Flexible Manufacturing System (FMS)

Unit-IV

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Introduction

Flexible manufacturing systems (FMSs) are the most automated and technologically sophisticated of the machine cell types used to implement cellular manufacturing.

A flexible manufacturing system (FMS) is a highly automated group technology machine cell, consisting of a group of processing workstations that are interconnected by an automated material handling and storage system, and controlled by a distributed computer system

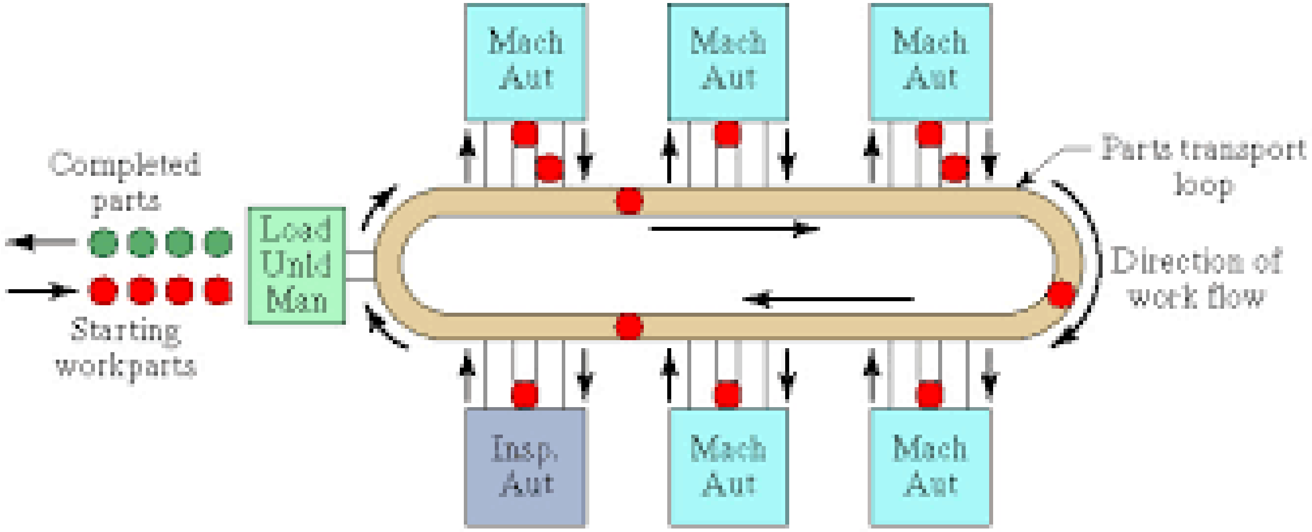
FMS components—

workstations,

material handling and storage,

computer control, and

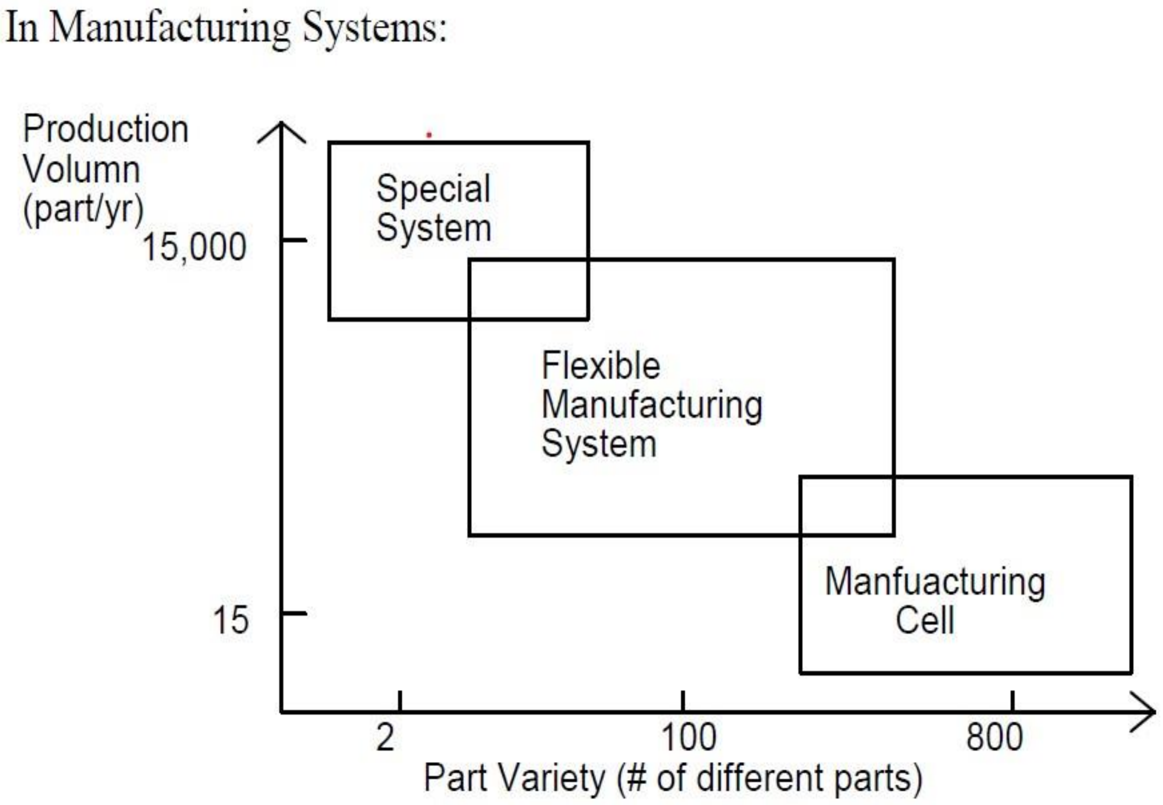
human resources



In Manufacturing Systems:

1. Special Mfg. System: the least flexible CIM system. It is designed to produce a very limited number of different parts (2 - 8).

2. Mfg. Cell: the most flexible but generally has the lowest number of different parts manufactured in the cell would be between 40 - 80. Annual production rates rough from 200 - 500.
3. Flexible Mfg. System: A typical FMS will be used to process several part families with 4 to 100 different part numbers being the usual case.



Flexibility measures the ability to adapt “to a wide range of possible environment”.

To be flexible, a manufacturing system must posses the following capabilities:

❖ Identification of the different production units to perform the correct operation

❖ Quick changeover of operating instructions to the computer controlled production machines

- Quick changeover of physical setups of fixtures, tools and other working units

The reason, the FMS is called flexible, is that it is capable of processing a variety of different part styles simultaneously with the quick tooling and instruction changeovers.

Also, quantities of productions can be adjusted easily to changing demand patterns.

Types of flexibility

1. **Machine Flexibility**. It is the capability to adapt a given machine in the system to a wide range of production operations and part styles.

The greater the range of operations and part styles the greater will be the machine flexibility. The various factors on which machine flexibility depends are:

- Setup or changeover time
- Ease with which part-programs can be downloaded to machines
- Tool storage capacity of machines
- Skill and versatility of workers in the systems

2. Production Flexibility. It is the range of part styles that can be produced on the systems. The range of part styles that can be produced by a manufacturing system at moderate cost and time is determined by the process envelope.

It depends on following factors:

 Machine flexibility of individual stations
 Range of machine flexibilities of all stations in the system

