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A novel approach to determine cell formation, intracellular machine layout and cell layout in the CMS problem based on TOPSIS method

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Abstract

This paper deals with the cellular manufacturing system (CMS) that is based on group technology (GT) concepts. CMS is defined as identifying the similar parts that are processed on the same machines and then grouping them as a cell. The most proposed models for solving CMS problems are focused on cell formation and intracellular machine layout problem while cell layout is considered in few papers. In this paper we apply the multiple attribute decision making (MADM) concept and propose a two-stage method that leads to determine cell formation, intracellular machine layout and cell layout as three basic steps in the design of CMS. In this method, an initial solution is obtained from technique for order preference by similarity to the ideal solution (TOPSIS) and then this solution is improved. The results of the proposed method are compared with well-known approaches that are introduced in literature. These comparisons show that the proposed method offers good solutions for the CMS problem. The computational results are also reported.

Scope and purpose

In the previous array-based clustering methods, arrays are defined by binary numbers that are indicated as the set of machines that process each part. The main problem of these methods is that grouping parts and machines are made regardless of production volume, operational sequences, production cost, inventory and other production system's limitations.

In this paper we consider the previous common problems of array-based clustering methods and apply the logical idea of TOPSIS method for solving the cellular manufacturing system problem in which arrays in the part-machine incidence matrix are defined by operational sequences. The TOPSIS is a multiple attribute decision making (MADM) technique in which the alternatives are ranked by their distances between positive and negative ideal solution.

Keywords: Group technology (GT); Cellular manufacturing system (CMS); Multiple attribute decision making (MADM); TOPSIS; SAW

1. Introduction

Group technology (GT) is a manufacturing philosophy that analyses, determines and assigns the parts, which are to be manufactured, into a number of part families and assigns the machines into a number of cells as well (Chana et al. [1]). Cellular manufacturing system (CMS) is based on the GT concept that is identified as a technique for

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improving productivity and efficiency in production firms by reducing setup times, lead times, working in process (WIP), lot sizes, throughput times, material handling cost, tooling cost, labor cost and production equipment cost. Cell formation, intracellular machine layout and cell layout are three basic and important steps in the design of CMS.

Cell formation problem (CFP) that is also called part-machine grouping problem is defined as grouping the parts into part families and the machines into machine cells and then assigns the part families into corresponding machine cells. Joines et al. [2] and Selim et al. [3] classified the proposed methods for solving CFP as follows: array-based method, heuristic methods, hierarchical methods, graph partition methods, artificial intelligence (AI) methods and mathematical programming methods.

The array-based clustering methods are based on the part-machine incidence matrix (PMIM). In the PMIM, rows and columns indicate machines and parts, respectively. Each column of PMIM is an array of "0–1" numbers, which indicates the set of machines that produce each part. The well-known array-based clustering methods are: the bond energy algorithm (BEA) by McCormick et al. [4], the rank order clustering method (ROC) by King [5] and the direct clustering algorithm (DCA) by Chan and Milner [6]. These methods, group parts and machines regardless of the production volume, operational sequences, production cost, inventory and other limitations in the production system, which is a main problem for them.

The hierarchical clustering based methods are defined by an input data set to determine similarity or distance function and determine a hierarchy of clusters or partitions. The single linkage clustering (SLC) dendogram proposed by McAuley [7] uses measure of similarity between machines. This model that is based on the mathematical coefficient uses the distance matrix to determine machine groups. But the major cause for drawback of SLC is the "chaining problem". Therefore, researchers improved it by adding more inputs, such as production volumes (proposed by Seifoddini [8] who uses average linkage clustering, (ALC) algorithm), part operational time and operation sequences (proposed by Gupta and Seifoddini [9]). Also, Yasuda and Yin [10] who proposed a method on dissimilarity measure for solving CFP.

Recently many researchers have focused on the approaches based on the AI for solving the part-machine grouping problem; for example, Tabu search approach [11,12], simulated annealing [13–16], neural network [17–19], genetic algorithms (GA) [20–23] and fuzzy mathematics [24,25]. Although these models have provided good results but their efficiency, measured by CPU time, has reduced since the number of parts and/or machines is increasing. Other methods for solving CFP are based on heuristic methods [26,27], graph partition methods [28,29] and mathematical programming methods [30–34].

According to the mentioned concepts, many papers are written on CFP, but there are few papers on the cell layout problem (CLP). The CLP is defined as a cell sequencing problem that arises when some parts cannot be finished within one cell only. They must be sent to another cell for further operations.

Chaieb and Korbaa [35] studied on a micro-view of CFP and suggested a solution for intracellular machine layout. AL-Hakim [36] studied on the facility layout problem (FLP) by GA. Both of them offered a solution that does not consider the CLP. Wong et al. [37] suggested a method for solving the local machining selection and process sequencing problem by fuzzy approach and GA as well as Das [38] who proposed a model for CLP. These papers have tried to find a solution for solving CLP without attending to CFP, thereby their solution is not so accurate to design a CMS. Chana et al. [1] proposed a two-stage method that solves CFP and CLP simultaneously by GA.

In this paper the approach presented by Ahi et al. [39] is modified to solve the CMS problem, completely, by considering the operational sequence. The reminder of this paper is organized as follows; a description of simple additive weighting (SAW) and technique for order preference by similarity to the ideal solution (TOPSIS) method is given in Section 2. It is followed by a description of the proposed method is Section 3. Numerical examples and results are shown in Section 4. And the paper is concluded in Section 5.

2. SAW and TOPSIS methods

First a description of SAW and TOPSIS methods that are used in this research will be introduced. Suppose a MADM problem has m alternatives, $A_1, A_2, \ldots, A_m$ and n decision criteria, $C_1, C_2, \ldots, C_n$. Each alternative is evaluated with respect to the n criteria. All the alternatives performances, related to each criterion from a decision matrix, are denoted by $\mathbf{R} = (r_{ij})_{m\times n}$. Let $W = (w_1, w_2, \ldots, w_n)$ be the relative vector presenting the criteria weights, satisfying $\sum_{j=1}^{n} w_j = 1$.