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Evolutionary algorithms for scheduling a flowshop manufacturing cell with sequence dependent family setups

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Abstract

This paper considers the problem of scheduling part families and jobs within each part family in a flowshop manufacturing cell with sequence dependent family setups times where it is desired to minimize the makespan while processing parts (jobs) in each family together. Two evolutionary algorithms—a Genetic Algorithm and a Memetic Algorithm with local search—are proposed and empirically evaluated as to their effectiveness in finding optimal permutation schedules. The proposed algorithms use a compact representation for the solution and a hierarchically structured population where the number of possible neighborhoods is limited by dividing the population into clusters. In comparison to a Multi-Start procedure, solutions obtained by the proposed evolutionary algorithms were very close to the lower bounds for all problem instances. Moreover, the comparison against the previous best algorithm, a heuristic named CMD, indicated a considerable performance improvement.

Keywords: Flowshop scheduling; Family sequence dependent setups; Manufacturing cells; Group technology; Evolutionary algorithms; Empirical results

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1. Introduction

Cellular manufacturing consists of processing a large number of parts on a given number of machines in such a way that it combines the flexibility of a job-shop while providing the efficiency offered by the flowshop production. It consists of grouping the machines (called *manufacturing cells*) and the parts into a specified number of *part families* where each part in a part family requires the same group of machines. In this environment, cellular manufacturing requires three planning activities before actual production can take place. First, the problem of grouping machines into various manufacturing cells (called *cell formation*) needs to be solved. This process also defines the part families where a part family is a set of parts (called *jobs* in this paper) that have similar requirements in terms of tooling, setups and operations sequences. Second, parts need to be assigned (loaded) to specified machines (called *machine loading*) in manufacturing cells. Third, the part families need to be scheduled in each of the manufacturing cells. Often, such scheduling problems consist of multiple manufacturing cells and may become rather complex. Therefore, attempts are made to develop a schedule by considering one manufacturing cell at a time. This paper deals with the scheduling problem of a *single manufacturing cell* assuming that the activities related to the cell formation and machine loading have been completed.

In forming and loading the manufacturing cells, part families are assigned to a manufacturing cell based on operation sequences so that materials flow and scheduling are simplified even though the part families produced by a cell may require different tooling. This process may result in each part family requiring the same set of machines where each part is processed on each machine in the same technological order. Such manufacturing cells are called *pure flowshop manufacturing cells* and resemble the traditional flowshops except for the existence of multiple part families. Since parts are assigned to families based on tooling and setup requirements, usually a negligible or minor setup is needed to change from one part to another within a family and hence can be included in the processing times of each job. However, a major setup is needed to change processing jobs in one part family to another part family. This major family setup may be independent or dependent of the sequence in which various part families are processed. To reduce the productivity loss due to family setups, cellular manufacturing uses the concept of group technology (GT) where parts of the same family are processed together on the same set of machines. As manufacturers want to take advantage of group technology (GT) environment, scheduling of jobs grouped into families has become quite significant. Existing applications and scheduling techniques for such problems are discussed by Schaller, Gupta, and Vakharia (2000).

Recent reviews of scheduling research involving separable setups by Allahverdi, Gupta, and Aldowaisan (1999) and Cheng, Gupta, and Wang (2000) showed that most prior research on manufacturing cell scheduling has assumed sequence independent setup times. For the flowshop manufacturing cell scheduling problem involving sequence dependent setup times, Hitomi, Nakamura, Yoshida, and Okuda (1977) described a simulation model and showed that the scheduling rules which considered explicitly sequence dependent setups outperformed rules that did not explicitly do so. Following Schaller et al. (2000) who developed and tested several heuristic algorithms for minimizing makespan in a flowshop with sequence dependent family setup times, this paper assumes that the major family setup times are sequence dependent.

To formally define the above manufacturing cell scheduling problem in a group technology environment, consider that a given set of n jobs, $N=\{1,2,\ldots,n\}$ is to be processed on m machines in the same technological order creating the flowshop structure. We assume that each job belongs to