IE360: CAD/CAM

Computer Aided Design and Computer Aided Manufacturing

Lecture (13)

Group Technology

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Outline

- Overview of group technology
- Group technology applications
- Benefits of group technology
- Problems in implementing group technology
- Group technology techniques
  - Visual inspection
  - Parts classification and coding
    - Opitz classification system
  - Production flow analysis
    - Rank order clustering
    - Single linkage cluster analysis

Overview of group technology:

- Group technology is a manufacturing philosophy in which similar parts are identified and grouped together to take advantage of their similarities in design and production.

- Similarities among parts permit them to be classified into ***part families***, as shown in Figure 1.
    - In each part family, processing steps are similar.

- The improvement is typically achieved by organizing the production facilities into ***manufacturing cell***s that specialize in production of certain part families.

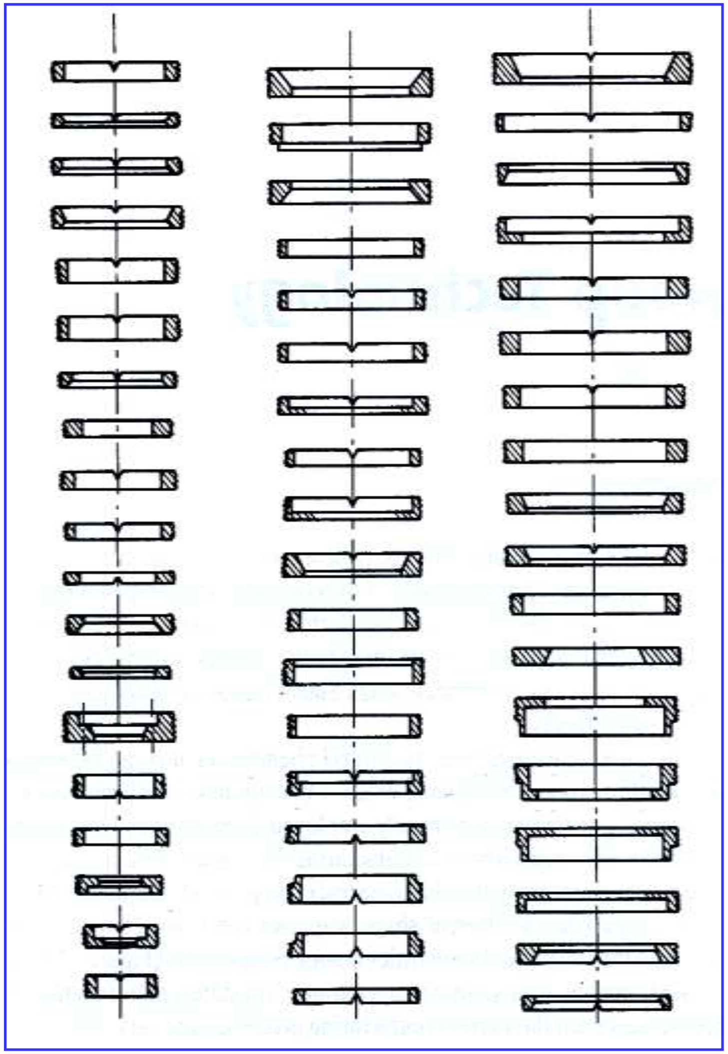

Figure 1: Part families

Group technology applications:

➢ In production systems, group technology can be applied in different areas.

- Component design:
  - A new design can be created by simply modifying an existing component design from the same family.
  - By using this concept, **composite components** can be identified, as shown in Figure 2.
  - Composite components are hypothetical parts that include all of the design and manufacturing attributes of the family.

