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A literature review on cell formation problem in a batch oriented production system

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ABSTRACT

One of the fundamental problems in cellular manufacturing system is the formation of part families and machine cells that is the cell formation. For cell formation the part families are identified that require similar processing on a set of machines. In turn, these machines are grouped into cells. Each cell is capable of satisfying all the requirements of the part family assigned to it. This paper address the major works in the field of machine part cell formation problem in a batch oriented production system. More specifically this paper discusses about different methods, models and algorithms developed for finding the solution for the primary problem of design of manufacturing cells.

Keywords- Cell formation problem, Cellular manufacturing, Mathematical programming, Group technology, Genetic algorithm.

1. INTRODUCTION

The group technology (GT) concept in manufacturing was first introduced by Flanders in 1925.In 1959, Mitrofonov published a book on scientific principles of GT and Burbidge in 1960 proposed a systematic planning approach for GT called production flow analysis. From then onwards there has been a lot of methods, models and algorithms developed for finding the solution for the primary problem of design of manufacturing cells. In the last three decades of research in cell formation, researchers have mainly used zero-one machine component incidence matrix as the input data for the problem. Group technology is a manufacturing philosophy in which similar parts are identified and grouped together to take advantages of their similarities in manufacturing and design. Cellular manufacturing is a successful application of group technology (GT) concepts. Burbidge [8] defined group technology(GT) as an approach to the optimization of work in which the organizational production units are relatively independent groups, each responsible for the production of a given family of products. One of the first problems encountered in implementation of a cellular manufacturing is formation of product families and machine cells. The objective of this product-machine grouping problem is to form perfect groups in which products do not have to move from one cell to the other for processing. When solving this problem researchers have concluded that the solution methodologies for the MPCF problem must focus attention on the block-diagonalization of the given machine-part incidence matrix.

The best solutions to MPCF problem are those that contain a minimal number of voids(zeros in the diagonal blocks) and a minimal number of exceptions(ones outside of the diagonal blocks). At the conceptual level of cell formation many manufacturing factors are ignored and only the machining operations of the products are considered. This has the advantage that the manufacturing system can be represented by a binary machine-part incidence matrix. In this paper, an attempt has been made to review the major works that has been done so far on machine part cell formation problem.

The rest of this paper is organized as follows: Section 2 describes about graphical approach used to solve the cell formation problem. Section 3 talks about array based clustering techniques used for cell formation problem .Section 4 gives brief description of mathematical programming methods for the solution of cell formation problem. Section 5 discusses about genetic algorithm based technique for manufacturing cell formation problem. Section 6 summarizes other different approaches used for cell formation. Finally in section 7, some general insight with future research direction is discussed.

2. GRAPHICAL APPROACH

Graphical method is first approach used by the researcher to solve the cell formation problem in GT. Graphical techniques are evaluated time to time to get optimum solution. Rajagopalan & Batra[35] used graph theory to solve the grouping problem.

Vannelli and Kumar [23] solved a graph decomposition problem to determine machine cells and part families for a fixed number of groups and with bounds on cell size. Their algorithm for grouping in flexible manufacturing systems is also applicable in the context of GT. Vannelli and Kumar [23] developed graph theoretic models to determine machines to be duplicated so that a perfect block diagonal structure can be obtained. Later Kumar and Vannelli [43] developed a similar procedure for determining parts to be subcontracted in order to obtain a perfect block diagonal structure.

3. ARRAY-BASED CLUSTERING TECHNIQUES

Array-based clustering methods perform a series of column and row permutations to form product and machine cells simultaneously. Existing cluster analysis methods are reviewed and a new approach using a rank order clustering algorithm is described which is particularly relevant to the problem of machine-component group formation by King [26]. A comprehensive comparison of three array-based clustering techniques is given by Chu and Tsai [13].The quality of the solution given by these methods depends on the initial configuration of the zero-one matrix. An efficient nonhierarchical clustering algorithm, based on initial seeds obtained from the assignment method, for finding part-families and machine cells for group technology(GT) is presented by Gupta & Seifoddini[20] which aim was to minimize the inter-cell movements and blanks(machine idling).Another efficient non-hierarchical clustering algorithm, based on initial seeds obtained from the assignment method, for finding part-families and machine cells for group technology(GT) is presented by Srinivasan & Narendran[38] which aim is to minimize the exceptional elements(inter cell movements) and blanks(machine idling).Later a clustering approach of the non-hierarchical type was proposed by Nair & T.T Narendran [32] which clusters machines and components on the basis of sequence data. The algorithm gives encouraging results which provide better optimum solution than the previous approaches.

4. MATHEMATICAL PROGRAMMING METHODS

Mathematical programming methods treat the clustering problem as a mathematical programming optimization problem. At first Choobineh [12] used a cluster algorithm to form the part families and an integer programming model was proposed for the cell formation. Then Gunasingh & Lashkari [19] formulated an integer programming problem to group machines and products for cellular manufacturing systems.

