



Group Technology Paves the Road for Automation

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ABSTRACT

Group technology (GT) has traditionally been a manufacturing philosophy in which parts are identified and grouped together to take advantage of their similarities in manufacturing and design. Similar parts are arranged into part families. In manufacturing, since each family possesses similar manufacturing characteristics, the processing of each member of a family is similar. This study illustrates the important role that GT plays in design of an automated manufacturing system. This is accomplished by creating an ideal application of GT to automation with manufacturing machine cells and part families based upon the design and manufacturing process. In this GT scheme, each machine cell takes care of an individual part family and is independent of rest of the system. Manufacturing cells that process such part families have fewer challenges to automation than cells that process parts without any grouping.

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1. Introduction

Group Technology (GT) is a manufacturing philosophy in which the parts having similarities (i.e. design geometry, manufacturing process, function) are grouped together to achieve a higher level of integration between design and manufacturing functions (Rajput,

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2007). GT-based manufacturing systems have been found to be particularly appropriate for discrete part manufacturing since they provide some of the strategic benefits of job shops, such as product customization, and simultaneously provide some of the operational benefits of the line process such as reduced WIP inventories (Luong, *et al.*, 2001). The idea behind GT is the decomposition of a manufacturing system into subsystems (Kusiak, 1987). This makes GT a strong reinforcement for cellular manufacturing and other areas of lean manufacturing.

There are, however other advantages to utilizing GT in advanced manufacturing technologies. For example, since it makes use of similarities in design and manufacturing attributes, GT greatly contributes to a more efficient integration of CAD and CAM to the product design, process design and process planning phases. This paper demonstrates the implementation of Group Technology as a foundation for the successful implementation of automation. This includes some examples of GT coding systems, as well as the applicability of GT to automation.

2. Implementing Group Technology

There are two major tasks that a company must undertake when it implements Group Technology: identifying the part family, and rearranging production machines and workstations into cells. Neural networks have been used in GT systems for classifying and coding parts. Schemes have been developed to group parts based on the shape similarity attribute using neural networks (Kaparthi and Suresh 1991). Neural networks allow computer systems to utilize algorithms to quickly identify groups among large numbers of parts, much more accurately and quickly than their human counterparts. This also is good for standardization of grouping attributes, which can be updated and parts re-grouped as necessary.

Part families are a collection of parts that are similar, either because of geometric shape and size or because similar processing steps are required in their manufacturing. The parts within the family will have some differences, but their similarities are close enough to where they would share similar manufacturing processes. These parts can therefore be grouped together according to their machining sequences.

3. Grouping Part Families

There are several methods for solving part families grouping, each of which has its own advantages and disadvantages. All require time-consuming analysis of extensive data by properly trained employees, while some can be facilitated using computer applications. Three major methods are (Suresh and Kay, 1998):

- 1) Visual or Intuitive Approaches
- 2) Classification and Coding Systems
- 3) Production Flow Analysis (PFA)

3.1 Visual Approaches

Visual Inspection method is the least sophisticated and least expensive method. It is also known as the intuitive or judgment method, as it requires intuition and judgment of an engineer that is very familiar with the production system. Eyeball techniques work for restaurants, but not in large job shops where the number of components may approach 10,000 and the number of machines 300 to 500 (Black, 1991). It involves the classification of parts into families by looking at the physical parts or their photographs and arranging them into groups which have similar features. Experienced engineers may be successful with an intuitive visual method, but this can be time-consuming and will very likely not lead to the most effective group method.

