UNIT III

CELLULAR MANUFACTURING

Group Technology (GT)

- Group technology (GT) is a manufacturing philosophy to increase production efficiency by grouping a variety of parts having similarities of shape, dimension and/or process route.
- GT may be defined as a manufacturing philosophy that justifies batch production by capitalizing on design and/or manufacturing similarities among component parts. In batch production, the products are made in small batches and in large variety.
- Every batch contains identical items but every batch is different from the others.
- For example, a plant producing many parts (say 5000 different parts) may be grouped into several distinct families (say 20 to 25 part families). Each family possesses similar design and manufacturing characteristics.
- This grouping philosophy results in increased manufacturing efficiencies.

Group Technology (GT)

- Efficiencies are due to reduced setup times, lower in-process inventories, better scheduling, streamlined material flow, improved quality, improved tool control and the use of standardized process plans.

- In many plants where GT has been implemented, the production equipment is arranged into 'machine groups' (also known as 'cells') to facilitate work flow and parts handling.GT is felt advantageous in the product design stage also. GT is a prerequisite for computer integrated manufacturing.

- GT is not an automation strategy associated with either the design or the production engineering area, Implementation of GT is a critical first step for computer-aided process planning (CAPP) and many of the production engineering activities.

Group Technology (GT)

BENEFITS OF GT

- Group technology, when successfully implemented, offers many benefits to industries.
- GT benefits can be realised in a manufacturing organisation in the following areas;

1. Product design
2. Tooling and setups
3. Materials handling
4. Production and inventory control
5. Process planning
6. Management and employees.

Group Technology (GT)

1.Product design

- Importance of GT for product design come in cost and time savings.
- Design engineers can quickly and easily search the database for parts that either presently exist or can be used with slight modifications, rather than issuing new part numbers.
- Similar cost savings can be realised in the elimination of two or more identical parts with different part numbers.
- Advantage is the standardisation of designs.
- Design features such as comer radii, tolerances, counter bores, and surface finishes can be standardized with GT.

Group Technology (GT)

2) Tooling and Setups

- In the area of tooling, group jigs and fixtures are designed to accommodate every member of a part family.
- Also work holding devices are designed to use special adapters in such a way that this general fixture can accept each part family member.
- Since setup times are very short between different parts in a family, a group layout can also result in dramatic reductions in setup times.

3) Materials Handling

- GT facilitates a group layout of the shop.
- Since machines are arranged as cells, in a group layout, the materials handling cost can be reduced by reducing travel and facilitating increased automation.

Group Technology (GT)

4) Production and Inventory Control

- GT simplifies production and planning control.
- Complexity of the problem has been reduced from a large portion of the shop to smaller groups of machines.
- Production scheduling is simplified to a small number of parts through the machines in that cell.
- In addition, reduced setup times and effective materials handling result in shorter manufacturing lead times and smaller work-in-process inventories.

Group Technology (GT)

5) Process Planning

- Concept of group technology parts, classification and coding lead to an automated process planning system.
- Grouping parts allows an examination of the various planning/route sheets for all members of a particular family.
- Once this has been accomplished, the same basic plans can be applied to other members, there by optimizing the shop flow for the group.

Advantages of Group Technology (GT)

- GT facilitates (a) efficient retrieval of similar parts, (b) development of a database containing effective product design data and (c) avoidance of design duplication.
- GT encourages standardization of designs, tooling, fixing and setups.
- GT facilitates (a) development of a computer-aided process planning (CAPP) system, (b) retrieval of process plans for part families and (c) development of standard routings for part families.
- Times and costs for material handling and waiting between stages are reduced.
- Production planning and control is simplified.
- Setup time and setup cost for each job are reduced, because several jobs are grouped and processed in sequence.
- Machining cells can reduce work-in-process inventory, resulting in shorter queues and shorter manufacturing throughput times.
- Part and product quality are improved.
- GT facilitates better employee involvement and increases workers satisfaction.

Limitations of Group Technology (GT)

- Implementing GT is expensive.
- Large costs may be incurred in rearranging the plant into machine cells or groups.
- Installing a coding and classification system is very time-consuming.
- As there is no common implementation approach, the implementation of GT is often difficult.

Part Families

- Part family is a collection of parts which are similar either because of geometric shape and size or because similar processing steps are required in their manufacture.

- Parts which are similar in their design characteristics (i.e. shape and geometry) are grouped in a family referred to as a design part family.

- Parts which are similar in their manufacturing characteristics are grouped in a family referred to as a manufacturing part family.

- Characteristics used in classifying parts are referred to as “attributes”.

Part Families

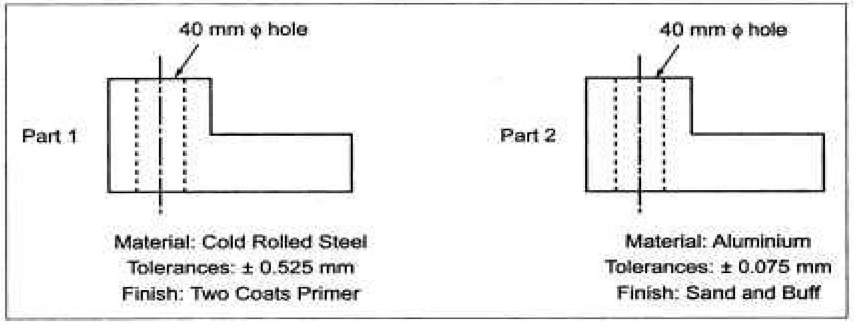
- The two parts are placed in the same family based on design characteristics.

- They have exactly the same shape and size.

