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Materials Today: Proceedings 5 (2018) 1766–1775

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Genetic Algorithm approach for Machine Cell Formation with Alternative Routings

Manash Hazarika*, Dipak Laha

Department of Mechanical Engineering, Jadavpur University, Kolkata-700032, India

Abstract

In cellular manufacturing systems, study and optimization of machine cell formation (CF) problems have long drawn attention of researchers. Optimum CF results in reduction of overall processing time, material handling cost, labor cost, in-process inventories and number of set-ups requirements. Also, it simplifies process plans and improves product quality. Since the modern manufacturing machines in a cell are generally multifunctional, the processing of parts are performed following alternative processing routes. The objective of study is to determine the optimal alternative processing route in order to minimize the total intercellular movements of parts in CF problems. Intercellular movements of parts depend on many factors such as parts volume including batch size and number of batches, sequence of processes and routes of production. In this paper, a genetic algorithm heuristic is presented for the CF problem with multiple process routes, sequence of processes and parts volume. Computational experimentation was performed with five benchmark problems. The results demonstrate that the performance of the proposed approach in terms of total intercellular movements of parts and best route selection are either better or competitive with the well-known existing methods.

Selection and Peer-review under responsibility of International Conference on Processing of Materials, Minerals and Energy (July 29th – 30th) 2016, Ongole, Andhra Pradesh, India.

Keywords: *Cellular manufacturing system; Genetic algorithm; Alternative process routings; Intercellular movement of parts; Best route selection*

1. Introduction

In cellular manufacturing systems (CMS), the application of group technology (GT) identifies part families and machine cells, which simplifies the layout design, product design and products flow processes. The application of GT reduces material time, cost, labor requirement, in-process inventories, processing times and number of set-ups [1]. It also, increases productivity, product quality, customers' satisfaction and better management [2-3].

* Corresponding author. Tel.: +91-943-540-3539
E-mail address: memhazarika12@rediffmail.com

Selection and Peer-review under responsibility of International Conference on Processing of Materials, Minerals and Energy (July 29th – 30th) 2016, Ongole, Andhra Pradesh, India.

GT in CMS helps to minimize number of intercellular movements of parts [4]. For grouping machines into machine cells, dissimilar machines are grouped into a machine cell such that processing operations can be accomplished with minimum number of intercellular movements, resulting in reduced overall cost.

In the literature survey, it is seen that most of the cell formation techniques have been applied for single process route, equal production volume and without any sequence of process [5-7]. But in advanced CMSs or in batch-type production systems, a part can be processed following multiple process routings, unequal production volume of parts [8].

In this paper, a genetic algorithm approach is proposed to solve the CF problem with alternative routings, operation sequence of the parts and uneven part volume. Section 2 deals a brief literature review on CF techniques. Section 3 presents the problem formulation of CF problems and problem formulation for alternative routing, operation sequence of the parts and uneven part volume. In Section 4, a genetic algorithm heuristic is presented to solve CF problems. The computational results are presented in Section 5 and finally, Section 6 concludes.

2. Literature review

In literature, most of the CF problems have been studied considering single process routing and unique volume parts. But now-a-days, manufacturing equipment are multifunctional and therefore, production process can be accomplished by more than one process routes. Alternative process routes provide better configuration of cell design and flexibility in cell design [9]. It also reduces intercellular material movements of parts [10] and capital investment in machines providing more independent cells and increase machine utilization [11].

Kusiak and Cho [12], Chow and Hawaleshka [13] recommended similarity coefficient methods for cell formation in alternative routing of parts problems. Chow and Hawaleshka [13] considered part volume also in their model. Gupta [14] extended Jaccard's similarity coefficient integration with alternative routes, operation sequences and uneven part volumes and used complete linkage clustering (CLINK) techniques.

Wafik and Kim [15] used Jaccard's similarity coefficient for cell formation, integrating with alternative routes only. Yin and Yasuda [16] extended the Wafik and Kim [15] used Jaccard's similarity coefficient by integration of process sequence, part volume and processing time. Farouq [17] proposed another modified the Jaccard's similarity coefficient integrated with process sequence and part volume. Hazarika and Laha [18] used Euclidean distances matrix to find correlations of machines for cell formation; integration of part volume, process sequence and process routes problems. They applied SLINK clustering for minimum Euclidean distance.

Other heuristic techniques for alternative routing, uneven part volumes and sequential CF problems include simulated annealing [4, 19], fuzzy approach [20], tabu search [21] and branch and bond [22].

3. Problem formulation

The machine-part cell formation problem is generally formulated as '$m \times p$' incidence matrix (where m is the number of machines and p is the number of parts) as shown in Table 1. Here, columns and rows stand for machines and parts respectively. Elements of the matrix represent operation indices of parts (no operation is performed in empty place). For example, in Table 1, $a_{2,1_1} = empty\ (or\ 0)$, i.e., no operation is performed in the machine M2 for the part P1 considering the first route; $a_{4,5_1} = 2$, second operation is performed for the part P5 considering the first route on machine M4 and so on.

Table 1. The cell formation problem with 5 Machines and 7 parts

Parts	Part route	Machines				
		M1	M2	M3	M4	M5
P1	1	2			1	
	2	1		2	3	
P2	1	1			2	
P3	1		2			1
	2		1	3		2
P4	1	2	1			3
	2		1	3		2
P5	1	1			2	
	2	1		2	3	
P6	1		1			2
P7	1		2			1