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FMS Introduction and Description

1.1 INTRODUCTION

In the middle of 1960s, market competition became more intense. During 1960 to 1970 cost was the primary concern. Later quality became the priority. As the market became more and more complex, speed of delivery became something customer also needed.

A new strategy was formulated (Customizability). The companies have to adapt to the environment in which they operate, to be more flexible in their operations and to satisfy different market segments. Thus the innovation of FMS became related to the effort of gaining competitive advantage.

First of all, FMS is a manufacturing technology. Secondly, FMS is a philosophy. “System” is the key word. Philosophically, FMS incorporates a system view of manufacturing. The buzzword for today’s manufacturer is “agility”. An agile manufacturer is one who is the fastest to the market, operates with the lowest total cost and has the greatest ability to “delight” its customers. FMS is simply one way that manufacturers are able to achieve this agility.

![Diagram of types of flexibilities](image)

**Fig. 1.1** Types of flexibilities
1.2 DEFINITION

A flexible manufacturing system (FMS) is an arrangement of machines ... interconnected by a transport system. The transporter carries work to the machines on pallets or other interface units so that work-machine registration is accurate, rapid and automatic. A central computer controls both machines and transport system.

Or

“FMS consists of a group of processing work stations interconnected by means of an automated material handling and storage system and controlled by integrated computer control system.”

FMS is called flexible due to the reason that it is capable of processing a variety of different part styles simultaneously at the workstation and quantities of production can be adjusted in response to changing demand patterns.

1.3 BASIC COMPONENTS OF FMS

The basic components of FMS are:

1. Workstations
2. Automated Material Handling and Storage system.
3. Computer Control System

1. Workstations: In present day application these workstations are typically computer numerical control (CNC) machine tools that perform machining operation on families of parts. Flexible manufacturing systems are being designed with other type of processing equipments including inspection stations, assembly works and sheet metal presses. The various workstations are

   (i) Machining centers
   (ii) Load and unload stations
   (iii) Assembly work stations
   (iv) Inspection stations
   (v) Forging stations
   (vi) Sheet metal processing, etc.

2. Automated Material Handling and Storage system: The various automated material handling systems are used to transport work parts and subassembly parts between the processing stations, sometimes incorporating storage into function.

   The various functions of automated material handling and storage system are

   (i) Random and independent movement of work parts between workstations
   (ii) Handling of a variety of work part configurations
   (iii) Temporary storage
   (iv) Convenient access for loading and unloading of work parts
   (v) Compatible with computer control
3. **Computer Control System:** It is used to coordinate the activities of the processing stations and the material handling system in the FMS. The various functions of computer control system are:

(i) Control of each work station
(ii) Distribution of control instruction to work station
(iii) Production control
(vi) Traffic control
(v) Shuttle control
(vi) Work handling system and monitoring
(vii) System performance monitoring and reporting

The FMS is most suited for the mid variety, mid value production range.

**Fig. 1.2** Application characteristics of FMS

**Fig. 1.3** Flexible manufacturing system
1.4 THE SIGNIFICANCE OF FMS IN THE 1990s

The installed worldwide FMS base in 1989 was estimated to be around 500 to 1200 systems, the higher figure arising when a system is defined as having 2 or more CNC machine tools connected by a materials handling system, and controlled by a central computer. Ranta and Tchijov suggest that this number will rise to around 2500–3500 by the year 2000. This led them to suggest that “the strategic majority of production of the metal-working industries in the industrialized countries will be produced by FMS or similar systems [by the year 2000].”

Kelley’s empirical research in 1987 strongly contradicts this. In a large (>1000 firms) survey of US metal working firms, she found that less than 5 per cent of those plants with computerized automation have an FMS and that FMS constituted only 1.5 per cent of the total number of installations of computerized automation. Why are there still so few FMS in the world given that small-batch engineering production is a significant proportion of manufacturing output?

There are significant practical reasons for the disparity between the promise of FMS in the 1980s and its narrowness and scarcity of application in the early 1990s. These reasons are outlined below separately, though they are very much interdependent. Different approaches to flexibility and their meanings are shown Table 1.1.

Table 1.1 Different approaches to flexibility and their meanings

<table>
<thead>
<tr>
<th>Approach</th>
<th>Flexibility meaning</th>
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<tbody>
<tr>
<td>1. Manufacturing</td>
<td>■ The capability of producing different parts without major retooling</td>
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<td></td>
<td>■ A measure of how fast the company converts its process from making an old line of products to produce a new product</td>
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<td></td>
<td>■ The ability to change a production schedule, to modify a part, or to handle multiple parts</td>
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<td>2. Operational</td>
<td>■ The ability to efficiently produce highly customized and unique products</td>
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<td>3. Customer</td>
<td>■ The ability to exploit various dimension of speed of delivery</td>
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<tr>
<td>4. Strategic</td>
<td>■ The ability of a company to offer a wide variety of products to its customers</td>
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<td>5. Capacity</td>
<td>■ The ability to rapidly increase or decrease production levels or to shift capacity quickly from one product or service to another</td>
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So, what is flexibility in manufacturing?

