# Recent Development in Virtual Cellular Manufacturing System


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**Abstract** Virtual cellular manufacturing has been known to a way to overcome the difficulties of both cellular manufacturing system and functional layout system. With virtual cellular manufacturing system, groups of resources are dedicated to the manufacturing of a part family, but these cells are not real in the manufacturing system. In virtual cellular manufacturing system, machines remain in their original layout, and the machine cells are instead formed in the planning and control system and remain virtual in nature. In the present work, different models for the formation of virtual cell have been discussed. Factors that may affect the efficiency of manufacturing system have also been discussed.

**Keywords** Group technology · Machine cell · Part family · Manufacturing system · Cellular manufacturing system

## 1 Introduction

Production is a process of transferring the materials into useful articles. If supporting activities like quality control and production planning are introduced along with production, it is known as manufacturing. Manufacturing is a systematic activity, so each manufacturing system has a specific objective. The useful output is transformed from the various inputs.

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The objective of manufacturing system is to get high efficiency and flexibility. Manufacturer has to solve a number of problems at the manufacturing floor. Traditional manufacturing system is not capable of satisfying the requirements of manufacturing system where quick response to the product design change is required. In today's era, manufacturing industry is under a continuous pressure to control the cost of its product. Competition is increasing day by day. A variety of products need different operation and machines. The concept of innovative manufacturing is being developed by management of manufacturing industries in order to minimize the production cost. It is possible by increasing the utilization of resources. Cellular manufacturing is termed as an application of group technology. Group technology is generally a selection and coding of machine cells for part families. In group technology and cellular manufacturing system (CMS), machine cell and part families are formed independently. Different researchers have developed different models to optimize the CMS. The main disadvantage of this CMS is that it fix the machine cell for specific part family. Machine cells are not fully utilized in many of the cases. Virtual cellular manufacturing systems (VCMS) are the most appropriate to overcome this problem. In VCMS, machine cells are not fixed. They are virtual in nature and the position of machine is not physically changed. The advantage of forming machine cell is to improve the utilization of resources. Different researchers have proposed different models to form a virtual cell. In VCMS, there is no need to move the machine, instead machine will remain in their original position. The virtual cell may result decrease in setup time, change in machine usage and decrease in material handling time. The points of interest may be to incorporate enhanced execution, higher system effectiveness, improved product generation control and better product quality.

Various designs and production tools are used in VCMS. Design tools may include computer-aided design for assembly and manufacturing. Production tools may include computer-integrated manufacturing, just in time, material requirement planning and manufacturing resources planning. VCMS depends upon utilization of the cellular manufacturing systems (CMS) and job shop manufacturing. It is furnished by making virtual gathering of the machine cell and part family incidentally in the creation and arranging the product in control system. Some of the machines may be accessible in more than one cell for the increased utilization of resources. The effectiveness of any manufacturing system may be enhanced by the maximum utilization of virtual cells. The objective is to find the similarity index among the part families and reduce the setup time. It was found that the virtual cellular manufacturing system is more valuable than other manufacturing system when product variety and demand variability are high [1] (Fig. 1).