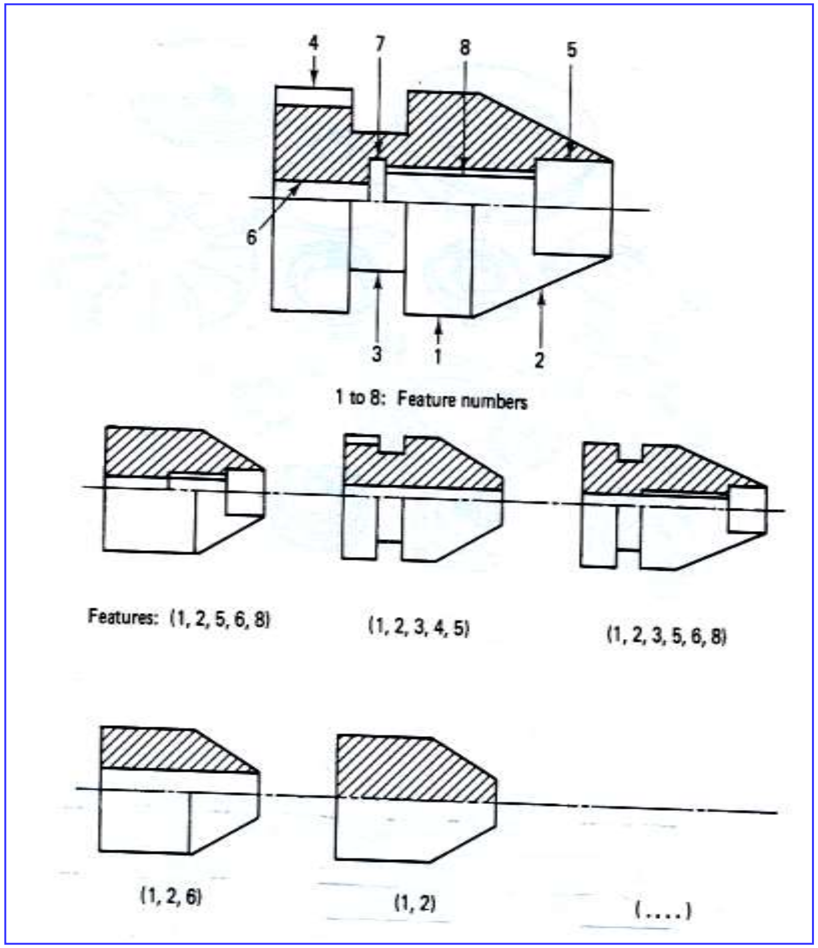

Figure 2: A composite component

- Manufacturing:
  - For manufacturing purposes, group technology represents a greater importance than simply a design philosophy.
  - Components that are not similar in shape may still require similar manufacturing processes. For example, in Figure 3, most components have different shapes and functions, but all require internal boring, face milling, and hole drilling.

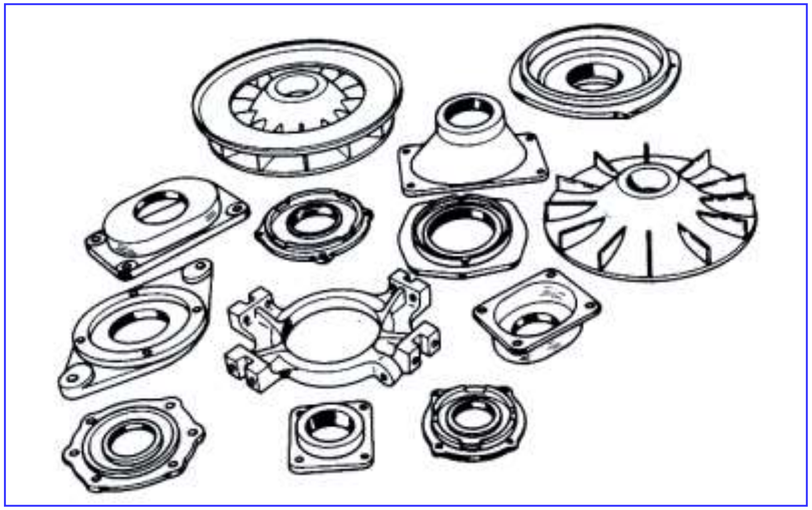

Figure 3: Production family

Benefits of group technology:

- Group technology is a management strategy to help eliminate waste caused by duplication of effort. Some of the well-known benefits of implementing group technology in companies are:
  - Reduction in new parts design.
  - Reduction in production floor space required.
  - Reduced material-handling effort.
  - Reduction in setup time and production time.
  - Improved machine loading and shortened production cycles
  - Improved material flow and reduced work-in-process inventory.
  - Faster response to schedule changes.
  - Improved usage of jigs, fixtures, pallets, tools, material handling, and manufacturing equipment.

