Introduction

Group Technology, a manufacturing philosophy has been recognized as a method for rationalizing small and medium batch production for some time. The term group technology or part family manufacture signifies a method which endeavors to analyze and to arrange the parts spectrum and the relevant manufacturing process according to the design and machining similarity so that a basis of groups and families can be established for the production processes in the area of small and medium batch sizes. GT makes use of the production engineering techniques that are applied for mass production.

A part family is a collection of geometric shape and size of parts, which are similar either because of geometric shape and size or because of similar processing steps, required in their manufacture. The parts within a family are different, but their similarities are close enough to merit their identification as members of the part family.

What is Group Technology?

Group technology is a manufacturing technique and philosophy to increase production efficiency by exploiting the underlying sameness of component shape, dimensions, process route, etc.

Background of Group Technology

- Generally there are three basic methods used for solving the group technology problems namely:
  
  1. Visual method
  2. Coding and classification method
  3. Production flow analysis method

Visual methods are defined as a classification of parts into families by looking at either physical parts or their photographs and arranging them groups having similar features. This method is considered to be least accurate among the three. Coding and classification method is defined as the classification of parts into families based on geometric shape and complexity, dimension, type of material, shape of raw material, required accuracy of the finished part etc. Using coding system each part is assigned a numerical or alphabetical code. Each digit of this code represents a feature of a part. Production flow analysis is defined as identifying part families and associated of grouping of machine tools; in other words, group technology is to group parts into part families and machines into machine cells.

The aim of group technology (GT) is to find part-families and machine
cells, which form self-sufficient units of production with a certain amount of functional autonomy that results in easier control. It implies the grouping of various technologies to achieve a competitive-edge based on a predefined operational strategy. Group technology generally refers the physical arrangement of manufacturing from the typical job shop cluster of similar machines to the not so typical cluster of dissimilar machines into cells to increase throughput and decrease part move time. Parts may be grouped or arranged for group technology based on:

1. Design characteristics or features
2. Manufacturing processes

Reviewing and grouping parts by design characteristics or attributes helps to minimize design application and creating a new part when an existing part may do the job. Grouping parts by manufacturing processes is really grouping manufacturing into corresponding grouped and specialized focus factory work cells instead of the traditional arrangement of machines according to function. Each work cell can be specially arranged to produce a given family of parts. Grouping parts into families to be processed on machines grouped for similar manufacturing processes can considerably reduce manufacturing costs related to the number of part setups, amount of material handling, length of lead time required, and the amount of in-process inventory.

In grouping part families, when choice has to be made between choosing to organize or arrange by design characteristics or manufacturing process, manufacturing needs should take precedence over design needs. This is because manufacturing costs account for such a high share of the final product cost.

The following techniques are employed in-group technology:

**VISUAL INSPECTION METHOD**
This method is the least sophisticated and least expensive method. It involves the classification of parts into families by looking at either the physical parts or photographs and arranging them into groups having similar features. Although this method is considered to be least accurate among the three, one of the first major success stories of GT in the United States made the changeover using the visual inspection method.

**CODING AND CLASSIFICATION METHOD**
Coding is a process of establishing symbols to be used for meaningful communication. Classification is a separate process in which items are separated into groups based on the existence or absence of characteristics attributes. Coding can be used for classification purposes, and classification requirements must be considered during the construction of a coding scheme. Therefore, coding and classification are closely related.
Before coding a scheme can be constructed, a survey of all component features must be completed and then code values can be assigned to the features. The selection of relevant features depends on the application of the coding scheme. For example, tolerance is not important for design retrieval; therefore it is not a feature in a design-oriented coding system. However, in manufacturing-oriented coding system, tolerance is indeed an important feature.

**Three structures used in classification and coding schemes**

- Hierarchical structure, known as a mono-code, in which the interpretation of each successive symbol depends on the value of the preceding symbols.

- Chain-type structure, known as a polycode, in which the interpretation of each symbol in the sequence is always the same; it does not depend on the value of preceding symbols.