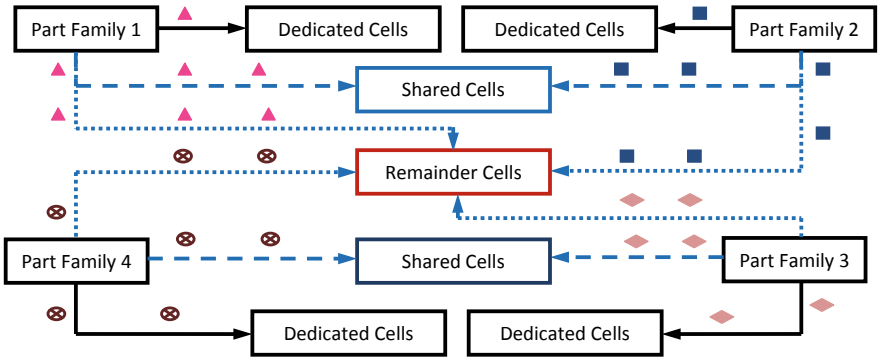


**Fig. 1** Virtual cellular manufacturing system

## 2 Development of Virtual Cellular Manufacturing System

The cellular manufacturing system has been emerged as a technique to optimize the manufacturing system. A numerical model is proposed in which logical group of cells is formed. This model was efficiently responding with change in demand and technological changes. The proposed model was able to maximize the product output and reduce the setup time. The suggested model was tested with randomly generated changes and other self-generated changes in demands. It was found that the proposed model is working efficiently as compared to cellular manufacturing system and functional layout systems [1]. A model of axiomatic design theory was proposed [2]. It is based on waste elimination theory and the objective is to minimize system cost and improve system efficiency. A model was planned in which coding is in LINGO programming and is kept running over utilitarian and disseminated courses of action of similar machines [3]. Mak et al. [4] build up a hereditary planning technique to investigate the manufacturing cell arrangement and genetic algorithm for VCMS. A new scheduling model has been developed using genetic algorithm. The objective of the proposed model is to minimize the total material movement. This may increase the overall efficiency of the manufacturing system. Slomp et al. [19] has build up a technique of creating VCMS by taking the original thought of group generation. Virtual cells are formed by taking multi-objectives in real time based on the demand. Labor grouping is also considered in addition to machine cell. Worker movement in inter-cell is also taken into account. Long [5] focused on research on virtual supply chain networks by combining agent technology and computational experiment. A bilateral model was proposed for dynamic VCMS and Supply chain management [6]. This covers multi-facility, multi-plants and market demands completely. This mathematical model was nonlinear and efforts were made to optimize this model. Transportation cost related to the distribution of finished products from each plant to markets is calculated. Exceptional elements and number of labor movements between active plants were also calculated.

A scientific model which intends to limit the average manufacturing cost with workforce requirements was developed [7]. A hybrid model using constraint programming and discrete particle swarm programming was introduced to solve the manufacturing problem. The proposed model was demonstrated with randomly generated data. Mak et al. [4] introduced a mathematical model to describe the characteristics of VCMS. A genetic algorithm model was developed to optimize the scheduling in the manufacturing system. The proposed model was compared with traditional manufacturing and cellular manufacturing system. It was found that result was comparatively more superior. Virtual manufacturing systems have problem because of dynamic environment and nonlinear nature of the problem. Sarker and Li [8] found this solution by developing heuristic solution which is found to be more realistic and responsive. It is observed that the virtual cell scheduling is more complicated due to overlapping among the cells and the multiplicity of possible virtual cell. A specific model is proposed for CMS that combines the setup efficiency obtained by traditional CMS with the flexibility of a job shop [9]. Efficiency with temporary allocation of machine to the part family rather than fixed allocation of machine to part family was compared.

Zamani [10] developed a model for producing capability-based CMS (CBVCMS). The objective function of the proposed model is to minimize the dissimilarities among the parts. The validity of the model was checked with examples available in the literature. The virtual cell gives the better results as compared to functional layout. Mak et al. [4] proposed a scheduling model for the manufacturing system. The objective of this model is to minimize the total distance travelled by all the parts. The performance with age-based genetic algorithm was compared with traditional genetic algorithm. Erenay et al. [11] concentrated on centers around stochastic cell-producing outline. A mathematical model was developed to create dedicated and remainder cells. It is also proposed to minimize the count of cells. Calculation for expected cells in utilization was done.

Ko and Egbelu [12] created two calculations to produce VCMS. The primary calculation was utilized to test directing information and produce sets of machines that show up every now and again. These VCMS are then broke down to utilizing the second calculation which indicates the last VCMS setup. A machine can appear in various VCMS (machine sharing) and a VCMS can serve numerous parts. Mak et al. [17] introduced a strategy to tackle the assembling cell arrangement and the issues for development of VCMS. The goal is to limit the average materials and segments voyaging separation acquired. Moodie et al. [13] proposed a structure for employments booking by utilizing VCMS. Each activity is allotted to an arrangement of workstations. This issue is fathomed by a straight programming where the goal is to limit both travel separations. Hamedi et al. [3] introduced a technique to pick a reasonable design that can enhance the execution of VCMS, particularly limiting the material stream between machines required by each family gathering. It is also presented in selecting a layout that may increase the efficiency of virtual manufacturing systems by lowering the flow of material in between the machines. A multi-objective programming is developed to form VCMS based on resource element.