A mathematical model and solution procedure for the group technology configuration is proposed by Askin & Chiu [3]for the grouping of individual machines into cells and the routing of components to machines within cells. A nonlinear mathematical programming model is developed by Adil,Rajamani,& strong [2] for cell formation that identifies part families and machine groups simultaneously

which objective is the minimization of the weighted sum of the voids and the exceptional elements.They developed an assignment allocation algorithm(AAA) and a simulated annealing algorithm(SAA) to solve the model.Later Akturk and Turkcan[14] proposed an integrated algorithm that solves the machine/product grouping problem by simultaneously considering the within-cell layout problem.

Another mathematical programming model for the cell formation problem with multiple identical machines, which minimizes the intercellular flow,is presented by Xambre & Vilarinho[44].Due to the combinatorial nature of this problem a simulated annealing algorithm is developed to solve it. After that, Tsai & Lee[29] developed a multi-functional MP model that incorporates the merits of related CF models based on the systematic study of MP models.The MP model can offer the suitable modules that include the different objective functions and constraints for user to solve the related problem.

A comprehensive mathematical model for the design of CMS based on tooling requirements of the parts and tooling available on the machines was proposed by Defersha & Chen[15].After that, Mahdavi,Shirazi & Paydar [49] developed a heuristic algorithm based on flow matrix for cell formation and layout design in a simultaneous fashion using sequence data.Mahdavi et al.[31] formulated a new mathematical model for cell formation in cellular manufacturing system(CMS) based on cell utilization concept which objective is to minimize the exceptional elements(EE) and number of voids in cells to achieve the higher performance of cell utilization.Later Mahdavi and Mahdevan [50] proposed an algorithm for cellular manufacturing system and layout design using sequence data which is able to identify the cells as well as the sequence of machines in the cells in a simultaneous fashion.

5. GENETIC ALGORITHM BASED TECHNIQUE

All the above techniques for cell formation problems are slightly complex and time consumable. None of the approaches presented above guarantees optimal solutions. So that the modern researchers have the tendency to continue their research activities in the field of group technology for machine part cell formation problem by using genetic algorithm.

Zulawinski, Punch & Goodman [48] developed a grouping genetic algorithm for Bin balancing which is better suited for grouping problems than the classical representations and operators usually applied to grouping or reordering problems. After their approach, genetic algorithms become more popular to the researchers for finding the optimum solution for the cell formation problem. Cheng et al.[10] formulated the cell formation problem as a travelling salesman problem(TSP) and a solution methodology based on genetic algorithms(GAs) is proposed to solve the TSP-cell formation problem.

A genetic algorithm (GA) approach to the machine-component grouping problem with multiple objectives: minimizing costs due to inter-cell and intra-cell part movements, minimizing the total within cell load variation and minimizing exceptional elements was given by Zhao and Wu [46].

Dimopoulos and Mort[16] used a genetic programming for the solution of a simple version of the problem.The methodology is tested on a number of problems taken from the literature and comparative results are presented.Onwubolu and Mutingi [33] developed a genetic algorithm(GA) meta-heuristic based cell formation procedure having the objective function of minimizing the intercellular movement and cell load variation.Zolfagharia and Liang[47] proposed a new genetic algorithm(GA) for solving a general machine/part grouping(GMPG) problem where processing times, lot sizes and machine capacities are all explicitly considered.Grouping efficacy index is used as the performance measure and fitness function of the proposed genetic algorithm. An approach has taken by Gonclaves and Resende [18] for solving the manufacturing cell formation problem in the term of group efficacy where they also used a local search heuristic genetic algorithm. Another genetic algorithm approach was done by Chiang & Lee[11] for cell formation and inter- cell layout to minimize the actual inter-cell flow cost, instead of the typical measure that optimizes the number of inter-cell movements.Yasuda,Hu and Yin [45] proposed an efficient method to solve the multi-objective cell formation problem(CFP) partially adopting Falkenauer's grouping genetic algorithm(GGA).The objectives are the minimization of both the cell load variation and intercellular flows considering the machines capacities, part volumes and part processing times on the machines. Brown & Keeling [22] presented a hybrid grouping genetic algorithm for the cell formation problem that combines a local search with a standard grouping genetic algorithm to form machine-part cells. They used grouping efficacy measurement for computing results for a set of cell formation problem. Pillai et al. [34] suggested a new approach (robust design) for forming part families and machine cells, which can handle all the change in demands and product mix without any relocation. The method suggests fixed machine cell for the dynamic nature of production environment by considering multi-period forecast of product mix and demand, which is solved by genetic algorithm. Tariq, Hussain and Ghafoor [40] developed an approach that combines a local search heuristic(LSH) with genetic algorithm(GA).The results show that new approach not only converges to the best solution very quickly but also produces solutions that are as accurate as any results reported so far in literature. Machine grouping and a genetic algorithm base solution methodology was developed by Shiyas and Pillai [9] where they minimize the heterogeneity of cells formed for the given part-machine incidence matrix by a non-linear integer programming model.