3.2 Classification and Coding Systems

The classification and coding grouping method is usually considered to be the most powerful and reliable method, and can be tailored to fit any situation (Kamrani and Salhieh, 2002). Thus, there are numerous commercial and non-proprietary classification and coding systems available and in development (Tatikonda and Wemmerlöv, 1992). Part classification and coding systems refers to the process of assigning codes to parts. Digits, symbols, and/or letters represent the attributes of the parts which are used to form the families of parts with similar attributes. The coding system determines the sequence of these digits and how codes are assigned to parts based upon attributes. The following are benefits of classification and coding systems:

- Facilitation of the formation of part families and manufacturing cells
- Quick retrieval of designs, drawings and process plans
- Reduced design duplication

- Faster design improvements and implementation
- Accurate estimation of machine tool requirements and logical machine loading
- Rationalization, improvement and standardization in tool and fixture design
- More accurate cost estimation
- Reliable work piece and process statistics

Classification and coding systems involve part definitions being decoded through digits to make the classification distribution automatic and controlled. A well-implemented classification and coding system would therefore be beneficial as part of a computer integrated manufacturing system. The three basic coding structures are (Radhakrishnan, *et al.*, 2000):

- Chain type coding (polycodes)
- Hierarchical coding (monocode)
- Hybrid coding (mixed or decision-free coding)

In chain type coding, or polycoding, each digit has its own interpretation which is independent of the preceding digits. As shown in the example chain structure in Figure 1, each code character represents a distinct piece of information of a particular part or product. Chain codes are compact and are relatively easy to construct and use compared with the other coding structures. However, chain codes cannot be as detailed as hierarchical structures with the same number of code digits.

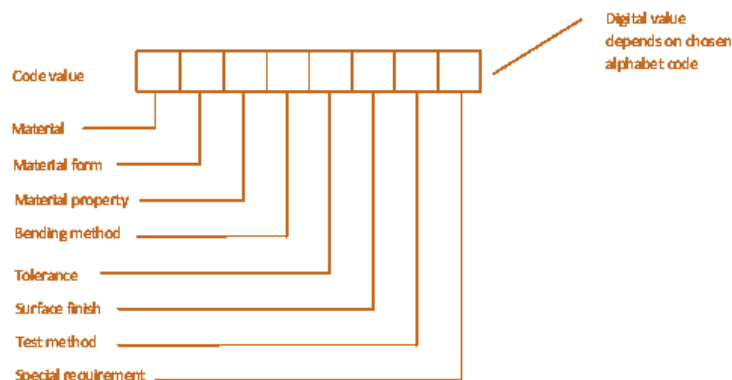


Figure 1: Chain type coding example.

In Hierarchical coding, or monocoding, the meaning of each code character depends upon the preceding characters. As shown in the example in Figure 2, the interpretation of each symbol depends upon the value of the preceding symbol; symbols are usually in digits..

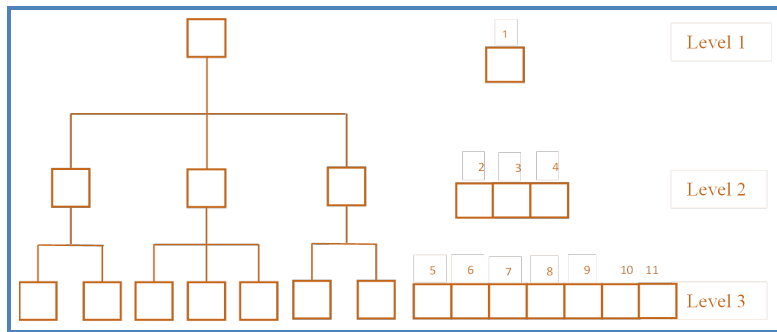


Figure 2: Hierarchical coding example.

Hybrid codes are typically a combination of hierarchical and chain type structures. Hybrid code retains the advantage of both the systems. The example in Figure 3 is a hybrid code consisting of a 2-digit chain code (polycode), followed by a 3-digit hierarchal code (monocode), followed by another 2-digit chain code.

