# UNIT-IV

## FLEXIBLE MANUFACTURING SYSTEM AND AGVS

## PART-A

1. **Define FMS.**

   A flexible manufacturing system (FMS) is a method for producing goods that is readily adaptable to changes in the product being manufactured, in which machines are able to manufacture parts and in the ability to handle varying levels of production.

2. **What are the advantages or benefits of FMS? (Nov/Dec 2016)**
   a. Reduced manufacturing cost
   b. Lower cost per unit produced,
   c. Greater machine efficiency,
   d. Improved quality,
   e. Increased system reliability,

3. **What are the types of FMS?**
   a. Sequential FMS
   b. Random FMS
   c. Dedicated FMS
   d. Engineered FMS
   e. Modular FMS

4. **Give the types of FMS layouts**.
   a. In-line layout
   b. Loop layout
   c. Ladder layout
   d. Open field layout
   e. Robot-centered layout

5. **Mention the applications of FMS.**
   a. Metal cutting machining
   b. Metal forming

c. Welding
d. Assembly
e. Testing
f. Inspection

**6. What do you mean by AGV?**

An automated guided vehicle or automatic guided vehicle (AGV) is a mobile robot that follows markers or wires in the floor, or uses vision, magnets, or lasers for navigation. They are most often used in industrial applications to move materials around a manufacturing facility or warehouse.

**7. What are the applications of AGVs? (Apr/May 2017)**

AGVs are used in,

a. Assembly lines
b. Delivery of supplies
c. Finished product handling
d. Raw materials handling
e. Pallet handling

**8. What are the material handling equipments in FMS?**

a. Trucks
b. Conveyors
c. Cranes and hoists
d. AGVs
e. Robots

**9. State the components of FMS.**

The basic components of FMS are:

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

**10. What are the various functions of automated material handling and storage system?**

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.

**11. List the four tests for flexibility in FMS research. (Apr/May 2017)**

- Part variety test
- Schedule change test
- Error recovery test
- New part test

**12. List out the types of AGV's. (Nov/Dec 2016).**

- AGVS towing vehicle
- AGVS unit load carriers
- AGVS pallet trucks
- AGVS forklift trucks
- AGVS light-load transporters
- AGVS assembly-line vehicles

## PART-B

**1. Explain flexibility and its types.**

Flexibility is an attribute that allows a mixed model manufacturing system to cope up with a certain level of variations in part or product style, without having any interruption in production due to changeovers between models. Flexibility measures the ability to adapt "to a wide range of possible environment". To be flexible, a manufacturing system must possess the following capabilities:

a. Identification of the different production units to perform the correct operation.
b. Quick changeover of operating instructions to the computer controlled production machines.
c. Quick changeover of physical setups of fixtures, tools and other working units.

These capabilities are often difficult to engineer through manually operated manufacturing systems. So, an automated system assisted with sensor system is required to accomplish the needs and requirements of contemporary business milieu. Flexible manufacturing system has come up as a viable mean to achieve these prerequisites. The term flexible manufacturing system, or FMS, refers to a highly automated GT machine cell, consisting of a group of computer numerical control (CNC) machine tools and supporting workstations, interconnected by an automated material handling and storage system, and all 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 with the quick tooling and instruction changeovers. Also, quantities of productions can be adjusted easily to changing demand patterns.

The different types of flexibility that are exhibited by manufacturing systems are given below:

**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

**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

**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. Mix flexibility provides protection against market variability by accommodating changes in product mix due to the use of shared resources. However, high mix variations may result in requirements for a greater number of tools, fixtures, and other resources. Mixed flexibility depends on factors such as:

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

**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

**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

**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

**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

**2. How AGVs are guided? (Apr/May 2017), (Nov/Dec 2016).**

**Wired:**

A slot is cut in to the floor and a wire is placed approximately 1 inch below the surface. This slot is cut along the path the AGV is to follow. This wire is used to transmit a radio signal. A sensor is installed on the bottom of the AGV close to the ground. The sensor detects the relative position of the radio signal being transmitted from the wire. This information is used to regulate the steering circuit, making the AGV follow the wire.

**Guide tape:**

AGVs (some known as automated guided carts or AGCs) use tape for the guide path. The tapes can be one of two styles: magnetic or colored. The AGC is fitted with the appropriate guide sensor to follow the path of the tape. One major advantage of tape over wired guidance is that it can be easily removed and relocated if the course needs to change. Colour tape is initially less expensive, but lacks the advantage of being embedded in high traffic areas where the tape may become damaged or dirty. A flexible magnetic bar can also be embedded in the floor like wire but works under the same provision as magnetic tape and so remains unpowered or passive. Another advantage of magnetic guide tape is the dual polarity. small pieces of magnetic tape may be placed to change states of the AGC based on polarity and sequence of the tags.

