

## Unit –I

# Automation

**Definition** :- It is technology concerned with the application of Mechanical, electronic & computer –based systems to operate and control production in order to improves productions.

**If Includes :-**

- 1) Automated m/c tools.
- 2) Automated assembly m/c's
- 3) Industrial robots.
- 4) Automated material handling & storages system
- 5) Automated inspection system for quality control
- 6) Feedback control & computer process control
- 7) Computer integrated system for planning, data collection decision making.

**Examples** : Automotive, Electronics, Applications, Aircraft manufacturing industries.

**Type of Automation :**

- 1) Fixed Automation
- 2) Programmable Automation
- 3) Flexible Automation

**1) Fixed Automation :-**

- Fixed automation is a system in which the sequence of processing is fixed by equipment configuration.
- The operation sequence are simple.
- Higher initial investment of custom equipment
- High production capacity
- Inflexible to accommodate product changes

Example : Automated material handling & transfer lines & assembly equipments.

**2) Programmable Automation:-**

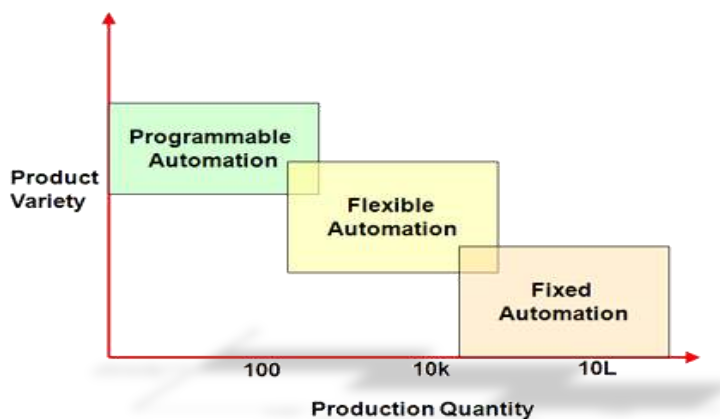
- In it production equipment is designed with the capability to change the sequence of operation to accommodate change of product design.
- The operation sequence is controlled by a program in form of coded instructions.
- For producing new batch of new design product the system can be reprogrammed.
- High investment initially
- Low production as compare to fixed automation.
- Flexibility to accommodate new design of product.
- It is most suitable of batch production.

Examples: - NC controlled m/c tolls & Industrial robots.

**3) Flexible Automation :-**

- It is an extension of programmable automation.
  - It is flexible automated system which can accommodate design change of product.
  - In it one advantage is that there is time lost for change over's from one product to the next.
  - There is no production time lost while reprogramming the system and allotting the physical setup of tooling, fixtures, machines setting.
  - High investment initially
  - Continuous production with Variety of product.
  - Medium production rate.
  - Flexibility for verity of product design change over.
- Example: - CNC m/c tools, reprogrammable Industrial robots.

### Diagraph:



### Reasons for Automation:-

#### 1) Increased productivity due competition

- Due to Industrialization and globalization the global competition escalates which causes increase the demand the stoner of productivity & quality.
- Automation of manufacturing operations promise to in erasing the productivity of labour.
- Automation causes higher out put to lesser input.
- Higher production rates are achieved with automation as compare to manual operations.

#### 2) High cost of Labour:-

- Automation system required less Labour hence increasing cost of Labour don't of heat on it.
- Higher cost of Labour is forcing businesses to substitute m/c's for human Labour.
- Machines can produce higher rates of output the use of automation results in a lower cost per unit of product.

### **3) Labour shortage:-**

- Many Advanced nations, there has been a shortage of Labour.
- Labour shortages stimulate the development of automation as a substitute of Labour.

### **4) Trend of Labour toward the sector :-**

- There are some social & institutional forces Labour toward the service sector.
- There has been a tendency for people to view factory work as tedious, demeaning & dirty.
- This view has caused them to seek employment in the service sector of the economy.

### **5) Safety:-**

- Automation delaminates the human role, work is made safer.
- The safety and physical well being of the worker is main objective of today's industries.