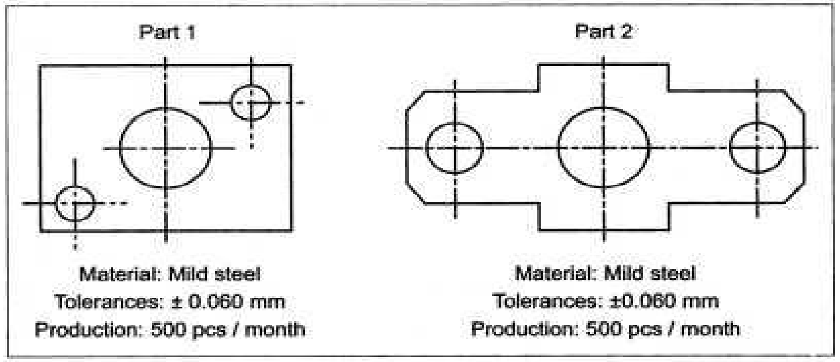
- They differ in terms of manufacturing requirements such as tolerances, production quantities and material.

Part Families

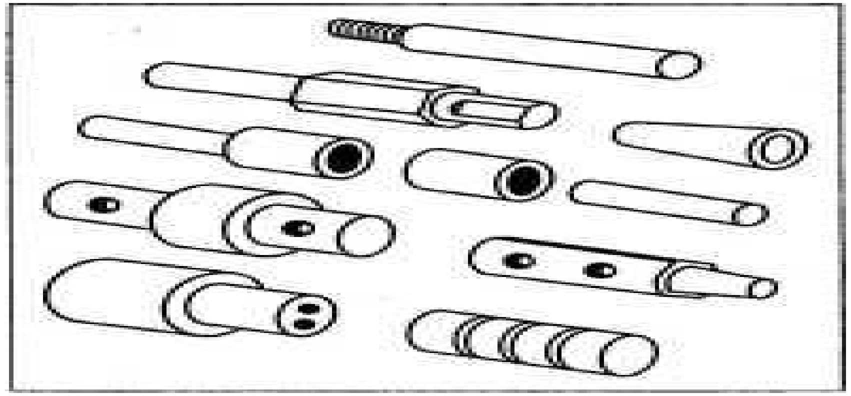
- Design part family



- Manufacturing part family



- A family of parts with similar manufacturing process requirements but different design attributes.



Part Families

Methods for Part Family Formation

- The three general methods for grouping parts into families are:

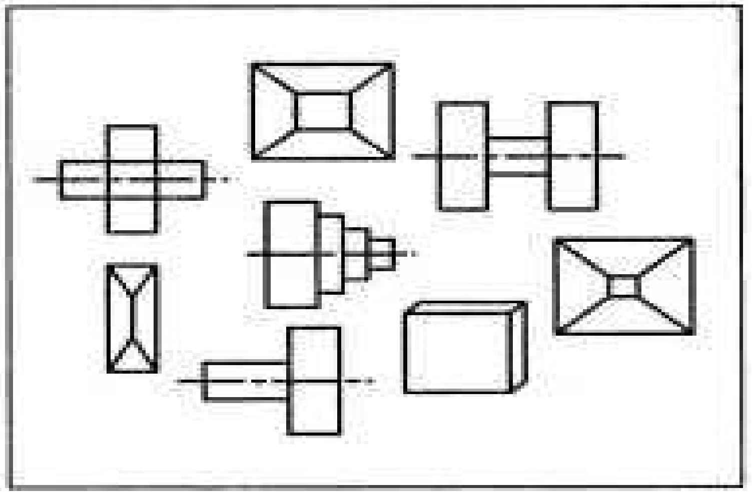
1.Visual inspection

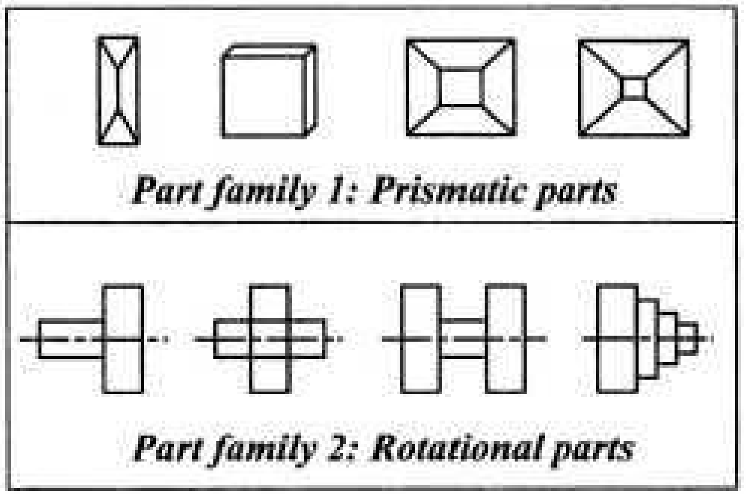
2.Parts classification and coding system

3.Production flow analysis.

Visual Inspection Method

- Visual inspection method is the simplest and least expensive method.
- It involves looking at parts, photos of parts or drawings of parts and arranging them into similar groups.





Parts Classification and Coding

- Coding is a systematic process of establishing an alphanumeric value for parts based on selected part features. Classification is the grouping of parts based on code values.

- It is the most sophisticated, most difficult, most time-consuming and widely used of the three methods.

- Here the various design and/or manufacturing attributes of a part are identified, listed and assigned a code number.

- Though several classification and coding systems have been developed, no system has been universally adopted. one of the reasons for this is that the information that is to be represented in the classification and coding system will vary from one company to another company.

Parts Classification and Coding

Design and Manufacturing Attributes

- Any parts classification systems fall into one of the following three categories:

1. Systems based on part design attributes.

2. Systems based on part manufacturing attributes.

3. Systems based on both design and manufacturing attributes.

Parts Classification and Coding

- Parts classified by design attributes can be coded from information on the engineering drawing. This first category systems are useful for design retrieval and to promote design standardization.

- In grouping of manufacturing attributes, in addition to drawing information, other information such as operation sequence, lot size, machines used, production processes, surface finish, etc. are also considered.

- Systems in the second category are used for computer-aided process planning, tool design and other production related functions.

