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CERTIFICATION COURSES

AUTOMATION IN PRODUCTION SYSTEMS AND MANAGEMENT

Group Technology and Automation in Manufacturing

PROF PRADIP KUMAR RAY

DEPARTMENT OF INDUSTRIAL AND SYSTEMS ENGINEERING

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Group Technology and Automation in Manufacturing

- **Lecture-1:** Group Technology (GT): Concept and Definition
- **Lecture-2:** Methods and Implementation of GT for Automation
- **Lecture-3:** Part Family Formation: Tools and Techniques
- **Lecture-4:** Numerical Examples on Part Family Formation
- **Lecture-5:** Application of GT for Designing Flexible and Programmable Automation

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Group Technology and Automation in Manufacturing

✓ **Group Technology (GT): Concept and Definition**

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Group Technology (GT): Concept and Definition

- Batch manufacturing is a dominant manufacturing activity in the world, generating a great deal of industrial output. It accounts for 60 to 80 percent of all manufacturing activities.

- The major difficulties in batch manufacturing are due to the high level of product variety and small manufacturing lot sizes.

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Group Technology (GT): Concept and Definition

- The product variations present design engineers with the problem of designing many different parts. The decisions made at the design stage significantly affect manufacturing cost, quality, and delivery lead times. The impact of these product variations in manufacturing is high investment in equipment, high tooling costs, complex scheduling and loading, lengthy setup time and costs, excessive scrap, and high quality-control costs.

- However, to compete in a global market, it is essential to improve the productivity in batch manufacturing industries.

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Group Technology (GT): Concept and Definition

- Some innovative methods are needed to reduce product cost and lead time and enhance product quality to help increase market share and profitability.
- What is also needed is a higher level of integration of the design and manufacturing activities in a company.
- Group technology provides such a link between design and manufacturing.
- The adoption of group technology concepts, which allow small batch production to gain economic advantages similar to those of mass production while retaining the flexibility of the job shop, will help address some of the problems.

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Group Technology (GT): Concept and Definition

- Group technology (GT) is a philosophy that implies the notion of recognizing and exploiting similarities in three different ways (Hyer and Wemmerlov, 1985):

  a) By performing like activities together
  b) By standardizing similar tasks
  c) By efficiently storing and retrieving information about recurring problems

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Group Technology (GT): Concept and Definition

- The primary advantage of GT implementation is that a large manufacturing system to produce a set of parts can be decomposed into smaller subsystems of part families based on similarities in design attributes and manufacturing features.

- The decomposition based on similarities of design attributes, manufacturing features and functions leads to improved productivity in various functional areas of an organization.

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Group Technology (GT): Concept and Definition

- In product design, parts are classified and coded on the basis of their geometric similarities.
- To implement GT, formal classification and coding systems are incorporated into a computerized design retrieval system.
- This results in reduced time and cost of product development.

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Group Technology (GT): Concept and Definition

- In manufacturing , productivity and cost savings are realized by exploiting similarities in machining operations, tooling, setup procedures, and material handling. Parts having similar manufacturing requirements can be processed together in dedicated work cells, leading to reduced setups, tooling, and material handling.
- Cellular manufacturing, which is an applications of GT in manufacturing, provides a strategy for obtaining economic advantages in an environment of high-variety, low-demand production that are normally associated with high-volume repetitive flow production.

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Design Attributes and Manufacturing Features

- Typical design attributes include part configuration (round or prismatic), dimensional envelope (length/diameter ratios), surface integrity (e.g., surface roughness, dimensional tolerances), material type, raw material state (e.g., casting, forging, bar stock), and so forth.

- The part manufacturing features include operations (such as turning, drilling, and milling) and their sequences, batch sizes, machine tools and cutting tools needed to perform operations, processing times, and so forth.

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List of Reference Textbooks

- Groover, M P, Automation, Production Systems, and Computer Integrated Manufacturing, Third Edition, Pearson Prentice Hall, Upper Saddle River.

- Groover, M P and Zimmers, E W Jr, CAD/CAM: Computer-aided Design and Manufacturing, Prentice-Hall of India Private Ltd.

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Group Technology and Automation in Manufacturing

- ✓ **Methods and Implementation of GT for Automation**

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GT Implementation

- A number of GT approaches have been developed to decompose a large manufacturing system into smaller, manageable systems based on similarities of design attributes and manufacturing features.
- Two classes (i) classification approaches using coding systems (ii) cell formation approaches using production flow information.
- There are two variations of classification methods: The visual inspection method and the coding method.

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GT Implementation

Visual Inspection Method

- Visual inspection method involves arranging a set of parts into groups known as part families by visually inspecting the physical characteristics of the parts or their photographs.
- Consider the set of parts in Fig 12.1a. These parts are arranged into two families by visual inspection as shown Figure 12.1b.
- This method is inexpensive, least sophisticated, and dependent on personal preferences.
- By its nature, its utility is limited to companies having smaller number of parts.

