Flexible Manufacturing System (FMS)
Flexibility in Manufacturing System

Flexibility can be defined as collection of properties of a manufacturing system that support changes in production activities or capabilities (Carter, 1986).

Flexible Manufacturing System

A flexible manufacturing system (FMS) is a manufacturing system in which there is some amount of flexibility that allows the system to react in the case of changes, whether predicted or unpredicted.
Types of Flexibility

1. Machine flexibility
   - Capability of a machine to perform a variety of operations on a variety of part types and sizes

2. Routing flexibility
   - Alternative machines, sequences or resources can be used for manufacturing a part for changes resulting from equipment breakdowns, tool breakages, controller failures, etc.

3. Process flexibility
   - Ability to absorb changes in the product mix by performing similar operations, producing similar products or parts.
Types of Flexibility

4. Product flexibility
   – Ability to change over to a new set of products economically and quickly in response to markets

5. Production flexibility
   – Ability to produce a range of products without adding capital equipment
Why Need Flexibility in Manufacturing Systems?

- Variety in products thus creating options for the consumers
- Optimizing the manufacturing cycle time
- Reduced production costs
- Overcoming internal changes like failure, breakdowns, limited sources, etc.
- Overcoming external changes such as change in product design and production system.
FMS and FMC

- Early FMSs were large and very complex, consisting of dozens of CNCs and sophisticated material handling systems. They were very expensive and controlled by incredibly complex software. There were only a limited number of industries that could afford investing in a traditional FMS as described above.

- Currently, the trend in FMS is toward small versions of the traditional FMS, called flexible manufacturing cells (FMC).
  
  - Two or more CNC machines are considered as flexible cell and two or more cells are considered as flexible manufacturing system.

  - A Flexible Manufacturing System (FMS) consists of several machine tools along with part and tool handling devices such as robots, arranged so that it can handle any family of parts for which it has been designed and developed.
FMS type - Distinguish by number of machines

1. Single machine cell* of a single style in defining styles and adapt to different parts and error recovery.
   *No error recovery if machine fails.

2. Flexible machine cell of equipment and limited parts and error recovery.

3. Flexible manufacturing system connected by common part handling system. Other stations may support the measuring machine (CMM) or washing of different parts and error recovery.
Flexible Manufacturing Cell (FMC)

- A flexible manufacturing cell (FMC) consists of two or more CNC machines, a cell computer and a robot.

- The cell computer (typically a programmable logic controller) is interfaced with the microprocessors of the robot and the CNCs.
The Cell Controller

- The functions of the cell controller include work load balancing, part scheduling, and material flow control.

- The supervision and coordination among the various operations in a manufacturing cell is also performed by the cell computer.

- The software includes features permitting the handling of machine breakdown, tool breakage and other special situations.
The Cell Robot

• In FMC, the cell robot performs tool changing and housekeeping functions such as chip removal, staging of tools in the tool changer, and inspection of tools for breakage or wear.

• When necessary, the robot can also initiate emergency procedures such as system shut-down.
FMS Components

Most FMS comprise of three main systems

- Work machines (typically automated CNC machines) that perform a series of operations
- An integrated material transport system and a computer that controls the flow of materials, tools, and information (e.g. machining data and machine malfunctions) throughout the system
- Auxiliary work stations for loading and unloading, cleaning, inspection, etc.
PART MOVEMENT

- CONVEYORS
- TOW CARTS
- RAIL CARTS
- AGV’S
SUPPORTING WORKSTATIONS

• LOAD/UNLOAD STATIONS
• AUTOMATIC PART WASHERS
• COORDINATE MEASURING MACHINES
CONTROLLER

• COMPUTER
• WORKER (ATTENDANT)
• TRACKING SYSTEM
  – PARTS
  – MACHINES
FMS Components
FMS Components

A 5 machine FMS for machining at Cincinnati Milacron, OH, USA
Machining centers with numerical control of movements in up to five axes. Spindle movement in x, y and z directions, rotation of table, and tilting of table.

**FIGURE 13.3 (a)** Numerically controlled horizontal spindle machining centers: three axes. (Courtesy of Guiddings & Lewis.)

**FIGURE 13.3 (c)** Numerically controlled horizontal spindle machining centers: five axes. (Courtesy of Guiddings & Lewis.)
FMS FEATURES

• PARTS CAN ARRIVE AT MACHINES IN ANY SEQUENCE
• MANY MACHINES CAN BE INCLUDED
• SMALL FMS LEAD TO FLEXIBLE CELLS
• FLOOR SPACE REDUCIBLE BY 33%
• EQUIPMENT UTILIZATION UP TO 85% OR MORE
• IDEAL FOR JIT
Advantages of FMS

- Reduction in manufacturing cost by lowering direct labor cost and minimizing scrap, re-work, and material wastage.
- Less skilled labor required.
- Reduced inventory, due to the planning and programming precision
- Reduction in production lead time permitting manufacturers to respond more quickly to the variability of market demand.
- Better process control resulting in consistent quality.
Disadvantages of FMS

