Available online at www.sciencedirect.com
ScienceDirect
Applied Mathematics and Computation 190 (2007) 662–670
APPLIED MATHEMATICS AND COMPUTATION
www.elsevier.com/locate/amc

Designing a new mathematical model for cellular manufacturing system based on cell utilization

Iraj Mahdavi [a,*], Babak Javadi [a], Kaveh Fallah-Alipour [a], Jannes Slomp [b]

[a] Department of Industrial Engineering, Mazandaran University of Science and Technology, P.O. Box 734, Babol, Iran
[b] Faculty of Management and Organization, University of Groningen, Landleven 5, P.O. Box 800, AV Groningen, The Netherlands

Abstract

In this paper, we propose a new mathematical model for cell formation in cellular manufacturing system (CMS) based on cell utilization concept. The objective of the model is to minimize the exceptional elements (EE) and number of voids in cells to achieve the higher performance of cell utilization. A number of test problems from the literature are carried out to verify the good ability of the proposed model to form part–machine grouping in comparison of the previous models ([S.J. Chen, C.S. Cheng, A neural network-based cell formation algorithm in cellular manufacturing, International Journal of Production Research 33 (2) (1995) 293–318], [I. Mahdavi, O.P. Kaushal, M. Chandra, Graph-neural network approach in cellular manufacturing on the basis of a binary system, International Journal of Production Research 39 (13) (2001) 2913–2922]).

Keywords: Cell formation; CMS; Mathematical model; Cell utilization

1. Introduction

Group technology (GT) is a manufacturing philosophy conceived during the 1940s in the USSR ([3]) for improving productivity in batch production system. Batch manufacturing is estimated to be the most common form of production. There is a growing in need to make batch manufacturing more efficient and productive. GT is best-suited to a batch-flow production system where many different parts, having relatively low annual volumes, are produced in small lot sizes. It involves the grouping of parts into part-families and machines into machine-cells so that a family of parts can be produced within a group of machines. The problem of determining machine-groups and part-families is called the machine-cell formation (MCF) or machine-component grouping (MCG) problem.

Cellular manufacturing is an application of the group technology philosophy to designing manufacturing systems. The main idea of group technology is to identify similar manufacturing processes and features, where machines are grouped into machine cells based on their contribution to the production process.

* Corresponding author.
E-mail address: irajarash@rediffmail.com (I. Mahdavi).

0096-3003/$ - see front matter
doi:10.1016/j.amc.2007.01.060

Defersha and Chen [5] proposed a comprehensive mathematical model for the design of CMS based on tooling requirements of the parts and tooling available on the machines. The model incorporates dynamic cell configuration, alternative routings, lot splitting, sequence of operations, multiple units of identical machines, machine capacity, workload balancing among cells, operation cost, cost of subcontracting part processing, tool consumption cost, setup cost, cell size limits, and machine adjacency constraints.

Tavakkoli-Moghaddam et al. [11] presented a new mathematical model to solve a facility layout problem in cellular manufacturing systems (CMSs) with stochastic demands. The objective is to minimize the total costs of inter and intra-cell movements in both machine and cell layout problems simultaneously.

Slomp et al. [9] considered a new type of virtual cellular manufacturing (CM) system, and a multi-objective design procedure for designing such cells in real time. Retaining the functional layout, virtual cells are addressed as temporary grouping of machines, jobs and workers to realize the benefits of CM. The virtual cells are created periodically, for instance every week or every month, depending on changes in demand volumes and mix, as new jobs accumulate during a planning period. The procedure included labor grouping considerations in addition to part–machine grouping. The procedure is based on interactive goal programming methods. Factors such as capacity constraints, cell size restrictions, minimization of load imbalances, minimization of inter-cell movements of parts, provision of flexibility, etc. are considered. In labor grouping, the functionally specialized labor pools are partitioned and regrouped into virtual cells. Factors such as ensuring balanced loads for workers, minimization of inter-cell movements of workers, providing adequate levels of labor flexibility, etc. are considered in a pragmatic manner.

Albadawi et al. [2] proposed a new mathematical approach for forming manufacturing cells. The proposed approach involves two phases. In the first phase, machine cells are identified by applying factor analysis to the matrix of similarity coefficients. In the second phase, an integer-programming model is used to assign parts to the identified machine cells.

Kizil and Ozbayrak [6] developed an algorithm to evaluate the tradeoff between conflicting objectives in process plan selection and cell formation. Consideration of the minimization of inter-cell material movement in cellular manufacturing is necessary but not in itself sufficient to produce a system for which the total work content is minimized. Solving the process plan selection and the cell formation problem for all possible alternative process plans is a time-consuming task, and therefore not economically justifiable.

Wang [12] presented a linear assignment algorithm for machine-cell and part-family formation for the design of cellular manufacturing systems. The present approach begins with the determination of part-family or machine-cell representatives by means of comparing similarity coefficients between parts or machines and finding a set of the least similar parts or machines. Using the group representatives and associated similarity coefficients, a linear assignment model is formulated for solving the formation problem by allocating the remaining parts or machines and maximizing a similarity index. Based on the formulated linear assignment model, a group formation algorithm is developed. The results of a comparative study based on multiple performance criteria and many existing data sets show that the presented approach is very effective and efficient, especially in dealing with large-sized problems.

Mahdavi et al. [7] proposed a graph-neural network manufacturing approach for cell formation problems in group technology. Effort has been made to develop an algorithm that is more reliable than conventional methods. This research has the ability to handle large scale industrial problems without the assumption of any parameter and the least exceptional elements in the presence of bottleneck machines and/or bottleneck parts.

Taboun et al. [10] presented a two-stage procedure for cost effective part family and machine cell formation. First, the problem is formulated as a mixed integer mathematical model for simultaneous machine grouping and part family assignment. This model, which they refer to as the single-stage model, considers the cost tradeoffs of cell configuration, machine procurement and salvage, subcontracting, inter-cell movement, and capital investment, all of which reflect the significance of real life planning aspects. To alleviate the computational burden of this single-stage model, they decompose it into two stages: the first stage is a heuristic for machine cell and part family formations; the second stage integrates the heuristic method with a mathematical program to optimize the various cost aspects.

Chen and Cheng [4] considered a neural network based cell formation algorithm in cellular manufacturing. The adaptive resonance theory (ART) neural network is a novel method for the cell formation problem in group technology (GT). The advantages of using an ART network over other conventional methods are its