Learning Objectives:
By the end of the lecture the student should be able to:
- Explain what GT is.
- Explain the concepts of part families.
- Explain what parts classification and coding is.
- Explain what cellular manufacturing is.
- Perform coding using Opitz.
- Provide applications and benefits of GT in manufacturing.
Group Technology (GT) Defined

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
  - In each part family, processing steps are similar
- The improvement is typically achieved by organizing the production facilities into **manufacturing cells** that specialize in production of certain part families
Part Family

A collection of parts that possess similarities in geometric shape and size, or in the processing steps used in their manufacture

- Part families are a central feature of group technology
  - There are always differences among parts in a family
  - But the similarities are close enough that the parts can be grouped into the same family
Part Families

- Two parts that are identical in shape and size but quite different in manufacturing: (a) 1,000,000 units/yr, tolerance = ±0.010 inch, 1015 steel; (b) 100/yr, tolerance = ±0.001 inch, 18-8 stainless steel
Part Families

- Ten parts are different in size, shape, and material, but quite similar in terms of manufacturing.
- All parts are machined from cylindrical stock by turning; some parts require drilling and/or milling.
Exercise 1
Exercise 2
Ways to Identify Part Families

1. Visual inspection
   - Using best judgment to group parts into appropriate families, based on the parts visual inspection

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
GT exploits the part similarities by utilizing similar processes and tooling to produce them.

Machines are grouped into cells, each cell specializing in the production of a part family:
- Called *cellular manufacturing*.

Cellular manufacturing can be implemented by manual or automated methods:
- When automated, the term *flexible manufacturing system* is often applied.
When to Use GT and Cellular Manufacturing

1. The plant currently uses traditional batch production and a process type layout
   - This results in much material handling effort, high in-process inventory, and long manufacturing lead times

2. The parts can be grouped into part families
   - A necessary condition to apply group technology
   - Each machine cell is designed to produce a given part family, or a limited collection of part families, so it must be possible to group parts made in the plant into families
Traditional Process Layout
Cellular Layout Based on GT

- Each cell specializes in producing one or a limited number of part families
Problems in Implementing GT

1. Identifying the part families
   - Reviewing all of the parts made in the plant and grouping them into part families is a substantial task

2. Rearranging production machines into GT cells
   - It is time-consuming and costly to physically rearrange the machines into cells, and the machines are not producing during the changeover
Parts Classification and Coding

Identification of similarities among parts and relating the similarities by means of a numerical coding system

- Must be customized for a given company or industry
- Reasons for using a coding scheme:
  - Design retrieval
  - Automated process planning
  - Machine cell design
Features of Parts Classification and Coding Systems

- Most classification and coding systems are based on one of the following:
  - Part design attributes
  - Part manufacturing attributes
  - Both design and manufacturing attributes
Part Design Attributes

- Major dimensions
- Basic external shape
- Basic internal shape
- Length/diameter ratio
- Material type
- Part function
- Tolerances
- Surface finish
Part Manufacturing Attributes

- Major process
- Operation sequence
- Batch size
- Annual production
- Machine tools
- Cutting tools
- Material type
Opitz Classification System

- One of the first published classification and coding schemes for mechanical parts
- Basic code = nine (9) digits
  - Digits 1 through 5 = form code – primary shape and design attributes (hierarchical structure)
  - Digits 6 through 9 = supplementary code – attributes that are useful in manufacturing (e.g., dimensions, starting material)
  - Digits 10 through 13 = secondary code – production operation type and sequence
Basic Structure of Opitz System

<table>
<thead>
<tr>
<th>Digit 1</th>
<th>Digit 2</th>
<th>Digit 3</th>
<th>Digit 4</th>
<th>Digit 5</th>
<th>Supplementary code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part class</td>
<td>Main shape</td>
<td>Rotational machining</td>
<td>Plane surface machining</td>
<td>Additional holes, teeth and forming</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>L/D 0.5</td>
<td>External shape element</td>
<td>Internal shape element</td>
<td>Machining of plane surfaces</td>
<td>Other holes and teeth</td>
</tr>
<tr>
<td>1</td>
<td>0.5 &lt; L/D &lt; 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>L/D 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>With deviation L/D &gt; 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>With deviation L/D &gt; 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Special</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>A/B 3</td>
<td>A/C 4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>A/B &gt; 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>A/B 3</td>
<td>A/C &lt; 4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Special</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Dimensions | Material hardness | Original shape of raw materials | Accuracy |

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Opitz Form Code (Digits 1 through 5)