- The third category represents an attempt to combine the functions and advantages of the other two systems into a single classification scheme..

Parts Classification and Coding

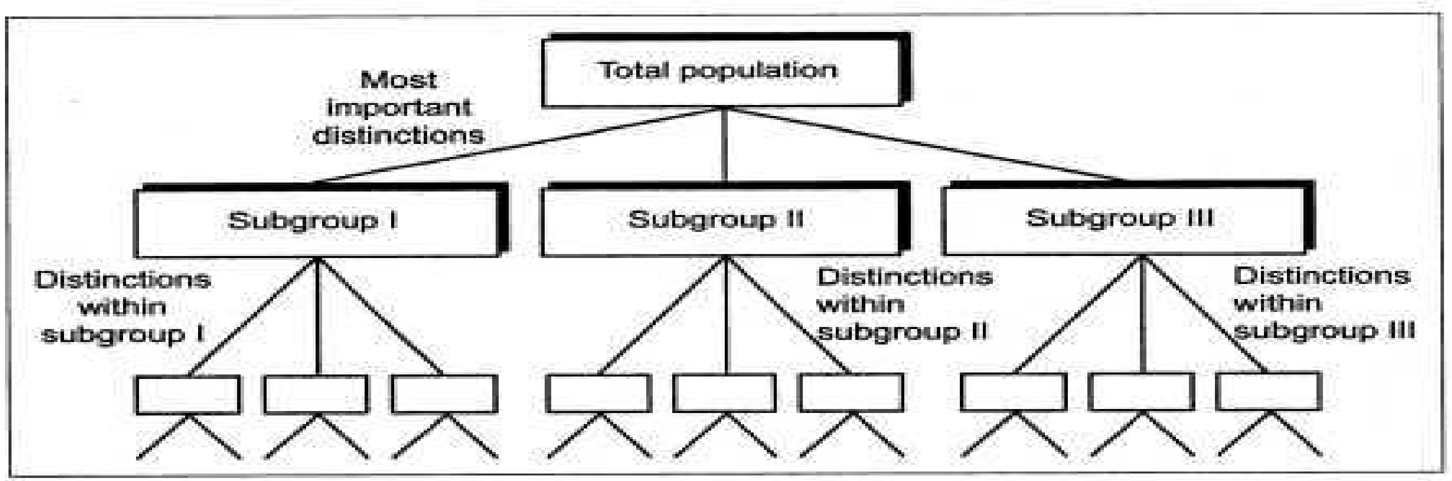
Coding System Structure

- A GT code is a string of characters capturing information about an item.
- A coding scheme is a vehicle for the efficient recording, sortingand retrieval of relevant information about objects.
- A part coding scheme consists of a sequence of symbols that identify the part's design and/or manufacturing attributes.
- The symbols in the code can be all numeric, all alphabetic or a combination of both types.

Parts Classification and Coding

1.Hierarchical Code (or Mono code)

- Interpretation of each successive symbol depends on the value of the preceding symbols.
- Each symbol amplifies the information contained in the preceding digit, so a digit in the code cannot be interpreted alone. Structure of these codes is like a tree in which each symbol amplifies the information provided in the previous digit.
- Hierarchical coding system can be depicted using a tree structure as shown in Figure.



Parts Classification and Coding

Merits and demerits of mono code system:

- Provides a large amount of information in a relatively small number of digits.
- This tree structure works well for designing an existing ordered structure but is more difficult to use in classifying things that have no apparent order.
- Defining the meanings for each digit in a hierarchical system (and hence the construction) is difficult.
- Frequently used in design departments for part retrieval.
- Their utility is limited in manufacturing departments, because it is difficult to retrieve and analyse process-related information when it is in a hierarchical structure.

Parts Classification and Coding

2) Attribute Code (or Poly code)

- In this structure, the interpretation of each symbol in the sequence does not depend on the value of preceding symbols.
- Each digit in this code represents information in its own right and does not directly qualify the information provided by the other digits.
- Attribute code is also known by other names ‘poly code’, ‘chain code’, ‘discrete code’ and ‘fixed-digit code’.

A.U.MEENAKSHI SUNDARESWARAN

Parts Classification and Coding

- Illustration: shows an example for attribute code.
- For the spur gear shown in Figure. using code, we can obtain the poly code as “22213”.

Digit	Class of feature	Possible value of digits			
		1	2	3	4
1	External shape	Cylindrical without deviations	Cylindrical with deviations	Boxlike	...
2	Internal shape	None	Center hole	Brind center hole	...
3	Number of holes	0	1-2	3-5	...
4	Type of holes	Axial	Cross	Axial cross	...
5	Gear teeth	Worm	Internal spur	External spur	...
⋮	⋮	⋮	⋮	⋮	⋮

Parts Classification and Coding

Merits and demerits of poly codes:

- The major advantages of poly codes are that they are compact and easy to use and develop.
- It is popular with manufacturing departments because it makes it easy to identify parts that have similar features that require similar processing.
- Because a poly code represents a class of items as a string of features, it is also particularly suitable for computer analysis.
- The primary disadvantage is that, for comparable code size, a poly code lacks the detail presence in a mono code structure. also poly codes tend to be longer than mono codes.

