Computers and Mathematics with Applications 60 (2010) 1014–1025

Contents lists available at ScienceDirect

Computers and Mathematics with Applications

journal homepage: www.elsevier.com/locate/camwa

Designing a mathematical model for dynamic cellular manufacturing systems considering production planning and worker assignment

Iraj Mahdavi [a,*], Amin Aalaei [a], Mohammad Mahdi Paydar [a], Maghsud Solimanpur [b]

[a] *Department of Industrial Engineering, Mazandaran University of Science and Technology, Babol, Iran*

[b] *Faculty of Engineering, Urmia University, Urmia, West Azerbaijan Province, Iran*

ARTICLE INFO

Keywords:
Dynamic cellular manufacturing system
Production planning
Worker assignment
Mathematical programming

ABSTRACT

Since workers have an important role in doing jobs on machines, assignment of workers to cells becomes a crucial factor for full utilization of cellular manufacturing systems. This paper presents an integer mathematical programming model for the design of cellular manufacturing systems in a dynamic environment. The advantages of the proposed model are as follows: considering multi-period production planning, dynamic system reconfiguration, duplicate machines, machine capacity, available time of workers, and worker assignment. The aim of the proposed model is to minimize holding and backorder costs, inter-cell material handling cost, machine and reconfiguration costs and hiring, firing and salary costs. Computational results are presented by solving some examples.

1. Introduction

Cellular manufacturing (CM) involves a number of machine cells where each cell is responsible for the processing of families of similar parts. CM has emerged because of the need of manufacturing organizations to cope with the shorter product life-cycles, time-to-market and a shift to demands for mid-volume and mid-variety product mixes. Comprehensive summaries and taxonomies of studies devoted to cell formation problem (CFP) have been presented in [1–4]. Singh [5] has classified the approaches to cell formation into coding and classification systems, machine-components group analysis methods, graph theoretic methods, neural networks and heuristics, fuzzy clustering based methods, similarity coefficient based mathematical models, knowledge and pattern recognition methods, mathematical and heuristic methods. Selim et al. [4] have classified the CFP approaches into cluster analysis, graph partitioning, descriptive procedures, mathematical programming and artificial intelligence approaches. Recent works on CM design focus on the development of more integrated models and solution methodologies [6–8].

In most researches, CFP has been considered under static conditions in which cells are formed for a single time period with known and constant product mix and demand. The concept of dynamic cellular manufacturing system (DCMS) has been discussed in [9]. In a dynamic environment, a multi-period planning horizon is considered where each period has different product mix and demand requirements. Consequently, the formed cells in a period may not be optimal and efficient for the next period. Reconfiguration involves three aspects: (1) swapping of existing machines between cells called machine relocation, (2) adding new machines to cells, and (3) removing existing machines from cells. Most methods assume that the production quantity is equal to the demand in each planning period, meaning that production planning is ignored in these studies.

* Corresponding author. Tel.: +98 911 113 1380; fax: +98 111 229 0118.
E-mail address: irajarash@rediffmail.com (I. Mahdavi).

doi:10.1016/j.camwa.2010.03.044

Several authors recently proposed models and solution procedures by considering dynamic cell reconfigurations over multiple time periods [10–15]. These methods assume that the production quantity is equal to demand in each planning period. In reality, however, production quantity may not be equal to the demand as it may be satisfied from inventory or backorders. Thus production quantity should be determined through production planning decisions in order to determine the number and type of machines to be installed in the system. However, in order to determine the production quantities in each planning period, the number and type of machines to be installed in manufacturing cells should in turn be known because of capacity consideration.

Defersha and Chen [16] addressed a dynamic cell formation problem incorporating several design factors such as cell reconfiguration, alternative routings, sequence of operations, duplicate machines, machine capacity, workload balancing, production cost as well as other realistic constraints. Ahkioon et al. [17] developed a preliminary CM model that integrates several manufacturing attributes considering multi-period planning, dynamic system reconfiguration, and production planning and alternate routings. Safaei and Tavakkoli-Moghaddam [18] extend the original model proposed by Safaei et al. [15] with a new contribution on the outsourcing by considering the carrying inventory, backorder, and partial subcontracting to cell formation (CF) and production planning in dynamic cellular manufacturing systems.

One of the main points in CM is the consideration of human issues since ignoring this factor can considerably reduce benefits of the cellular manufacturing. In some previous researches this issue is discussed. Nembhard [19] described a greedy heuristic approach based on individual learning rate for the improvement of productivity in organizations through targeted assignment of workers to tasks. Norman et al. [20] proposed a mixed-integer programming model for assigning workers to manufacturing cells in order to maximize the profit. Bidanda et al. [21] presented an overview and evaluation of the diverse range of human issues involved in CM based on an extensive literature review. In [22], a workforce planning model is presented that incorporates individual worker differences in ability to learn new skills and perform tasks. The model allows a number of different staffing decisions (i.e., hiring and firing) in order to minimize workforce-related and missed production costs. Aryanezhad et al. [23] presented a mathematical model to deal with dynamic cell formation and worker assignment problem with considering part routing flexibility and machine flexibility and also promotion of workers from one skill level. Solimanpur et al. [24] presented a fuzzy goal programming based approach for solving a multi-objective mathematical model of cell formation problem and production planning in dynamic virtual cellular manufacturing systems considering worker flexibility.

In this paper, an integrated mathematical model of the multi-period cell formation and production planning in a dynamic cellular manufacturing system considering the flexibility in worker assignment is proposed. The objective function is to minimize the summation of machine, reconfiguration, inter-cell material handling, inventory holding, backorder, worker hiring, firing and salary costs.

This paper is organized as follows. In Section 2, the proposed mathematical programming model is presented. Section 3 presents an example with computational results to validate and verify the proposed model. The paper ends with conclusions.

2. Problem formulation

In this section the mathematical model of cell formation problem is presented based on dynamic cellular manufacturing system with worker assignment. The objective is minimizing the sum of the penalty of deviation of production volume from the desirable value of the part demand (holding and backorder cost), inter-cell material handling, machine and reconfiguration, hiring, firing and salary worker costs. Main constraints are machine capacity, available time of workers, and production volume. The problem is formulated according to the following assumptions:

- The processing time of each operation of each part type on each machine type is known.
- The demand for each part type in each period is known.
- The capacity of each machine type is known.
- The available time of each worker type is known.
- The number of cells is given and constant through all periods.
- Only one worker is allotted for processing each part on each corresponding machine type.
- Inter-cell material handling cost is constant for all moves regardless of distances.
- Holding and backorder inventories are allowed between periods with known costs. Thus, the demand for a part in a given period can be satisfied in the preceding or succeeding periods.
- Maintenance and overhead costs of each machine type are known. These costs are considered for each machine in each cell and period irrespective of whether the machine is active or idle.
- System reconfiguration involves the addition and removal of machine to any cell and relocation from one cell to another between periods.
- Salary of each worker type is known. This cost is considered for each worker in each cell and period irrespective of whether the worker is active or idle.
- Reconfiguration involves the addition and removal of worker (hiring and firing) to any cell and relocation from one cell to another between periods.