<table>
<thead>
<tr>
<th>Digit 1</th>
<th>Digit 2</th>
<th>Digit 3</th>
<th>Digit 4</th>
<th>Digit 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part class</td>
<td>External shape, external shape elements</td>
<td>Internal shape, internal shape elements</td>
<td>Plane surface machining</td>
<td>Auxiliary holes and gear teeth</td>
</tr>
<tr>
<td>0</td>
<td>L/D 0.5</td>
<td>Smooth, no shape elements</td>
<td>No hole, no breakthrough</td>
<td>No auxiliary hole</td>
</tr>
<tr>
<td>1</td>
<td>0.5 &lt; L/D &lt; 3</td>
<td>No shape elements</td>
<td>No shape elements</td>
<td>Axial, not on pitch circle diameter</td>
</tr>
<tr>
<td>2</td>
<td>L/D 3</td>
<td>Thread</td>
<td>Thread</td>
<td>Axial on pitch circle diameter</td>
</tr>
<tr>
<td>3</td>
<td>Rotational parts</td>
<td>Threaded (both ends)</td>
<td>Smooth, or stopped at one end</td>
<td>Radial, not on pitch circle diameter</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>Functional groove</td>
<td>Smooth, stopped at one end</td>
<td>Axial and/or radial and/or other direction</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>Smooth, stopped at one end</td>
<td>Smooth, stopped at one end</td>
<td>Axial and/or radial on ECD and/or other directions</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>Functional groove</td>
<td>Functional groove</td>
<td>Spur gear teeth</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td>Functional groove</td>
<td>Internal plane surface and/or slot</td>
<td>Bevel gear teeth</td>
</tr>
<tr>
<td>8</td>
<td></td>
<td>Functional cone</td>
<td>Internal and external polygon, groove and/or slot</td>
<td>Other gear teeth</td>
</tr>
<tr>
<td>9</td>
<td></td>
<td>Other parts</td>
<td>All others</td>
<td>All others</td>
</tr>
</tbody>
</table>

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Example 1: Opitz Form Code

Form code in Opitz system is __________
Benefits of Group Technology in Manufacturing

- Standardization of tooling, fixtures, and setups is encouraged
- Material handling is reduced
  - Parts are moved within a machine cell rather than the entire factory
- Process planning and production scheduling are simplified
- Work-in-process and manufacturing lead time are reduced
- Improved worker satisfaction in a GT cell
- Higher quality work
Product Design Applications of Group Technology

- Design retrieval systems
  - Industry survey: For new part designs,
    - Existing part design could be used - 20%
    - Existing part design with modifications – 40%
    - New part design required – 40%
- Simplification and standardization of design parameters such as tolerances, chamfers, hole sizes, thread sizes, etc.
  - Reduces tooling and fastener requirements in manufacturing
Clustering Methods

- Using Process Similarity methods:
  - Create Machine – Part Matrices
  - Compute machine ‘pairwise’ Similarity Coefficient comparisons:

$$S_{ij} = \frac{x_{ij}}{(x_{ij} + x_{jj})}$$

Here:
- $x_{ij}$ is # of parts (in matrix) visiting both machines of the pair
- $x_{jj}$ is # of parts visiting one but not both machines

Curtsey of: R. R. Lindeke, PhD, University of Minnesota
Example:

<table>
<thead>
<tr>
<th>Machine ID</th>
<th>Part ‘Number’</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td>A</td>
<td>1</td>
</tr>
<tr>
<td>B</td>
<td>1 1</td>
</tr>
<tr>
<td>C</td>
<td>1</td>
</tr>
<tr>
<td>D</td>
<td>1 1 1</td>
</tr>
<tr>
<td>E</td>
<td>1 1 1</td>
</tr>
</tbody>
</table>

Curtsey of: R. R. Lindeke, PhD, University of Minnesota
Computing Similarity Coefficients:

- Total Number is:
  - \[\frac{(N-1)N}{2} = \frac{(5-1)5}{2} = 10\]
- For 25 machines (typical number in a small Job Shop): 300 \(S_{ij}\)’s
- Here they are:

\[
S_{AB} = \frac{1}{1+2} = .33
\]
\[
S_{AC} = \frac{0}{0+4} = 0
\]
\[
S_{AD} = \frac{2}{2+1} = .67
\]

Curtsey of: R. R. Lindeke, PhD, University of Minnesota
Continuing:

\[
S_{AE} = \frac{0}{0+5} = 0
\]
\[
S_{BC} = \frac{0}{0+4} = 0
\]
\[
S_{BD} = \frac{2}{2+1} = .67
\]
\[
S_{BE} = \frac{0}{0+5} = 0
\]
\[
S_{CD} = \frac{0}{0+5} = 0
\]
\[
S_{CE} = \frac{2}{2+1} = .67
\]
\[
S_{DE} = \frac{0}{0+6} = 0
\]

- Here, if the similarity coefficient is \(\leq .33\) consider clustering
- This criteria means clustering: 
  - A&D, A&B, B&D
  - C & E
- Declustering: 
  and C&D, D&E

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Continuing:

- Examining our Matrix and our freshly clustered ‘machine cells,’ we develop 2 part families:
  - For the Cell A/D/B: Part Numbers 2, 3 & 5
  - For the Cell C/E: Part Numbers 1, 4 & 6
- Care must be taken (in most cases) to assure that each cell has all the machines it needs – sometimes a couple of families need a key machine
  - In this case, the manager must decide to either replicate the common machine or share it between the cells creating a bottleneck and scheduling problem for each cell
  - This is typically one of the major cost problems

Curtsey of: R. R. Lindeke, PhD, University of Minnesota
Summarizing:

- Make Machine/Part Matrix
- Compute Similarity Coefficients
- Cluster Machines with positive \( .33 \) \( S_{ij} \)’s
- Determine Part Families for the clusters (cells)
- Decide if machine replication is cost effective
- Re-layout facility and Cross Train workforce

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