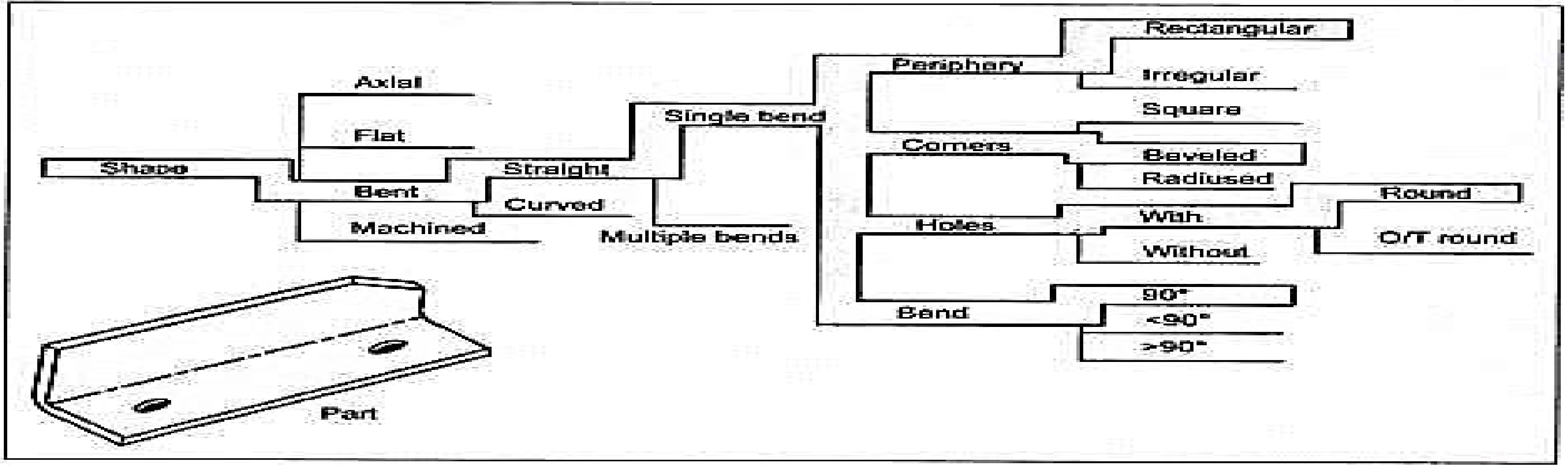
Parts Classification and Coding

3.Decision-Tree (or Hybrid) Code

- A hybrid code captures the best features of the hierarchical and poly code structures.
- This system is also known as decision-tree coding and it combines both design and manufacturing attributes.
- In practice, most coding systems use a hybrid construction to combine the best.
- To reduce the length of a strict poly code, the first digit of such a system may split the population into appropriate subgroups, as in a mono code structure. Then each subgroup can have its own poly code structure.
- For example, the first digit might be used to denote the type of part, such as gear.
- The next four positions might be reserved for a short attribute that would describe the attributes of the gear.

Parts Classification and Coding

features of monocodes and polycodes.



- The next digit position 6, might be used to designate another subgroup, such as material, followed by another attribute code that would describe the attributes. Thus, a hybrid code can be generated.
- Hybrid code is relatively more compact than a pure attribute code while retaining the ability to easily identify parts with specific characteristics.

Production Flow Analysis

- Developed by Burbridge in 1971, Is a method for identifying part families and associated machine groupings that uses the information contained on production route sheets rather on part drawings.

- Work parts with identical or similar routings are classified into part families.

- PFA neither uses a classification and coding system nor part drawings to identify families.

- It uses the information such as part number, operation sequence, lot size, etc., contained on the route sheet.

- This method is based on the route sheet information and sometimes referred as the route sheet inspection method.

Production Flow Analysis

Steps Involved in PFA

- The following four steps are followed to carryout PFA:

(i) Data collection

(ii) Sortation of process routings

(iii) Preparation of PFA chart

(iv) Cluster analysis.

Production Flow Analysis

Step 1: Data collection

- The step in the PFA procedure is to collect the necessary data.
- Route sheets of all the components to be manufactured in the shop are prepared.
- Route sheet should contain the part number and operation sequence.
- Other data that can be collected/obtained from route sheet/operation sheet include lot size, time standards and annual demand.

Step 2: Sortation of process routes

- The second step in the PFA is to arrange the parts into groups according to the similarity of their process routings.
- A typical card format is required for organizing the data such as the part number, sequence of code and lot size. A sortation procedure is used to arrange the parts into 'packs'.
- Pack is nothing but a group of parts with identical process routings. Some pack may even contain only one part number. A pack identification or letter is provided for each pack.

Production Flow Analysis

Step 3: PFA chart

- A PFA chart is a graphical representation of the process used for each pack.
- It is a tabulation of the process or machine code numbers for all of the part packs. Also known as 'part-machine incidence matrix' or 'component-machine incidence matrix'.
- The table below Illustrates a typical PFA chart having 7 machines (M1 to M7) and 9 parts (P1 to P9).

Machines	Parts								
	P1	P2	P3	P4	P5	P6	P7	P8	P9
M1	1	1		1				1	
m2					1				1
m3			1		1				1
m4		1		1		1			
M5	1							1	
m6			1						1
m7		1				1	1		

Production Flow Analysis

- In this matrix, the entries have a value x_{ij} = 1 or 0:
- A value of x_{ij} = 1 indicates that the corresponding part i requires processing on machine j
- x_{ij} = 0 indicates that no processing of component i is accomplished on machine j
- However, in Table , the 0's are indicated as blank (entry) entries for better clarity of the matrix.

Machines	Parts								
	P1	P2	P3	P4	P5	P6	P7	P8	P9
M1	1	1		1				1	
m2					1				1
m3			1		1				1
m4		1		1		1			
M5	1							1	
m6			1						1
m7		1				1	1		

Production Flow Analysis

Step 4: Cluster analysis

- From the PFA chart, related grouping are identified and rearranged into a new pattern that brings together packs with similar machine sequences.
- Table shows one possible rearrangement of the original PFA chart.
- It is clear that for the PFA chart considered we have three part families and three machine cells, as shown below.

