International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249 – 8958, Volume-3 Issue-6, August 2014

Review on Cellular Manufacturing System and its Components

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Abstract— Shorter product life cycle, variable demands and international competitions become challenging issues nowadays hence, most of manufacturer made attempts to select type of manufacturing system for their company which be able to respond to these issues. Group technology [GT] is one of the most recent manufacturing philosophies which is able to cover the existed problems. Cellular manufacturing system [CMS] is one of the main applications of GT during these decades. Importance of CMS during these decades makes author motivated for haveing a brief review on literature of this topic. This paper made attempts to have a brief review on Cellular manufacturing system and its main components.

Index Terms — Cellular manufacturing system, Cell formation, Machine layout Design.

I. INTRODUCTION

In previous decades, manufacturers faced a lot of challenges because of globalization and high competition in markets. These problems arise from shorting product life cycle, rapid variation in demand of products, and also rapid changes in manufcaturing technologies. Nowadays, for overcoming these kind of problems, manufacturers try to select and implement the type of manufacturing system which be able to produce mid-variaty and mid-volume of products. During past decades, manufactureres implemented traditional type of manufacturing system such as flow line and job shops in their company. For instnace, as flow line manufacturing system has been showin in figure 1, all facilities are arranged based on the operation sequence of each products; therfore, these system can be suitable for high production rate with a few type of products. In contrast,the job shop system which has been shown in figure 2, facilities will be arranged based on their functions and also similar processes are located together. This manufacturing sysem responds to the wide variaty of products with a small volumes.

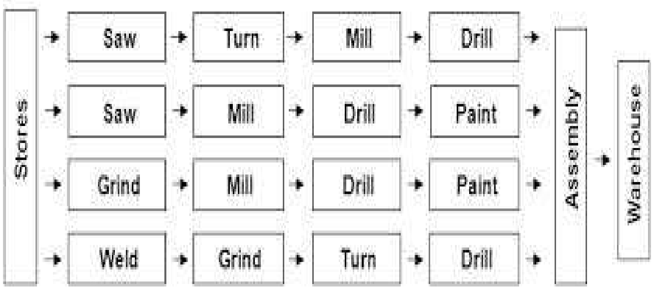

Figure 1 A Flow Line Layout

Manuscript Received on August 2014.

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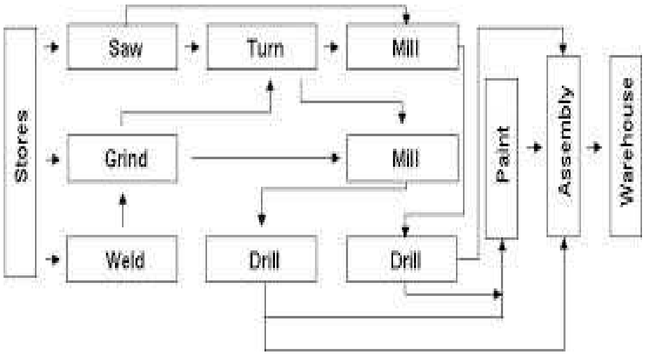

Figure 2 A Job Shop Layout

Table 1 shows some spesifications of these two models. Since both flow line and job shop were traditional model; hence, they were not able to satisfy the new requirements of today market. Cellular manufacturing system is an effecient application of group technology which is able to mix both spesifications of flow line and job shop and be responseded to the new requirements of the market and it is able to overcome some of the traditional's weakness. In other words, cellular manufacturing system combines efficiency of flow line with flexibility of job shop. Cellular manufacuring system can be considered as a successful application of group technology which is able to fulfill today's requiremnets [1].

Type	Variation	Volume	Advantages	Disadvantges
Flow line	Low	High	• Simplifies production planning and control systems. • Reduces materials handling. • Unskilled workers	• Lack of process flexibility • Lack of flexibility in timing • Large investments
Job shop	High	Low	• Customization in services. • Less disruption in work. • General purpose and flexible equipment.	• High volume of work in process • skilled workers • High production cost

Table 1 Spesifications of Flow line and Job Shop

Ariafar [2] expressed some of the main benefits of implementing CMS in comparison with traditional manufacturing system that are as follows:

- Reduction in inventory
- Reducing the work in process
- Decreasing the set up time and throughput time

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- Reduction in material handling cost
- Simplification of production planning and scheduling
- Improvement of the quality of products.