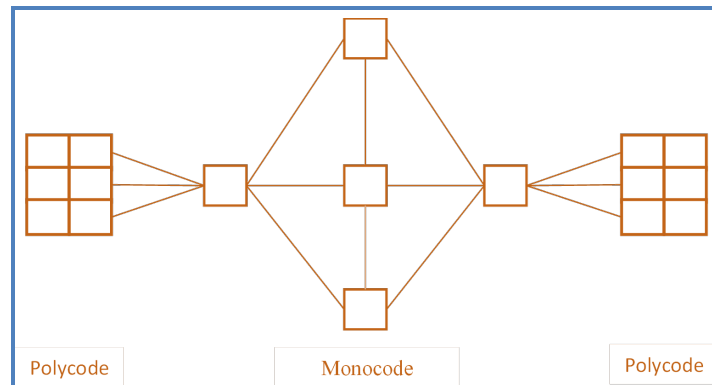


Figure 3: Hybrid coding example.

Due to the great flexibility of hybrid coding, most coding and classification systems use this code structure (Fuchs, 1988). Additionally, there exist some well-known and well-developed hybrid coding systems, such as the Opitz classification system. This classification system was inspired by Opitz, at the Technical University of Aachen, 1970. It is intended for machined parts and uses the following digits sequence (MacConnell, 1971):

- 1 2 3 4 “Form Code” or “Geometric Code” - describes primary design attributes
- 6 7 8 9 “Supplementary Code” - describes some of the manufacturing attributes
- A B C D “Secondary Code” – optional code to describe production details.

3.3 Production Flow Analysis

Production flow analysis (PFA) is a method for identifying part families and associated machine groupings by using the information contained on process plans rather than on part

drawings. Work parts with identical or similar process plans are classified into part families. These families can then be used to form logical machine cells in group technology layout, as seen in Figure 4.

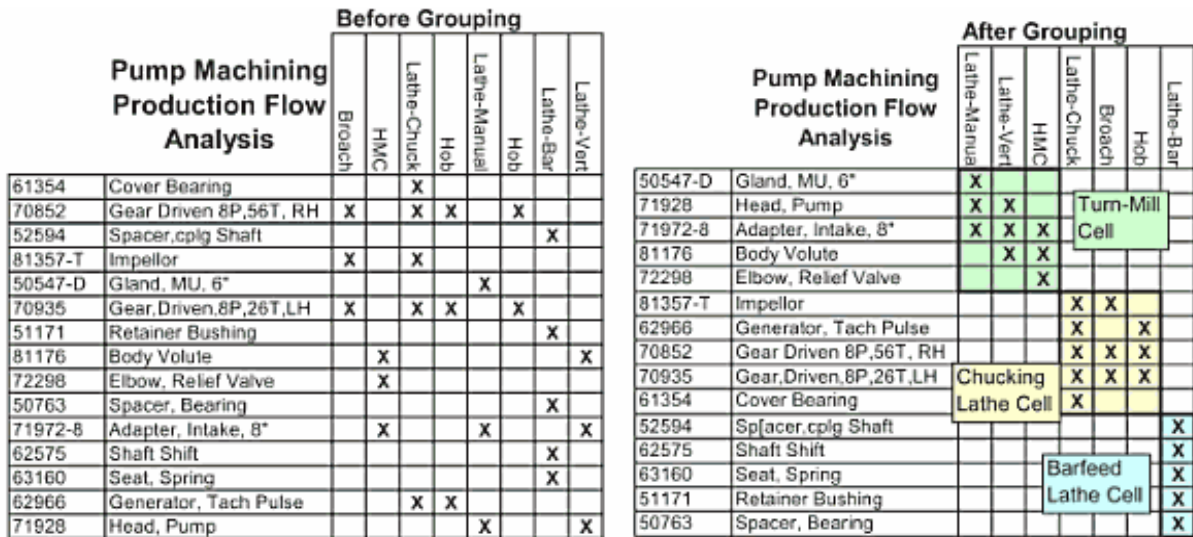


Figure 4: PFA uses the information in the route sheets to suggest new product grouping.