Machines	Parts								
	P_1	P_8	P_2	P_4	P_6	P_7	P_9	P_3	P_5
M_1	1	1	1	1					
m_5	1	1							
m_4			1	1	1				
m_7			1		1	1			
m_3							1	1	1
m_6							1	1	
m_2							1		1

A.U.MEENAKSHI SUNDARESWARAN

Production Flow Analysis

Table : Rearranged PFA chart, indicating possible machine grouping

Part Families: Cell groups:

PF_1 ={P_1, P_8}C,= { M_1, M_5}

PF_2 ={P_2, P_4, P_6}C_2= {M_4, M_7}

PF_3 ={P_3, P_5, P_9}C_3={M_2, M_3, M_6}

Machines	Parts								
	P_1	P_8	P_2	P_4	P_6	P_7	P_9	P_3	P_5
M_1	1	1	1	1					
m_5	1	1							
m_4			1	1	1				
m_7			1		1	1			
m_3							1	1	1
m_6							1	1	
m_2							1		1

Production Flow Analysis

Advantages of PFA

- Parts classification and coding uses design data and the PFA uses manufacturing data (i.e., route sheet) to identify part families.
- Due to this fact, as pointed out by Groover, PFA can overcome two possible anomalies that can occur in parts classification and coding.
- First, parts whose basic geometries are quite different may nevertheless require similar or identical process routings.
- Second, parts whose geometries are similar may nevertheless require process routings that are quite different.
- Also PFA requires less time than a complete parts classification and coding procedure.

Production Flow Analysis

Disadvantages of PFA

- PFA does not provide any mechanism for rationalizing the manufacturing routings.
- No consideration being given to routing sheet whether the routings are optimal or consistent or logical.
- Process sequences from route sheets are prepared by different process planners, hence the routings may contain processing steps that are non- optimal, illogical and unnecessary.

Cellular Manufacturing

- It is an application of group technology in which dissimilar machines have been aggregated into cells, each of which is dedicated to the production of a part family.
- Primary advantage of CM implementation is that a large manufacturing system can be decomposed into smaller subsystems of machines called cells. Cells are dedicated to process part families based on similarities in manufacturing requirements. Parts having similar manufacturing requirements can be processed entirely in that cell.
- In addition, cells represent sociological units conducive to team work which lead to higher levels of motivation for process improvements.
- Benefits associated with the application of CM include improved market response, more reliable delivery promises, reduced tooling and fixtures and simplified scheduling.
- Literature surveys confirm substantial benefits from implementing cellular manufacturing in manufacturing industries.

Cellular Manufacturing

Rank	Reasons for implementing manufacturing cells	Average improvement
1	Reduce manufacturing lead time	61
2	Reduce work-in-process	48
3	Improve part and/or product quality	28
4	Reduce response time for customer orders	50
5	Reduce more distances/more times	61
6	Increase manufacturing flexibility	—
7	Reduce unit costs	16
8	Simplify production planning and control	—
9	Facilitate employee involvement	
10	Reduce set-up times	44
11	Reduce finished goods inventory	39

Cellular Manufacturing

- Design Considerations Guiding the Cell Formation
- We know that cell formation is the early activity in the cell design process where part families and associated machine groups are identified. Cell formation is influenced by a variety of objectives and concerns.
- Lists the important design considerations that should be taken into account during cell formation.

Rank	Design considerations
1	Parts/products to be fully completed in the cell
2	Higher operator utilization
3	Fewer operators than equipment
4	Balanced equipment utilization in the cell
5	The number of part/product assigned to the cell
6	Unidirectional (linear) material flows
7	The number of cell operators
8	High utilization on expensive equipment
9	The number of workstations/machines in the cell
10	High equipment flexibility to ease new product introduction over time
11	High flexibility in selecting alternative routes through the cell

Composite Part Concept

- Mitrofanov (1959) and Edwards (1970) have proposed composite part approach to implement the concept of cellular manufacturing.
- A composite part is formed by merging the primitives of all the parts of a part family.
- Composite is a single hypothetical part that can be completely processed in a manufacturing cell/group.
- If a new part is loaded in a machine group, the degree of dissimilarity of the part of its related part family or the hypothetical composite should have minimum deviation and desired to be zero.
- The manufacturing facility could be planned on the basis of composite part to facilitate economical production.

Composite Part Concept

- The primitives of three parts shown are merged into composite part by incorporating all the primitives of the three parts.

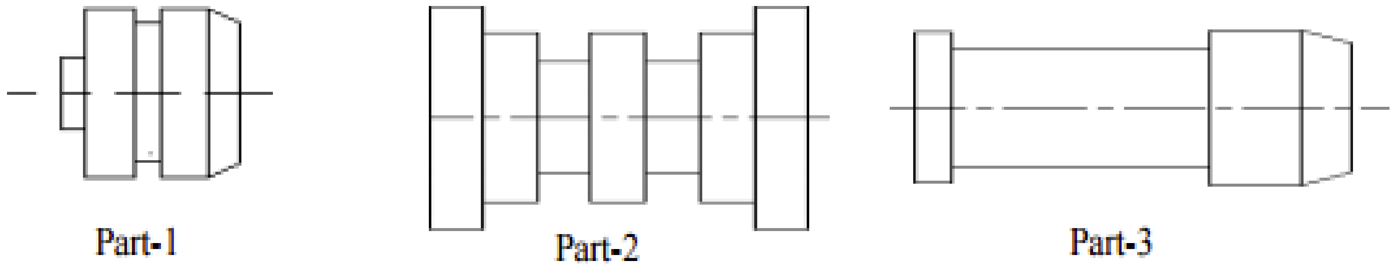
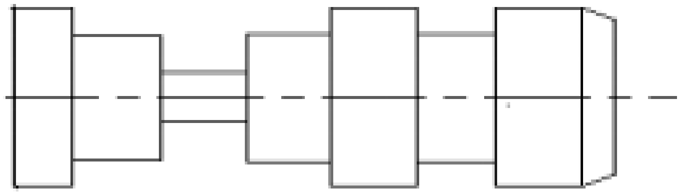