Design of Cellular manufacturing system includes cell formation and layout design [3]. Parts are grouped based on their similaritiies (shape, geometrics, process plan) and allocated to the machines which located in each cell, this process will be called cell formation in CMS. In addition, the arrangment of machines in each cell and also cell in shop floor will be important issues that are considered as a layout design in CMS. Layout has a tremendous impact on performance of manufacturing system. Put differently, a poor placement and layout decresae system performance and also customer satisfaction [4]. Figure 3 shows a schematic layout of CMS.

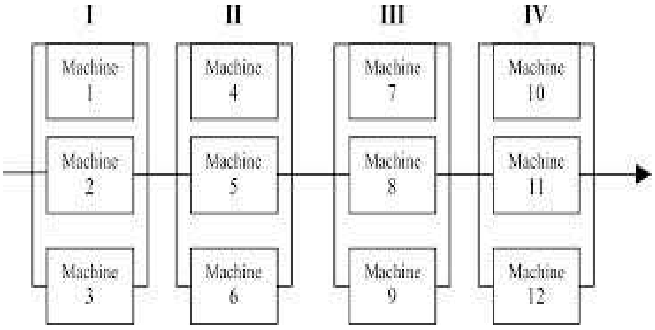

Figure 3 A layout of CMS

II. CELLULAR MANUFACTURING SYSTEM

Nowadays, shorter product life cycle, customized products, variable demand and international competitions are the challenges which manufactures face them. These issues force them to be more flexible and also adopt themselves with the challenges. Job shop and flow line are traditional manufacturing system which previously were applicable but they cannot fulfill today market's requirements; therefore, during these decades manufacturers tries to replace the traditional style with the new manufacturing system which be able to respond to the rapid changes in customer's needs. Group technology is one of the most recent manufacturing philosophy which is based on grouping parts with regards to their similarities in designing and manufacturing stages [5]. CMS is one of the application of GT which is considered as a promising alternative manufacturing system [6]. CMS makes an attempt to have flexibility of job shop and high production rate of flow line. CMS includes two steps which are cell formation and layout design as is shown in figure 4.

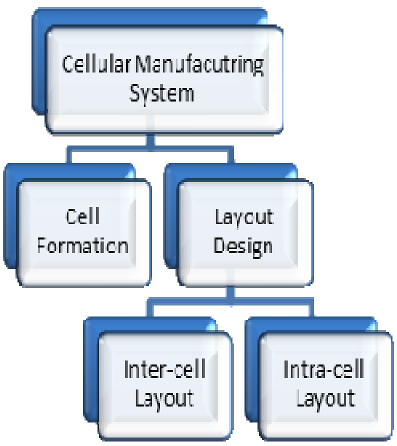

Figure 4 Elements of CMS

Cell formation is the first step in designing CMS. In the cell formation step:

a) Parts are grouped based on their processing requirements as part families.

b) Machines are grouped into the cell.

c) Part families are assigned to the cell.

The main objective of cell formation is constructing machine cell and part families and also assigning part families to the machines and cells in order to optimize some performance criteria such as intra and inter cell material handling cost, grouping efficiency [7]. To put it another way, in the cell formation step, parts are grouped in to the part families by considering their similarities in manufacturing requirements, moreover, different machines are dedicated to process these parts. Cell formation in CMS attracts a lot of attention to itself during previous three decades. Different methods such as mathematical programming, heuristic, optimization procedures and clustering have been proposed as a solution for the cell formation problems [8]. In layout design step, position of machines in cells and also position of cells in shop floor will be determined. In the other words, the arrangements of cells and machines in the most efficient way will be identified in this stage. The efficiency of the layout has been interpreted differently and there are different objectives for this mean. Anyway, the most important objective for the efficient layout is having minimum material handling cost [9]-[11]. Indeed, a good placement of machines and cells lead to increase the system performance and also customer satisfaction; hence, layout design is a crucial issue in designing the CMS which must be considered a lot. Most of the previous researchers completely separated the cell formation step from layout design [8]. In traditional design of CMS, these two steps were done in two separated phases and designer of the layout have not taken in to the account the cell formation phase. It was a big problem for traditional design of CMS; therefore, it is so important to consider the layout design simultaneously with the cell formation phase. Actually, considering the layout design concurrently with the cell formation step enables designers to consider more data and information in their designing steps which result in having an efficient CMS. In spite of few researches which have concentrated on both issues simultaneously, this combination needs to be investigated more in further research.