- Limited ability to adapt to changes in product or product mix (e.g., machines are of limited capacity and the tooling necessary for products, even of the same family, is not always feasible)
- Expensive, costing millions of dollars
- Technological problems of exact component positioning and precise timing necessary to process a component to maintain consistent quality
- Sophisticated manufacturing systems
FMS layouts

1. Loop layout

2. Open field

3. Automated guided vehicles (4)

4. Automatic chip removal system
FMS Example

One Design + One Assembly Process = Multiple Models

When different models are designed to be assembled in the same sequence they can be built in the same plant. This maximizes efficiency and allows the company to respond quickly to changing customer
FMS Example

Through the use of reprogrammable tooling in the body shop, standardized equipment in the paint shop and common build sequence in final assembly, Ford can build multiple models on one or more platforms in one plant.

**Body Shop**

In the body shop, where the sheet metal comes together to form the vehicle’s body, flexibility means more than 80 percent of the tooling is not specific to one model. It can be reprogrammed to weld a car or a truck or a crossover of similar size.

**Paint Shop**

In the paint shop, flexibility means robotic applicators are programmed to cover various body styles – as they move through the paint booth – with equal precision. This results in minimizing waste and environmental impact while maximizing quality.

**Final Assembly**

In the final assembly area, flexibility means the build sequence is the same among multiple models on one or more platforms allowing for efficient utilization of people and equipment.
FMS Example

Virtual Verification

Virtual manufacturing technology allows Ford to quickly add various models into an existing facility – or to reconfigure an existing facility to produce a new model. In the virtual world, manufacturing engineers and plant operators evaluate tooling and product interfaces before costly installations are made on the plant floor. This method of collaboration improves launch quality and enables speed of execution.
Flexibility to …..Adaptability

The late 1990s and the early part of this century have seen the dramatic impact of technology on productivity.

- The efficiency benefits of push manufacturing
- The quality benefits of lean manufacturing
- The responsiveness benefits of flexible manufacturing

The customer has finally been crowned king, and companies that adapt quickly and efficiently to the king’s variable demands are destined for success. Adaptive manufacturing is the key characteristic driving this success.
Flexibility to ……Adaptability

Adaptability has two primary characteristics, flexibility and velocity. Flexibility enables a manufacturing unit to scale efficiently while velocity determines its ability to switch operational modes rapidly such as high-volume/low-mix to high-volume/high-mix product loadings.

Adaptive manufacturing enterprises are expected to achieve required flexibility and velocity by linking technology to factory processes, production equipment, and factory systems. This integrated technology will allow them the profitable manufacturing of products for increasingly time-sensitive and competitive markets.
Flexibility to ...... Adaptability

- **Technology**
  - **Adaptive Manufacturing**
    - ETO
    - MTO
    - Others
  - **Flexible Manufacturing**
    - ETO
    - ATO
    - MTS
  - **Lean Manufacturing**
    - ATO
    - MTS
  - **Push Manufacturing**
    - MTS

- **Responsiveness**
  - Technology that links people and applications enables responsiveness and velocity
  - Higher fill rates even in times of variability, but cost of flexibility can erode margins
  - Lowered inventory, but requires low demand variability
  - High labor and capacity utilization - inventory levels are very high
Manufacturing Challenges

Despite significant improvements in manufacturing efficiencies over the years, producing to near real-time demand is easier said than done. Especially in a business environment where variability is continually increasing. Some of the drivers responsible for this increase in variability and thus challenging manufacturing to achieve adaptive capabilities are:

• **Fragmented manufacturing facilities.** Globally distributed manufacturing locations are increasing exponentially, demanding new manufacturing collaboration.

• **Mass customization.** The rapidly increasing cross-industry demand for product variety presents challenges in areas such as manufacturing capacity and resource planning.
Manufacturing Challenges

- **Shrinking life cycles.** Product life cycles are rapidly shortening, and pose challenges in areas such as manufacturing cycle time and inventory management.

- **Response velocity.** Customer empowerment is driving managers to target new levels of flexibility, leading to higher manufacturing capacity costs and labor deployment challenges.

- **Zero defect quality.** Product quality requirements are becoming increasingly stringent, causing manufacturers to focus on “Zero Defect” production capabilities.
Manufacturing Challenges

- **Proprietary practices.** Arrays of proprietary interfaces, platforms, and communication protocols at shop-floor levels make it difficult to extract information to central databases.

- **Data management.** The explosive growth of data collection and analysis requirements is hindered by lack of integration and analytical capabilities.

- **Shop-floor visibility.** The detailed line and inventory scheduling done at floor levels is not visible to planning and execution systems. Shop floors rarely have visibility into last-minute changes in customer orders. This lack of visibility has a spiraling effect on future production schedules and impacts how resources are used.