

Group Technology in Design of Manufacturing Systems- A Review

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Abstract

One of the most significant changes in the global economy over the last few decades is the shift of power, in shaping the market demand from producers to consumers. In the ever growingly competitive environment, manufacturers are forced to continuously respond to market changes for their survival. The pressure of competitive pricing, short delivery dates, and high customization has shifted the manufacturing system design emphasis to flexibility and responsiveness. It has reduced traditional manufacturing systems to sub-optimal and paved the way for newer ideas of technical and managerial innovations. A number of newer manufacturing system paradigms have emerged over the years to cater to these modern day manufacturing challenges. Group Technology, the management philosophy of handling common problems together, has found central place in most of these paradigms. The present paper is an attempt to provide a succinct review of the literature on this issue in three parts. First part deals with review of drawbacks of various classical manufacturing system paradigms. In the second part the emergence of various modern manufacturing system paradigms is chronologically discussed in the light of drawbacks of classical paradigms. The second part will also attempt to bring out how Group Technology has emerged as the backbone of all these paradigms. In the third part of the paper, an exhaustive review of the research works on part classification (and/or machine groups' formation) used across various modern manufacturing systems has been presented. Literature is classified chronologically as well as on the basis of various approaches such as coding and classification, clustering, knowledge based systems, heuristics, soft computing, simulation etc. The paper also attempts to classify the literature on the basis of parameters used, objectives considered and the focus orientation. Finally, it sums up with a vision for future research in this area.

Keywords: *Group Technology, Manufacturing Systems*

1. Introduction

Manufacturing industries are under intense pressure from increasingly competitive global marketplace. Shorter product life-cycle, time-to-market, and diverse customer needs have challenged manufacturers to improve the efficiency and productivity of their production activities. Manufacturing systems must be able to manufacture products with low production costs and high quality as quickly as possible in order to deliver the products to customers in time. In addition, the systems should be able to adjust or respond quickly to changes in product design and product demand without major investment. Traditional manufacturing systems, such as job shops and flow lines, are not capable of satisfying such requirements [2].

This paper presents a literature review on emergence of GT as a backbone for designing various types of manufacturing systems. A

significant, but not exhaustive, list of research papers is identified and classified on the basis of different type of manufacturing systems. The surveyed papers are compared on the basis of constraints, objectives involved and solution methodology employed. For static and deterministic production requirements, there is only one possible set of product mix and demand which are known. In contrast, static and stochastic production requirements have a set of possible product mixes and demands to occur; each has its probability of occurrence.

Group Technology (GT), although being used in the manufacturing environment since late 1950s, is still drawing increasing interest from manufacturers and researchers because of its many applications for boosting productivity [3].

As a consequence, small "focused factories" are being created as independent operating units within large facilities [4]. More generally, Group Technology can be considered a theory of

management based on the principle that "similar things should be done similarly"[4]. The principle of group technology is to divide the manufacturing facility into small groups or cells of machines. The term cellular manufacturing is often used in this regard. While reviewing literature, it is observed that the research objectives undertaken by the researchers, focused mostly on the design and control issues of Cellular Manufacturing. The Cellular Manufacturing System design includes only cell formation and group layout. It is a complex, multi-criteria and multi-step process and even under fairly restrictive conditions is NP-complete [6]. On the other hand, the control function of CMS is partitioned into cell loading and cell scheduling. A typical control system needs to allocate jobs to the cells and then assign jobs to the machines and operators in those cells [38]. The present paper is summarized as follows: In first section a glimpse of features of classical manufacturing systems are discussed, second part represents the modern manufacturing systems and explains how the Group Technology has emerged as the backbone of all the paradigms, the third and final part explains the general review of the recent research on various manufacturing systems followed by conclusion.

2. Classical Manufacturing Systems: A Glance

In industrial practice, there are four basic approaches to structuring the processing area for discrete manufacturing: the job shop, project shop, cellular system and flow line. In a job shop, machines with the same or similar material processing capabilities are grouped together: the lathes form a turning work centre, the milling machines form milling work centre, and so forth [7]. The job shop is characterized by its high flexibility in the production of various types of products while the volume of production in this type of manufacturing system is low. In a project shop, a product's position remains fixed during manufacturing because of its size and/or weight [9]. Materials, people, and machines are brought to the product as needed. In manufacturing systems organized according to the cellular arrangement, the equipment or machinery is grouped according to the process combinations that occur in families of parts. Each cell contains machines that can produce a certain family of parts. In case of Virtual cellular manufacturing systems which are based on highly flexible manufacturing concept designed to improve the performance of classical cellular manufacturing systems and job shop manufacturing environments by creating virtual grouping of the resources temporarily in the

production planning and control system. In an environment with fluctuating demand and unpredictable parts mix compositions, the efficiency of cellular systems necessitates the use of virtual cells [1] [34] [45].