A. CELL FORMATION

As explained in previous section, cell formation is the first stage in designing CMS. In this step the parts are grouped with the closest features to the part families and then they will be allocated to the machines in each cell. That is to say, which part will be assigned to which machine and also which machine will be allocated to which cell. Since CMS become a popular and efficient manufacturing system which is able to overcome the existed problems in traditional manufacturing system; thus, the cell formation became a well-studied topic during these decades [2]. Although, there are many researchers who carried out a research on this area, in this section just some of them can be noted: Lee et al., [12] applied genetic algorithm for solving the cell formation problem in cellular manufacturing system. They considered alternative routing together with process sequence and production volume in their work. The best alternative routing,

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part families and machine cell had been determined in their research based on parts and machine's similarities. Moreover, Vakharia and Chang [13] proposed mathematical programming approach for cell formation in cellular manufacturing system. The objectives of their approach were minimizing total inter-cell movements cost and machines investment cost. In addition, operation sequences, machine replication, production volume and cell size had been considered in their approach. HSu and Su [14] applied simulated annealing method in order to solve the cell formation problem in CMS. They made attempts to minimize machine cost and intra and inter-cell moves in their work for forming efficient cells. Furthermore, Nair and Narendran [15] developed an eight steps algorithm for forming machine cell in cellular manufacturing system. In their algorithm, they considered production sequence data in order to design more productive cells. Sofianopoulou [16] proposed a simulated annealing method for solving cell formation problem in CMS by considering the alternate routings and process sequences. Baykasogle et al., [17] proposed non-linear programming model for solving cell formation problem and also defining process part requirement in CMS. They applied simulated annealing algorithm for reaching model's objective which were minimization of dissimilarity between parts, cell load variation and extra capacity requirement. Mak and Wang [18] presented a mixed-integer non-linear model in CMS. They used this model in order to solve cell formation problem and also define production scheduling. Their goal was minimization of total travel distance of parts. In addition, they applied genetic algorithm as a method for solving proposed model. In addition, Yin and Yasuda [19] considered operation sequences, alternative routing, operation times and production volume simultaneously in their work. They proposed two stages heuristic methods for solving the cell formation problem in cellular manufacturing system. Das et al., [20] proposed a multi-objective model for solving cell formation problem and also defining the process route in cellular manufacturing system. They made attempt to minimize failure rate of machine and simultaneously concentrate on minimization of machine variable cost, inter-cell material handling cost and machine non-utilization cost. They applied Simulated annealing method for solving the proposed model. Moreover, Schaller [21] presented a mathematical model in order to solve the cell formation problem under the stochastic demand situation, for this mean, he applied five heuristic methods for solving the model. Ameli and Arkat [22] developed a pure linear integer program for configuring the cell in the cellular manufacturing system. In their research, they considered machine reliability and alternative process routing in order to become more close to the reality. Their model showed that machine reliability has significant effect on overall system efficiency. Besides, they applied the Lingo software for validating their model. Tavakkoli et al., [23] presented a mathematical model which tried to minimize the makespan, intra-cellular movement, tardiness and sequence-dependent set up cost simultaneously. They proposed this model in order to solve the cell formation problem and also production scheduling problem in CMS. In addition, they developed a meta-heuristic algorithm for solving the proposed model based on scatter search. Moreover, Mahdavi et al., [24] solved three dimensional machine–part–worker incidence matrix for designing cell in cellular manufacturing system.

B. LAYOUT DESIGN

The next prominent step in implementing cellular manufacturing system is layout design. It is related to arranging the facilities such as departments, aisles, machines, tools in the cell and also in the shop floor in the most efficient layout. Layout design includes two arrangements, the first one is related to locating cells in suitable positions in the shop floor which is named inter-cell layout design and the second one is related to arranging machines in each cell which is called intra-cell layout design that is shown in figure 5.