Problems in implementing group technology:

- Identifying the part families
  - Reviewing all of the parts made in the plant and grouping them into part families is a substantial task.
- Rearranging production machines into group technology cells
  - It is time-consuming and costly to physically rearrange the machines into cells, and the machines are not producing during the changeover.

Group technology techniques:

- There are three general methods for grouping parts into families: visual inspection, parts classification and coding, and production flow analysis. These methods are briefly described in the following slides.

1. Visual inspection
   - Using best judgment to group parts into appropriate families, based on the physical parts or their photos.

2. Parts classification and coding
   - Identifying similarities and differences among parts and relating them by means of a coding scheme.

3. Production flow analysis
   - Using information contained on route sheets to classify parts

➢ *Parts classification and coding:*

- ***Classification*** of a part involves placing the part in a group, or family, based on the existence or absence of similar attributes.

- ***Coding*** of a part involves assigning symbols to the part; these symbols should reflect the attributes or features of the part.

- There are three different ***types of code structure*** in group technology coding systems:
    1. Hierarchical structure (monocode),
    2. Chain-type structure (polycode), and
    3. Hybrid or mixed-code structure.

➢ Hierarchical structure (monocode):

- In the hierarchical structure, each code number has a different meaning depending on the preceding characters. For example, in Figure 4, the fourth digit indicates threaded or not threaded for a 322X family.
- One advantage of a hierarchical structure is that it can represent a large amount of information with very few code positions.
- Its drawback is the difficulty of developing and modifying the codes because all the branches in the hierarchy must be defined. Also, it is difficult to identify the meaning of a digit because the entire hierarchy has to be traced.

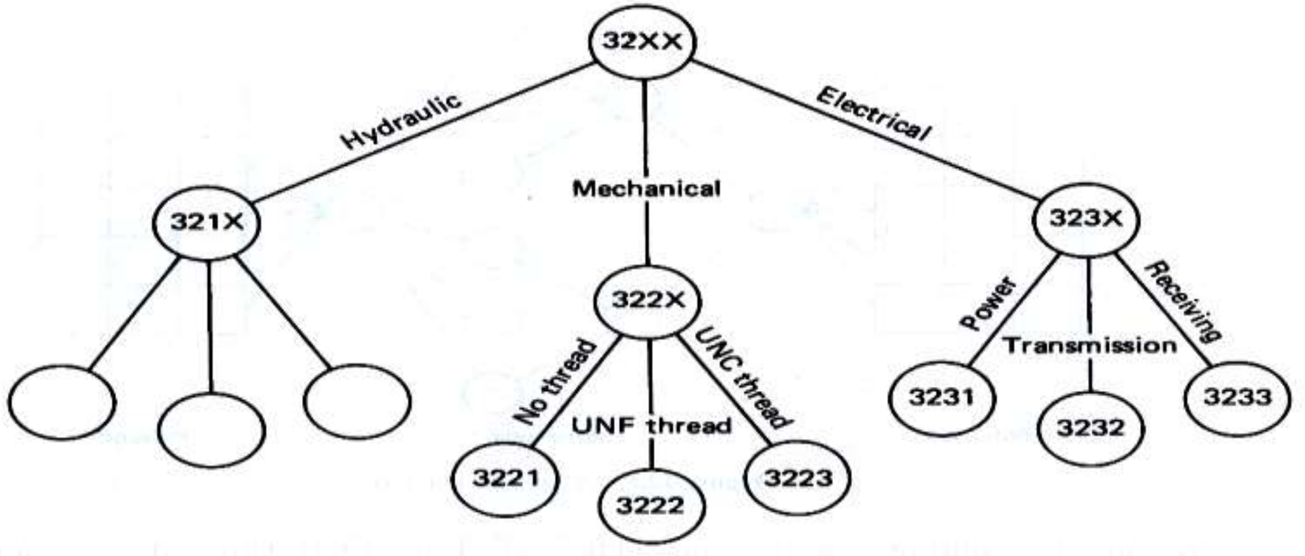

Figure 4: Hierarchical structure

➢ Chain-type structure (polycode):

- In a chain structure (see Figure 5), each digit represents a distinct bit of information, regardless of the previous digit.
- Chain codes are much easier to construct and modify.
- The primary drawback is that they carry much less information than hierarchical structures of the same number of coding digits.

