Introduction to Flexible Manufacturing System (FMS)

- A *flexible manufacturing system (FMS)* is a highly automated GT machine cell, consisting of a group or processing workstations (usually CNC machine tools), interconnected by an automated material handling and storage system, and controlled by a distributed computer system.

- The reason the FMS is called *flexible* is that it is capable of processing a variety of different part styles simultaneously at the various workstations, and the mix of part styles and quantities of production can be adjusted in response to changing demand patterns.

- The FMS is most suited for the mid-variety, mid-volume production range.
What Make It Flexible?

• Three capabilities that a manufacturing system must possess to be a flexible.

1. The ability to identify and distinguish among the different part styles processed by the system.

2. Quick changeover of operating instructions, and

3. Quick changeover of physical setup.
Tests of Flexibility

• To qualify as being flexible, a manufacturing system should satisfy several criteria. The following are four reasonable tests of flexibility in an automated manufacturing system:

  - **Part variety test.** Can the system process different part styles in a nonbatch mode?.

  - **Schedule change test.** Can the system readily accept changes in production schedule, and changes in either part mix or production quantity.

  - **Error recovery test.** Can the system recover quickly from equipment breakdowns, so that the production is not completely disrupted.

  - **New part test.** Can new part designs be introduced into the existing product mix with relative ease.

• If the answer to all of these questions is “YES” for a given manufacturing system, then the system can be considered flexible.
# Types of Flexibility in Manufacturing

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<tr>
<th>Flexibility Type</th>
<th>Definition</th>
<th>Depends on Factors Such As</th>
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<tr>
<td><strong>Machine flexibility</strong></td>
<td>Capability to adapt a given machine (workstation) in the system to a wide range of production operations and part styles. The greater the range of operations and part styles, the greater the machine flexibility.</td>
<td>Setup or changeover time. Ease of machine reprogramming (ease with which part programs can be downloaded to machines). Tool storage capacity of machines. Skill and versatility of workers in the system.</td>
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<tr>
<td><strong>Production flexibility</strong></td>
<td>The range or universe of part styles that can be produced on the system.</td>
<td>Machine flexibility of individual stations. Range of machine flexibilities of all stations in the system.</td>
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<td><strong>Mix flexibility</strong></td>
<td>Ability to change the product mix while maintaining the same total production quantity; that is, producing the same parts only in different proportions.</td>
<td>Similarity of parts in the mix. Relative work content times of parts produced. Machine flexibility.</td>
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<td><strong>Product flexibility</strong></td>
<td>Ease with which design changes can be accommodated. Ease with which new products can be introduced.</td>
<td>How closely the new part design matches the existing part family. Off-line part program preparation. Machine flexibility.</td>
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<td><strong>Volume flexibility</strong></td>
<td>Ability to economically produce parts in high and low total quantities of production, given the fixed investment in the system.</td>
<td>Level of manual labor performing production. Amount invested in capital equipment.</td>
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<td><strong>Expansion flexibility</strong></td>
<td>Ease with which the system can be expanded to increase total production quantities.</td>
<td>Expense of adding workstations. Ease with which layout can be expanded. Type of part handling system used. Ease with which properly trained workers can be added.</td>
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Comparison of Four Criteria of Flexibility in a Manufacturing System and the Seven Types of Flexibility

<table>
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<tr>
<th>Flexibility Tests or Criteria</th>
<th>Type of Flexibility (Table 16.1)</th>
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<tr>
<td>1. <strong>Part variety test.</strong> Can the system process different part styles in a non-batch mode?</td>
<td>Machine flexibility</td>
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<td></td>
<td>Production flexibility</td>
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<tr>
<td>2. <strong>Schedule change test.</strong> Can the system readily accept changes in production schedule, changes in either part mix or production quantities?</td>
<td>Mix flexibility</td>
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<td>Volume flexibility</td>
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<td>Expansion flexibility</td>
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<td>3. <strong>Error recovery test.</strong> Can the system recover gracefully from equipment malfunctions and breakdowns, so that production is not completely disrupted?</td>
<td>Routing flexibility</td>
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<td>4. <strong>New part test.</strong> Can new part designs be introduced into the existing product mix with relative ease?</td>
<td>Product flexibility</td>
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Number of Machines

- Flexible manufacturing systems can be distinguished according to the number of machines in the system. The following are typical categories:
  
  - Single machine cell (Type I A)
  - Flexible manufacturing cell (usually type II A, sometimes type III A)
  - Flexible manufacturing system (usually Type II A, sometimes type III A)
Single Machine Cell (SMC)

- A single machine cell consists of one CNC machining center combined with a parts storage system for unattended operation.
- Completed parts are periodically unloaded from the parts storage unit, and raw workparts are loaded into it.
Flexible Manufacturing Cell (FMC)

- A flexible manufacturing cell consists of two or three processing workstations (typically CNC machining centers) plus a part handling system.