Figure 1: Individual parts



Composite Part Concept

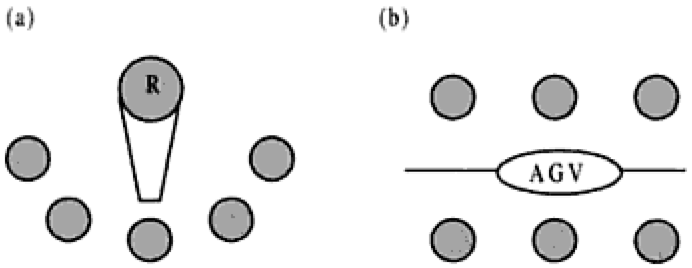
- It may not be judicious to merge all the primitives of parts due to various production considerations,
- In such situation the shop will converge back to a large job shop and all the benefits of CMS will be lost. Size of the manufacturing group depends on initial capital investment capacity, machines available and outsourcing facilities.
- Individual parts features (in terms of primitives) could be merged in the composite part based on their repetitions in the parts.
- Primitives having more repetitions will be more eligible candidates for merging in the composite part.
- Various techniques could be used for selection of optimum primitives for merging in composite parts.
- Genetic algorithm is proved to be one of the effective techniques.

Machine Cell Design and Layout

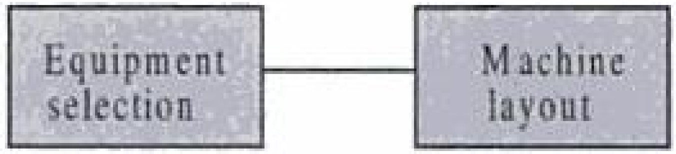
- Machine layout aims at determining the best arrangement of machines in each product cell.
- Minimization of material handling cost is an often used objective in determining the layout of machines in a cell.
- Constraints related to the availability of space, material handling system type and so on are considered.
- Type of operations and parts are not the only factors that impact the layout of machines.
- Type of material handling system to be used also needs to be considered;

Machine Cell Design and Layout

- Example, the articulated robot (R) in figure(a) implies a circular arrangement of machines.
- If an AGV had been selected to tend the same machines, it would have been necessary to use the layout in figure(b).



- Two step design of system



Machine Cell Design and Layout

- Goal of machine cell layout is to arrange the product or functional cells formed on the factory floor.
- Determining the layout of machine cells involves locating the cells in order to minimize the total material handling cost subject to some constraints (e.g. shape of the facility).
- If all cells were square in shape and of the same size, then the cell layout could be modelled as the quadratic assignment problem (QAP).
- Cell layout problem can be viewed as a machine layout problem, where each machine represents a cell.
- Though cellular manufacturing offers numerous benefits, it is not always implemented due to the following:

1. Parts and machines may not form mutually exclusive clusters.
2. The data required from the formation of cells might not be available.

Quantitative analysis in Cellular Manufacturing

Rank Order Clustering Method

- It also known as binary ordering algorithm (BOA), It is a simple algorithm used to form machine-part groups. it was Developed by J.R.King (1980).
- It considers two data:
- Number of components and Component sequences. Based on the component sequences, a machine-part incidence matrix is developed.
- Rows of the machine component incidence matrix represent the machines which are required to process the components. Columns of the matrix represent the component numbers.

Quantitative analysis in Cellular Manufacturing

Concept:

- Each row and each column of the matrix are considered as binary words.

- Example, in a row if we have numbers (1 0 1 0 1), then the decimal equivalent is computed as follows:

- Row decimal equivalent $= (1\times 24) +(0\times23) + (1 \times 22) + (0 \times 21) + (1 \times 20)$

  $= 16 + 0 + 4 + 0+ 1 = 21$

Quantitative analysis in Cellular Manufacturing

Concept:

- If a column has the following entries from top to bottom, the decimal equivalent is computed as explained below:
- Column entries = (11010)
- Column decimal equivalent = $(1 \times 24) + (1 \times 23) + (0 \times 22) + (1 \times 21) + (0 \times 20)$

  $= 16 + 8 + 0 + 2 + 0 = 26$
- Row with the largest decimal equivalent is considered to have the highest rank 1 among the rows.
- Column with the largest decimal equivalent is considered to have the highest rank among the columns.
- Procedure to obtain final machine component incidence matrix is summarized below.

Quantitative analysis in Cellular Manufacturing

Steps in ROC Algorithm

The steps in ROC algorithm are given below:

Step 0: Input: Total number of components, component sequences.

Step 1: Form the machine-component incidence matrix using the component sequences.

Step 2: Compute binary equivalent of each row.

Step 3: Rearrange the rows of the matrix in rank wise (high to low from top to bottom).

Quantitative analysis in Cellular Manufacturing

Steps in ROC Algorithm

Step 4: Compute binary equivalent of each column and check whether the columns of the matrix are arranged in rank wise (high to low from left to right). If not, go to Step 7.

Step 5: Rearrange the columns of the matrix rank wise and compute the binary equivalent of each row.

Step 6: Check whether the rows of the matrix are arranged rank wise, If not, go to Step 3; otherwise, go to Step 7.

Step 7: Print the final machine-component incidence matrix.

Quantitative analysis in Cellular Manufacturing

Arranging Machines in a GT cell

There are three basic ways to arrange machines in a GT cell are :

1. Line (or product) layout.

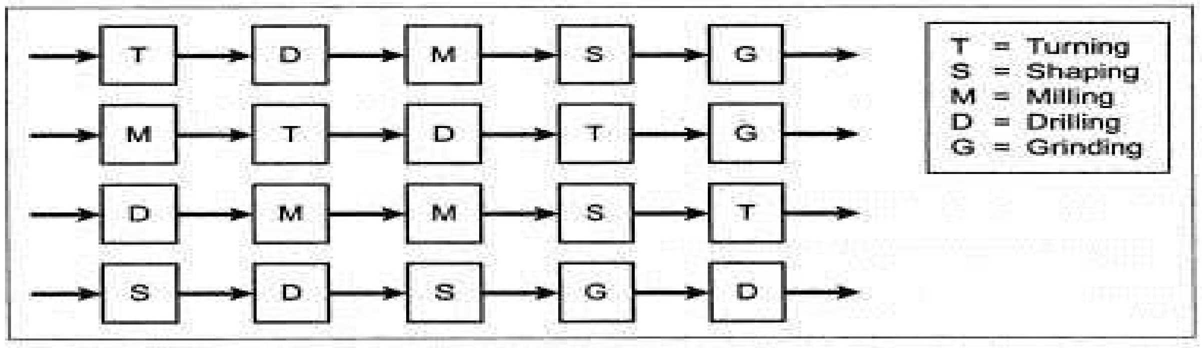
2. Functional (or process) layout.

