Handling of Bottleneck Machines Parts: A Strategic Approach

David Ang, and Johnny Ho

***Abstract*—** The cellular manufacturing system (CMS) has been very popular since 1990's because it could achieve manufacturing benefits and efficiencies. The cell formation, grouping families of parts and machines is very important in CMS application. There has been a large proportion of research conducted in reporting on part-machines grouping methods and algorithms. The grouping is not always possible to ensure that all parts of a family can be processed within a machine-cell due to bottleneck machines and parts. Grouping methods and algorithms were also developed with the intent of eliminating the bottleneck machines and parts. However, the developed grouping methods and algorithms could not eliminate bottleneck machines and parts, but could only result in a cell formation design with minimum numbers of bottleneck machines and parts. This paper suggested that the bottleneck machines and parts problem in the CMS should be best resolved through company's strategic competitive priorities and long term objectives considerations...

***Keywords*—**Strategic, Part-Machine Families, Bottleneck Machines, Cellular Manufacturing Systems.

I. Introduction

THE cell formation is one of the main focuses in implementing the CMS. The cell formation process requires the ability to classify parts and machines into parts and machines families. The CMS is a production system that will allow a set of dissimilar machines to be grouped into a machine cell to process a group of product/part family. A product/part family is a group of parts that can be processed and produced by the same sequence of machining operations because of similarity in design and processing attributes. This will allow the systems to exploit the similarity between parts and manufacturing processes. The grouping of part and machine families is known as the cell formation process in the CMS and there are many methods and algorithms have already been developed to dates. Unfortunately, the grouping is not always possible to ensure that all parts of a family can be processed within a machine-cell and tends to create the intercellular movement so that the parts could be completely produced and manufactured by different machines within another machine cells. The parts that need to be moved to another machine cells are known as the bottleneck parts and the machines that process the bottleneck parts are known as the bottleneck machines. Most of the grouping methods employ M x P machine-part incidence matrix (see Figure 1) to group machines and parts into parts and machines families.

Machine # (i) \ Part # (j)	1	2	3	4	5	6	7	8
1	1		1				1	1
2	1	1			1			1
3	1	1	1	1				
4	1			1	1	1	1	
5		1			1			1
6				1		1		

Fig. 1 Machine Part Incidence Matric

The incidence matrix is a matrix that describes the machines requirements to process each part type. The matrix consists of binary entries of blanks or '1s', in which an entry of '1' indicates that machine i is used to process part j, i = 1, 2… 6 and j = 1, 2 …8. When an initial machine-part incidence matrix is constructed such as shown in Figure 1, each machine-cell that is dedicated to manufacture of a specific part family is not visible. However, when a leading methodology or algorithm is employed, machine-cell and its part family can be identified (see Fig. 2).

		PF-1			**PF-2**			**PF-3**	
		1	3	7	2	5	8	4	6
MC-1	1	1	1	1			1		
	3	1	1		1			1	
MC-2	2	1			1	1	1		
	5				1	1	1	1	
MC-3	4	1		1		1		1	1
	6							1	1

Fig. 2 Bottleneck Machine and Parts

Fig. 2 shows the formation of machine cells (MC) and part families (PF) after the grouping process. Parts that are in the same family can be processed by its machine family. For instance, parts that are grouped into PF-1 can now be processed or produced by machine family, MC-1. However, Fig. 2 also showed that not all members of a part family can be processed within a single machine cell. The members having operations in more than one machine-cell are called bottleneck parts and the machines processing them are known as bottleneck machines. For instance, Part Type 1 in Figure 2 is a bottleneck part. Part Type 1 has to transfer to Machine