In PFA, parts that go through common operations that are grouped into part families. The machine used to perform these common operations may be grouped as a cell; consequently this technique can be used in facility layout or value stream mapping (Lee and Snyder, 2006). PFA as a GT grouping scheme uses a matrix of part numbers to group families. This method is simple, cheap, and fast, but more analytical than tactical judgment (Black, 1991). However, PFA can become cumbersome if the product mix is more than 100 items (Lee and Snyder, 2006). The procedure for PFA consists of following steps:

1. Data Collection – the minimum data needed are part numbers (or another part identification code) and operation sequences obtained from the process plan. Additional data, such as manpower assignment, time standards, batch sizes and annual production rates may also be useful for designing machine cells of a desired production capacity.

2. Sorting of process plans is used to group parts with identical process plans. One method to accomplish this step is to input the data collected into a data collection database.

3. Charting of the PFA for each group is then displayed graphically on a PFA chart as shown in Figure 5.

Machines	Parts								
	A	B	C	D	E	F	G	H	I
1	1			1				1	
2					1				1
3			1		1				1
4		1				1			
5	1							1	
6			1						1
7		1				1	1		

Figure 5: Production Flow Analysis chart.

Machines	Parts								
	C	E	I	A	D	H	F	G	B
1	1	1	1						
2		1	1						
3			1						
4				1	1	1			
5				1		1			
6							1	1	1
7							1		1

Figure 6: Clustering Analysis chart.

4. Clustering Analysis, which is an attempt to uncover and display similar clusters or groups in an input object-object or object– attribute data matrix, as seen in Figure 6. It is a technique to re-arrange rows and columns of the input matrix- typically a binary matrix that determines whether or not a part is processed on particular machine (Heragu, 2006).

4. Key Features for Successful GT Application

GT is not naturally a success in all production situations. The three basic features for a successful FT application include (Burbidge, 1975):

- Group layout
- Short cycle flow control
- Planned sequence of machine loading

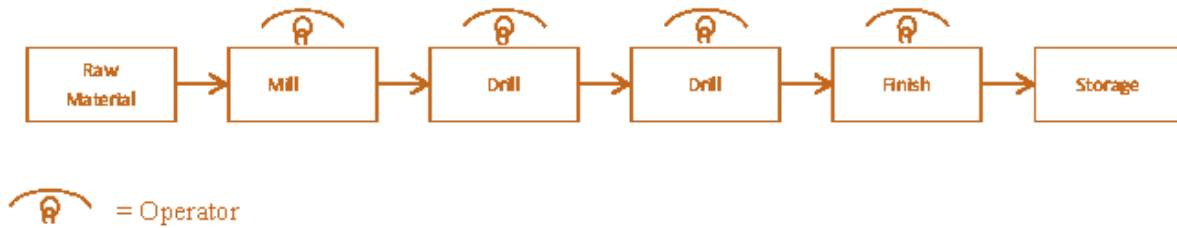


Figure 7: Schematic of dedicated flow line layout.

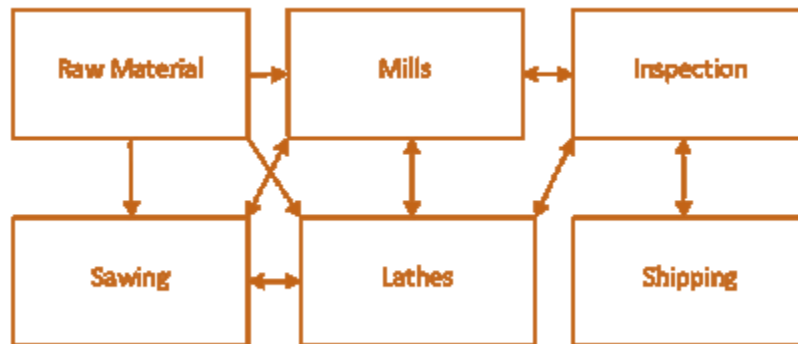


Figure 8: Schematic of a basic functional layout.

Group layout differs from the other two major types of layout – line layout and functional layout – in that group layout is completely based upon groups of parts. Line layout, depicted in Figure 7, is used for continuous assembly and mass production of components required in very large quantities. In line layout the machines are always used in same sequence, and the time an item spends at each station or location is fixed and equal (balanced) (Black, 1991). In a functional layout (see Figure 8), all machines of same type are laid out together in the same section under the same foreman (Schönsleben, 2007). Each supervisor and team of workers specializes in one process and work independently, which is why it is often called process specialization.