3. **Mix Flexibility**. It is defined as the ability to change the product mix while maintaining the same total production quantity that is, producing the same parts only in different proportions. It is also known as process flexibility.

Mixed flexibility depends on factors such as:

- Similarity of parts in the mix
- Machine flexibility
- Relative work content times of parts produced

4. **Product Flexibility**. It refers to ability to change over to a new set of products economically and quickly in response to the changing market requirements. The change over time includes the time for designing, planning, tooling, and fixturing of new products introduced in the manufacturing line-up.

It depends upon following factors:

- Relatedness of new part design with the existing part family
- Off-line part program preparation
- Machine flexibility

5. **Routing Flexibility**. It can define as capacity to produce parts on alternative workstation in case of equipment breakdowns, tool failure, and other interruptions at any particular station. It helps in increasing throughput, in the presence of external changes such as product mix, engineering changes, or new product introductions.

Following are the factors which decides routing flexibility:

- Similarity of parts in the mix
- Similarity of workstations
- Common tooling

6. **Volume Flexibility**. It is the ability of the system to vary the production volumes of different products to accommodate changes in demand while remaining profitable. It can also be termed as capacity flexibility.

Factors affecting the volume flexibility are:

- Level of manual labor performing production
- Amount invested in capital equipment

7. **Expansion Flexibility**. It is defined as the ease with which the system can be expanded to foster total production volume.

Expansion flexibility depends on following factors:

- Cost incurred in adding new workstations and trained workers
- Easiness in expansion of layout
- Type of part handling system used

A measure of flexibility must quantify the term “penalty of change (POC)”, which is defined as follows:
POC = penalty x probability
Here, penalty is equal to the amount upto which the system is penalized for changes made against the system constraints, with the given probability.
Lower the value of POC obtained, higher will be the flexibility of the system

Comparison between attributes of flexible and conventional manufacturing systems

Item	Flexible	Conventional
Set-up	Defined	Varies
Volume	Low-Medium	Medium-High
WIP (work-in-process)	Low	High
Flexibility	High	Low
Scrap	Low	Unpredictable
Labor	Low	High
Equipment cost	High (short term)	Low (short term)
Equipment ROI	Low	High
Plant ROI	High	Low
Queuing	Low	High
Automation	High level	Low level
Future	Lead to integration	Dead end
Quality	Controlled	Varies
Inspection	Automatic tie-in	Doesn't flow
Tooling and fixturing	Flexible	Rigid
Market changes	Flexible	Rigid

