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Computers & Industrial Engineering 46 (2004) 571–588
computers & industrial engineering
www.elsevier.com/locate/dsw

Coordinating production planning in cellular manufacturing environment using Tabu search

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Received 8 July 2002; accepted 24 February 2004

Abstract

In this paper, an integrated model for production planning in cellular manufacturing (CM) systems is proposed. The model considers general CM features such as quadratic terms for inter-cell material handling and decisions for manufacturing cell construction. In addition, the solution of the model will provide production planning decisions such as times to start part processing and levels of finished part inventory. The model is then transformed to equivalent simpler models and is solved by Tabu search based procedure. Results from testing numerical examples show encouraging behaviors of the developed model and algorithm.

Keywords: Production planning; Cellular manufacturing; Integer programming; Tabu search

1. Introduction

Cellular manufacturing (CM) is a widely used approach for organizing machines and people into groups to produce a variety of parts in part families. CM is also effective in implementing flexible manufacturing systems and is normally associated with automated batch production (Singh, 1996). Successful CM implementations have resulted in reduced set-up times, reduced material flow and in-process inventory, better system management, improved production efficiency and product quality (Hyer & Wemmerlov, 1989; Wemmerlov & Johnson, 1997). In the past 30 years, CM problems have been studied by many researchers as summarized by Reisman, Kumar, and Cheng (1997), and Sarker and Mondal (1999). Recently, CM research has expanded to developing integrated models and methods as discussed in Song and Choi (2001). For example, Atmani, Lashkari, and Caron (1995) presented a model

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0360-8352/$ - see front matter
doi:10.1016/j.cie.2004.02.002

for simultaneous cell formation and operation allocation. Lockwood, Mahmoodi, and Mosier (2000) studied CM scheduling problems. Production planning in CM systems was discussed in Chen (2001) and Olorunniwo (1996). A variety of effective methods were developed to investigate and solve CM problems. These include traditional mathematical programming (Chen, 1998; Heragu & Chen, 1998) and simulation studies (Shang & Tadikamalla, 1998; Shinn & Williams, 1998). Non-traditional methods such as neural networks, Tabu search, genetic search and simulated annealing have also been used to search for optimal solutions of various CM problems as can be found in Jamal (1993), Joines, Culbreth, and King (1996), Lozano, AdensoDiaz, and Onieva (1999), Rao and Gu (1995), Sofianopoulou (1997). Some of the methods were compared in Asokan, Prabhakaran, and Kumar (2001) for their effectiveness and efficiency in solving CM problems.

In this paper, we followed the integrated approach to study a production planning problem over a certain planning horizon in CM systems with fixed charge cost. Most existing mathematical programming models for cell formation assume that the number of cells has been given and the cells have been identified. The solutions of the problems were then to allocate proper machines to the cells and to decide the part families to be processed. The purposes are to minimize certain criteria such as material handling cost or dis-similarities among part families. For CM planning, Schaller, Erenguc, and Vakharia (2000) proposed an integer programming model to simultaneously determine the cells to be used and units of parts to be processed in different time periods. In this paper, we consider a similar production planning problem, but the integer programming model developed in this research has more general features where not only the number of cells, but also the formation of the cells are to be determined by the solution of the model. The objective of the model is to minimize the total cost including inter-cell material handling cost, fixed cell set-up cost, production set-up cost and product inventory cost in the system. Detailed description of the problem and the development of the integer programming model are given in Section 2. Due to the NP-hardness of the model we employ an embedded optimization technique to transform the original model to a parametric LP problem. A specially designed Tabu search (Glover & Laguna, 1997) procedure is developed to find optimal or near-optimal solution of the transformed problem. Model transformations are presented in Section 3. Details of the Tabu search process are discussed in Section 4. We tested the developed methods using several numerical examples. Detailed data and computational results of one of the example problems are presented in Section 5. In Section 6, we present the summary, conclusions and our plans for future research in this area.

2. Model description

Consider a manufacturing system consisting of a number of machines to process different types of parts. Each part-type may require some or all of the machines for processing. Machines are grouped into a number of manufacturing cells. The types and units of machines to be allocated in the constructed cells will be determined for minimum production costs. In addition, we need to decide the best time periods for part processing in a production planning horizon of multiple time periods. Finished parts inventory is allowed in the production system. A non-linear mixed integer programming model was developed to solve this CM production planning problem. The objective function of this model is to minimize the total cost including inter-cell material handling cost, fixed cost for setting up cells, fixed production cost, inventory cost and machine cost. In solving this problem, we assume that there is a single process plan for each part-type. Since there is no alternative process plans, part processing cost is not included in