- The part handling system is connected to a load/unload station.
Flexible Manufacturing System (FMS)

- A flexible manufacturing system has four or more processing workstations connected mechanically by a common part handling system and electronically by a distributed computer system.
Some of the distinguishing characteristics of the three categories of flexible manufacturing cells and systems are summarized in figure below.
### Flexibility Criteria Applied to the Three Types of Manufacturing Cells and Systems

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<tbody>
<tr>
<td>Single machine cell (SMC)</td>
<td>Yes, but processing is sequential, not simultaneous.</td>
<td>Yes</td>
<td>Limited recovery due to only one machine.</td>
<td>Yes</td>
</tr>
<tr>
<td>Flexible manufacturing cell (FMC)</td>
<td>Yes, simultaneous production of different parts.</td>
<td>Yes</td>
<td>Error recovery limited by fewer machines than FMS.</td>
<td>Yes</td>
</tr>
<tr>
<td>Flexible manufacturing system (FMS)</td>
<td>Yes, simultaneous production of different parts.</td>
<td>Yes</td>
<td>Machine redundancy minimizes effect of machine breakdowns.</td>
<td>Yes</td>
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Level of Flexibility

- Another classification of FMS is according to the level of flexibility designed into the system. Two categories are distinguished here:
  - Dedicated FMS
  - Random-order FMS

- *A dedicated FMS* is designed to produce a limited variety of part styles, and the complete universe of parts to be made on the system is known in advance.

- *A random-order FMS* is more appropriate when
  1. the part family is large,
  2. there are substantial variations in part configurations,
  3. there will be new part designs introduced into the system and engineering changes in parts currently produced, and
  4. the production schedule is subjected to change from day-to-day.
A comparison of dedicated and random-order FMS types
## Flexibility Criteria Applied to Dedicated FMS and Random-order FMS

<table>
<thead>
<tr>
<th>System Type</th>
<th>Flexibility Criteria (Tests of Flexibility)</th>
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<tr>
<td>Dedicated FMS</td>
<td>Limited. All parts known in advance.</td>
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Components of FMS

- There are several basic components of an FMS:
  1. Workstations.
  2. Material handling and storage systems.
  3. Computer control system.
  4. People are required to manage and operate the system.
Workstations

- Following are the types of workstations typically found in an FMS:
  1. Load/Unload Stations.
  2. Machining Stations.
  3. Other processing Stations. (punching, shearing, welding, etc.)
  4. Assembly Station.
  5. Other Stations and Equipment. (Inspection, Vision, etc)
Material Handling and Storage System

- **Functions of the Handling System**
  1. Independent movement of workparts between stations.
  2. Handle a variety of workpart configurations.
  3. Temporary storage.
  4. Convenient access for loading and unloading workparts.
  5. Compatible with computer control.

- **Material Handling Equipment**
  The material handling function in an FMS is often shared between two systems:
  - **Primary handling system** establishes the basic layout of the FMS and is responsible for moving workparts between stations in the system. (Conveyor)
Material Handling and Storage System

2. **Secondary handling system** consists of transfer devices, automatic pallet changing, and similar mechanisms located at the workstations in the FMS.

- The function of the secondary handling system is to transfer work from the primary system to the machine tool or other processing station and to position the parts with sufficient accuracy and repeatability to perform the process or assembly operation.

- **FMS Layout Configurations**

  - The material handling system establishes the FMS layout. Most layout configurations found in today’s FMS are:
    
    1. In-line layout
    2. Loop layout
    3. Rectangular layout
Computer Control System

- The FMS includes a distributed computer system that is interfaced to:
  - the workstations,
  - Material handling system, and
  - Other hardware components.

- A typical FMS computer system consists of a central computer and microcomputers.
  - Microcomputers controlling the individual machines and other components.
  - The central computer coordinates the activities of the components to achieve smooth overall operation of the system.
Human Resources

• Human are needed to manage the operations of the FMS. Functions typically performed by human includes:
  - Loading raw workparts into the system,
  - Unloading finished parts (or assemblies) from the system,
  - Changing and setting tools,
  - Equipment maintenance and repair,
  - NC part programming in a machining system, and
  - Programming and operation the computer system.