Digit position	1	2	3	4
Class of feature	External shape	Internal shape	Holes	...
Possible value				
1	Shape 1	Shape 1	Axial	...
2	Shape 2	Shape 2	Cross	...
3	Shape 3	Shape 3	Axial and cross	
⋮	⋮	⋮	⋮	⋮

Figure 5: Chain-type structure

➢ Hybrid or mixed-mode structure:

- In the hybrid structure, some digits are arranged hierarchically and others are fixed. In other words, it is a mixture of the hierarchical and chain structures, as shown in Figure 6.
- Most existing coding systems used in industry are based on a hybrid structure in order to exploit the advantages of both structures. A good example is the widely used **Opitz** code.

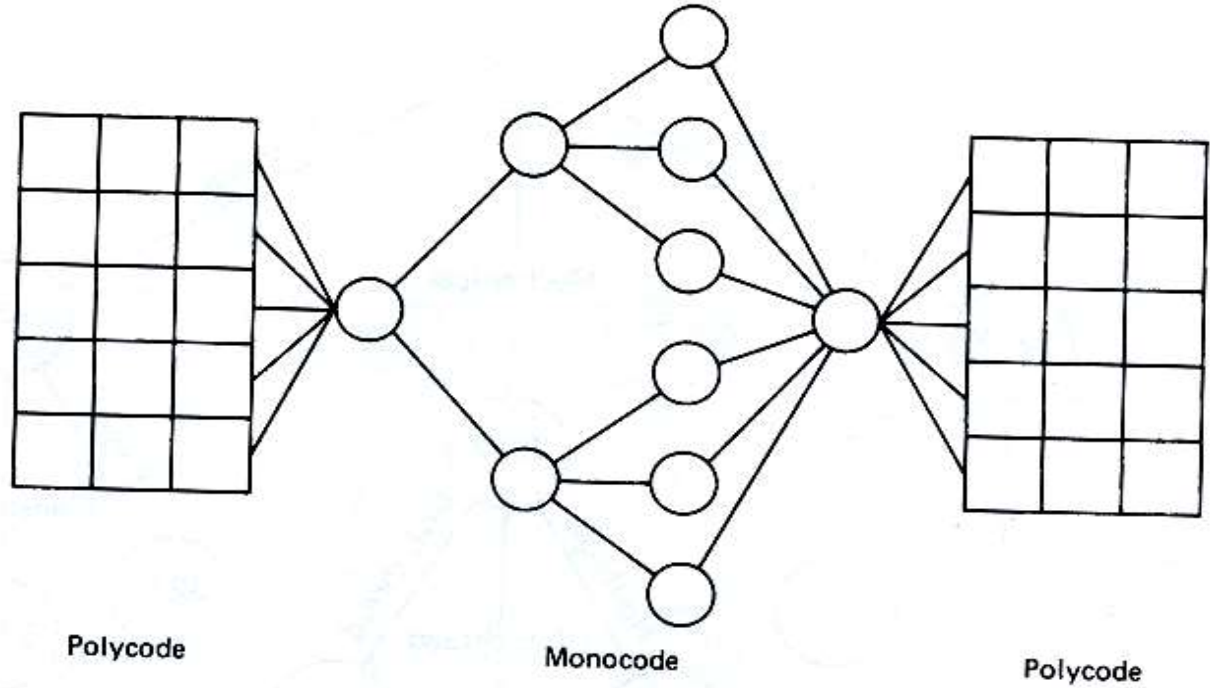

Figure 6: Hybrid structure

➢ *Opitz classification system:*

- The Opitz system is one of the first published classification and coding schemes for mechanical parts and is still widely used.

- The basic code consists of 9 digits. The interpretation of these digits is given in Figure 7.
  - The first five digits are called the *form code*. This describes the primary design attributes of the part, such as external shape (for example, rotational versus rectangular) and machined features (for example, holes, threads, gear teeth, and so forth).

  - The next four digits constitute the *supplementary code*, which indicates some of the attributes that are useful in manufacturing (for example, dimensions, work material, starting shape and accuracy).

  - The basic code can be extended by adding 4 more digits, which are referred to as the *secondary code*. These digits are intended to identify the production operation type and sequence.