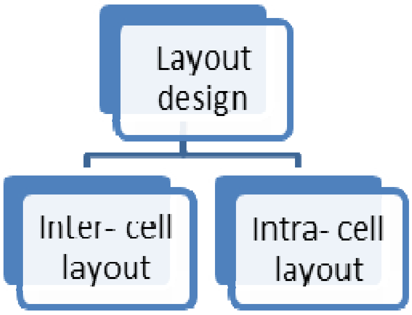

Figure 5 The Elements of Layout Design

These arrangements must be done with regards to the defined criteria for evaluating the efficiency. Material handling cost, throughput time, lead time and level of work in process can be considered as evaluation criteria based on literature review. 20-50 percent of operating expenses is assigned to material handling cost, indeed with a good layout, it is possible to reduce material handling cost and consequently have reduction in operating expenses of manufacturing system [2],[25]. That is to say, a well-designed layout causes decreasing material handling cost, lead time and throughput time while, inefficient layout results in high material handling cost and accumulated work in process. To put in a nutshell, layout design has an important role and impact on manufacturing system's performance [2]. In spite of importance of layout design in CMS, it rarely absorbed the attentions of researchers in comparison with cell formation [26]- [28], but nowadays a lot of researchers made attempts to focus on this issue since it has a significant effect on productivity and efficiency of system [29]-[30]. In this section some of the main researches which have been carried out on this area will be explained: Jajodia et al., [31] presented a new method for solving inter and intra-cell layout problem in cellular manufacturing system. They applied simulated annealing for this mean. Their goal was minimization of total material flow cost and they reached the equal or better results with the similar existed methods. Won [32] proposed a linear mathematical model in order to determine machine sequence in each cell. Their objective was minimizing the backward flow in cellular manufacturing system.

Moreover, Wang et al., [33] formulated a model in order to solve inter and intra-cell layout in CMS. The objective of the model was minimization of total material handling distance and Simulated annealing was improved for solving their model. Besides, Bazargan–lari [34] proposed a methodology in order to design the inter and intra-cell layout in cellular

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manufacturing system for the food industry in Australia. He made attempt to minimize the material handling cost in his work. With his proposed method, the company was able to have safer shop floor which previously was a big problem for them, in addition, company saw significant reduction in material handling cost by implementing new inter and intra-cell layout. Wang et al., [35] formulated a mathematical model in order to solve both inter and intra-cell layout design in CMS. Minimization of material handling cost was their goal. They presented a simulated annealing algorithm for this mean which was able to reach the logical results in a reasonable time. Moreover, Chang et al., [36] presented an approach for solving cell layout problem in the manufacturing system which was able to produce a few number of products with small to medium lot sizes. Solimanpur et al., [37] presented an Ant colony algorithm in order to solve inter-cell layout design in CMS. They formulated a mathematical model that was based on minimization of material flow between cells. Their results showed that their algorithm is effective and efficient as compared to other existing algorithms. Iranshahi et al., [38] developed a simulated annealing algorithm for solving inter and intra-cell layout design problem in cellular manufacturing system. Furthermore, Tavkkoli-Moghadam et al., [3] proposed a mathematical model which was able to solve both inter and intra-cell layout design in CMS by considering stochastic demand. Their goal was reaching minimum inter and intra-cell material handling cost. They applied Lingo software for validating and verifying their model. Zhu and Ye [39] applied particle swarm algorithm in order to solve proposed model of Iranshahi in 2005. Their model had been proposed for determining inter and intra-cell layout design in cellular manufacturing system. In addition, Jolai et al., [40] presented a mixed integer mathematical model for identifying the optimum inter and intra-cell layout in CMS. They developed particle swarm algorithm for solving the model. Khaksar-Haghani et al., [41] carried out a research for designing cell layout in multi-floor of cellular manufacturing system, plus, they tried to locate machines in each cell with considering the multi-row arrangement. The goal of their integer linear programing model was to reach minimum material handling cost for CMS. Moreover, Ariafar [2] proposed two mathematical models for layout design in CMS. He considered stochastic demand for the proposed models. He applied Lingo software for validating his models. The results showed that uncertainty in product demand cause changes in the facility arrangement of manufacturing system. Last but not least, it is important to express an effective element in layout design which is dimension of facilities. To put differently, size of facilities can be defined as equal or unequal and it is crucial to consider the size of facilities in arrangement of them,. Most of previous researches in facility layout problem focused on equal-area facility in order to simplify their model which leads to restrict their study and become far from reality such as: Afrazesh et al., [42], Kia et al., [43]. During these decades, some of the researchers became interested to focus on unequal-area facility and proposed some mathematical model for arranging the unequal-area facilities in shop floor like: Li and Love [44] , Dunker et al., [45], Hakobyan [46], Mckendall and Hakobyan [47] ,Hernandez Gress [48], Samarghandi et al., [49]. These models were more complicated than previous studies which focused on equal-area facilities but these studies had been more adapted to the real situation. Although considering the dimensions of facilities is so crucial in layout problem, none of previous research models employed dimensions of facilities in CMS especially in dynamic environment, just a recent research of kia et al., [50] incorporated the size of machines in designing the DCMS. They proposed a mathematical model for designing the unequal-area machines in each cell of cellular manufacturing system.