TYPES OF FMS:
Flexible manufacturing systems can be divided into various types depending upon their features. They all are discussed below:

1. **DEPENDING UPON KINDS OF OPERATION-**

Flexible manufacturing system can be distinguished depending upon the kinds of operation they perform:

I. Processing operation. Such operation transforms a work material from one state to another moving towards the final desired part or product. It adds value by changing the geometry, properties or appearance of the starting materials.

II. **Assembly operation.** It involves joining of two or more component to create a new entity which is called an assembly/subassembly. Permanent joining processes include welding, brazing, soldering , adhesive bonding, rivets, press fitting, and expansion fits.

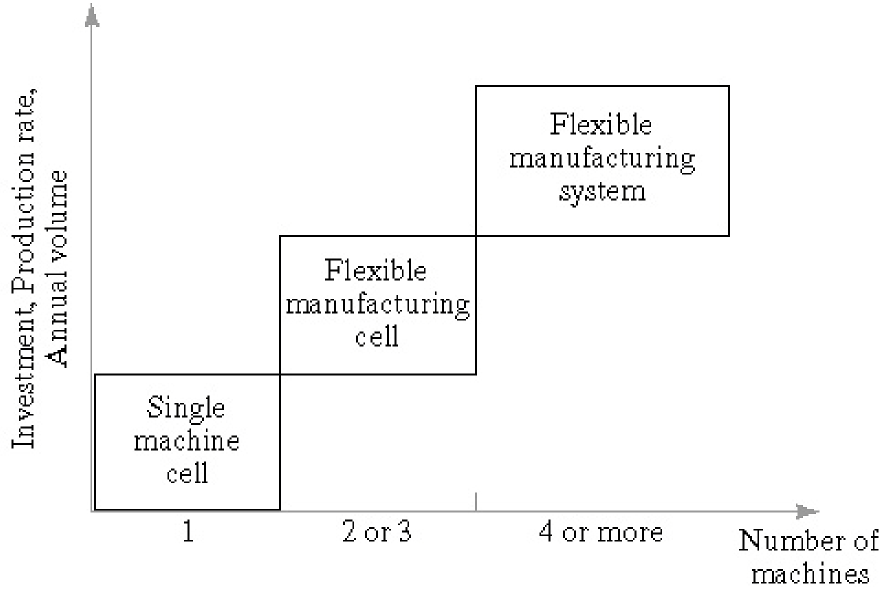
2. DEPENDING UPON NUMBER OF MACHINES –

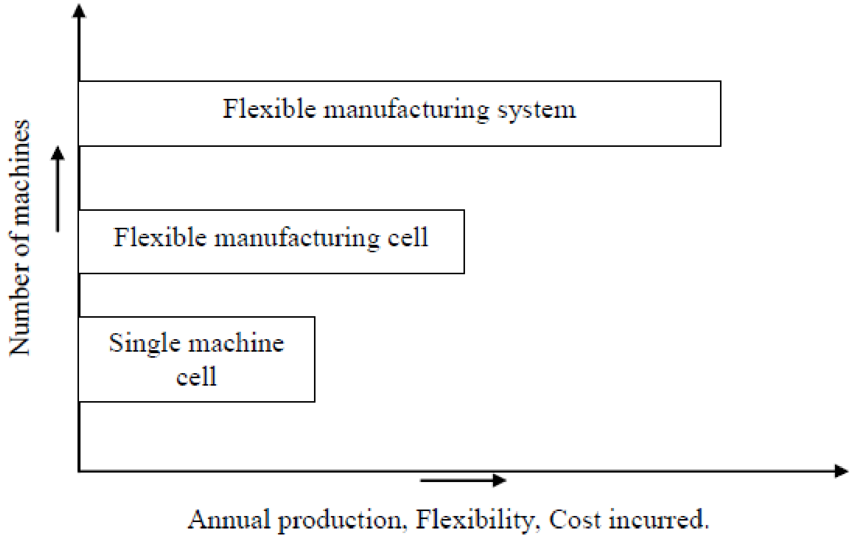
The following are typical categories of FMS according to the number of machines in the system:

I. single machine cell (SMC). It consist of a fully automated machine capable of unattended operations for a time period longer than one machine cycle. It is capable of processing different part styles, responding to changes in production schedule, and accepting new part introductions. In this case processing is sequential not simultaneous.

II. Flexible manufacturing cell (FMC). It consists of two or three processing workstation and a part handling system. The part handling system is connected to a load/unload station. It is capable of simultaneous production of different parts.