- Mixed-mode structure, which is a hybrid of the two previous codes.

**Hierarchical (monocode)**

In hierarchical structure each code number is classified by the preceding characters. One advantage is that it can represent a large amount of information with a very few code positions. A drawback is the potential complexity of the system. Hierarchical codes are difficult to develop because all the branches in the hierarchy must be defined.

**Example:**

Consider all parts to be classified in terms of a feature: rotational symmetry.

1 == Non-rotational (prismatic) parts.
2 == Rotational parts.

Within these groups, we can further classify by feature: presence of hole(s).

0 == No holes
1 == Has holes

**Advantages of monocodes:**
1. With just a few digits, a very large amount of information can be stored.
2. The hierarchical structure allows parts of the code to be used for information at different levels of abstraction.

Disadvantages:

1. Impossible to get a good hierarchical structure for most features/groups
2. Different sub-groups may have different levels of sub-sub-groups, thereby leading to blank codes in some positions.

Chain (polycode)
A chain structure, each digit in the code position represents a distinct bit of information, regardless of the previous digit. Chain codes are compact and are much easier to construct and use. The major drawback is that they cannot be as detailed as hierarchical structures with the same number of coding digits.

The hybrid structure is a mixture of the hierarchical chain structures. Most existing coding systems use a hybrid structure to obtain advantages of both the structures.

Advantages:

1. Easy to formulate

Disadvantages:

1. Less information is stored per digit; therefore to get a meaningful comparison of, say, shape, very long codes will be required.
2. Comparison of coded parts (to check for similarity) requires more work.

Some of the important systems

- Opitz classification system (the University of Aachen in Germany, nonproprietary, Chain type)
- Brisch System (Brisch-Birn Inc.)
- KK3
- CODE (Manufacturing Data System, Inc.)
- CUTPLAN (Metcut Associates)
- DCLASS (Brigham Young University)
• MultiClass (OIR: Organization for Industrial Research),
  hierarchical or decision-tree coding structure

• Part Analog System (Lovelace, Lawrence & Co., Inc.)

**Optiz system**

In an Optiz system, intended for machined parts, uses the following digit sequence

**12345 6789 ABCD**

The basic code consists of nine digits, which can be extended by adding four more digits. The first nine are intended to convey both design and manufacturing data. The first five digits 12345 are called the form code. It describes the primary design attributes of the part, such as the external shape and the machined features. The next four digits 6789 are called as supplementary code, which indicates some of the attributes that would be of use in manufacturing. The extra four digits, ABCD are referred to as the secondary code and are intended to identify the production operation type and sequence.

**Multiclass system**

Multiclass system developed by the Organization for Industrial Research (OIR). The system is basically flexible, allowing the user company to customize the classification and coding scheme to a large extent to fit its own products and applications.

Multiclass uses a hierarchical or a decision tree coded structure in which the preceding digits depend on values of the previous digits. In the application of the system, a series of menus is picked lists, tables, and other interactive prompting routines are used to code the part. This helps to recognize and provide discipline to the coding procedure. The coding consists of 30 digits these are divided into two regions, one provided by OIR, and the second designed by the user to meet specific needs and requirements. A prefix precede the code number and ids used to identify the type of part.

**Hybrid Structure:**

In this case, the code for a part is a mixture of polycodes and monocodes. Such coding methods use monocodes where they can, and use polycodes for the other digits -- in such a way as to obtain a code structure that captures the essential information about a part shape. This is the most commonly used method of coding and classification.
Production Flow Analysis

Production flow analysis (PFA) is a method for identifying part families and associated machine groupings that uses the information contained on production route sheets rather than on part drawings. Workparts with identical or similar routings are classified into part families. The procedure for production flow analysis must begin by defining the scope of the study, which means deciding on the population of parts to be analyzed. Choice should be made if all the parts in the shop be included in the study, or a representative sample be selected for analysis. Once, this decision is made, and then the procedure in PFA consists of the following steps:

Data collection: The minimum data needed in analysis are the part number and operation sequence, which is contained in shop documents called route, Sheets may be operation sheets or some similar name. Each operation is usually associated with a particular machine, so determining the operation sequence also determines the machine sequence.