Dedicated manufacturing systems or transfer lines, are based on fixed automation and produce a company's core products or parts at high-volume. Each dedicated line is typically designed to produce a single part (e.g., specific engine block) at high production rate. When the volume is high, the cost per part is relatively low. Therefore, DMSs are cost effective as long as market demand matches the supply; but with increasing pressure from global competition, there are many situations in which dedicated lines do not operate at full capacity, and thereby create losses. Of course, producing product variety is impossible with a DMS, and therefore their role in modern manufacturing is decaying [11].

Flexible manufacturing systems (FMS) consist of computer numerically controlled (CNC) machines and other programmable automation and can produce a variety of products on the same system. Despite this advantage, however, our survey shows that flexible systems have not been widely adopted, and many of the manufacturers that bought FMSs are not pleased with their performance [14][18].

Drawbacks of FMSs are that they require more expensive machines than DMSs, and because of the single-tool operation of CNC machines, the production rate of FMSs is very small compared with their DMSs counterparts. In addition, the production capacity of FMSs is usually lower than that of dedicated lines, and they are not designed for a quick change in their capacity, namely, they are not responsive to market changes.

The comparison between the two systems, shown in Table 1, identifies key limitations in both types of systems. The challenge of coping with large fluctuations in product demand cannot be solved with dedicated lines that are not scalable. There are quite often opportunities to supply a larger demand of a product are ignored even though the available production capacity for another product remains largely underutilized.

Table 1: Comparison between DMS and FMS

DMS	FMS
Limitations: <ul style="list-style-type: none"> • Not Flexible • Fixed Part-Not Scalable 	Limitations: <ul style="list-style-type: none"> • Expensive • Slow – single-tool operation
Advantage: <ul style="list-style-type: none"> • Low Cost • Fast-multi-tool operation 	Advantages: <ul style="list-style-type: none"> • Convertible • Scalable capacity

[14]

FMS generally utilizes high-power, general purpose 5-axis CNCs with a very large tool magazine and multiple sets of tools – a very expensive solution. As summarized in Table 2, building a system with adjustable structure, scalability, and flexibility focused on a part family creates a responsive reconfigurable system. Highly productive, cost-effective systems are created by (i) part family focus and (ii) customized flexibility that enables the operation of simultaneous tools (similar to a dedicated machine). The flexibility of RMS, although it is indeed just “customized flexibility,” provides all the flexibility needed to process the part family, and therefore is less expensive than the general flexibility of FMS [14] [18].

Table 2: Comparison of System Features (DMS, FMS, RMS)

Features	DMS	FMS/C NC	RMS/RMT
System Structure	Fixed	Adjustable	Adjustable
Machine Structure	Fixed	Fixed	Adjustable
System Focus	Part	Machine	Part Family
Scalability	No	Yes	Yes
Flexibility	No	General	Customized
Simultaneously Operating Tool	Yes	No	Yes
Productivity	High	Low	High
Lifetime Cost	Low for Single Part, when fully utilized	Reasonable, for simultaneous production of many parts (at low volume); otherwise-High	Medium or production at minimum to high volume variable demand during system lifetime.

[14] [18]

In summary, RMS embraces the best qualities of DMS and FMS systems, For instance, borrowing from dedicated lines that are designed around a single part/product, RMS focuses on families of parts, cylinder heads for example. Between four-, six-, and eight-cylinder models there are many differences, but they also have many common features. DMS and FMS are limited in capacity-functionality, RMS capacity and functionality

change over time as the system reacts to changing market circumstances.

The DMS has a constant capital cost up to its maximum planned capacity, and then an expensive, additional line must be built. This added line doubles the capacity, which in many cases is not needed, and therefore it is a questionable addition. The FMS is scalable at a constant capacity rate of small cost-increments expressing adding more machines in parallel. The RMS is scalable, but at a non-constant capacity rate that depends on the initial design of the RMS and the changing market circumstances [14].

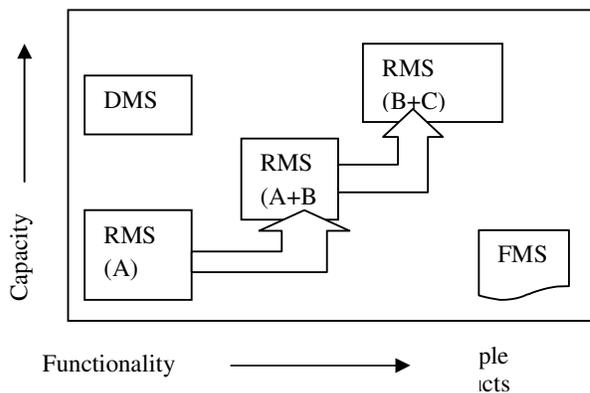


Figure 1: Comparison of Capacity and Functionality allocation: DMS, FMS and RMS

[14]

3. Emergence of GT as a Backbone

Group technology (GT) is a manufacturing philosophy which advocates simplification and standardization of similar entities (parts, assemblies, process plans, tools, instructions, etc.) in order to reduce complexity and achieve economies of scale effects in batch manufacturing. One vehicle for implementing GT is classification and coding (CC), a methodology which organizes similar entities into groups (classification) and then assigns a symbolic code to these entities (coding) in order to facilitate information retrieval.