3. Group (or combination) layout.

Quantitative analysis in Cellular Manufacturing

1) Line (or Product) Layout

- Here the machines are arranged in the sequence as required by the product.
- If volume of production of one or more products is large, the facilities can be arranged to achieve efficient flow of materials and lower cost per unit.



Suitability:

- Suitable for the continuous mass production of goods as it makes it possible for the raw material to be fed into the plant and take out finished product on the other end.

A.U.MEENAKSHI SUNDARESWARAN

Quantitative analysis in Cellular Manufacturing

Advantages	Disadvantages
Smooth and continuous work flow. Less space requirements for the same production volume. Automatic materials handling possible.	Lack of flexibility. That is product changes require major changes in layout. Large capital investment.
Lesser work-in-process inventory. Reduced product movement and processing time. Simple production planning and control, better co-ordination. Less skilled workers can serve the purpose.	Dedicated or special purpose machines. Dependence of the whole activity on each part. breakdown of any one machine in the sequence may result in stoppage of production.

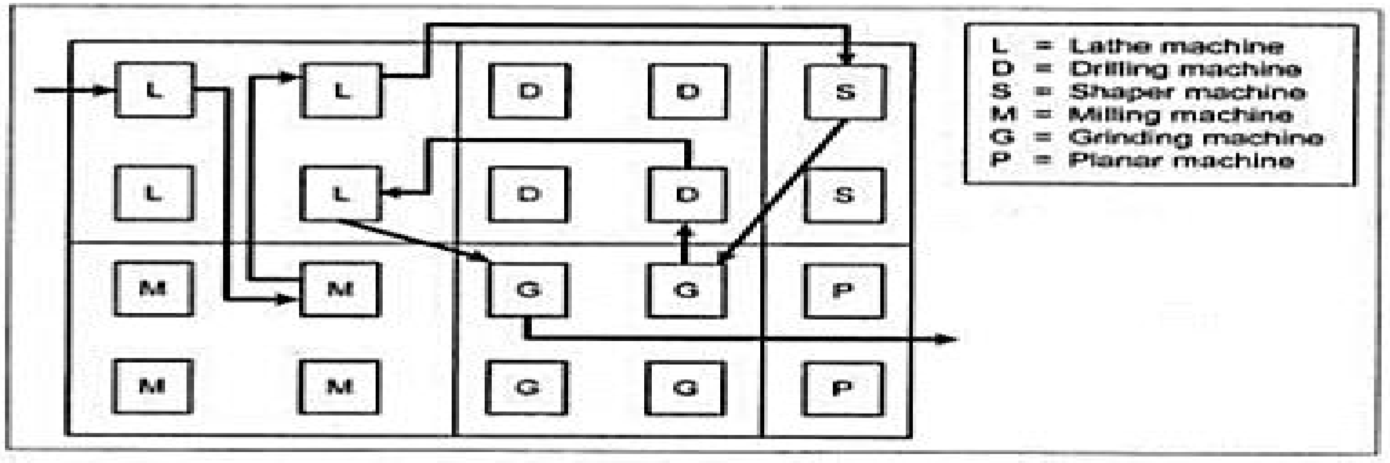
Table: Advantages and disadvantages of line layout

Quantitative analysis in Cellular Manufacturing

2) Functional (or Process) Layout

- Characterized by keeping similar machines, operations at one location, i.e. all lathes at one place, all milling machines at another place.
- In process layout, machines are arranged according to their functions.

Suitability: Suitable for job order/non-repetitive type production.



A.U.MEENAKSHI SUNDARESWARAN

Quantitative analysis in Cellular Manufacturing

Advantages	Disadvantages
Flexibility in assigning work to equipment and workers.	Automatic material handling is extremely difficult.
Better equipment utilisation.	Difficult production planning and control.
Comparatively less number of equipment needed.	More space is required.
Better product quality because of specialisation.	Large work-in-process inventory.
Variety of job makes the job challenging and interesting.	Higher grades of skill required.
	Lower productivity due to number of setups.