There are three levels of manufacturing flexibility.

(a) Basic flexibilities

■ **Machine flexibility:** The ease with which a machine can process various operations

■ **Material handling flexibility:** A measure of the ease with which different part types can be transported and properly positioned at the various machine tools in a system

■ **Operation flexibility:** A measure of the ease with which alternative operation sequences can be used for processing a part type
(b) System flexibilities

- **Volume flexibility**: A measure of a system’s capability to be operated profitably at different volumes of the existing part types
- **Expansion flexibility**: The ability to build a system and expand it incrementally
- **Routing flexibility**: A measure of the alternative paths that a part can effectively follow through a system for a given process plan
- **Process flexibility**: A measure of the volume of the set of part types that a system can produce without incurring any setup
- **Product flexibility**: The volume of the set of part types that can be manufactured in a system with minor setup

(c) Aggregate flexibilities

- **Program flexibility**: The ability of a system to run for reasonably long periods without external intervention
- **Production flexibility**: The volume of the set of part types that a system can produce without major investment in capital equipment
- **Market flexibility**: The ability of a system to efficiently adapt to changing market conditions

1.5 DIFFERENT TYPES OF FMS

The different types of FMS are

- Sequential FMS
- Random FMS
- Dedicated FMS
- Engineered FMS
- Modular FMS

**Sequential FMS**: It manufactures one-piece part batch type and then planning and preparation is carried out for the next piece part batch type to be manufactured. It operates like a small batch flexible transfer line.

**Random FMS**: It manufactures any random mix of piece part types at any one time.

**Dedicated FMS**: It continually manufactures, for extended periods, the same but limited mix of piece part batch types.

**Engineered FMS**: It manufactures the same mix of part types throughout its lifetime.

**Modular FMS**: A modular FMS, with a sophisticated FMS host, enables and FMS user to expand their FMS capabilities in a stepwise fashion into any of the previous four types of FMS.

1.6 TYPES OF FMS LAYOUTS

The different types of FMS layouts are:
1. Progressive or Line Type
2. Loop Type
3. Ladder Type
4. Open field type
5. Robot centered type

1. **Progressive or Line type:** The machines and handling system are arranged in a line as shown in the Fig.1.4 (a). It is most appropriate for a system in which the part progress from one workstation to the next in a well defined sequence with no back flow. The operation of this type of system is very similar to transfer type. Work always flows in unidirectional path as shown in Fig.1.4 (a).

2. **Loop Type:** The basic loop configuration is as shown in Fig. 1.4 (b). The parts usually move in one direction around the loop, with the capability to stop and be transferred to any station. The loading and unloading station are typically located at one end of the loop Fig.1.4 (b)

3. **Ladder Type:** The configuration is as shown in Fig. 1.4 (c). The loading and unloading station is typically located at the same end. The sequence to the operation/transfer of parts from one machine tool to another is in the form of ladder steps as shown in Fig.1.4 (c)
Fig. 1.4 (Contd.)
4. **Open Field Type**: The configuration of the open field is as shown in Fig.1.4 (d). The loading and unloading station is typically located at the same end. The parts will go through all the substations, such as CNC machines, coordinate measuring machines and wash station by the help of AGV’s from one substation to another.

5. **Robot Centered Type**: Robot centered cell is a relatively new form of flexible system in which one or more robots are used as the material handling systems as shown in Fig.1.4 (e). Industrial robots can be equipped with grippers that make them well suited for handling of rotational parts.

### 1.6.1 Factors Influencing the FMS Layouts

The various factors influencing the layouts of FMS are:

- Availability of raw material
- Proximity to market
- Transport facilities
- Availability of efficient and cheap labor
- Availability of power, water and fuel
- Atmospheric and climatic condition
- Social and recreation facilities
- Business and economic conditions

### 1.6.2 Seeking Benefits on Flexibility

Today’s manufacturing strategy is to seek benefits from flexibility. This is only feasible when a production system is under complete control of FMS technology. Having in mind the Process-Product Matrix you may realize that for an industry it is possible to reach for high flexibility by making innovative technical and organizational efforts. See the Volvo’s process structure that makes cars on movable pallets, rather than an assembly line. The process gains in flexibility. Also, the Volvo system has more flexibility because it uses multi-skill operators who are not paced by a mechanical line. So we may search for benefits from flexibility on moving to the job shop structures.

Actually, the need is for **flexible processes** to permit rapid low cost switching from one product line to another. This is possible with **flexible workers** whose multiple skills would develop the ability to switch easily from one kind of task to another.