### **6) High cost of raw materials:-**

- The high cost of raw materials in manufacturing results in the need for greater efficiency in using these materials.
- The reduction of scrap is one of the benefits of automation.

### **7) Improved Product Quality:-**

- Automated operation not only produces parts at faster rates but they produce parts with greater consistency and conformity to quality.

### **8) Reduced manufacturing Lead time:-**

- Automation allows the manufacturer to reduce the time between custom order and product delivery.

### **9) Reduction of in process inventory:-**

- Holding large inventories of work in process represent a significant cost to the manufacturer because it ties up capital.
- In process inventory is of no value.
- It is to the manufacturer's advantage to reduce work in progress to a minimum.
- Automation plays a big role in reducing the time a work part spends in the factory.

### **10) High cost of not automation:-**

- The benefits of automation often show up in intangible and unexpected ways. Such as improved quality, higher sales, better Labour relations and better company image. Companies that do not automate are likely to find themselves at a competitive disadvantage with their customers, their employees & the general public.

### **Automation Strategies:-**

There are certain fundamental strategies that can be listed as follows.

### **1) Specialization of operations:-**

- It is strategies which involves use of specialized purpose equipments designed to perform one operation with greatest efficiency.
- It is strategy which involves used of specialized Labour to handle automation for improving the productivity.

### **2) Combined operations:-**

- It is the strategy of combined operations on some complex parts reducing the number of distinct production m/c's or workstations through which the part must be routed.

### **3) Simultaneous operations:-**

- It is a extension of combined operation strategy to perform same operations with less time simultaneously.
- In effect, two or more processing operations are being performed simultaneous on same work part reducing processing time.

### **4) Integration of operations:-**

- It is link several workstations into a single integrated mechanism using automated work handling devices.

### **5) Increased flexibility:**

- It attempts to use maximum utilizations of equipments for productions.
- By using the one equipment for variety of products. There by reducing set up time and programming time for production m/c's.

### **6) Improved material handling and storage:-**

- It is useful for reducing lots of non-operative time hence reduction in lead time.

### **7) On- line inspection:-**

- Inspection for quality of work is performed after the process traditionally.
- On line inspection into the manufacturing process permits corrections to the process as product is being made.
- This reduces scrap and brings the overall quantity of product closer to the nominal specifications intended by the designer.

### **8) Process control & optimization:-**

- It is included a wide range of control schemes intended to operate the individual process and associated equipment move efficiently.

### **9) Plan operations control:-**

- This strategy is concerned with control at the plant – Level.
- It is to manage and co-ordinate the aggregate equipment more efficiently.

## 10) Computer Integrated manufacturing (CIM):-

- This is use of computer applications, computer database and computer networking in the company.

### Arguments in favor of automation & against: - Argument in favor:-

- 1) Automation brings safer working conditions for the workers.
- 2) Automation is the they to minimize working time due to which increases production, hence higher quality of life.
- 3) Automated production has resulted in better products at lower prices.
- 4) The growth of automation industry has created newer Job opportunities. This has resulted incretion of various specialized departments.
- 5) Automation is the mean of increasing standard of living & increases productivity which resulted into increases in wages salaries & incentives etc.

### Argument in against:-

- 1) Automation has resulted in unemployment.
- 2) As productivity will be increased but creation of job will not occurs faster
- 3) Automation tends to transfer the skill required to perform work from human to machines.
- 4) Automation causes inflation and unemployment due to automation causes increase of poorly.
- 5) Due to the poorly the product will not sale which resulted in to markets will be flooded with the products and also inventories in industries increases in industry. Which would result in stopping the production and hence economic depression?

## Functions of Automation in manufacturing

For a firm engaged in making discrete products. The certain basic functions as –

- 1) Processing
- 2) Assembly
- 3) Material handling & storage
- 4) Inspection & Testing
- 5) Control

### 1) Processing operations:-

- It is the operations which transforms the product from one state of completion into a more advanced state of completion.
- It classified.

