

A flexible machining cell (FMC) consists of several highly versatile numerically controlled machines. FMCs typically machine a wide variety of parts and require a corresponding wide variety of cutting tools. Systems comprised of one or more FMCs are the fastest growing class of flexible manufacturing systems. This paper addresses the problem of generating a job and tool schedule for an FMC with identical machines. Schedule quality is a function of job completion times (as measured according to the weighted flow time criterion) and tool movement where the relative importance between these two potentially conflicting performance measures can vary from problem to problem. A heuristic procedure is proposed and evaluated in an experiment that draws on data from industry.

1. Introduction

Many scheduling problems in practice are characterized by two basic objectives--the timely completion of jobs and high system efficiency. The relative importance between these two potentially conflicting objectives may vary from shop to shop or even from day to day within a single shop. In spite of this common property, procedures which incorporate both objectives are rare in the scheduling literature. In the following, we propose and evaluate a scheduling procedure for a problem that includes both objectives.

This research is motivated by the problem of scheduling jobs and tools in a multiple resource constrained flexible machining cell (FMC). An FMC is a flexible manufacturing system (FMS) that performs machining operations and consists of several (often identical) highly versatile machines. Jaikumar and Van Wassenhove (1989) report that systems comprised of one or more FMCs are the fastest growing class of FMSs. These cells typically machine a wide variety of parts and require a corresponding wide variety of cutting tools.

Much of the research in FMS scheduling is based on a model where
tool scheduling decisions can be separated from detailed job scheduling decisions; job schedules are developed assuming that tool-to-machine assignments are fixed for the duration of a given production window. (In actuality, some tool movement usually occurs as worn-out tools are replaced but this level of detail is typically not addressed at this stage in the planning process.) However, there is a need for methods where the scheduling of tool movement is allowed to be more dynamic and not limited to a few select points in time (see Ammons, Lofgren, and McGinnis 1985; Buzacott and Yao 1986; Rachamadugu and Stecke 1986; Rhodes 1988).

The production system under study is modeled after a Cincinnati Milacron FMC that is comprised of identical machines. Each job can be processed in its entirety by any one of the machines provided the appropriate tools reside in the tool magazine. Tools may be added to, and removed from, a tool magazine while the machine is running. This feature, which is common to many FMCs, invites consideration of schedules which include more regular tool movement.

The problem is constrained by multiple resources. One machine and multiple tools are simultaneously required for the processing of a job. However, it is also true that machines are the dominant binding resource in practice. This phenomenon is a result of the large cost difference between a machine and a tool.

A candidate list of jobs with known process times and tooling requirements is given, and a job and tool schedule is to be developed. The forward visibility of a job and tool schedule is important for this problem type. Tools cannot instantaneously be loaded into a tool magazine. A schedule allows for tools to be in place by the time they are needed. A job schedule specifies job start and completion times by machine; a tool schedule specifies times or time windows during which tools are to be added to, or removed from, particular tool magazines.

Schedule quality is a function of tool movement and projected job completion times. Tool movement occurs when tools are reassigned to another machine and when tools are removed from a tool magazine in order to make room for new tools. In general, schedules with a high level of tool movement require a high level of coordination between system components and are therefore susceptible to inefficiencies (for example, high management effort, instances where a machine is idle awaiting the installation of tools). Therefore, a schedule with low tool movement is desirable. On the other hand, a strict policy of no tool movement during a production window limits schedule flexibility and can result in the delay of high priority jobs.