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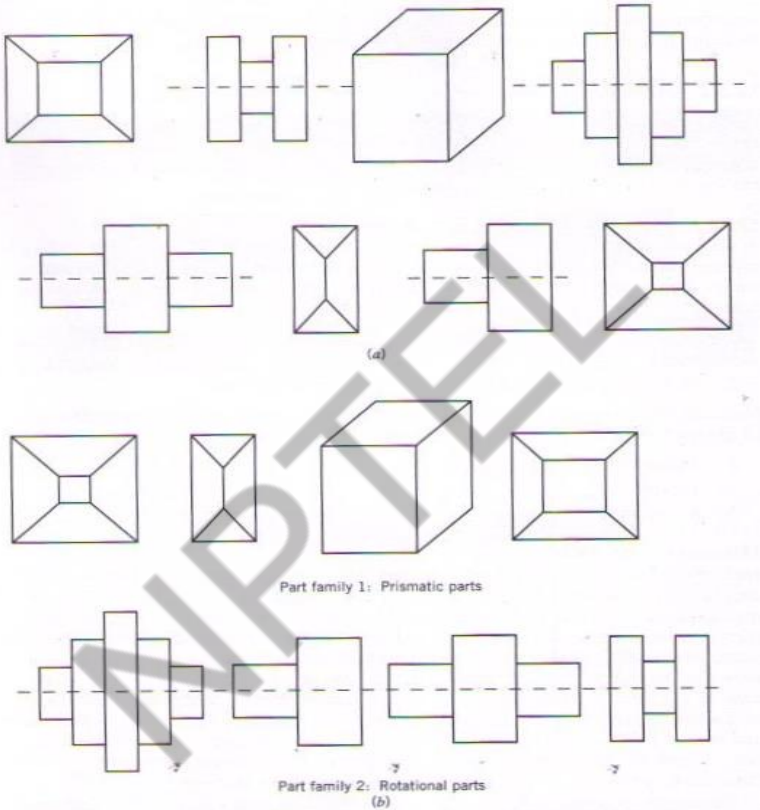

FIGURE 12.1 (*a*) A set of parts with dissimilar features. (*b*) Parts decomposed into part families by visual inspection.

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GT Implementation

Coding Methods

- Coding refers to the process of assigning symbols to the parts.
- The symbols represent design attributes of parts, manufacturing features of parts, or both.
- Classification refers to the process of categorization of a set of parts into part families.

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GT Implementation

Coding Methods

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GT Codes and Coding System Structures

- A GT code is a string of characters capturing information about an item. A coding scheme is a vehicle for the efficient recording, sorting, and retrieval of relevant information about objects.
- A large number of coding schemes have been developed.
- These coding schemes differ:
  a. In terms of the symbols they employ such as numeric, alphabetic, or alphanumeric.
  b. In the assignment of these symbols to generate codes.

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GT Codes and Coding System Structures

- Three distinct types of codes:
  a. Monocode or hierarchical code
  b. Polycode
  c. Mixed – mode code

- **Monocode or Hierarchical Code:**

The structure of these codes is like a tree in which each symbol amplifies the information provided in the previous digit.