Sortation of process routings: In this step the parts are arranged into groups according to the similarity of their process routings. To facilitate this step, all operation or machines included in the shop are reduced to code numbers. For each part, the operation codes are listed in the order in which they are performed. Sortation procedure is then used to arrange parts into packs, which are groups of parts with identical routings.

PFA Chart: The processes used for each pack are then displayed in a PFA chart this chart is a tabulation of the process or machine code numbers for all the part packs. In recent GT literature, the PFA chart has been referred to as part-machine incidence matrix. In this matrix, the entries have a value $x_{ij}=1$ or $0$: a value $x_{ij}=1$ indicates that the corresponding part I requires processing on the machine j, and $x_{ij}=0$ indicates no processing of component I is accomplished on machine j. For clarity of presenting the matrix, the 0's are often indicated as empty entries, usually in table.

Cluster analysis: From the pattern of a data in the PFA chart, related groupings are identified and rearranged into a new pattern that brings
Composite Part Concept

- A *composite part* for a given family is a hypothetical part that includes all of the design and manufacturing attributes of the family.
- In general, an individual part in the family will have some of the features of the family, but not all of them.
- A production cell for the part family would consist of those machines required to make the composite part.
- Such a cell would be able to produce any family member, by omitting operations corresponding to features not possessed by that part.
- Composite part concept: (a) the composite part for a family of machined rotational parts, and (b) the individual features of the composite part.

<table>
<thead>
<tr>
<th>S.No</th>
<th>Design feature</th>
<th>Corresponding operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>External cylinder</td>
<td>Turning</td>
</tr>
<tr>
<td>2</td>
<td>Face of cylinder</td>
<td>Facing</td>
</tr>
<tr>
<td>3</td>
<td>Cylindrical step</td>
<td>Turning</td>
</tr>
<tr>
<td>4</td>
<td>Smooth surface</td>
<td>External cylindrical grinding</td>
</tr>
<tr>
<td>5</td>
<td>Axial hole</td>
<td>Drilling</td>
</tr>
<tr>
<td>6</td>
<td>Counterbore</td>
<td>Counterboring</td>
</tr>
<tr>
<td>7</td>
<td>Internal threads</td>
<td>Tapping</td>
</tr>
</tbody>
</table>

Machine Cell Designs (Types of GT cells)

- Single machine
- Multiple machines with manual handling
- Multiple machines with mechanized handling
- Flexible manufacturing cell
- Flexible manufacturing system

Methods of part family matrix formulation in-group technology

1. Similarity coefficient method (single linkage clustering)
2. Rank order clustering algorithm
3. Cluster identification algorithm

Similarity coefficient methods (single linkage cluster analysis):

Single linkage cluster analysis defined as the similarity of two groups as the similarity of a pair of members (one in each group) having the highest similarity between all pairs of members. Mr. Mc.Auley who has been developed in this method on 1972. The clustering methods consists of two essential steps.

1. Define a similarity coefficient showing the interdependence for each machine part combination.
2. cluster machine based on similarity coefficients

The similarity coefficient method of group technology is flexible and can be easily computerized. Indeed the majority of work in machine part group formation is based on this method, which uses the PFA machine – part matrix. In this method a similarity coefficient is first calculated for each pair of machines. This similarity coefficient is an indicator that describes how alike the two machines are in terms of the number of parts that visit both machines i and j for their processing and the total number of parts that are processed by both the machines jointly or individually. The similarity coefficient for machines i and j is defined

\[
N_{ij} = \text{no. of parts that visit both machines } i \text{ and } j
\]

\[
M_{ij} = \text{no. of parts that visit one machine but not the other}
\]

After calculating similarity coefficient for each pair of machines the next problem is to determine machine groups (GT) by using these coefficients. In grouping machines in GT cells, cluster analysis is used to form groups of similar items. Generally this method does not give any optimality in grouping of items but provides a good solution to classification problems. It clusters those items highly related with a highly specified similarity coefficient.
Some of the calculations:

Machine cell 1=(p1,p4,p8,p2)  
Machine cell 2=(p3,p6,p7)  
Machine cell 3=(p5,p9)  
Machine cell 4=(p10)  

Rank order cluster algorithm:

King 1979 presented a rank order cluster algorithm that is quite simple. We use his method to show how component families can be determined in our shop. King’s algorithm can be stated as follows:

Step 1: For all $j$ calculate the total weight of the column $W_j$
Step 2: If $W_j$ is in ascending order, go to step 3. Otherwise rearrange the columns to make $W_j$ fall in ascending order.

Step 3: For all $i$ calculate the total weight of row $W_j$

Step 4: If $W_i$ is in ascending order, stop. Otherwise rearrange the rows to make $W_i$ fall in an ascending order. Go to step 1

Example:
Cluster Identification Matrix

Step 0: Set the iteration number \( k = 1 \).

Step 1: Select any row \( i \) of incidence matrix \([a_{ij}]^k\) and draw horizontal line \( h_i \) through it (\([a_{ij}]^k\) is read: read matrix \([a_{ij}]\) at iteration \( k \)).

Step 2: For each entry of 1 crossed the horizontal line \( h_i \) draw a
vertical line \( v_j \).

Step 3: For each entry of 1 crossed once by a vertical line \( v_j \) draw a horizontal line \( h_k \).

Step 4: Repeat steps 2 and 3 until there are no more crossed once entries of 1 in \([a_{ij}]^k\). All crossed twice entries of 1 in \([a_{ij}]\) form machine cell MC-\( k \) and part family PF-\( k \).

Step 5: Transform the incidence matrix \([a_{ij}]^k\) into \([a_{ij}]^{k+1}\) by removing rows and columns corresponding to all the horizontal and vertical lines drawn in step 1 through 4.

Step 6: If matrix \([a_{ij}]^{k+1}=0\) (where 0 denotes a matrix with all elements equal to zero), stop. Otherwise set \( k = k+1 \) and go to step 1.

Example:

Step 0: Set the iteration number \( k = 1 \).

Step 1: Row 1 of incidence matrix (1) is selected and horizontal line \( h_1 \) is drawn through it. The outcome of steps 1 and 2 is presented in matrix (2).

Step 2: Three vertical lines \( v_2, v_3, v_5 \) are drawn.

Step 3: Two horizontal lines \( h_5 \) and \( h_7 \) are drawn through all the crossed once entries of 1 matrix (2) as shown in matrix (3).
Step 4: Since the entries (5,8) and (7,8) of matrix (3) are crossed once, vertical line \(v_8\) is drawn as shown in the matrix (4). Since there are no more crossed once entries, all the crossed twice entries of the matrix (4) form:

Machine cell \(MC-1 = \{1, 5, 7\}\)
Part family \(PF-1 = \{2, 3, 5, 8\}\)

Step 5: Matrix (4) is transformed onto matrix (5)

In the second iteration \(k=2\). Steps 1 through 4 are performed on matrix (5). This iteration results in incidence matrix (6).
Also machine cell $MC_2 = \{2,4\}$ and Part family $PF_2 = \{1,6\}$ are obtained.

In the third iteration $(k=3)$ matrix (7) is generated.

From this matrix $MC_3 = \{3,6\}$ and $PF_3 = \{4,7\}$ are obtained. This final clustering result is illustrated in matrix (8).

**Advantages**

1. Reduced production lead times
2. Reduced work in process
3. Reduced labour
4. Reduced tooling
5. Reduced rework and scrap material
6. Reduced set-up time
7. Reduced order time delivery
8. Improved human relation
9. Reduced paper work

**Disadvantage**

1. Cost of material handling system is more.
2. Cost of implement in machine cell is more
3. Preparation of process planning time is more.

**Application**

1. Shop layout
2. Process planning
3. Design(parametric, retrieval and fixture)
4. Scheduling
5. N.C part programming
6. Cost estimation