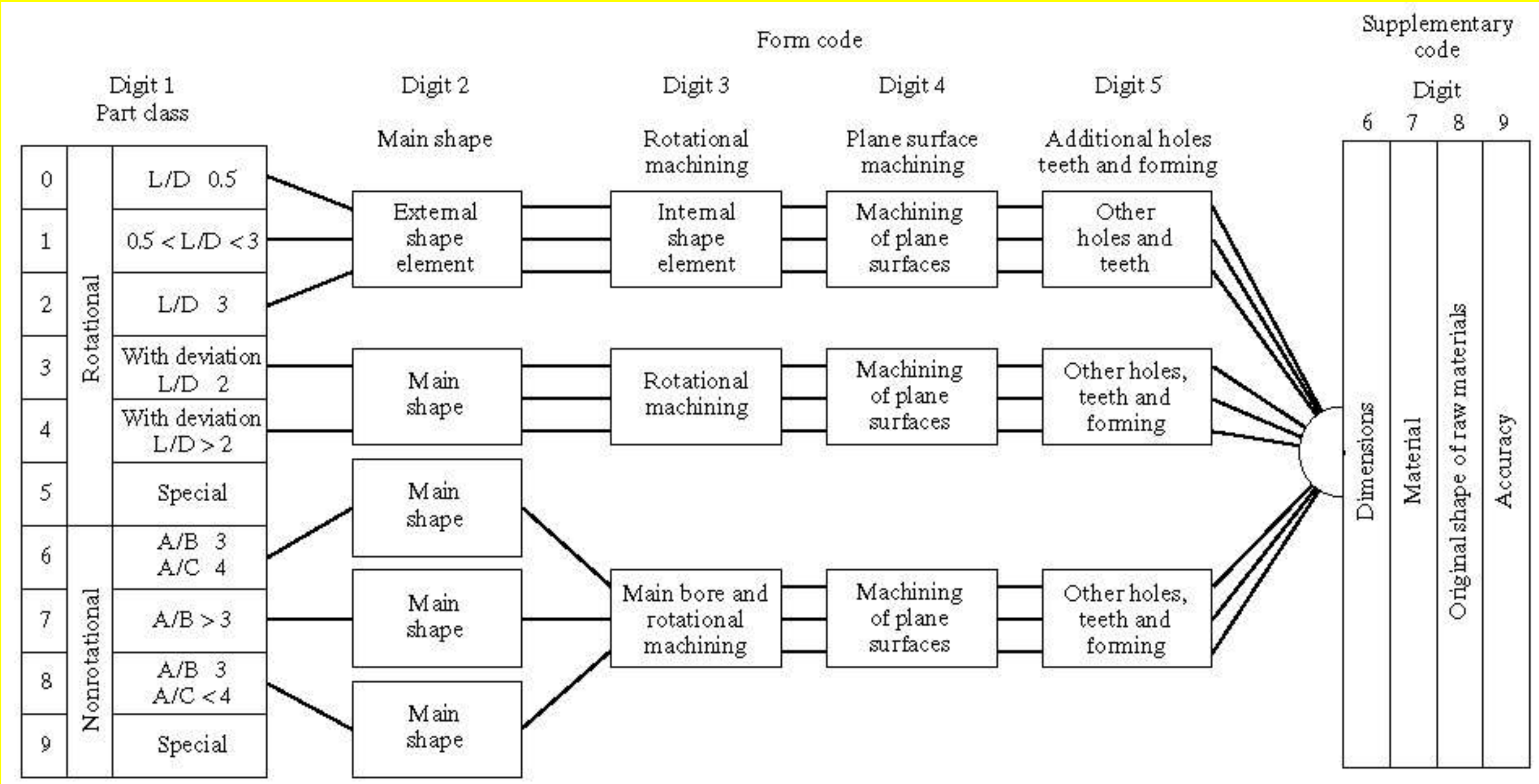

Figure 7: Basic structure of Opitz system

	Digit 1		Digit 2		Digit 3	Digit 4		Digit 5
	Part class		External shape, external shape elements		Internal shape, internal shape elements	Plane surface machining		Auxiliary holes and gear teeth
0	Rotational parts	L/D 0.5		Smooth, no shape elements		No hole, no breakthrough	No surface machining	No gear teeth	No auxiliary hole
1		0.5 < L/D < 3	Stepped to one end or smooth	No shape elements	Smooth or stepped to one end	No shape elements	Surface plane and/or curved in one direction, external		Axial, not on pitch circle diameter
2		L/D 3		Thread		Thread	External plane surface related by graduation around the circle		Axial on pitch circle diameter
3				Functional groove		Functional groove	External groove and/or slot		Radial, not on pitch circle diameter
4			Stepped to both ends	No shape elements	Stepped to both ends	No shape elements	External spline (polygon)		Axial and/or radial and/or other direction
5				Thread		Thread	External plane surface and/or slot, external spline		Axial and/or radial on PCD and/or other directions
6	Nonrotational parts			Functional groove		Functional groove	Internal plane surface and/or slot	With gear teeth	Spur gear teeth
7				Functional cone		Functional cone	Internal spline (polygon)		Bevel gear teeth
8				Operating thread		Operating thread	Internal and external polygon, groove and/or slot		Other gear teeth
9				All others		All others	All others		All others

Figure 8: Opitz form code (Digits 1 through 5)

➢ Example: Given the rotational part design in Figure 8, determine the form code in the Opitz system.

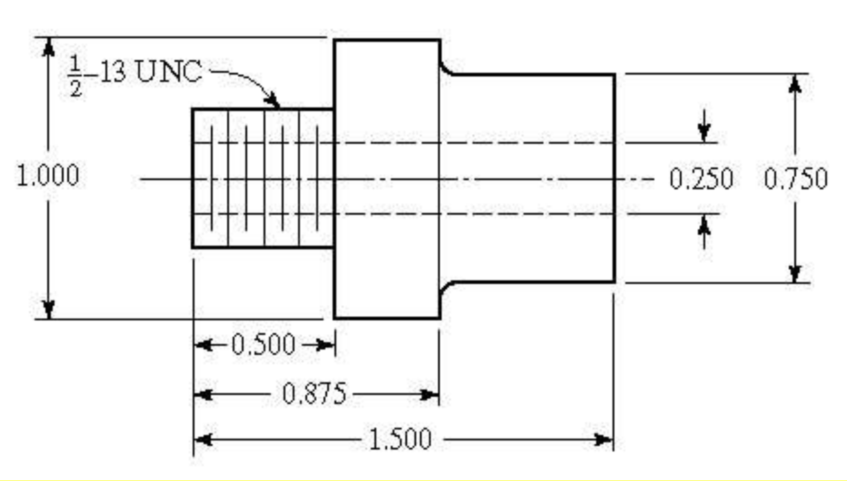

Figure 9: Part design

➢ Solution: The five-digit code is developed as follows:

- Length-to-diameter ratio, L/D = 1.5 — Digit 1 = 1
- External shape: stepped on both ends with screw thread on one end — Digit 2 = 5