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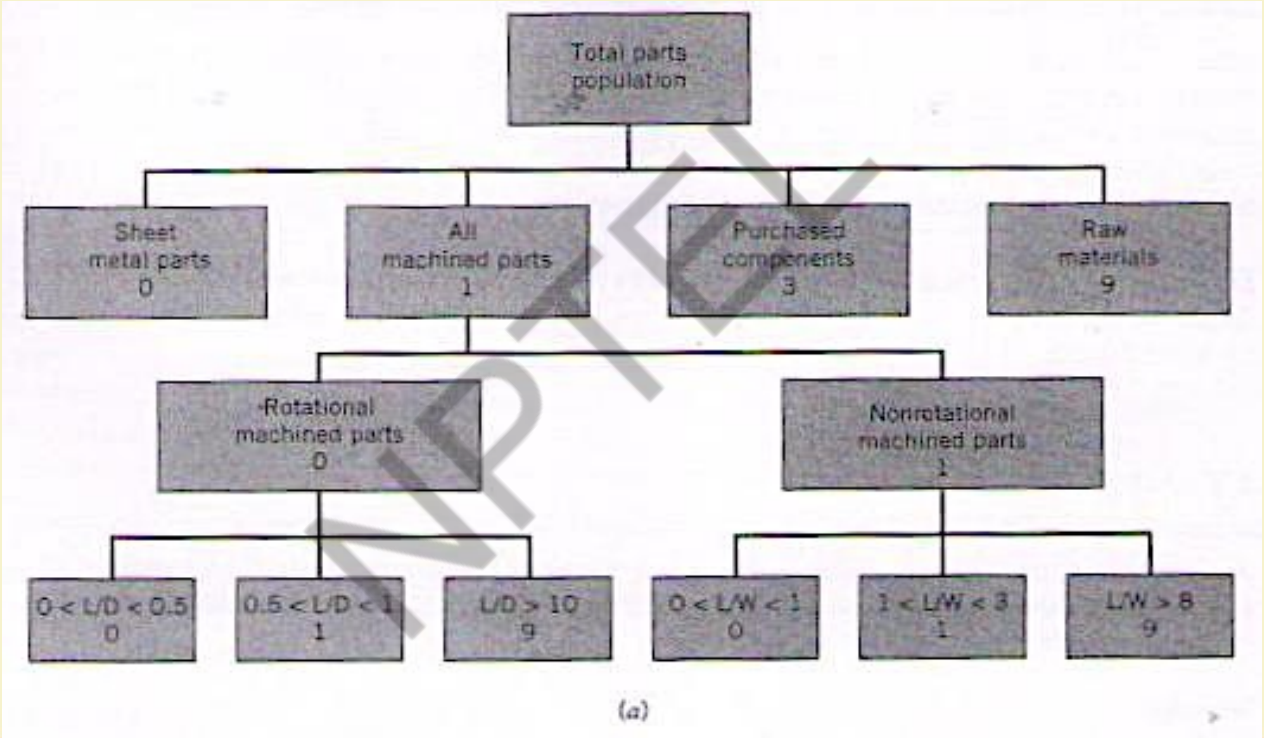
GT Codes and Coding System Structures



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GT Codes and Coding System Structures

- Figure 12.2a depicts the monocode generation scheme.
- Consider a code of 110 in Figure 12.2a
- Major advantage of hierarchical code (i) is that it captures a great deal of information in a relatively short code. (ii) The hierarchical nature of the code makes it useful for storage and retrieval of design-related information such as part geometry, material, and size. (iii) The applicability of these codes in manufacturing is rather limited as it is difficult to capture information on manufacturing sequences in a hierarchical manner.
- Disadvantage of this type of code (i) is that it requires expertise to conceive such a coding system for a part spectrum.

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GT Codes and Coding System Structures

Polycode:

- Polycode is also known by many other names, such as chain code, discrete code, and fixed-digit code.
- In Polycode the code symbols are independent of each other.
- Each digit in a specific location of the code describes a unique property of the workpiece.
- It is easy to learn and useful in manufacturing situations in which the part functions or the manufacturing processes have to be described .
- The length of a Polycode may become excessive because of its unlimited combinational features.

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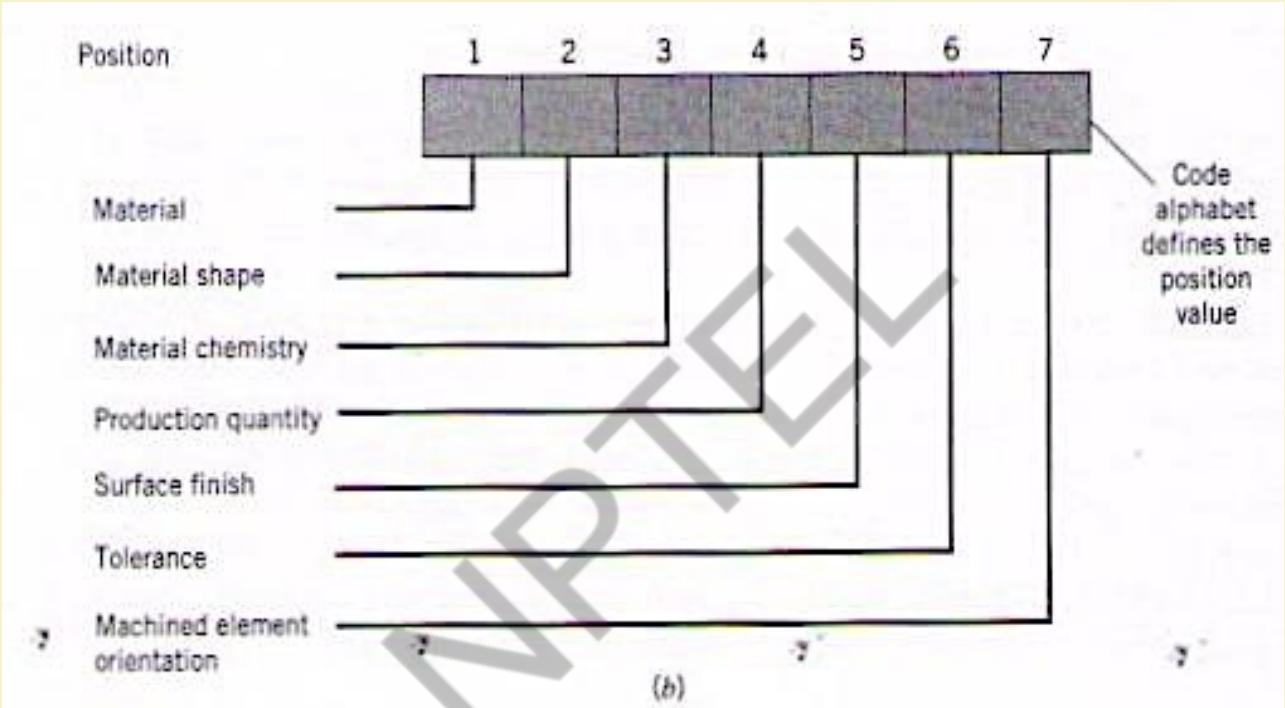