**Laser target navigation:**

The navigation is done by mounting reflective tape on walls, poles or fixed machines. The AGV carries a laser transmitter and receiver on a rotating turret. The laser is transmitted and received by the same sensor. The angle and (sometimes) distance to any reflectors that in line of sight and in range are automatically calculated. This information is compared to the map of the reflector layout stored in the AGV's memory. This allows the navigation system to triangulate the current position of the AGV. The current position is compared to the path programmed in to the reflector layout map. The steering is adjusted accordingly to keep the AGV on track. It can then navigate to a desired target using the constantly updating position.

- **Modulated Lasers:**

  The use of modulated laser light gives greater range and accuracy over pulsed laser systems. By emitting a continuous fan of modulated laser light a system can obtain an uninterrupted reflection as soon as the scanner achieves line of sight with a reflector. The reflection ceases at the trailing edge of the reflector which ensures an accurate and consistent measurement from every reflector on every scan. By using a modulated laser a system can achieve an angular resolution of ~ 0.1 mrad (0.006°) at 8 scanner revolutions per second.

- **Pulsed Lasers**:

  A typical pulsed laser scanner emits pulsed laser light at a rate of 14,400 Hz which gives a maximum possible resolution of ~ 3.5 m rad (0.2°) at 8 scanner revolutions per second. To achieve a workable navigation, the readings must be interpolated based on the intensity of the reflected laser light, to identify the centre of the reflector.

**Inertial (Gyroscopic) navigation:**

Another form of an AGV guidance is inertial navigation. With inertial guidance, a computer control system directs and assigns tasks to the vehicles. Transponders are embedded in the floor of the work place. The AGV uses these transponders to verify that the vehicle is on course. A gyroscope is able to detect the slightest change in the direction of the vehicle and corrects it in order to keep the AGV on its path. The margin of error for the inertial method is ±1 inch. Inertial can operate in nearly any environment including tight aisles or extreme temperatures. Inertial navigation can include use of magnets embedded in the floor of the facility that the vehicle can read and follow.

**Natural features (Natural Targeting) navigation:**

Navigation without retrofitting of the workspace is called Natural Features or Natural Targeting Navigation. One method uses one or more range-finding sensors, such as a laser range-finder, as well as gyroscopes or inertial measurement units with Monte- Carlo/Markov localization techniques to understand where it is as it dynamically plans the shortest permitted path to its goal. The advantage of such systems is that they are highly flexible for on-demand delivery to any location. They can handle failure without bringing down the entire manufacturing operation, since AGVs can plan paths around the failed device. They also are quick to install, with less down-time for the factory.

**Vision guidance:**

Vision-Guided AGVs can be installed with no modifications to the environment or infrastructure. They operate by using cameras to record features along the route, allowing the AGV to replay the route by using the recorded features to navigate. Vision- Guided AGVs use Evidence Grid technology, an application of probabilistic volumetric sensing, and was invented and initially developed by Dr. Moravec at Carnegie Mellon University. The Evidence Grid technology uses probabilities of occupancy for each point in space to compensate for the uncertainty in the performance of sensors and in the environment. The primary navigation sensors are specially designed stereo cameras. The vision-guided AGV uses 360-degree images and build a 3D map, which allows the vision-guided AGVs to follow a trained route without human assistance or the addition of special features, landmarks or positioning systems.

**Geo- guidance:**

A geo-guided AGV recognizes its environment to establish its location. Without any infrastructure, the forklift equipped with geo-guidance technology detects and identifies columns, racks and walls within the warehouse. Using these fixed references, it can position itself, in real time and determine its route. There are no limitations on distances to cover or number of pick-up or drop-off locations. Routes are infinitely modifiable.

3. **What are the safety systems in AGVs?**

**Warning and Alarm Lights:**

AGVs have warning lights, audible-warning signals, emergency stop buttons, and non-contact obstacle detectors. When the AGV is approaching a turn, the warning lights function as directional signals to alert personnel in the area of the AGV's intention to branch right or left on the Guide path. When the AGV goes into an alarm mode, the Alarm Lights blink to indicate an alarm.