### Into one of the following four categories.

- 1) Basic processes
- 2) Secondary processes
- 3) Finishing operations

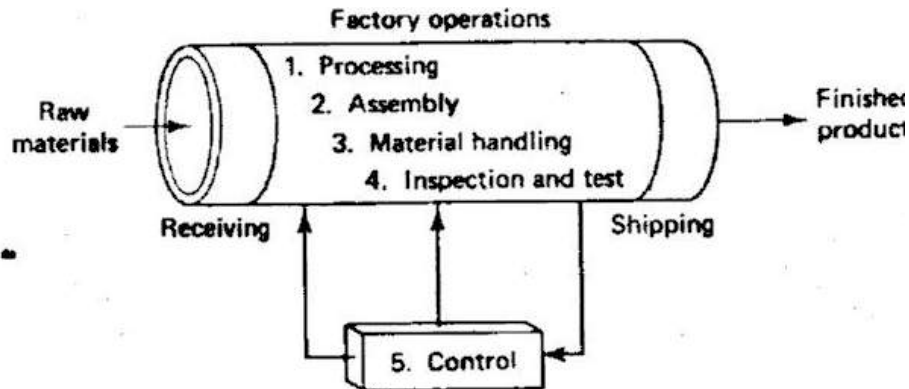
4) Operations to enhance physical properties.

### 1) Basic process:-

Basic process is those which gives the work material its initial form.

For example: - Metal casting & plastic molding both cases the raw material are converted into basic geometry of the desired product.

**Diagram:**



### 2) Secondary Processes:-

➤ It follow the basic process and are performed to give the work parts final desired geometry.

For example :- machines like turning, drilling milling etc. & press working operations like blanking forming, drawing etc.

### 3) Operations to enhance physical properties:-

➤ It is to change the physical geometry of the work part. Instead the physical properties of the materials are improved in some way. Heat treating operations to strengthen metal parts and preshrinking used in the garment industry are examples in this category.

### 4) Finishing operations:-

➤ It is the final processes performed on the work part.  
➤ It is for improving appearance or to provide to protective coating.  
For example: - Polishing, painting and chrome plating.

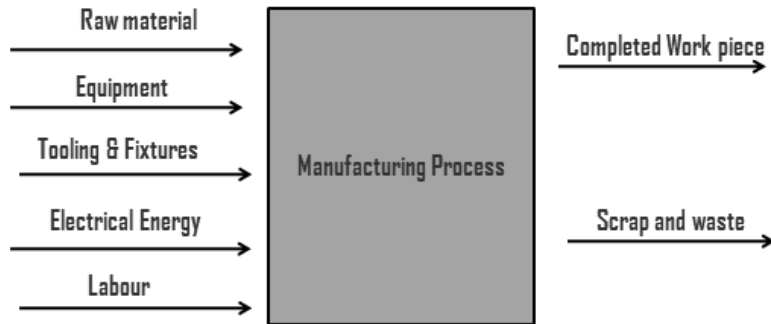
**Most manufacturing process required five inputs.**

- 1) Raw materials
- 2) Equipment (machine tools)
- 3) Tooling and fixtures.
- 4) Energy
- 5) Labour

The manufacturing process produces two outputs.

- 1) The completed workplace
- 2) Scrap & waste

**Diagram :**



#### **5) Assembly operation :-**

- In it the distinguishing feature is that two or more separate components are joined together.
- It included mechanical fostering operations, which make use of screws nuts, rivets and so on, and going processes such as welding, brazing & soldering.

#### **6) Material handling and storage :-**

- A means of moving and storing materials between the processing and assembly operations must be provided.
- Material spend move time being moved and stored than being processed.
- Mostly the cost would be required for handling, moving & storing of materials.

#### **7) Inspection & Testing :-**

- It is purpose of inspection is to determine the product meets the established design standards & specifications.