FIGURE 12.2 (*a*) Examples of a monocode (Reproduced with permission from Hyer and Wemmerlöv, 1985). (*b*) A polycode.

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GT Codes and Coding System Structures

Example 12.1:

Assume that a code consists of five symbols and that in each of the five code fields the digits 0 to 9 are used. Determine how many mutually exclusive characteristics can potentially be stored in the monocode and the Polycode.

Solution:

Number of characteristics stored in a monocode = $10^1+10^2+10^3+10^4+10^5$ = 111110

Number of characteristics stored in a Polycode = 10+10+10+10+10 = 50

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GT Codes and Coding System Structures

- The information storage capacity of monocodes grow exponentially compared with the linear growth in the polycodes.
- However, monocode will take relatively more time to retrieve information.

Mixed Code:

- Mixed code retains the advantages of both mono- and polycodes. Therefore, most coding systems use this code structure.
- For example, the Opitz classification system.
- A large number of classification and coding systems exists and a number of commercial codes are available.

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✓ **Part Family Formation: Tools and Techniques**

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Opitz Classification System

- Opitz system has the following characteristics:
  a) It is non-proprietary
  b) It is widely used.
  c) It provides a basic framework for understanding the classification and coding process.
  d) It can be applied to machined parts, non-machined parts (both formed and cast), and purchased parts.
  e) It considers both design and manufacturing information.
- The Opitz system was developed at the Technical University of Aachen under the auspices of the German Machine Tool Association.

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Opitz Classification System

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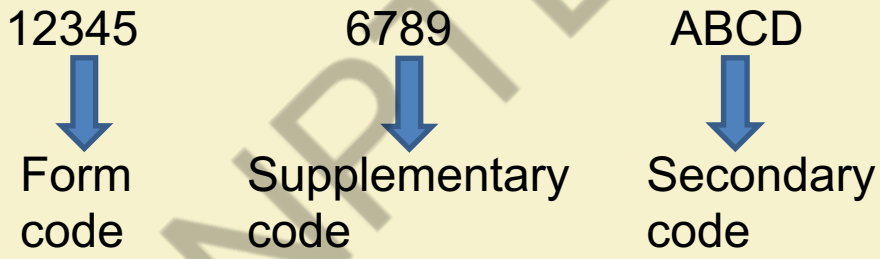