Routing similarities are mainly discussed in design-oriented papers, whereas processing similarities are mainly discussed in operation-oriented studies. Babu et al. [14] evaluated the importance of enterprise modeler (EM), cell design manager (CDM), cell operation manager (COM), simulator (SIM), performance evaluator (PE) and report generator (REP). Mak and Ma [15] proposed a numerical model which is utilized for creating ideal generation plans for VCMS working under a multi-period fabricating situation. Thomalla [16] recommended the arrangement of issues yet with the goal of limiting delay. In this work, Lagrangian unwinding approach is utilized. An alternate approach is recommended by Mak and Wang [17], who tried a hereditary calculation to get arrangement of issues with the aim of limiting aggregate travel separations. There are many optimization techniques like genetic algorithm (GA) and simulating annealing (SA). These are already suggested by researchers to have better solution of cell formation problems. The use of information technology in Enterprise resource planning (ERP) is also increasing day by day. This may lead to the availability of data for VCMS. The available details on different manufacturing system like tooling, allowance of fixtures and tolerances are mapped with the manufacturing system. We can therefore conclude that VCMS design may enhance efficiency of manufacturing system using data from ERP systems. The cell formation under random product demands is a new avenue for research. In an innovation manufacturing system, cloud-based design and manufacturing has emerged as a new development in the manufacturing system. The proposed model and existing model were also discussed. The proposed model indicates that VCMS has emerged from the interaction of fuzzy machine agents with fuzzy agent attractor [18]. It may improve the overall efficiency of the manufacturing system. Mahadevi [19] presented an arithmetic model for planning a dynamic VCMS with possibilities of change of workers and machines. To verify the model, LINGO software was used.

## 3 Discussion

The evolution of manufacturing system from production flow analysis to virtual manufacturing system has been occurred. Production flow analysis was developed by Burbidge. The previous demand was stable but now it has been changed to unstable and dynamic in nature. The continuous change in demand forced to change the manufacturing system employed. Thereafter group technology and cellular manufacturing system came in existence. These systems also have their own limitations. Researchers have proposed various models to optimize the cellular manufacturing system. Various authors have also addressed the limitations and improvements in the cellular manufacturing system. This may include under-utilization of machines and high setup time. Virtual cellular manufacturing can be effectively executed to meet the challenges from the change of location of machine cell. Different researchers have proposed different models to form virtual cell. Extensive work on designing of cellular manufacturing system have been undertaken for minimizing mean flow time

of parts and also maximizing the production. This has been done for different conditions. The simulation tools were also used in simulating potential cellular designs before making the decisions for selection. Economic justification and managerial issues were also addressed in group forming of part and machine cells. Various techniques and methodologies have been designed and developed by researchers for various functional areas of CMS and VCMS. But it is felt that most of the studies were being concentrated upon the clustering of the machines into machine cells and parts into part families with various techniques.

## 4 Conclusion

After going through the systematic review of the work done in the development of virtual manufacturing system, design may be done in various methods. These methods may include machine-component group analysis, genetic algorithm based approach, fuzzy clustering approach, graph partitioning approach and artificial intelligence approach. Virtual cellular manufacturing builds on the notion that a manufacturing system should have a physical and a logical design. Virtual manufacturing system in industry is implemented to decrease setup time, decrease in work in advance, decrease in lead time, improve in quality that can be accomplished by execution of CMS. VCMS is executed without physically revamping existing manufacturing formats. Therefore, VCMS can be actualized to fulfill the changed needs of clients with no cost of manufacturing plant design change. Some arrangement can be utilized for planning the groups of parts with a specific end goal to effectively actualize VCMS. It has been observed that less work has been addressed in the area of combinational complexity of VCMS design problem. In any case, consolidating different research could fundamentally upgrade the quality and effectiveness of the system considered. The incorporation of observational investigation into either plan or operational examinations could upgrade the authenticity of the system, particularly as parameter ranges, informational indexes and asset types. Research on the development in manufacturing system and the development of efficient tools is going on to achieve good solutions in reasonable processing time.