**Audible Warning/Alarm Signals:**

Two distinct tones are used during the vehicle's operation, an acknowledge tone and an alarm tone. The AGV emits a slow repeating acknowledge (run) tone during normal operation. The alarm tone sounds when an alarm is active.

**Emergency Stop Buttons:**

Emergency stop buttons are provided on each AGV. When activated, the AGV enters an emergency stop state and all motion capable equipment will become inactive.

**Collision Avoidance System:**

The non-contact collision avoidance system on the AGV can utilize a number of different laser sensors mounted on the front, rear, side, and upper locations of the AGV. When the AGV is traveling on the Guide path, this system will detect an obstacle in any of the coverage locations.

When the obstacle is within the warning field of any of these sensors, the AGV will decelerate to a slower speed in anticipation of a full stop. If the obstacle is still detected within protective field of the sensor, the AGV will apply its brakes so that it comes to a complete stop before contact is made. AGV will resume automatic operation approximately three seconds after the obstacle is removed from the protective field.

**4. Explain the components of FMS. (Nov/Dec 2016)**

A flexible manufacturing system consists of two subsystems:

- Physical subsystem
- Control subsystem

Physical subsystem includes the following elements:

**Workstations:**

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

**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.

**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:

**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.

**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:

**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.

**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 re-grinders and provision of spares also help for the same.

**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.

**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.

**Other components**

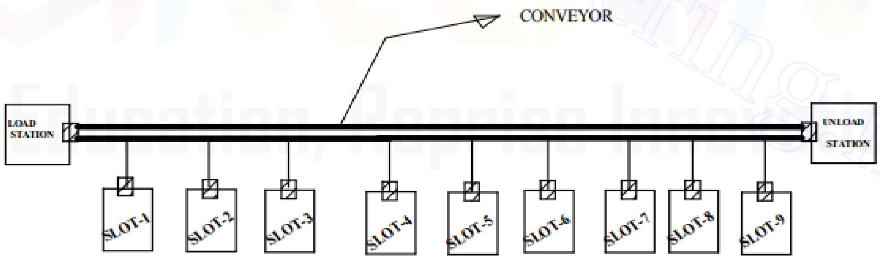
It includes a central coolant and efficient chip separation system. Their features are:

- 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.

**5. Explain FMS layout.**

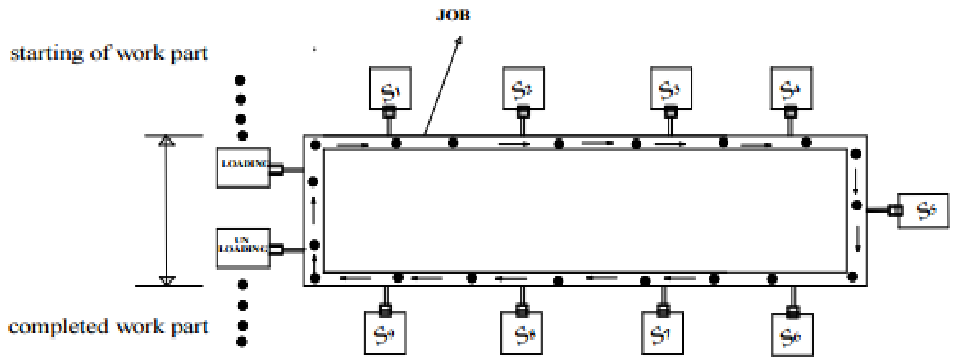
**Line layout:**

An Automated guided vehicle is most efficient when the movement is in straight-lines along the AGV path in a single-row machine layout. Machines are arranged only on one side of AGV path, and in double row machine layout, machines are arranged on both sides. A possible arrangement of this layout is shown in figure.