CC is typically viewed as a computer-based technology. The adoption and implementation of computer-based manufacturing technologies have been discussed by [6], and others. A limited subset of the literature focuses on the selection, implementation and usage of GT codes. [31] in a non-empirical paper, discuss GT code structures, uses, and prescriptive guidelines for implementation. [31] [32] present results from a broad-based survey of 53 GT users, 33 of whom

used CC. [33] documents and analyses recommended and actual selection and justification procedures for GT software, using information from software vendors, interviews with manufacturers, and published sources. Practitioner articles present individual case studies of CC implementation and usage [20]. Group Technology

has significant role in increasing most of the parameters like Productivity, Customer service, order potential, responsiveness, customized flexibility, reliability etc.

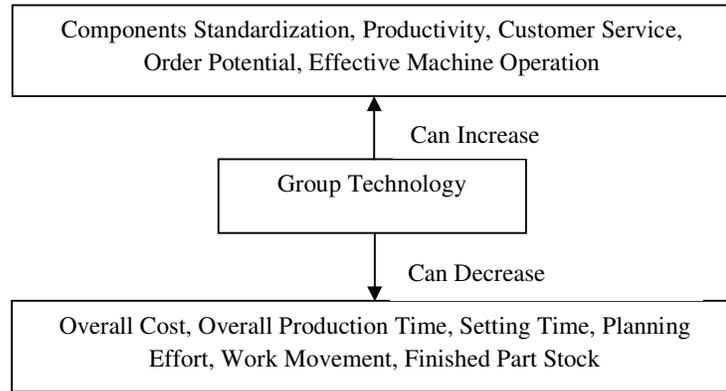


Figure 2: Benefits of Group Technology

3. A Review of use of GT for Design of Manufacturing Systems

Table 3: A Review of use of GT for Design of Manufacturing Systems

S.No.	Type of Manufacturing System	Research started form the year	Number of Objectives	Technique Used	Parameters Taken	Consideration of Responsiveness and Flexibility
1.	CMS	1975	Single objectives were used in Models studied from beginning to mid 90s	ROC, ROC2, MODROC	Productivity, System Efficiency	No
2.	VCMS	1982	Multi-objective	FEA and CFD	Productivity and Flexibility	No
3.	FMS	1985	Multi-Objective	Similarity Order Clustering	Flexibility	Yes
4.	RMS	1990	Multi-Objective	Soft Computing Techniques like GA, ACO, NN	Customized Product Variety	Responsiveness and Customized Flexibility

In order to address the time constraints and increased flexibility requirements which were placed on manufacturing behaviour in the mid 90s, manufacturing system must alter its focus from the specific products it produces to the process resources required for their production. Initially the

manufacturing systems were based on the techniques like BEA, ROC, ROC2, MODROC etc. In virtual manufacturing systems the techniques such as computational fluid dynamics (CFD), finite elements analysis (FEA), and optimization of complex systems were used which helped in

improving the result every time. The main focus during these systems was not on the flexibility of the system but was on how the productivity of the system could be increased. But as the time passes away and the researches were going on, the focus has been shifted from single objective criteria to multi objective and how the responsiveness and flexibility of the system can be increased. So, in the late 90's Reconfigurable Manufacturing Systems were developed which are capable of tailoring their configuration to meet the resource demands of an ever changing merge of products. Now days, the use of soft computing techniques like ACO, GA, NN etc. has also opened up the new ways of designing the manufacturing systems. The present manufacturing systems are multi-objectives and are mainly concentrated on the responsiveness and customized flexibility which automatically increase the market share and standing of organization.

4. Conclusion

Various manufacturing systems and methodology have been briefly studied with their salient features. The study brings the attention towards the need for designing the manufacturing system for most favourable performance and how the Group Technology is still the backbone of every manufacturing system existing in any organization. Most of the past research work has been concentrated to the clustering of the machine and parts into cell and part families. So, acute need is to develop the models to specify the optimal number of groups and optimal production mix subject to technological and logistical constraints for optimal performance of cellular manufacturing system. There is a need to develop more efficient tools enabling manufacturing system designer to achieve optimal solution in reasonable processing time.

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