C. COMBINATION OF CELL FORMATION AND LAYOUT DESIGN

In contrast with a large number of papers in cell formation, there is just few numbers of researches which have been concentrated on intra and inter-cell layout design in CMS. Since, effective facility layout will decrease material handling cost, lead time and throughput time and increase productivity and efficiency of the system; therefore, facility layout planning became an important issue during these years and attracts a lot of attention to itself. On the other hand, during these years some of the researchers combined both cell formation and layout design in order to become more close to the reality in manufacturing system. To put it another way, concentrating on cell formation and layout design simultaneously help designers to consider layout design in the initial step of cell formation; hence, it brings more productivity and efficiency to the system. Due to this fact, nowadays most of the researches concentrate on these issues concurrently [51]. Just few numbers of related papers are mentioned here: Herague [52] developed a method for solving the CMS design. The initial stage was related to machine grouping and the second stage involved cell arrangement in the shop floor and machine arrangement within a cell. In addition, Sarker and Wu [53] integrated cell formation and intra-cell layout design in one model in order to minimize material handling cost and also machine investment. Bazargan-lari et al., [34] proposed an integrated approach for solving the parts/machines grouping, intra and inter cell layout design. They tried to manage these three decisions concurrently in CMS for the white-good manufacturing company in Australia. Moreover, Akturk and Turkcan [54] solved the cell formation problem and also intra-cell machine layout problem simultaneously in CMS. Furthermore, Chan et al., [55] presented two mathematical models for solving cell formation and machine layout design in CMS. The first mathematical model was able to configure cells then by using second model, the optimum layout with regards to minimum intra and inter-cell part movements had been obtained. In other words, output of the first model had been considered as an input for the second model. Although this research considered both cell formation and cell layout, the lack of integrated mathematical model for both have been seen there. Nsakanda et al., [56] presented a model which tries to minimize inter, intra-cell and outsourcing cost in order to solve cell formation problem, machine allocation and part routing problem. Moreover, their model concentrated on part demand, machine capacity limits, multiple process plans, alternative routing and part process sequence. Wu et al., [57] proposed a mathematical model which combine cell formation and group layout design in one algorithm for CMS. Put differently, the hierarchical genetic algorithm was

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developed by them in order to determine the cells and layouts in CMS. Besides, Mahdavi and Mahadevan [8] presented an algorithm in order to configure cells and also arrange the machines in each cell for cellular manufacturing system. This algorithm used sequence data as an input parameter for the problem in order to become more close to reality. Ahi et al., [26] proposed a novel approach for solving cell formation, inter and intra-cell layout problem in cellular manufacturing system. They applied Topsis method for their work and reached considerable results. Their approach was able to cover three basic steps in designing the CMS. Plus, Paydar [58] proposed a method for solving cell formation problem and intra-cell layout design in cellular manufacturing system. Their method was based on multiple travelling salesman problems. Moreover, Dixit and Mishra [59] presented a method for determining the part families/machine grouping and also arranging cell in shop floor and machines in cell. Sangwan and Kodali [60] integrated cell formation, intra and inter cell layout design problem. In their model, they considered transfer batch size, production volume and operation sequences to make it more practical and close to reality. In addition, Chang et al., [51] presented a new approach for solving cell formation problem and group layout design in CMS. Their work was a two stages mathematical model that integrated the three critical issues in CMS. Tabu search algorithm was applied in order to solve their model.

III. CONCLUSION

Since during these years the group technology especially cellular manufacturing system become more applicable in the companies and factories due to shorter life cycle of product, variable products demands and also high international competition; therefore, this paper made attempts to review the literature of CMS and its components. To put differently, in this study, author tried to focus on all published papers which were related to cellular manufacturing system, cell formation, and layout design.

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