Abstract We consider the problem of simultaneously determining the number of machines (and/or workers), the assignment of tasks (and related tools and components) to these machines, and the number of jobs circulating in a flexible assembly system (FAS), to satisfy steady-state throughput requirements for a family of similar products at minimum cost. We focus on situations where there are precedence relations among the various tasks, as is common in assembly systems. We present a framework for solving this problem based on a heuristic decomposition approach which involves the solution of only a few types of sub-problems. We demonstrate the efficiency and effectiveness of the overall procedure using a number of example problems.

Keywords Manufacturing system design · Flexible manufacturing systems · Capacity planning

1 Introduction

Flexible assembly systems (FASs) are used to accommodate the increased product variety and volatile demands that have become common in today’s
competitive marketplace as product life cycles become shorter. Making decisions regarding equipment acquisitions in such a context is not easy. Unlike more traditional inflexible systems, many different products are assembled concurrently, and the production rate of the system as a whole may be very sensitive to the allocation of machines to tasks, and the resultant product routings. Consequently, standard capacity planning models, which simply constrain the total processing time assigned to a machine to be less than the total number of machine hours available, are unable to account for the impact of these factors.

Clearly, important equipment acquisition decisions should not be made without a very careful and detailed analysis. Yet, oftentimes, the most difficult part of this process is “getting in the right ballpark,” and understanding the interactive effects of various decisions. Our goal in this paper is to present a framework that permits one to identify “ballpark” solutions quickly. In the process, we also provide tools that allow a better understanding of the interactive effects of various operational decisions. We consider systems with a particular structure in order to illustrate our framework. Systems with significantly different features may need to be modeled and analyzed using different methods. However, our framework provides a pragmatic approach to decomposing the problem into manageable pieces, and we view this decomposition as the primary contribution of this paper. We now turn to a description of the structure of the system we use to illustrate our framework.

We consider flexible assembly flow systems in which all machines within the system have identical capabilities, although at any point in time, the specific tasks that each machine can perform are limited by the tooling and numerical control (NC) programs currently loaded, and the capabilities of the machine operator, where appropriate. The system consists of multiple stations in series, where each station contains one or more identically equipped machines (same tools, same NC programs, and same operator capabilities). A part proceeds from one station to the next, in the specified sequence, bypassing those where no work needs to be performed.

In most assembly systems, processing times are short relative to the time required to move a job from machine to machine. Consequently, performing multiple tasks on the same machine may considerably reduce job flow time and material handling effort. More than one machine may be assigned to a station to ensure that there is sufficient capacity to satisfy production targets. When a part needs to be processed by a station, it is processed by only one machine at that station, since all machines in the station are capable of performing the same set of tasks.

Our reason for considering multiple stations is that it is often impossible or impractical for a single machine or worker to perform all of the tasks required to complete a finished product. In assembly systems, one primary reason for this is that all of the assembly components cannot be conveniently stored at or near the station. We associate a staging space with each task: typically, the staging space would be based on the size of the various assembly components and the associated feeders needed for the task (see Fig. 1).