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Cell-2 (MC-2) and Machine Cell 3 (MC-3) for processing after going through processing in Machine Cell-1 (MC-1). The machine #2 in MC-2 is a bottleneck machine. The part types 1, 7, 2, 5, 8, and 4 are termed as the bottleneck parts. The machines 1, 3, 2, 5, and 4 that are required to process the bottleneck parts are called the bottleneck machines. Thus, the existence of a production requirement that necessitates a part having to move between work or machine cells, otherwise slowing or impeding overall efficient production, creates an exceptional element. The bottleneck parts create interactions between machine-cells such as the intercellular movements, which is the obstacle of achieving cellular manufacturing systems efficiencies and the simplicity of production control. Many researchers have studied the handling of bottleneck machines and parts. Numerous research methods were proposed by the researchers to resolve the bottleneck machines and parts problems during or after the cell formation. To dates, research indicates that the existence of the numbers of bottleneck machines and parts after the grouping could not be completely eliminated, but could only be minimized. This paper is to discuss the bottleneck machines and parts problem in the CMS can be best resolved through company's strategic competitive priorities and long term objectives considerations.

II. Literature Review

Some of the current research on cell formation includes Torabia, S.A & Shamekhi Amiri, A [1], Renna. P & Ambrico, M [2], Tariqa, A., Hussainb, I., Ghafoora, A. [3], Mukattash, A., Adel, M., & Tahboub, K [4], Arikan, Gungor [5], Many cell formation grouping methodologies have emerged since 1970. The leading methodologies to cell formation are the Machine-component Group Analysis [6], Coding and Classifications [7], [8] Similarity Coefficients Analysis [9], [10], [11], Knowledge-Based [12], [13], Fuzzy Theory [14], Mathematical programming [15], Heuristics & Algorithms [16], [17], Multi-Criteria Objectives [18], [19], and Simulation [20], [21]. A comprehensive review on the cell formation design can be found in [22], [23].

As compared to cell formation research, the studies of handling of the bottleneck machines and parts problems are much less. Numerous researchers have investigated the problems. They studied and developed algorithms to eliminate the handling of exceptional elements after the cell formation grouping process. Chow and Hawaleshka [24] proposed a more effective algorithm, which reduced the number of bottleneck parts compared with the average clustering algorithm Seifoddini and Wolfe [11] and linear cell clustering algorithm of Wei and Kern [25]. The other researchers that had developed algorithm to reduce the appearance of the bottleneck parts and machines include Chan and Milner [26], King & Nakornchai [27], Kern & Wei [28], Tsai, Chu, and Barta [29] and Won [30]. The grouping algorithms that were developed by these researchers can only reduce the existence of bottleneck parts, but the bottleneck parts could still be present. Vannelli and Kumar [31] proposed to eliminate bottleneck parts through bottleneck machines duplication and subcontracting bottleneck parts. They proposed to duplicate bottleneck machines irrespective of the machine cost and cell size constraint and requirement. This model purports to solve the exceptional element problem by duplication bottleneck machine cells that possess the largest number of inter cellular moves and continues duplication until no machine generates more intercellular moves than specified by a threshold value. Seifoddini [32] presented a cost-based duplication procedure, which uses the duplication cost and the associated reduction in intercellular material handling cost as a basis for decision making in the duplication process. The bottleneck machine is duplicated if the duplication cost is less than the associated cost reduction in intercellular material handling. Ang [33] developed an algorithm for eliminating bottleneck parts that minimizes total duplication costs for the entire system and its duplication process. Ang's method only assumed bottleneck machines duplication is the only viable method to use to eliminate bottleneck parts. Ang [34] presented a comprehensive literatures review on methods and algorithms that were developed to handle or resolve the bottleneck machines and parts problems in CMS.