III. **A Flexible Manufacturing System (FMS).** It has four or more processing work stations (typically CNC machining centers or turning centers) connected mechanically by a common part handling system and automatically by a distributed computer system. It also includes non-processing work stations that support production but do not directly participate in it. e.g. part / pallet washing stations, co-ordinate measuring machines. These features significantly differentiate it from Flexible manufacturing cell (FMC).



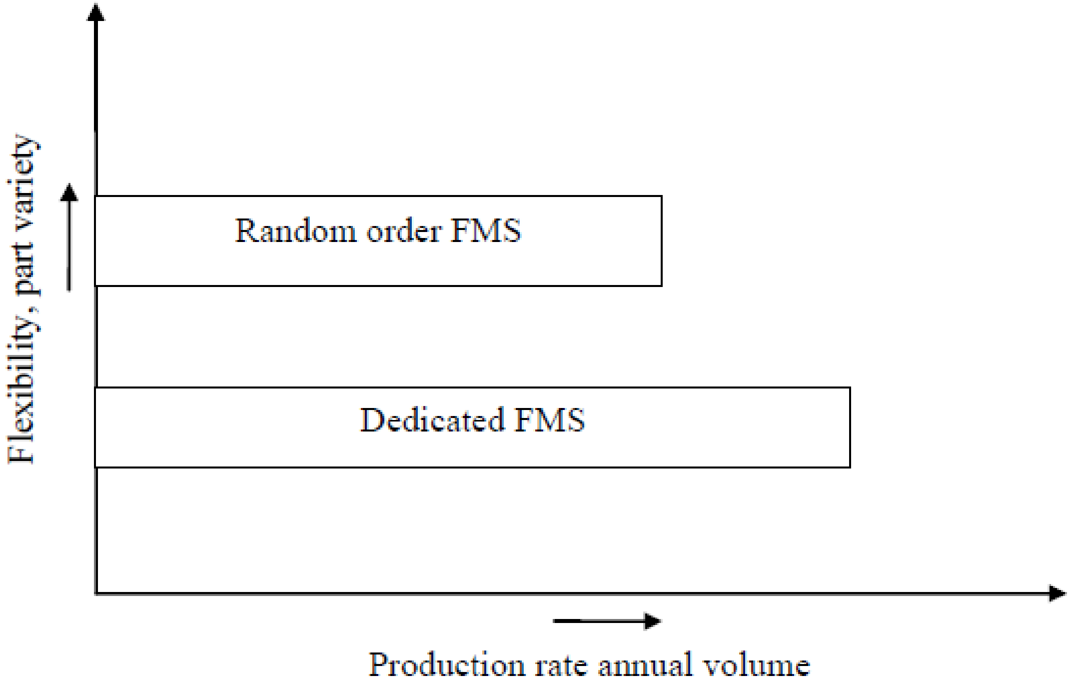


3. DEPENDING UPON LEVEL OF FLEXIBILITY–

Another classification of FMS is made according to the level of flexibility associated with the system. Two categories are distinguished here:

I. **Dedicated FMS.** It is designed to produce a particular variety of part styles. The product design is considered fixed. So, the system can be designed with a certain amount of process specialization to make the operation more efficient.

II. Random order FMS. It is able to handle the substantial variations in part configurations. To accommodate these variations, a random order FMS must be more flexible than the dedicated FMS. A random order FMS is capable of processing parts that have a higher degree of complexity. Thus, to deal with these kinds of complexity, sophisticated computer control system is used for this FMS type.



Types of FMS

The different types of FMS are :

1.Sequential FMS

2. Random FMS
3. Dedicated FMS
4. Engineered FMS
5. 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.

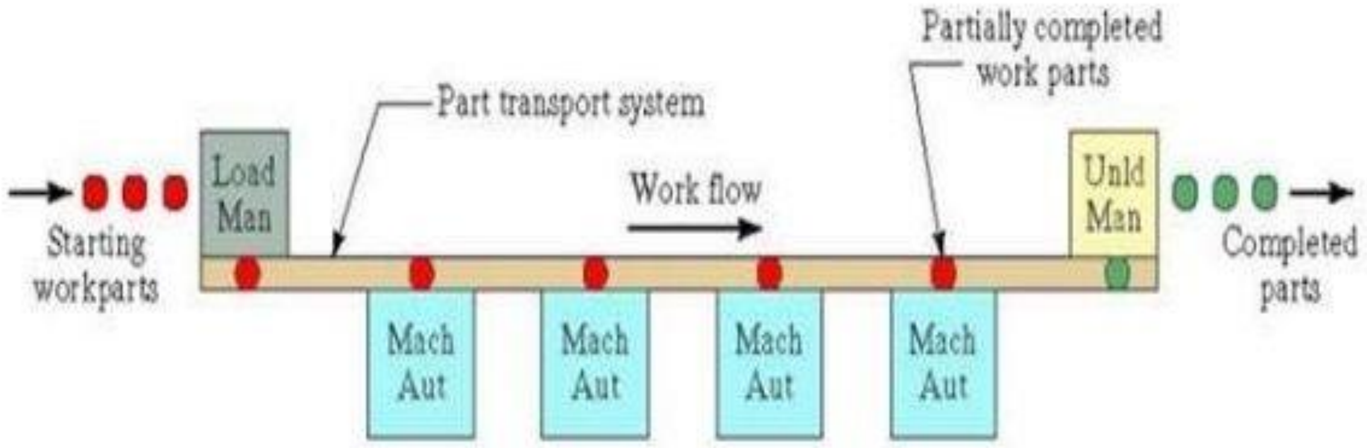
Dedicated FMS : It continually manufactures, for extended periods, the same but limited mix of piece part batch types.