As main resources, flexible processes and flexible workers would create **flexible plants** as plants which can adapt to changes in real time, using movable equipment, knockdown walls and easily accessible and re-routable utilities.

### 1.7 FMS—AN EXAMPLE OF TECHNOLOGY AND AN ALTERNATIVE LAYOUT

The idea of an FMS was proposed in England (1960s) under the name “System 24”, a flexible machining system that could operate without human operators 24 hours a day under computer control. From the beginning the emphasis was on automation rather than the “reorganization of workflow”.

Early flexible manufacturing systems were large and very complex, consisting of dozens of Computer Numerical Controlled machines (CNC) and sophisticated material handling systems.
They were much automated, 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). Today two or more CNC machines are considered as a flexible cell and two or more cells are considered a flexible manufacturing system.

Thus, 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.

### 1.8 Objectives of an FMS

A study, carried out with West Germany manufacturing has shown the major aims of installing an FMS to be:

- Decreased Lead Times
- Increased Throughput
- Increased machine utilization
- Improved Due Date Reliability
- Decreased Store Inventors Levels
- Decreased Work in Progress
- Increased Quality

### 1.9 Aims of FMS

- To reduce costs
- Better utilization of the production equipment reduction of stocks (ex: Work in progress—capital shorter through put times)
- Reduction of piece part unit costs.
- To increase Technical Performance:
  - Increased production levels
  - Greater product mixture
  - Simultaneous product mixture manufacturing
  - Integration of the production system into the factory’s logistical system
  - Smaller batch sizes
  - Shorter or zero change over or reset of times
- To improve Order Development:
  - Shorter lead times/delivery times
  - Determination of production capacities
- To assist future Corporate Security:
  - Increased Competitiveness
  - Increased Quality
  - Improved Company Image
1.10 THE PRINCIPLE OBJECTIVES OF FMS

The principle objectives of FMS are

1. To improve operational control through:
   - Reduction in the number of uncontrollable variables.
   - Providing tools to recognize and react quickly to deviations in the manufacturing plan
   - Reducing the dependence of human communication.

2. To reduce direct labor:
   - Removing operators from the machining site (their responsibilities activities can be broadened).
   - Eliminating dependence on highly skilled machines (their manufacturing skills can be better utilized in manufacturing engineering functions).
   - Providing a catalyst to introduce and support unattended or lightly attended machining operation.

3. To improve short run responsiveness consisting of:
   - Engineering changes
   - Processing changes
   - Machining downtime or unavailability
   - Cutting tool failure
   - Late material delivery

4. To improve long-run accommodations through quicker and easier assimilation of:
   - Changing product volumes
   - New product additions and introductions
   - Differentiation part mixes
   - Increase Machine Utilization by:
     - Eliminating machine setup
     - Utilizing automated features to replace manual intervention
     - Providing quick transfer devices to keep machines in the cutting cycle
   - Reduce inventors by:
     - Reducing lot sizes
     - Improving inventors turn-over
     - Providing the planning tools for JIT manufacturing

1.11 ADVANTAGES AND DISADVANTAGES OF FMS IMPLEMENTATION

The various advantages and disadvantages of FMS implementation are

1.11.1 Advantages
   - Faster, lower-cost changes from one part to another which will improve capital utilization
   - Lower direct labor cost, due to the reduction in number of workers
- Reduced inventory, due to the planning and programming precision
- Consistent and better quality, due to the automated control
- Lower cost/unit of output, due to the greater productivity using the same number of workers
- Savings from the indirect labor, from reduced errors, rework, repairs and rejects

1.11.2 Disadvantages

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

1.12 AREA OF APPLICATION OF A FMS IN INDUSTRY

The following chart in the Fig. 1.5 shows the various applications in an industry.
1.13 VARIOUS EQUIPMENTS AND THEIR FUNCTIONS REQUIRED FOR AN FMS

The two important equipments of FMS are:

1. **Primary equipment**: It adds value to the piece parts being manufactured. It consists of work centers, which physically machine a piece part, and process centers, which assemble, check or wash, etc. the piece parts.

2. **Secondary equipment**: It is used to support the primary equipment in achieving this goal. It consists of support stations such as pallet/fixture load-unload stations and tool commissioning/setting area, etc. It also consists of support equipments such as robots, pallet/fixture/stillage stores, pallet buffer stations, tool stores, raw material stores, transport system (AGVs, RGVs, robots) for tooling and piece parts, etc.