Table: Advantages and disadvantages of process layout

Quantitative analysis in Cellular Manufacturing

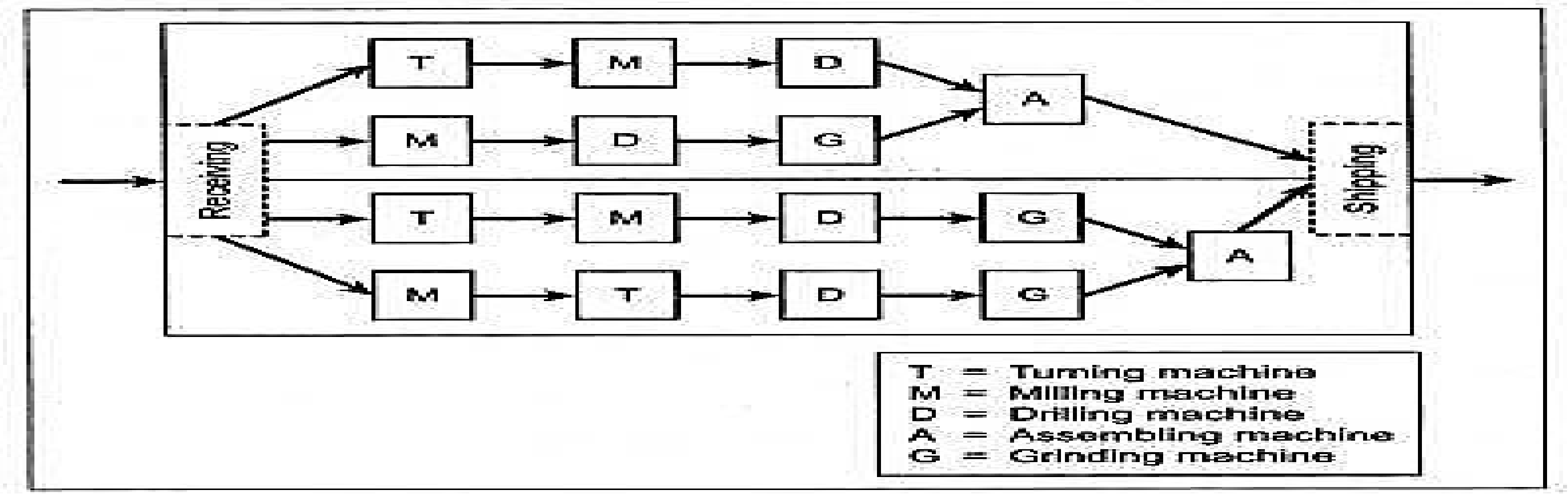
3) Group (or Combination) Layout

- It is a combination of the product layout and process layout.
- This layout Combines the advantages of both layout systems.
- Here machines are arranged into cells, each cell is capable of performing manufacturing operations on one or more families of part.
- If there are m machines and n components, in a group layout, the m-machines and n -components will be divided into distinct number of machines-component cells (groups) such that all the components assigned to a cell are almost processed within that cell itself.
- Objective is to minimize the inter-cell movements.

Suitability: Preferred for batch type production, where the products are n batches and in large variety.

Quantitative analysis in Cellular Manufacturing

3) Group (or Combination) Layout



- If there are m machines and n components, in a group layout, the m-machines and n - components will be divided into distinct number of machines-component cells (groups) such that all the components assigned to a cell are almost processed within that cell itself.

- Objective is to minimize the inter-cell movements.

Suitability: Preferred for batch type production, where the products are n batches and in large variety.

Quantitative analysis in Cellular Manufacturing

Advantages	Disadvantages
Group technology layout can increase.	This type of layout may not be feasible for all situations. if the product mix is completely dissimilar, then we may not have meaningful cell formation.
Component standardization and rationalisation	
Reliability of estimates	Comparatively high investment in equipment is required.
Effective machine operation.	
Productivity	
Costing accuracy	Higher grades of skill are required.
Customer service	Groupings of machines may lead to poor utilization of some machines in the group.

Hollier Method-Simple Problems

Hollier Method 1:

- The first method uses the sums of flow "From" and "To" each machine in the cell. The method can be outlined as follows:

1. Develop the From—To chart from part routing data. The data contained in the chart indicates number of part moves between the machines for workstations)

2. Determine the "From" and "To" sums for each machine. This is accomplished by summing all of the "From" trips and "To" trips for each machine (or operation).The "From" sum for a machine is determined by adding the entries in the corresponding row and the "To" sum is found by adding the entries in the corresponding column.

3. Assign machines to the cell based on minimum "From" or To sums. The machine having the smallest sum is selected. If the minimum value is a "To" sum, then the machine is placed at the beginning of the sequence. If the minimum value is a “From” sum, then the machine is placed at the end of the sequence. Tie breaker rules:

Hollier Method-Simple Problems

Hollier Method 1:

(a) If a tie occurs between minimum. "To" sums or minimum "From" sums, then the machine with the minimum “From/To” ratio is selected.

(b) If both "To" and "From" sums are equal for a selected machine, it is passed over and the machine with the next lowest sum is selected.

(c) If a minimum "To" sum is equal to a minimum "From" sum, then both machines are selected and placed at the beginning and the end of the sequence respectively.

Hollier Method-Simple Problems

Hollier Method 1:

(a) If a tie occurs between minimum. "To" sums or minimum "From" sums, then the machine with the minimum “From/To” ratio is selected.

(b) If both "To" and "From" sums are equal for a selected machine, it is passed over and the machine with the next lowest sum is selected.

(c) If a minimum "To" sum is equal to a minimum "From" sum, then both machines are selected and placed at the beginning and the end of the sequence respectively.

- Reformat the From-To chart After each machine has been selected, restructure the From-To chart by eliminating the row and column corresponding to the selected machine and recalculate the "From" and "To" sums. Repeat steps 3 and 4 until all machines have been assigned.

Hollier Method-Simple Problems

Hollier Method 2:

- This approach is based on the use of From/To ratios formed by summing the total flow from and to each machine in the cell. The method can be reduced to three steps:

1. Develop the From—To chart. This is the same step as in Hollier Method 1.

2. Determine the From/To ratio for each machine. This is accomplished by summing up all of the "From" trips and "To" trips for each machine (or operation). The "From" sum for a machine is determined by adding the entries in the corresponding row and the "To" sum is determined by adding the entries in the corresponding column. For each machine, the From/To ratio is calculated by taking the "From" sum for each machine and dividing by the respective "To" sum.

Hollier Method-Simple Problems

Hollier Method 2:

- **3. Arrange machines in order of decreasing From/To ratio.** Machines with a high From/To ratio distribute work to many machines in the cell but receive work from few machines. Conversely machines with a low From/To ratio receive more work than they distribute. Therefore, machines are arranged in order of descending From/Ip ratio. That is, machines with high ratios are placed at the beginning of the work flow and machines with low ratios are placed at the end of the work flow. In case of a tie, the machine with the higher "From" value is placed ahead of the machine with a lower value.

Hollier Method-Simple Problems

Percentage of in-sequence moves

- Percentage of backtracking moves.
- The percentage of in sequence moves is computed by adding all the values representing in sequence moves and dividing by the total number of moves.
- The percentage of back tracking moves is determined by summing all of the values representing back tracking moves and dividing by the total number of moves.