6. OTHERS DIFFERENT APPROACHES

Beside the above approaches, there are some other techniques which were developed by the researchers in different time. Some local heuristic models, non-heuristic network techniques and simulated annealing approaches are formulated to solve the cell formation problem in GT. Waghodekar & Sahu [42] presented a heuristic approach based on the similarity coefficient of the product type for the problem of machine-component cell formation in group technology.

Then Seifoddini & Wolfe [37] developed a similarity coefficient method(SCM) to form the machine cells in group technology applications which is more flexibility into the machine component grouping process and more easily lends itself to the computer application.Askin & Subramaniam[4] proposed a heuristic approach to the economic determination of machine groups and their corresponding component families for group technology.The procedure considers costs of work-in-process and cycle inventory,intra-group material handling, set-up, variable processing and fixed machine costs.After that,Srinivasan, Narendran & Mahadevan [39] presented an assignment model to solve the grouping problem where a similarity coefficient matrix is used as the input to the assignment problem. A non-heuristic network approach is developed by Vohra et al.[41] to form manufacturing cells with minimum intercellular interactions. The machine-part matrix containing machining times was represented as a network which was subsequently partitioned by using a modified Gomory-Hu algorithm to find a minimum intercellular interaction.At first Kumar & Chandrasekharan [27] proposed the concept of grouping efficacy which objective is to maximize the grouping efficiency by reducing the number of voids in the cell and inter-cell movements for the cell formation in group technology.Later Boctor [6] suggested a new linear zero-one formulation to avoid the disadvantages of other alternative formulations to solve the cell formulation problems which having better computational feasibility and efficiency. Finally, a simulated annealing approach is also presented to deal with large-scale problems.

A network flow methodology was developed by Lee & Garcia-Diaz [30] to measure the functional similarity between machines and then to group the machines into cells in such a way that all the parts in each family can be processed in a machine cell. Heragu & Kakuturi [21] solved a real-world machine grouping and layout problem in which the objective is not only to identify machine cells and corresponding part families but also to determine a near-optimal layout of machines within each cell and the cells themselves. A cell formation problem is solved by Islam & Sarker [24] measuring similarity coefficient where a mathematical model is used. They also developed optimum methodology by using a heuristic procedure. Later Adenso-Diaz et al.[1] proposed a configuration of machine cell to minimize the transportation cost by recommending the alternative path routing for the parts movement. Sarker [36] presented a critical review of existing grouping measures, introduces a new measure called 'doubly weighted grouping efficiency measure' and evaluates its relative performance with other existing measures. After that,Kim,Baek &Baek [25] deal with the multi-objective machine cell formation problem to determine the part route families and machine cells such that the total sum of inter-cell part movements and maximum machine workload imbalance are simultaneously minimized. A new Branch-and-Bound(B&B) enhancement is then proposed by Boulif & Atif [7] to improve the GA's performance which is used to solve the cell formation problem by using the binary coding system that has proved superior to the classic integer coding systems.

7. CONCLUSION

One of the key issues in batch oriented production is determining the best formation of the separate manufacturing cells. This is called the machine –part cell formation (MPCF) problem. This problem includes the identification of parts that have similar processing requirements (a part family) and the identification of the set of machines that can process each family of parts. For cells to operate efficiently, all of the machines within a cell should be fully utilized and the amount of inter cell traffic should be kept to a minimum. In order to determine the utilization of machines and the inter cell flow of parts much research has focused on the machine –part incidence matrix. Array-based clustering methods perform a series of column and row permutations to form product/part and machine cells simultaneously. The main problem in array- based clustering methods is that the quality of the solution given by these methods depends on the initial configuration of the zero-one matrix. So in future a new approach can be introduced where the quality of solution does not depend on the initial configuration of the zero-one matrix. Hierarchical methods have the disadvantages of not forming part and machine cells simultaneously. So in future we can develop an approach that can easily overcomes these disadvantages. One limitation of graphical method is that the machine cells and part families are not formed simultaneously. These methods are found to depend on the initial pivot element choice. So we need to develop a method that can overcome these limitations. Mathematical programming methods can solve the machine part grouping problem simultaneously by considering the within-cell layout. But this technique is slightly complex & time consuming. Also none of the approaches presented above guarantees optimal solutions. So that the modern researchers have the tendency to continue their research activities in the field of group technology for machine part cell formation problem by using genetic algorithm.Zulawinski, Punch & Goodman [48] developed a grouping genetic algorithm for Bin balancing which is better suited for grouping problems than the classical representations. After their approach, genetic algorithms become more popular to the researchers for finding the optimum solution for the cell formation problem. The objective of this paper is to presents detail insight about research works on machine part cell formation problem that has been done so far & provides direction for future research so in future; researchers could extend their works & develop new procedure, method & algorithm for manufacturing cell formation problem.

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