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

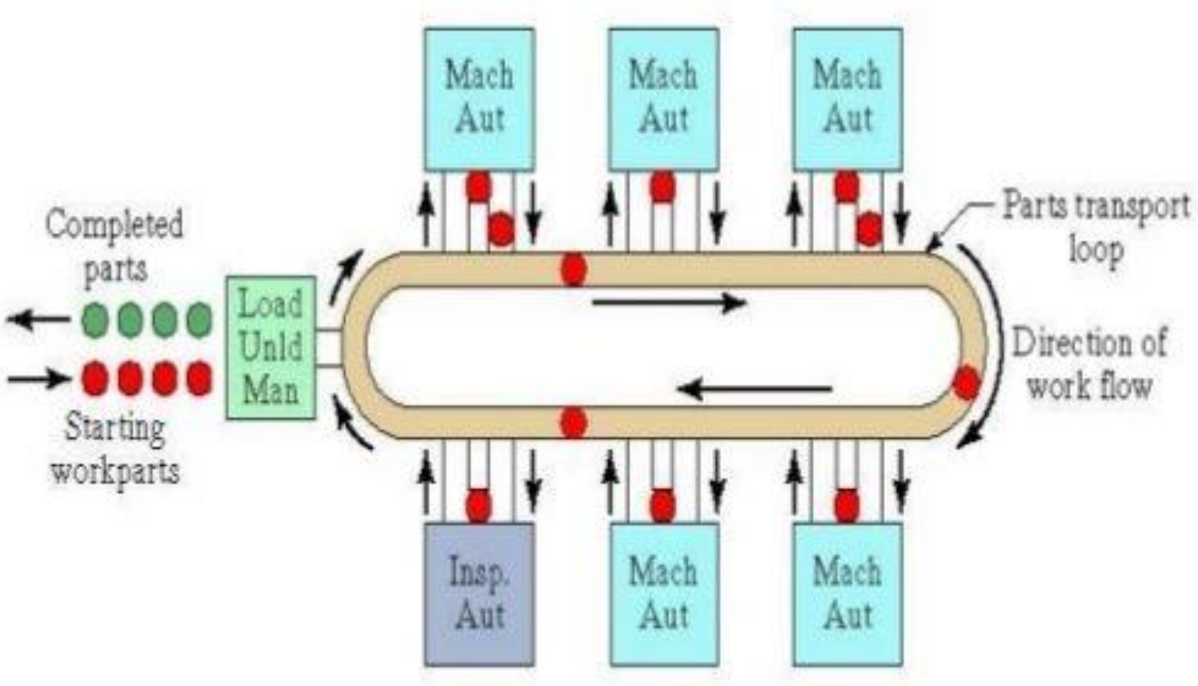
Modular FMS :A modular FMS, with a sophisticated FMS host, enables and FMS user to expand their FMS capabilities in a stepwise fashion into any of the previous four types of FMS.

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 in this type of system. 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 the figure below.