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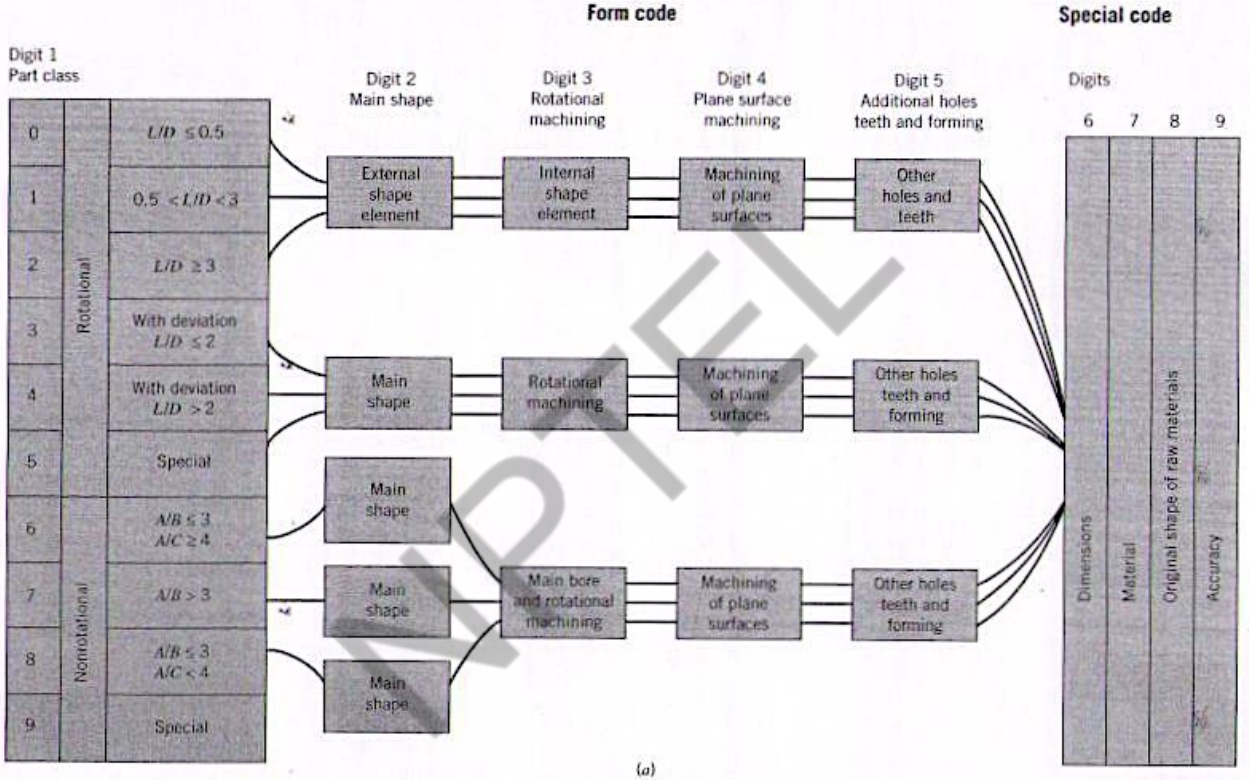

FIGURE 12.3 (*a*) Basic structure of Opitz code. (*b*) Attributes of rotational parts (Opitz code).

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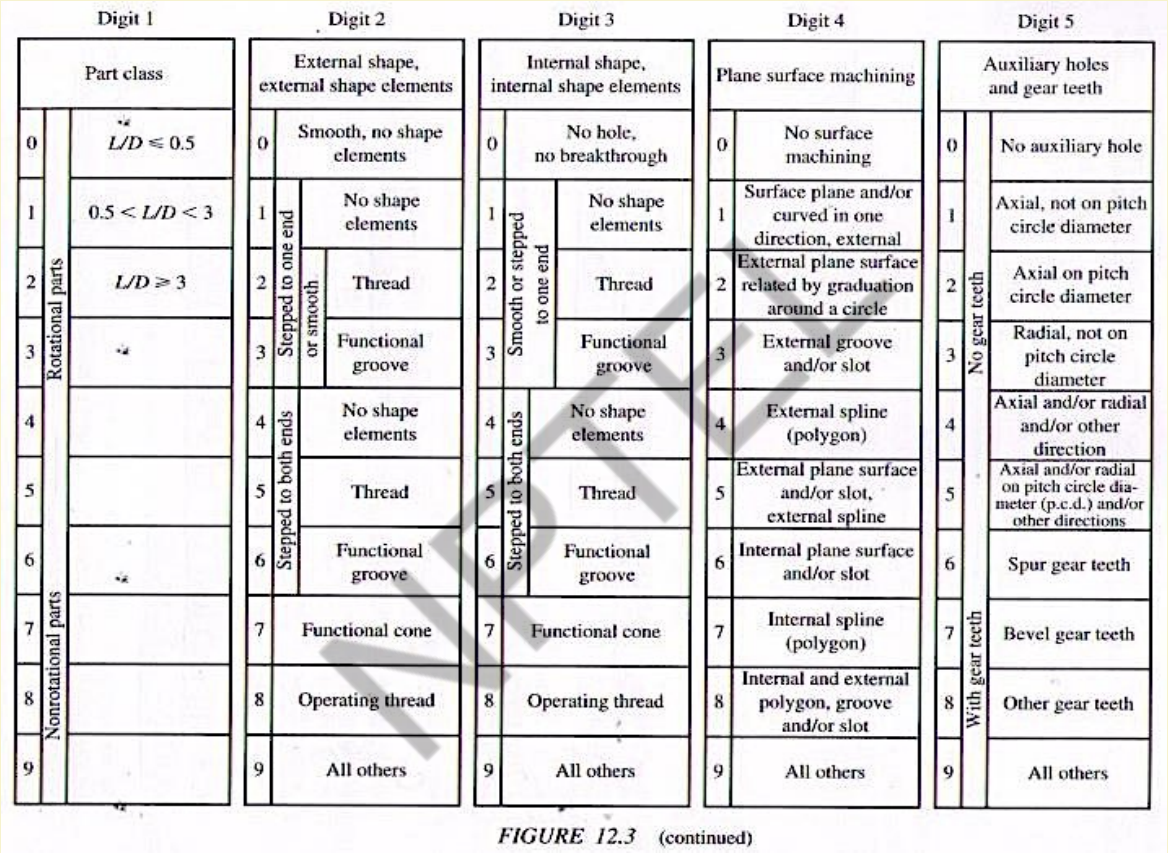