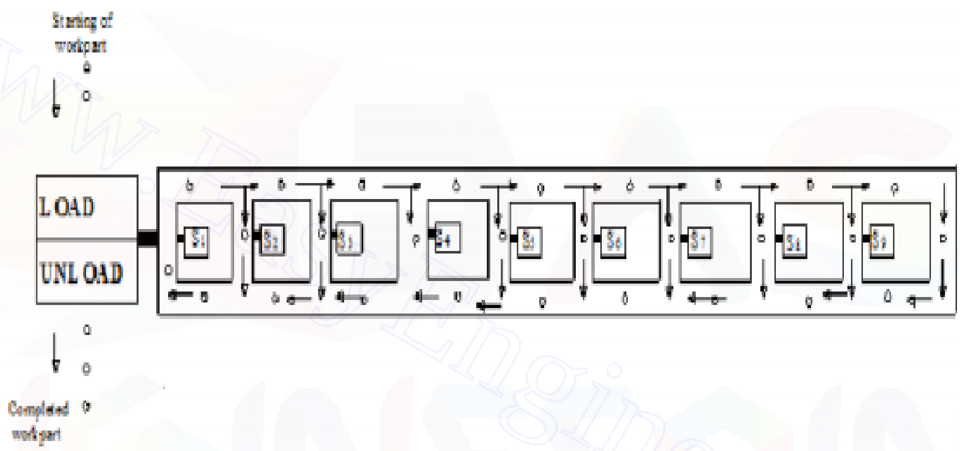

**Loop layout**:

The loop layout uses conveyor systems that allow unidirectional flow of parts around the loop. A secondary material handling system is provided at a workstation which permits the flow of parts without any obstruction. A possible arrangement of this layout is shown in figure.



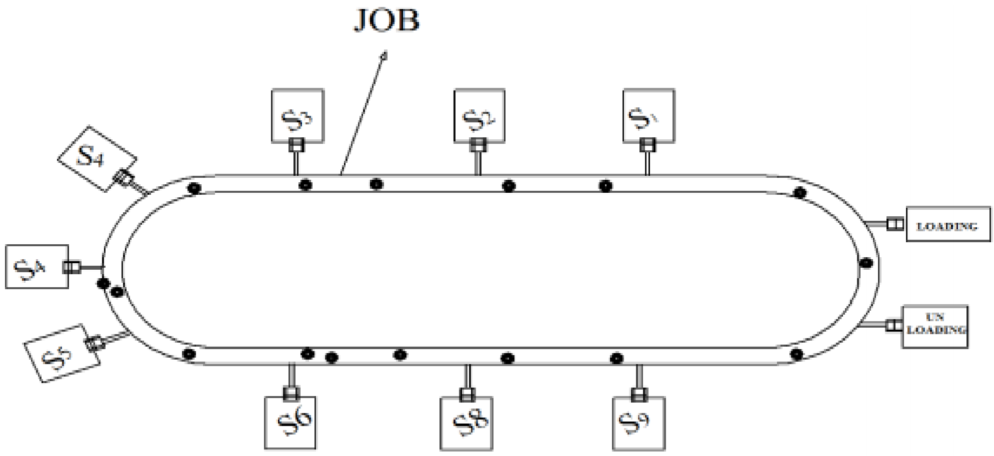

## Ladder type layout:

Ladder type layout consists of rungs on which workstations are located. This reduces the average travel distance thereby reducing the transfer time between workstations. A possible arrangement of this layout is shown in figure.



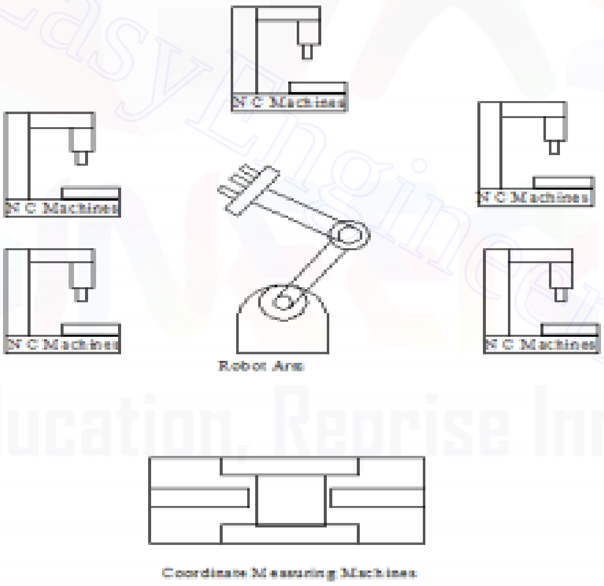

## Carousel layout:

In the Carousel layout configuration, parts flow in one direction around the loop. The load, unload stations are placed at one end of loop, A possible arrangement of this layout is shown in figure.




**Robot centered cell:**

If a handling robot is used in a Flexible manufacturing system cell , the machines are laid out in a circle, such a layout is called circular layout. A possible arrangement of this layout is shown in figure.




**The open field layout**:

The open field layout is also an adoption of the loop configuration. The open field layout consists of loops and ladders organized to achieve the desired processing requirements. This is used for the processing of a large family of parts. The number of different machines may be limited, and the parts are routed to different workstations depending on availability of machines. A possible arrangement of this layout is shown figure.