- Internal shape: part contains a through hole — Digit 3 = 1
- Plane surface machining: none — Digit 4 = 0
- Auxiliary hole, geer teeth, etc.: none — Digit 5 = 0
- Therefore, the form code in the Opitz system is 15100.

Production flow analysis:

- Production flow analysis (PFA) is an approach for identifying part families and associated machine groupings based on production route sheets rather than part design data.

- Advantages of using route sheet data
  - Parts with different geometries may nevertheless require the same or similar processing.
  - Parts with nearly the same geometries may nevertheless require different processing.

- Steps in production flow analysis:
  - Data collection – operation sequence and machine routing for each part.
  - PFA chart – displaying all machines used for processing all parts in a PFA chart, also called a *part-machine incidence matrix*.
  - Cluster analysis – purpose is to group parts with similar routings into part families and the corresponding machines into cells.

➢ *Rank order clustering:*

- The rank order clustering algorithm provides an efficient routine for taking an arbitrary 0-1 machine-part matrix and reordering the machine rows and part columns to obtain nearly ***block diagonal structure***.
- Block diagonal means that we can partition the matrix such that the “boxes” on the main diagonal contain 0’s and 1’s but the off-diagonal boxes contain 0’s, as shown in Table 1.

Machines	Parts												
	P13	P2	P8	P6	P11	P5	P1	P10	P7	P4	P3	P12	P9
M2	1	1	1	1									
M4	1	1		1	1								
M1						1	1	1					
M5						1	1	1					
M6									1	1	1		
M3									1	1			
M7											1	1	1
M8												1	1

Table 1: machine-part matrix

➢ Each column represents a part, each row a machine. A “1” indicates that the part visits the corresponding machine. Part 13, for instance, requires machines M2 and M4. Parts 13, 2, 8 and 6 visit machine M2.