Digit 1		Part class
0	Rotational parts	$L/D \leq 0.5$
1		$0.5 < L/D < 3$
2		$L/D \geq 3$
3		
4		
5		
6	Nonrotational parts	
7		
8		
9		

Digit 2			External shape, external shape elements
0			Smooth, no shape elements
1	Stepped to one end or smooth		No shape elements
2			Thread
3			Functional groove
4	Stepped to both ends		No shape elements
5			Thread
6			Functional groove
7			Functional cone
8			Operating thread
9			All others

Digit 3			Internal shape, internal shape elements
0			No hole, no breakthrough
1	Smooth or stepped to one end		No shape elements
2			Thread
3			Functional groove
4	Stepped to both ends		No shape elements
5			Thread
6			Functional groove
7			Functional cone
8			Operating thread
9			All others

Digit 4		Plane surface machining
0		No surface machining
1		Surface plane and/or curved in one direction, external
2		External plane surface related by graduation around a circle
3		External groove and/or slot
4		External spline (polygon)
5		External plane surface and/or slot, external spline
6		Internal plane surface and/or slot
7		Internal spline (polygon)
8		Internal and external polygon, groove and/or slot
9		All others

Digit 5		Auxiliary holes and gear teeth
0	No gear teeth	No auxiliary hole
1		Axial, not on pitch circle diameter
2		Axial on pitch circle diameter
3		Radial, not on pitch circle diameter
4		Axial and/or radial and/or other direction
5		Axial and/or radial on pitch circle diameter (p.c.d.) and/or other directions
6	With gear teeth	Spur gear teeth
7		Bevel gear teeth
8		Other gear teeth
9		All others

FIGURE 12.3 (continued)

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Part Family Formation: Classification and Coding Systems

- One of the primary uses of coding systems in manufacturing is to develop part families.

- For example, Opitz form code 132. This implies that the attributes associated with the family members are length /diameter ratio in the range 0.5 to 3.0, all parts stepped to one end, and internal shape elements with threads.

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Part Family Formation: Classification and Coding Systems

- A number of mathematical approaches have also been developed to form part families using classification and coding systems.

- For example, (i) a hierarchical clustering algorithm to form part families (ii) a p-median formulation (iii) a multi-objective clustering algorithm to form part families.

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Selection of Classification and Coding Systems

Some of the important classification and coding system attributes:

1. Flexibility for various applications such as part family formation, process planning, costing, and purchasing
2. Accuracy, to provide correct information on parts
3. Expendability, to accommodate information on more part attributes deemed important later on
4. Ease of learning
5. Ease of retrieval
6. Reliability and availability of software
7. Suitability for specific applications

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Benefits of Group Technology

1. Engineering Design
2. Layout Planning
3. Specification of equipment, tools, jigs, and fixtures
4. Manufacturing: Process Planning
5. Manufacturing: Production Control
6. Manufacturing: Quality Control
7. Purchasing
8. Customer Service

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- ✓ **Numerical Examples on Part Family Formation**

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Numerical Example-1

- Assume that a code consists of eight symbols and that in each of the eight code fields the digits 0 to 9 are used. Determine how many mutually exclusive characteristics can potentially be stored in a monocode and a polycode.

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Numerical Example-2

- Consider the following matrix of eight parts and five machines:

Machines	Components							
	1	2	3	4	5	6	7	8
M1		1	1		1		1	1
M2	1	1		1	1			1
M3	1			1	1	1	1	1
M4		1		1		1		
M5	1		1	1		1	1	1

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Numerical Example-2

a. Determine similarity coefficients between all pairs of machines.

b. Use the single-linkage cluster analysis method and develop a dendrogram.

c. Analyze all the cell configurations in the similarity range 0.5 to 0.8.

d. Assuming that intercell moves cost five times intracell moves, determine the optimal cell configuration to minimize the total cost of inter- and intracell material handling.

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Numerical Example-3

- Use the rank order clustering algorithm for the cell design for the part machine matrix given in Numerical Example-2. Discuss how you are going to resolve the issues of exceptional elements and bottleneck machines. Compare with the results obtained in Numerical Example-2.