In most of today’s factories it is possible to divide all manufactured components into families and all machine tools into groups, in such a way that all the parts in each family can be completely processed in one dedicated machine group or cell only. Group layout therefore involves each foreman and his/her team specializing in production of one list of parts and co-operating in the completion of common tasks. This type of layout is based on component specialization, and machine tools in each group need not be used in same sequence (Burbidge, 1973).

5. Application of Group Technology

The first step in quality control must be to control design, since a good design should make it possible for the product, to be manufactured by current equipment with a high level of quality maintained. This means that a good design should contribute something to increase quality while reducing costs. GT can be a tool to help designers reach these two conflicting goals.

Basically, the cluster algorithms of GT can be classified into two major classes. A design-oriented approach relies on the design features of parts to perform the necessary analysis. The production-oriented approach, on the other hand, is based on routing information to group parts or machine (Kroll and Wang, 1994).

The objectives or constraints under which the GT system design problem is typically tackled are as follows (Vakharia and Wemmerlöv, 1990):

- Minimize the intercellular materials handling cost (or maximize cell independence). A primary focus of GT is to identify cells where the between-cell interaction is restricted.
- Minimize investment in equipment. In reorganizing a job shop into a GT cell system, there is typically an increase in the number of machines required. Hence, this objective focuses on minimizing the additional investment in such equipment.
- Maintain acceptance equipment utilization levels. A cell system design is feasible if the utilization of equipment in each cell is less than the maximum acceptable level.
- Identify the cells of reasonable size. The size of the GT cell will impact how easily the cell can be managed and controlled. Hence cells identified should not contain more than a specified number of machines.

6. Benefits of GT Toward Automation

Since manufacturing costs are major determinants of ultimate product costs, it is not surprising that optimizing the manufacturing process by grouping parts together can produce a significant return on investment.

By analyzing a part database, it is possible to identify groups of parts that are similar from manufacturing point of view. This requires a production-oriented grouping method, such as Opitz classification and coding or PFA (Modak, *et al.*, 2011). Having done that, the next step is standardization – by manufacturing engineers – of manufacturing processes for group of similar parts. This manufacturing standardization leads to a best practice approach to making parts, and provides the basis for work instructions to the shop floor.

The grouping of parts into families can then lead to the development of a new type of mass production and the introduction of mass production methods for those families of parts. The costs associated with classification and standardization therefore do not have to be applied to lot sizes of just a few parts; they can be given to families of parts that may run much larger numbers (Houtzeel, 2001). The following are some of the major benefits of GT:

- Faster implementation of design and process improvements
- Reduction of inventory (incoming, in-process and finished)
- Reduction in wait time
- Reduction in production planning effort
- Simplification of parts and their manufacturing processes
- Component standardization
- Reduction of overall production cost
- Higher accuracy of estimates
- Improvement in employee morale
- Improvement in space utilization
- Setup time reduction
- Higher productivity
- Improvement in quality
- Improvement in material flow

Utilizing GT captures certain advantages such as reduced setup times, reduced in-process inventories, improved product quality, shorter lead time, reduced tool requirements, improved productivity, and better overall control of operations. It is these benefits that allow GT to pave the road towards automation. For example, if there is a single family's flow of parts and/or products that is consistent and controlled, we can put in place a reliable and repeatable way of handling these materials via robotics and autonomous vision systems with pick-and place capabilities. This process will ensure that our incoming parts are being automatically

classified and distributed, then automatically taken and off-loaded to each part's designated manufacturing cell. The robotics and vision systems can then take over and handle the parts virtually by itself (with proper programming). These, as well as listed in Table 1, are just a few of many functions that are possible with an automated manufacturing system.

Table 1: Computer functions of an automated system.