1.14 INNOVATIONS THAT HAVE ADVANCED THE MANUFACTURING INDUSTRIES

![Fig. 1.6 Innovations that have advanced the manufacturing industries](image-url)
1.15 CIM TECHNOLOGY

Fig. 1.7  CIM Technology

CAPP  Computer Aided Process Planning  FMS  Flexible Manufacturing System
CAP   Computer Aided Planning       FMC  Flexible Manufacturing Cell
CAQ   Computer Aided Quality Control FAS  Flexible Manufacturing Assembly
CAD   Computer Aided Design         DNC  Direct Numerical Control
CADD  Computer Aided Design and Drafting DAS  Data Acquisition System
MRP   Materials Resource Planning PDA Production Data
CIM   Computer Integrated Manufacturing AC  Area Control
CC    Cell Control

1.16 HIERARCHY OF CIM

The computer integrated manufacturing includes all of the engineering functions of CAD/CAM along with firm’s business functions that are related to manufacturing.
The activities in factory’s environment can be logically distributed into a hierarchy to run on a data exchange network system.

There are 5 levels of control or organization as shown Fig. 1.8.

Control functions are executed at Level 1 and 2 of the CIM hierarchy consisting of CNC, NC, RC and PLC equipments.

Levels 3, 4 and 5 define the organizational levels such as FMS host, area controller, plant control or MRP computer, etc.

Level 1 of the hierarchy include the drives, motors, limit switches, etc. of the production equipment.

**Fig. 1.8 CIM hierarchy**
Level 2 includes the controllers, which enable a machine to achieve an autonomous standalone capability. The CNCs, PLCs and microcomputers enable the machine to which they are dedicated to run unsupported from controllers on other hierarchy levels.

A production cell host computer can be installed above the stand-alone machine to provide organization and monitoring of a group of such machines. This is the level 3(a) where usually personal computers and minicomputers are installed. It is often dependent upon the size of the system and complexity, whether the manufacturing industries define these systems as

3. Flexible manufacturing system (FMS)—Large systems
4. Flexible manufacturing cells (FMC)—Small systems

Level 3(b) is the one where the host computer is often known as a coordination or master host.

Level 4 configures the control level for an area within a factory. The input and output of material into the area is planned at this level. The planning for a particular area involves an interactive dialogue between the computer on this level and say FMS host, the computer is termed as an area controller. If not and the planning is carried out without any feedback, the computer at this level is an open loop shop floor scheduling system.

If no planning is carried out by the computer, but only the collection and evaluation of data from level 3, the computer is classed as a management information system. The minicomputers and mainframes of level 5 provide the automation of the factory wide or corporate functions. Such functions include CAP, CAD, MRP, finance, marketing, etc.

### 1.17 DIRECT REAL TIME SCHEDULE CONTROL

The major functions of an FMS host are illustrated in the Fig. 1.9

Planned work is only allocated to a specific machine when the individual piecepart has been setup in a fixture on a pallet and a machine is available, with all its necessary equipment and programs, to process it. The object of the host is to keep the expensive capital equipment utilized by supplying with it with work. This is best achieved when preparatory work is carried out simultaneously whilst the machine is still working. The host organizes the preparation and transportation of the work so that it is readily available to the machine when it next requests some work. The best machine utilization can be obtained when a machine’s layout includes an internal machine buffer. The host can then organize this internal buffer to be always loaded with work. If this buffer is always loaded with work there will always be work available for the machine to transfer immediately into the spindle’s work area. Piece parts are moved from a machine under the organization of the host to other machines, or to a system buffer station, if the next machine in a piecepart’s process route is busy and cannot accept a piecepart into its buffer.
1.18 FMS CONCEPTS

To get clear information with application of FMS the concepts concerned to FMS must be understood. The concepts cover mixes, machine allocations, flows, planning and scheduling.

System mixes:

(a) Piece part mix: The distinction must be made between:
- total piece part mix
- planned piece part mix
- ‘live’ order mix
- ‘live’ piece parts
The total piece part mix is that mix, which over the months and years, FMS has the manufacturing capability.

The host of FMS can organize the manufacture of a wide range of various piece parts within the given primary equipments manufacturing capabilities.

The machines have a finite capacity for any particular period in which production is to be followed or planned.

A subset of the total live piece part mix is manufactured simultaneously in the system. As the piece parts drop out of the system more piece parts of the planned live mix can enter the system at the load and unload stations, thus the FMS is constantly fed with new work.

(b) **Piece part mix types:** The piece parts can classified as
- Prismatic (cuboid shaped components—for drilling, milling, reaming, etc.)
- Rotational (round cylindrical components)—or turning, grinding, etc.
- Hybrid (rotational and prismatic shaped components) ex-crank shaft

(c) **Machine allocation mix:** An operation on a piecepart needs a NC program loaded into a machine tool’s controller for the machine to execute the operation. When an FMS operation is considered, then as a single NC program which itself has several operations, each one better known as a cutting operation.

The allocation of work centers to machine the different operations of a piece part is defined as either interchangeable allocation or complementary allocation as shown in the Fig. 1.10.

![Fig. 1.10 Process routings in an FMS](image-url)