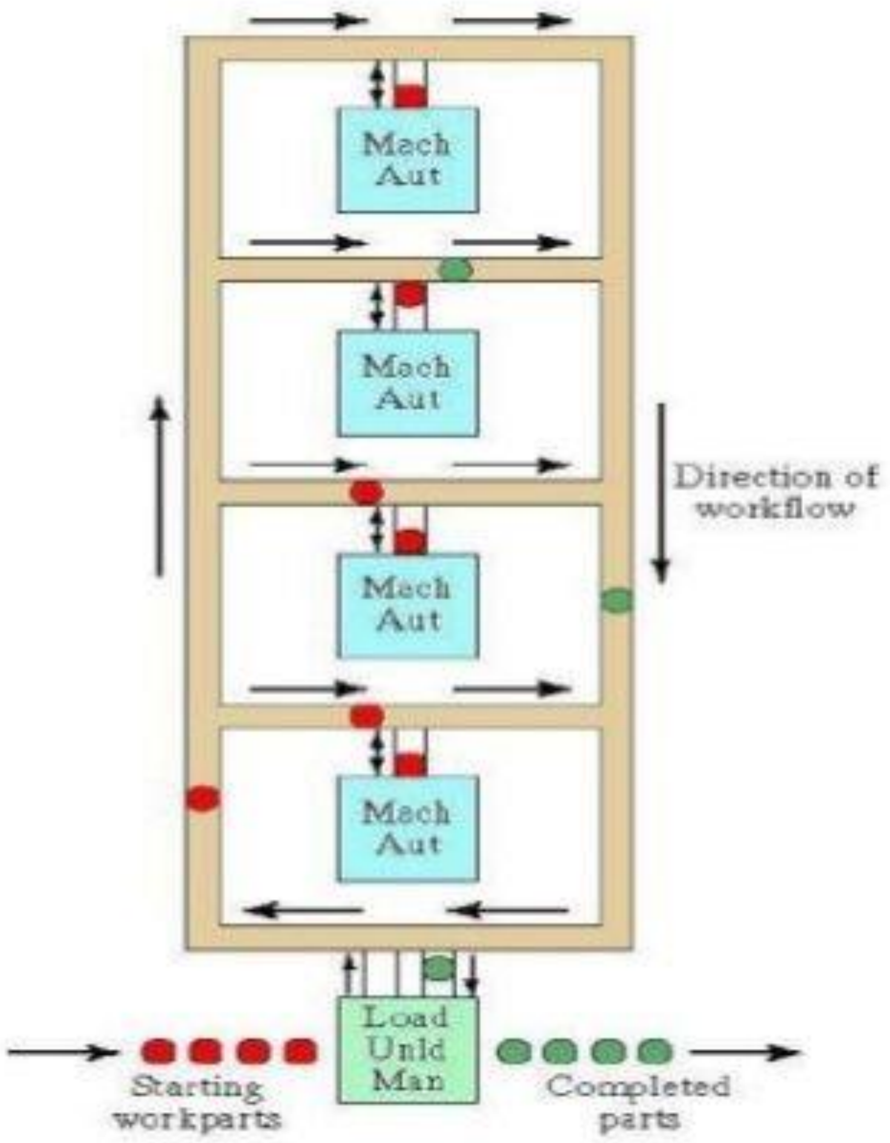


2.Loop Type : The basic loop configuration is as shown in figure below. The parts usually move in one direction around the loop, with the capability to stop and be transferred to any station. The loading and unloading station are typically located at one end of the loop as shown in the figure below



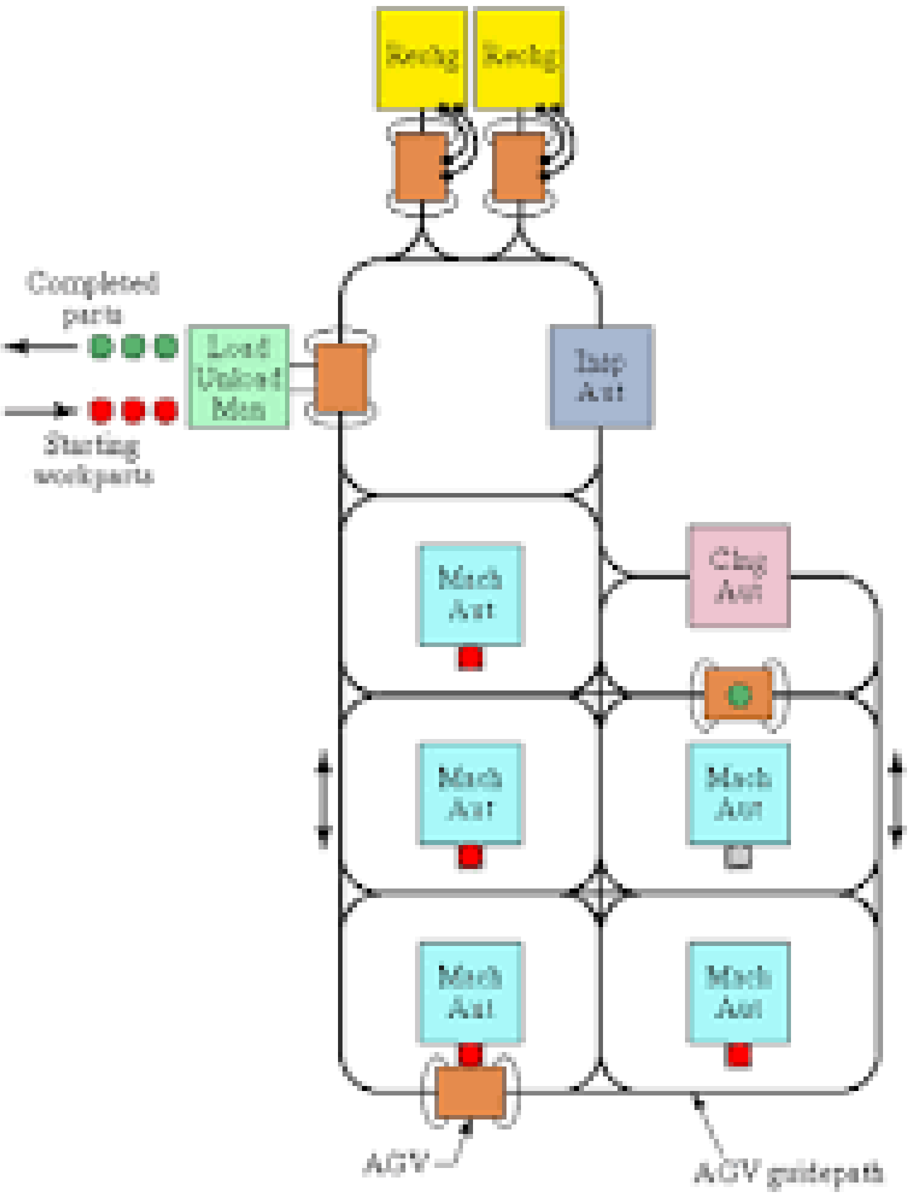
3.Ladder Type:

The configuration is as shown in the figure below. 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 the figure.



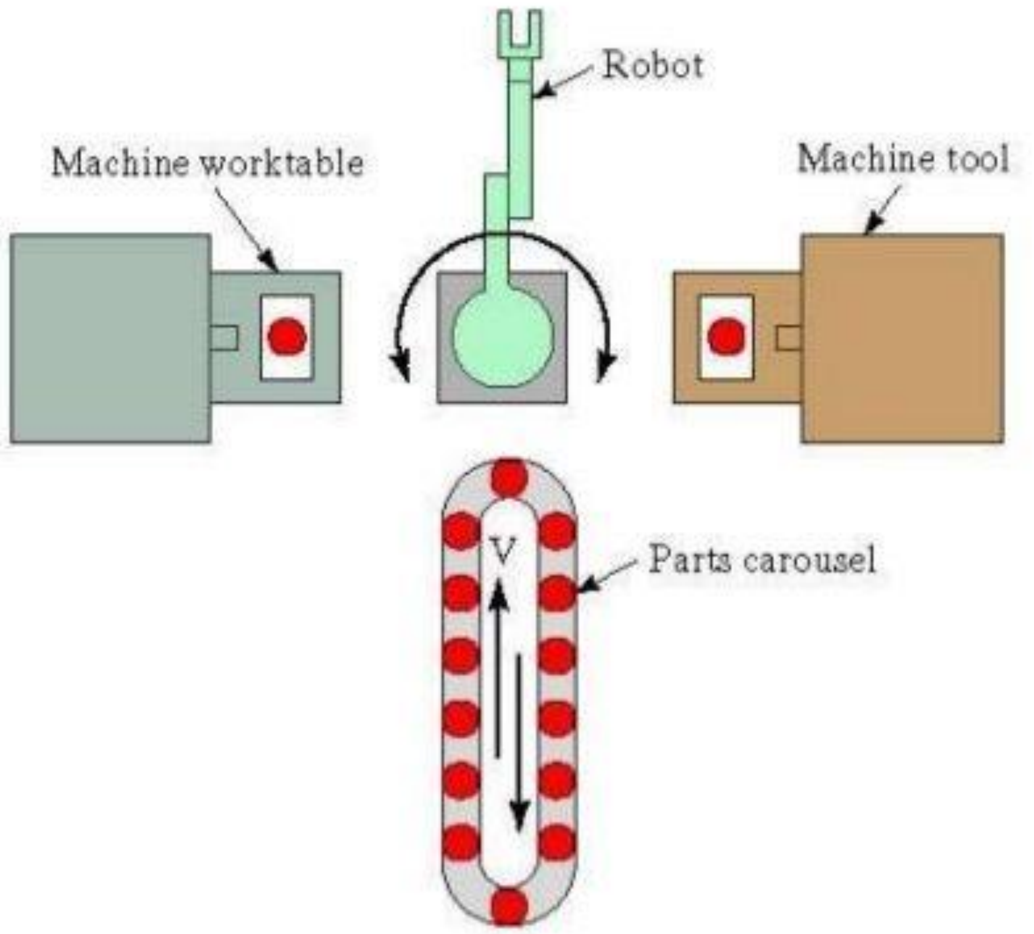
4. Open Field Type :

The configuration of the open field is as shown in the figure. 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.