- The steps of the rank order clustering algorithm are as follows:

    1. Order rows: Assign value 2^{n-k} to column *k*. Evaluate each row. Sort rows in non-increasing order. If rows were previously ordered, and no change just occurred, stop: otherwise go to 2.

    2. Order columns: Assign value 2^{m-k} to row *k*. Evaluate each column. Sort columns in non-increasing order. If no change, stop. Otherwise go to 1.

    (n = number of parts , m = number of machines)

- Example: Form part families and machine groups for the 8-parts and 6-machines problem given in Table 2.

M/C	Part							
	1	2	3	4	5	6	7	8
A	1	1			1			
B			1					1
C		1	1			1	1	
D				1				1
E			1	1		1	1	
F	1	1			1			

Table 2: machine-part matrix

- Solution: Step 1:

Mach-ine	Part								Va-lue
	1	2	3	4	5	6	7	8	
A	1	1			1				200
B				1				1	17
C		1	1			1	1		102
D				1				1	17
E			1	1		1	1		54
F	1	1			1				200
2^{n-k}	128	64	32	16	8	4	2	1	

➢ Step 2:

Machine	Part								2^{m-k}
	1	2	3	4	5	6	7	8	
A	**1**	**1**			**1**				**32**
F	**1**	**1**			**1**				**16**
C		**1**	**1**			**1**	**1**		**8**
E			**1**	**1**		**1**	**1**		**4**
B				**1**				**1**	**2**
D				**1**				**1**	**1**
Value	**48**	**56**	**12**	**7**	**48**	**12**	**12**	**3**	

➢ Step 1:

Mac-hine	Part								Va-lue
	2	1	5	3	6	7	4	8	
A	1	1	1						224
F	1	1	1						224
C	1			1	1	1			156
E				1	1	1	1		30
B							1	1	3
D							1	1	3
2^{n-k}	128	64	32	16	8	4	2	1	

From the above Table, part families are {2, 1, 5}, {3, 6, 7} and {4, 8}, and the corresponding machine cells are {A, F}, {C, E}, and {B, D}.

- ***Single linkage cluster analysis:*** The single linkage cluster analysis (SLCA) algorithm helps in constructing *dendrograms*.

  - Essentially, a dendrogram is a pictorial representation of bonds of similarity between machines as measured by the similarity coefficients.

  - It is used to present the clustering results. The branches represent machines in the machine cell and the horizontal lines connecting branches represent the threshold values at which machine cells are formed.

- The steps of the SLCA algorithm are as follows:

  - Step1: Compute the similarity coefficient for all possible pairs of machines.

  - Step 2: Select the two most similar machines to form the first machine cell.

- Step 3: Lower the similarity level (threshold) and form new machine cells by including all machines with similarity coefficients not less than the threshold value.

- Step 4: Continue step 3 until all the machines are grouped into a single cell.

- The first two steps are repeated until all parts and machines are assigned to subgroups.

- The final step involves combining subgroups into groups of the desired size. Subgroups with the greatest number of common machine types are combined. This combination rule reduces the number of extra machines that will be needed and makes it easier to balance machine work loads. Ultimately, each group must be assigned sufficient machines and staff to complete its assigned parts.

- The similarity coefficient between two machines is defined as the ratio of the number of parts visiting both machines and the number of parts visiting one of the two machines as follows:

$$S_{ij} = \frac{\sum_{k=1}^{N} X_{ijk}}{\sum_{k=1}^{N} (Y_{ik} + Z_{jk} - X_{ijk})}$$

X_{ijk} = operation on part k performed both on machine i and j.

Y_{ik} = operation on part k performed on machine i.

Z_{jk} = operation on part k performed on machine j.

➢ Example: Consider the matrix of 5 machines and 10 parts given in Table 3. Develop a dendrogram and discuss the resulting cell structures?

