performance of FMSs. Matsui et al. [7] found that system throughput in the case of infinite local buffers is greater than that in the case of finite local buffers. Almedia and Kellert [8] focused on using queuing network (QN) models for quantitatively evaluating the steady-state performance of flexible manufacturing systems at the strategic and tactical decision levels. The rationale of using QN is due to the fact that QN specifies the behavior of each station of the network with regard to customers that may visit this station from the resource point of view.

FMS operations involve several decisions making. It can be divided into planning and scheduling. The planning phase considers pre-arrangement of parts and tools before an FMS begins to process, and the scheduling phase considers routing parts while the FMS is in operation. Tang et al. [9] presented an alternative machine approach to scheduling parts, machines and AGVs. Tung et al. [10] also developed an FMS scheduling system that pursues the global benefit of a system in multi-objective and multi-task environment. Mohamed et al. [11] examined the effects of scheduling rules and routing flexibility on the performance of a constrained, random FMS. Results indicated that the behavior of scheduling rules in a more constrained FMS environment were very similar to those of less constrained environment. O'Kane [12] analyzed reactive scheduling in FMSs. Selecting the appropriate scheduling rules is important in FMS decision making. Sabuncuglu [13] suggested that performances of FMSs can be improved considerably by using appropriate scheduling rules. Zhao and Wu [14] presented a genetic algorithm approach to flexible-routing scheduling problems. They implemented the concepts of a flexible-routing scheduling problem, which involves routing selection, machine selection, and processing sequence selection. Pelagagge and Cardarelli [15] suggested that loading strategy, which is a dynamic rule that a group of jobs is loaded for production based on some heuristic rules, is the most critical and important scheduling decision in an FMS. Xiaobo et al. [16] investigated the optimal work routing policy that maximizes the total expected reward earned by operating machines for an FMS.

Chan [17] and Caprihan and Wadhwa [6] studied the effects of different levels of routing flexibility to the performance of an FMS based on Taguchi experimental design. Product mix flexibility is an important issue in FMSs. Product mix flexibility is the ability to produce a wide range of different products, to accommodate modifications to exiting products, and to assimilate new products. Anderson [18] studied the combined impact of product mix on capacity management decision