Function	Description
Communication	Operators must get instructions from computer system when operating a manual workstation.
Download part programs	Computer-controlled machines have to get their instructions from programs which are downloadable.
Material Handling	To ensure efficiency, material handling and machine availability should be coordinated.
Production Schedule	Computer systems should monitor average cycle times and how many units are produced in one shift so proper scheduling can be a result.
Diagnose Failures	Equipment failures, spare parts, and maintenance must be monitored.
Safety	Systems must operate in a safe manner.
Quality Control	Detection and rejection of bad parts, acceptance of good parts.
Manage Operations	Monitoring overall performance of the manufacturing system.

7. Automated Group Technology

A highly automated GT machine cell consists of a group of processing stations (usually CNC machine tools), interconnected by an automated material handling and storage system, and controlled by an integrated computer system. Figure 9 depicts a simple automated manufacturing cell with two machine tools and a robotic parts handling system. If truly automated in accordance with the features listed in Table 1, this setup would be typical of a small automated GT work cell. This would be accomplished by following the principles of a Flexible Manufacturing System.

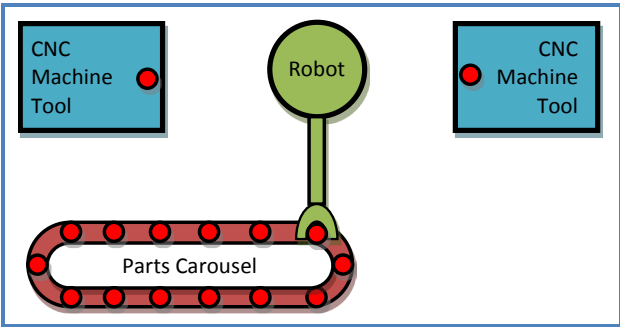


Figure 9: Automated manufacturing cell.

The Flexible Manufacturing System (FMS) operates in parallel with the principles of GT. No manufacturing system can produce an unlimited range of products, but a Flexible

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Manufacturing Cell (FMC) is capable of producing single part family or a limited range of part families. This flexibility is a key advantage of an FMC – the ability to cope with changes in part design, changes in production, equipment malfunctions, and variations within a part family. These principles – especially variation within a part family – imply common characteristics of GT and FMS.

Table 2: Typical functions of an FMS (Groover, 2010).

Function	Description
NC Programming	Development of NC programs for new parts introduced into system.
NC Program Download	NC part programs must be downloaded to individual stations as required for the product mix.
Production Control	Product mix, machine scheduling , and other planning functions.
Work-Part Control	Monitor status of each work-part in the system, status of pallet fixtures, orders on loading/unloading pallet fixtures.
Tool Management	Tool inventory control and queue location, tool status relative to expected tool life, tool changing and re-sharpening, and transport to and from tool sharpening/storage location.
Transport Control	Scheduling and control of work handling system.
System Management	Compiles management reports on performance (utilization, piece counts, production rates, etc.).

Looking back at the automated work cell in Figure 12, therefore, this cell could be set up as an FMC and allow for a single part family, not just a single part. This would be done by incorporating some of the basic FMS functions as applicable to this setup. Table 2 lists some of the common functions of an FMS. These functions indicate how an FMC is not only well-adapted, but would work ideally with a GT system (Kusiak, 1985).

8. Conclusion

This paper presents various approaches to Group Technology (GT), as well as the advantages of each. GT can be a gateway for automation because through production-oriented grouping, one can easily design work cells that are dedicated to single families and therefore easily created as FMCs. Furthermore, with GT, processes can be controlled, material handling can be controlled, inventory can be controlled more efficiently, flow of classified parts can be controlled, and with all the money that is saved by utilizing group technology, investments for automation can be made. This would include robotic arms and programmable logic controllers along with additional vision systems. So not only will distribution, classification along with inventory be automatically monitored and controlled, but the ability to pick and place these objects just by programming a robot with a vision system makes the system that much more autonomous. With these autonomous systems and a controlled manufacturing environment, the engineers and managers of a manufacturing system can grab the future by the horns and take it head on.

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