Machines	Parts									
	1	2	3	4	5	6	7	8	9	10
M1	1	1	1	1	1		1	1	1	1
M2		1	1	1					1	1
M3	1				1	1	1			
M4		1	1	1				1	1	1
M5	1	1	1	1	1	1	1	1		

Table 3: Machine/part information matrix

- Solution:
  - Step 1: Determine similarity coefficients between all pairs of machines. The similarity coefficient between machine 1 and machine 2 is determined as follows:

$$SC_{12} = \frac{5}{9+5-5} = 0.55$$

Similarly, other similarity coefficients are calculated and are given in Table 4:

		Machines				
Machines		M1	M2	M3	M4	M5
	M1	-	0.55	0.30	0.67	0.70
	M2		-	0.00	0.83	0.30
	M3			-	0.00	0.50
	M4				-	0.40
	M5					-

Table 4: Similarity coefficients calculated using data given in Table 3.

- Solution (cont.):
  - Step 2: Select machines M2 and M4, having the highest similarity coefficient of 0.83, to form the first cell.
  - Step 3: The next lower coefficient of similarity is between machines M1 and M5. Use these to form the second cell.
  - Step 4: The next lower coefficient of similarity is now 0.67 between machines M1 and M4. At this threshold value machines M1, M2, M4 and M5 will form one machine group. The next lower coefficient of similarity is 0.55 between machines M1 and M2 which is dominated by the similarity coefficient 0.67 (See Table 5). The lowest non-dominated similarity coefficient is 0.50 between M3 and M5 at which all the machines belong to one cell.

- In the dendrogram given in Table 5, cells can be identified at different threshold values by drawing a horizontal line at the value. For example, four cells {M2, M4}, {M5}, {M1}, and {M3} will be formed at threshold value of 0.80, whereas only one cell is formed at a threshold value of 0.40.

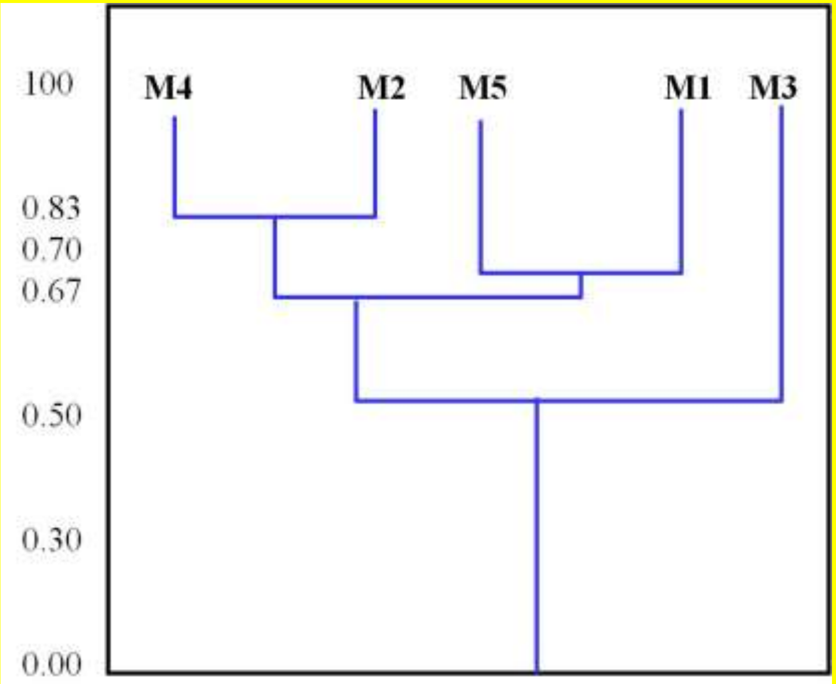

Table 5: The dendrogram constructed using the similarity coefficient data given in Table 4.

Exercise 7:

➢ Apply the rank order clustering technique to the part-machine incidence matrix in the table that follows to identify logical part families and machine groups. Parts are identified by letters, and machines are identified numerically.

	Parts								
Machines	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		

Exercise 8:

- Consider the part-machine incidence matrix in the table that follows, construct a dendrogram using the single linkage cluster analysis algorithm and discuss the resulting machine cell structures? Parts are identified by letters, and machines are identified numerically.

	Parts								
Machines	A	B	C	D	E	F	G	H	I
1			1	1	1				
2	1	1					1	1	1
3						1	1	1	
4	1	1		1					
5			1		1				
6		1						1	1
7	1		1	1					
8		1				1		1	1