## References

1. Khilwani N, Ulutas B, Islier A, Tiwari M (2009) A methodology to design virtual cellular manufacturing systems. J Intell Manuf 22(4):533–544
2. Han W, Zhao J, Chen Y (2012) A virtual cellular manufacturing system design model based on axiomatic design theory. Appl Mech Mater 271–272:1478–1484
3. Hamedi H, Ismail N, Esmaeilian G, Ariffin M (2012) Virtual cellular manufacturing system based on resource element approach and analyzing its performance over different basic layouts. Int J Ind Eng Computations 3(2):265–276

4. Mak K, Lau J, Wang X (2005) A genetic scheduling methodology for virtual cellular manufacturing systems: an industrial application. Int J Prod Res 43:2423–2450
5. Long Q (2014) An agent-based distributed computational experiment framework for virtual supply chain network development. Expert Syst Appl 41(9):4094–4112
6. Aalaei A, Davoudpour H (2016) Revised multi-choice goal programming for incorporated dynamic virtual cellular manufacturing into supply chain management: a case study. Eng Appl Artif Intell 47:3–15
7. Mak K-L, Ma J, Su W (2010) Production scheduling for virtual cellular manufacturing systems with workforce constraints using a hybrid algorithm. In: 2010 sixth international conference on natural computation (ICNC 2010), pp 4445–4449
8. Sarker B, Li Z (2001) Job routing and operations scheduling: a network-based virtual cell formation approach. J Oper Res Soc 52:673–681
9. Kannan VR, Ghosh S (1996) Cellular manufacturing using virtual cells. Int J Oper Prod Manag 16(5):99–112
10. Zamani MR (2017) Dependency of capability-based virtual cellular manufacturing systems performance on basic layouts. Int J Eng Tech Res 7:183–189
11. Erenay B, Suer G, Huang J, Maddisetty S (2015) Comparison of layered cellular manufacturing system design approaches. Comput Ind Eng 85:346–358
12. Ko KC, Egbelu PJ (2003) Virtual cell formation. Int J Prod Res 41(11):2365–2389
13. Moodie CL, Drolet J, Ho YC, Warren GMH (1994) Cell design strategies for efficient material handling. In: Tanchoco JMA (ed) Material flow systems in manufacturing (Chap. 3). Chapman & Hall, New York, NY, pp 76–101
14. Subash Babu A, Nandurkar K, Thomas A (2000) Development of virtual cellular manufacturing systems for SMEs. Logistics Inf Manag 13(4):228–242
15. Mak KL, Ma J (2011) A novel hybrid algorithm for multi-period production scheduling of jobs in virtual cellular manufacturing systems. In: Proceedings of the World Congress on engineering WCE 2011, London, UK
16. Thomalla CS (2000) Formation of virtual cells in manufacturing systems. In: Proceedings of group technology/cellular manufacturing world symposium, San Juan, Puerto Rico, 13–16
17. Mak K, Wang X (2002) Production scheduling and cell formation for virtual cellular manufacturing systems. Int J Adv Manuf Technol 20:144–152
18. Slomp J, Chowdary BV, Suresh NC (2005) Design and operation of virtual manufacturing cells: a mathematical programming approach. Robot Comput Integr Manuf 21(3):273–288
19. Mahdavi I, Aalaei A, Paydar MM, Solimanpur M (2009) Production planning and cell formation in dynamic virtual cellular manufacturing systems with worker flexibility. In: IEEE proceedings—computational intelligence for modeling, control, and automation, pp 663–667