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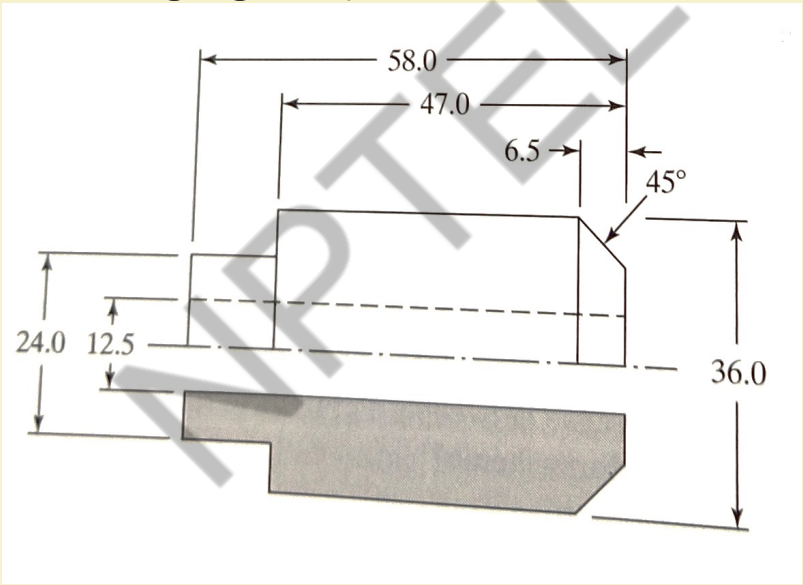
Numerical Example-4

- Develop the form code (first five digits) in the Opitz System for the part illustrated in the following figure (dimensions are in millimeters):



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Numerical Example-5

- Apply the rank-order clustering technique to the part-machine incidence matrix in the following table 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
1	1				1	
2				1		1
3	1	1				
4			1	1		
5		1			1	
6			1	1		1

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Applications of Group Technology

- **GT Manufacturing Applications**

- **Informal scheduling and routing of similar parts through selected machines**. This approach achieves setup advantages, but no formal part families are defined and no physical rearrangement of equipment is undertaken.

- **Virtual machine cells.** This approach involves the creation of part families and dedication of equipment to the manufacture of these part families, but without the physical rearrangement of machines into cells.

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Applications of Group Technology

- **Formal machine cells.** This is the conventional GT approach in which a group of dissimilar machines are physically relocated into a cell that is dedicated to the production of one or a limited set of part families. The machines in a formal machine cell are located in close proximity to one another in order to minimize part handling, throughput time, and work-in-process.

- Other GT applications in manufacturing include process planning, family tooling, and numerical control (NC) part programs.

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Applications of Group Technology

❑ GT Product Design Applications

- The application of group technology in product design is principally for design retrieval systems that reduce part proliferation.
- Other design applications of group technology involve simplification and standardization of design parameters such as tolerances, inside radii on corners, chamfer sizes on outside edges, hole sizes, and thread sizes.
- There is also a benefit in reducing the amount of data and information that the company must handle. Fewer part designs, design attributes, tools, fasteners, and so on mean fewer and simpler design documents, process plans, and other data records.

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Benefits of Group Technology

- GT promotes standardization of tooling, fixturing, and setups.
- Material handling is reduced because the distances within a machine cell are much shorter than within the entire factory.
- Process planning and production scheduling are simplified.
- Setup times are reduced, resulting in lower manufacturing lead times.
- Work-in-process is reduced.
- Worker satisfaction usually improves when workers collaborate in a GT cell.
- Higher quality work is accomplished.

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- ✓ **Application of GT for Designing Flexible and Programmable Automation**

