Impact of Interruptions on Schedule Execution in Flexible Manufacturing Systems

SANJAY JAIN
Virginia Polytechnic Institute and State University, Alexandria Research Institute, 206 N. Washington Street, Suite 400, Alexandria, VA 22314, USA

WILLIAM J. FOLEY
Rensselaer Polytechnic Institute, Decision Sciences and Engineering Systems, Troy, New York 12180-3590, USA

Abstract. Finite capacity scheduling software packages provide a detailed advance plan of production events. However, the execution of this advance plan is disrupted by a myriad of unanticipated interruptions, such as machine breakdowns, yield variations, and hot jobs. The alternatives available to respond to such interruptions include modifying the existing schedule, regenerating the complete schedule, or doing nothing and letting the production system gradually absorb the impact of the interruption. This article reports on a simulation study aimed at understanding the impact of an interruption on a schedule in order to build a knowledge base for intelligent selection of a response from a set of alternatives. The results of the experimental study are used to identify significant major factors and their interactions. The results are discussed to draw insights into the performance of a flexible manufacturing system following an interruption. The causes leading to particular performance anomalies are extensively discussed and mechanisms for propagation and absorption of the effect of interruptions in manufacturing systems are inferred. Practical implications for the development and implementation of schedules are deduced and areas for further research proposed. This study provides the groundwork necessary to proceed with the development of strategies for responding to interruptions.

Key Words: absorption, FMS, interruption, propagation, scheduling

1. Introduction

Schedules for a manufacturing system are typically generated based on assumptions of static job lists, deterministic operation times, no machine tool failure, and no specific allowance for material handling (Hadavi, Shaharay, and Voigt, 1990; Sule, 1994). In real life these assumptions are not met and interruptions occur leading to a part flow pattern that is different from that predicted by the schedule. Some parts arrive later and others earlier than their scheduled time at processing stations (Parunak, 1991). Such disruptions to the schedule lead to a performance that is worse than planned.

At the operational level, decisions have to be made on how to cope with these disturbances so that the effect on schedule performance is minimized. For example, one decision to be made at each processing station is “which part goes next.” Conventionally, these operational level decisions have been the responsibility of the shop foremen, who, based on their perception of the shop floor information and due dates, decided the response to the

*To whom correspondence should be addressed.
interruptions by choosing the next part. In many cases, the decision is made by the operator. However, such decisions call for a more detailed investigation than has been traditionally given to them (Samadi, Morris, Rubin, Wong, and Ekroot, 1990).

The need for a more detailed analysis becomes even more crucial in the case of flexible manufacturing systems (FMSs). An FMS contains capital-intensive equipment that often necessitates high utilization in order to justify the investment. High utilization calls for efficient scheduling and control, including the decision making involved at the operational level. At times an FMS may be restricted to low utilizations in order to achieve a fast response. Again, the goal of a fast response necessitates efficient scheduling and control. Of course, another major reason for a well-defined decision framework is that in an FMS, the shop foreman or operator may no longer be available to make the operation-level decisions; the logic for such decisions has to be built into the controlling computer. Systems for supervisory control of manufacturing systems have been proposed (Manivannan and Banks, 1992).

A hierarchical manufacturing control system in Figure 1 is envisaged as a context for this work (Suri and Whitney, 1985). Under this hierarchy, the operation control level has to respond to different kinds of interruptions. The objectives for the operation control level are provided in the form of a schedule by the scheduling level. On the occurrence of an interruption, the operation level has to react in a way so as to minimize the effect on the performance of the schedule. In the event that the operation control level is unable to “cope” with the interruptions, it requests the higher level to modify its objectives, that is, the schedule. Note that the system status information flow from operation control level to scheduling level will be on an exception basis within a scheduling period, and on a regular basis at the end of each scheduling period. However, the system status and schedule status information flow from the real system to the operation control level is on a real-time basis.

Jain (1988) proposed a decision framework for interruption handling in FMSs. The response to an interruption is based on its estimated impact. The impact on the scheduled

![Figure 1. Information flow for FMS operation control level.](image-url)