6.**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 the figure below. Industrial robots can be equipped with grippers that make them well suited for handling of rotational parts.



Flexible manufacturing relies on what’s called “group technology” in order to achieve the manufacturing objective. Dedicated machinery is often employed in manufacturing when cost savings are important, however, these machines lack the flexibility that a more expensive lathe, drill press, or other manually operated tool might have. By using an FMS, manufacturing can be done in smaller batches with the ease and efficiency of mass production.

Pros

- Lower cost
- Higher productivity vs manual machinery
- Higher quality vs manual machinery
- Fairly reliable
- Smaller inventory footprint
- Shorter lead times

Cons

- Higher complexity vs manual machinery
- Higher initial cost vs manual machinery
- Requires skilled workers
- Pre-planning can be difficult

Factors Influencing FMS :

The various factors influencing the layouts of FMS are:

1. Availability of raw material
2. Proximity to market
3. Transport facilities
4. Availability of efficient and cheap labor
5. Availability of power, water and fuel
6. Atmospheric and climatic condition
7. Social and recreation facilities
8. Business and economic conditions

https://www.youtube.com/watch?v=lRqCIPiBXEY https://www.youtube.com/watch?v=BiOzGlaAE_8 https://www.youtube.com/watch?v=UzDT9Ev4DDU

A flexible manufacturing system consists of two subsystems:

- Physical subsystem
- Control subsystem

Physical subsystem includes the following elements:

1. **Workstations**. It consists of NC machines, machine-tools, inspection equipments, loading and unloading operation, and machining area.

2. Storage-retrieval systems. It acts as a buffer during WIP (work-in-processes) and holds devices such as carousels used to store parts temporarily between work stations or operations.

3. Material handling systems. It consists of power vehicles, conveyers, automated guided vehicles (AGVs), and other systems to carry parts between workstations.

Control subsystem comprises of following elements:

1. Control hardware. It consists of mini and micro computers, programmable logic controllers, communication networks, switching devices and others peripheral devices such as printers and mass storage memory equipments to enhance the working capability of the FMS systems.

2. Control software. It is a set of files and programs that are used to control the physical subsystems. The efficiency of FMS totally depends upon the compatibility of control hardware and control software

Basic features of the physical components of an FMS are discussed below:

1. Numerical control machine tools.

Machine tools are considered to be the major building blocks of an FMS as they determine the degree of flexibility and capabilities of the FMS. Some of the features of machine tools are described below;

- The majority of FMSs use horizontal and vertical spindle machines. However, machining centers with vertical spindle machines have lesser flexibility than horizontal machining centers.
- Machining centers have numerical control on movements made in all directions e.g. spindle movement in x, y, and z directions, rotation of tables, tilting of table etc to ensure the high flexibility.
- The machining centers are able to perform a wide variety of operations e.g. turning, drilling, contouring etc. They consist of the pallet exchangers

interfacing with material handling devices that carry the pallets within and between machining centers as well as automated storage and retrieval systems.

2. Work holding and tooling considerations.

It includes pallets/fixtures, tool changers, tool identification systems, coolant, and chip removal systems. It has the following features:

- Before machining is started on the parts, they are mounted on fixtures. So, fixtures must be designed in a way, to minimize part-handling time. Modular fixturing has come up as an attractive method to fixture a variety of parts quickly.
- The use of automated storage and retrieval system (AS/RS) and material handling systems such as AGVs, lead to high usage of fixtures.
- All the machining centers are well equipped with tool storage systems called tool magazines. Duplication of the most often used tools in the tool magazines is allowed to ensure the least non-operational time. Moreover, employment of quick tool changers, tool regrinders and provision of spares also help for the same.

3. Material-Handling Equipments

The material-handling equipments used in flexible manufacturing systems include robots, conveyers, automated guided vehicle systems, monorails and other rail guided vehicles, and other specially designed vehicles. There important features are:

- They are integrated with the machine centers and the storage and retrieval systems.
- For prismatic part material handling systems are accompanied with modular pallet fixtures. For rotational parts industrial robots are used to load/unload the turning machine and to move parts between stations.

The handling system must be capable of being controlled directly by the computer system to direct it the various work station, load/unload stations and storage area

4. Inspection equipment

It includes coordinate measuring machines (CMMs) used for offline inspection and programmed to measure dimensions, concentricity, perpendicularity, and flatness of surfaces. The distinguishing feature of this equipment is that it is well integrated with the machining centers.

5. Other components

It includes a central coolant and efficient chip separation system. Their features are:

- The system must be capable of recovering the coolant.
- The combination of parts, fixtures, and pallets must be cleaned properly to remove dirt and chips before operation and inspection.