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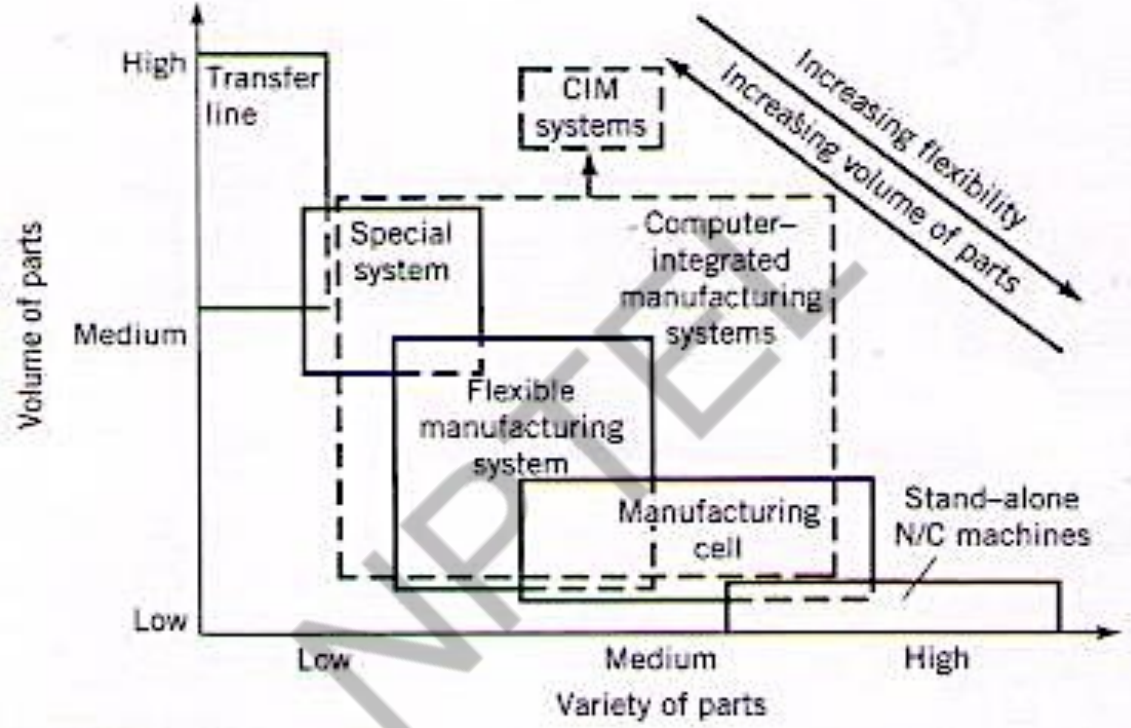

FIGURE 13.1 Volume–variety relationships categorizing production systems.

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Volume-Variety Relationships For Understanding Production Systems

❑ **Transfer Line**

- Machines dedicated to manufacture of one or two product types: system permits no flexibility at all.
- Maximum utilization and very high production volume.
- Direct labour involvement is minimal.
- Low unit cost of production.

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Volume-Variety Relationships For Understanding Production Systems

- **Flexible Manufacturing Module (Stand-alone NC Machines)**

- Highest level of flexibility; any job can be processed provided it is in the range of process capability of the NC machine.
- Low utilization and low production volume.
- Unit cost of production is much higher than for a similar product manufactured on a transfer line.

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Volume-Variety Relationships For Understanding Production Systems

- **Manufacturing Cell**

- Low to mid volume
- A variety of parts are manufactured in batch mode.
- A manufacturing cell is n FMS without central control.
- More flexible than an FMS but lower production rate.

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Volume-Variety Relationships For Understanding Production Systems

❑ **Special Manufacturing System**

- A fixed-path material-handling system links the machines together.
- Least flexible category of CIM system.
- Uses multispindle head and low-level controller.
- High production rate and low unit production cost.

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Volume-Variety Relationships For Understanding Production Systems

❑ **Flexible Manufacturing System**

- True mid-volume, mid-variety manufacturing system consisting of a series of flexible machines, automated material-handling system, automated tool changer, other equipment such as coordinate measuring machines, part washers, and so on, all under high-level centralized computer control.
- Permits both sequential and random routing of a wide variety of parts.
- Higher production rate than a manufacturing cell and much higher flexibility than a special manufacturing system.

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Benefits of Group Technology

- **Engineering System**

- Reduction in new parts design.
- Reduction in the number of drawings through standardization.
- Reduction of drafting effort in new shop drawings.
- Reduction of number of similar parts, easy retrieval of similar functional parts, and identification of substitute parts.

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Benefits of Group Technology

- **Layout Planning**

- Reduction in production floor space required.

- Reduced material-handling effort.

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Benefits of Group Technology

- **Specification of Equipment, Tools, Jigs, and Fixtures**

- Standardization of equipment.
- Implementation of cellular manufacturing systems.
- Reduced number of tools, pallets, jigs, and fixtures.
- Significant reduction in up-front costs incurred in the release of new parts for manufacture.

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Benefits of Group Technology

- **Manufacturing: Process Planning**

- Reduction in setup time and production time.
- Alternative routing leading to improved part routing.
- Reduction in number of machining operations and numerical control (NC) programming time.

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Benefits of Group Technology

- **Manufacturing: Quality Control**

- Reduction in number of defects leading to reduced inspection effort.
- Reduced scrap generation.
- Better output quality.
- Increased accountability of operators and supervisors responsible for quality production, making it easier to implement total quality control concepts.

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Benefits of Group Technology

- **Purchasing**

- Coding of purchased parts leading to standardized rules for purchasing.
- Economies in purchasing possible because of accurate knowledge of raw material requirements.
- Reduced number of parts and raw materials.
- Simplified vendor evaluation procedures leading to just-in-time purchasing.

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Benefits of Group Technology

- **Customer Service**

- Accurate and faster cost estimates.

- Efficient spare parts management, leading to better customer service.

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