III. Problem Statement

In the past decade, the cellular layout has become popular as the backbone of modern factories because of its ability to achieve manufacturing efficiency and effectiveness benefits. Cell formation can differ considerably in size, in automation, and in the variety of parts processed. As reported in the literature review, a majority of these cell formation methods and algorithms have neglected to build the practical manufacturing practices and considerations into the design. These cell formation methods and algorithms assumed little or no set up time between successive jobs within the manufacturing cell and failed to include job scheduling difficulty considerations. In addition, the processing time and cycle time at each workstation within the cell are assumed to be balanced. The machinery equipment capacity constraints such as maintenance time and downtime time were never incorporated into design consideration. In addition, the methods and algorithms tend to create bottleneck machines and parts at the end of the grouping process. The bottleneck parts create interactions between machine-cells and the intercellular movements. The intercellular movement is the obstacle of achieving cellular manufacturing systems efficiencies and production control. Many researchers have developed methods and algorithms to handle and resolve the bottleneck machines and parts problems. However, the existence of the bottleneck machines and parts could only be reduced by these methods and algorithms, but would not eliminate the existence of the bottleneck machines and parts completely.

IV. Proposed Resolution

As discussed in the literature review, methods and algorithms that were reported are able to reduce, but not able to eliminate the existence of the bottleneck machines and parts at the end of the grouping analysis. These methods and algorithms addressed the tactical treatment of the handling the bottleneck machines and parts. The handling of bottleneck machines and parts problem should be more directly related to the firm's competitive priorities and long-term strategic objectives such as the firm's manufacturing focus, strategic objectives, system performance measures and competitive advantage in the marketplace. The handling of bottleneck machines and parts problem should not simply be based on a coding scheme of partial geometry similarity and similarity of the production routing sequence.

Fig. 3 demonstrates that the cell formation design and handling of bottleneck machines and parts decision should be driven by the manufacturer's strategic objectives and competitive priority analysis. These strategic objectives and competitive priority considerations should include design factors such as cell capacity constraints, stochastic job arrivals, characteristics of part mix, and the effects of set-up time reduction.

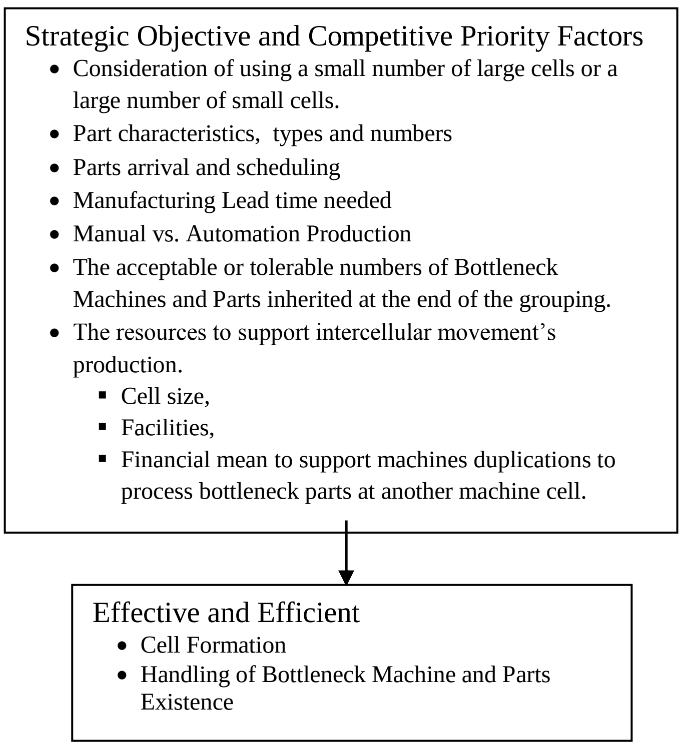

Fig. 3 Strategic Handling of Bottleneck Machines and Parts

V. Conclusions

This paper suggests that the handling of bottleneck machines and parts in CMS varies according to the manufacturer's objectives and competitive priority principles. Cell formation design and algorithms should be derived and developed according to the company priority and competitive advantages. The handling of bottleneck machines and parts in CMS should not just be based on the part geometry coding scheme similarity, routing processing sequence similarity, or minimizing the numbers of exceptional machines or parts. Methods and algorithms must be designed according to an organization's manufacturing focus, strategic objectives, system performance measures, and marketplace competitive advantage.

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