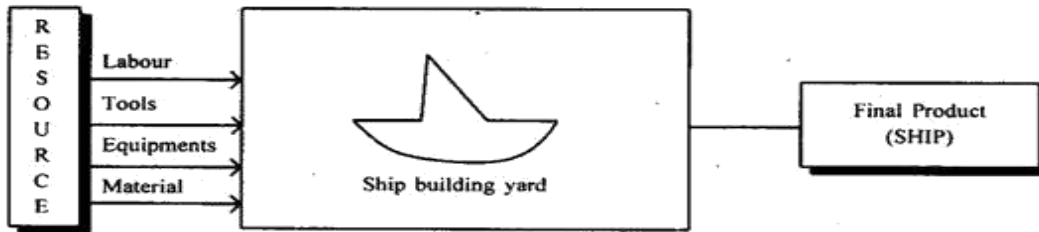
#### **Control :-**

- The control function in manufacturing includes both regulation of individual processing and assembly operation.
- Control at the process level involves the achievement of certain performance objectives.
- It is included effective u se of Labour maintenance of the equipment, moving materials in the factory.

#### **Plant Layout :-**

- It refers to the arrangement of these physical facilities in a production plant.
- Therefore three principal types of plant Layout.
  - 1) Fixed position layout
  - 2) Process layout
  - 3) Product flow layout
  - 4) Group technology layout

**Diagram :**



**1) Fixed position Layout:-**

- In this type of layout, because of size & weight the product remains in one Location and the equipment used in it is brought to it.
- Larger aircraft assembly and ship-building are comes under the fixed position layout.
- In it product is even totally moved but of the plant and the plant remains for the next job.

**2) Process layout:-**

- In it the production machines are arranged into groups according to the general type of manufacturing process.
- The advantage of this type of layout is its flexibility. Different parts, requires its our unique sequence of operation.

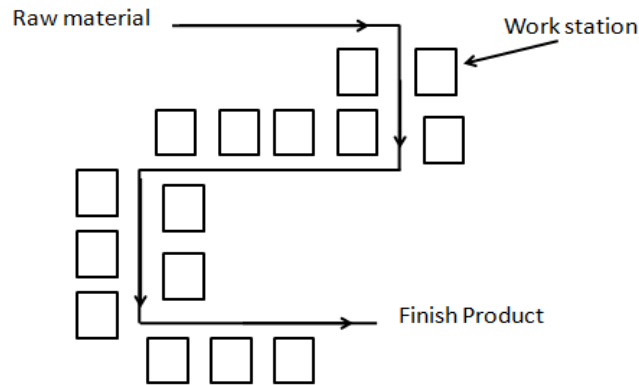
Shipping and Receiving	Lathe Dept.	Milling Dept.	Drill Dept.	office
	Assembly	Finishing Dept.	Grinding Dept.	

**3) Product flow layout:-**



- In this type of layout, the processing and assembly facility and placed along the line of flow of the product.

**Diagram:**

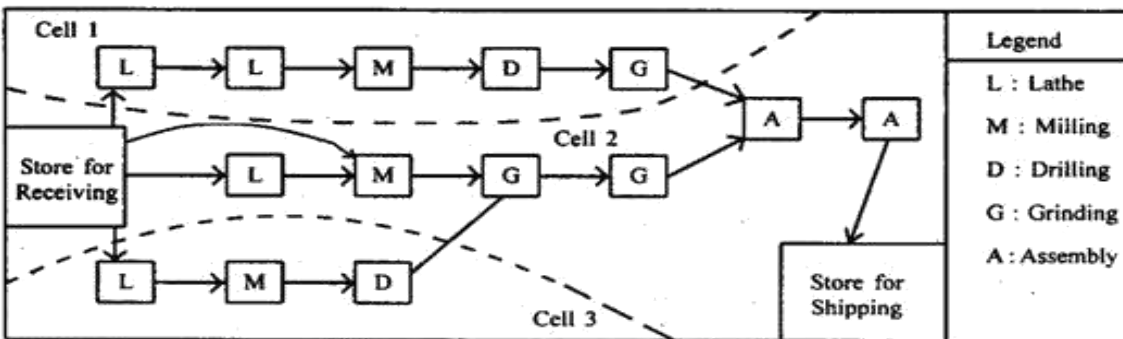


- The product is progressively lubricated as it flows through the sequence of workstations.

#### 4) Group technology Layout:

- It is the layout in which combines the efficiency of flow layout with process layout.
- In it machines arranged in to cells.
- Each cell is organized to specialize in the manufacture of a particular part of the family.
- Its advantages are gained in perform of reduced work piece manufacturing lead time, Lower setup prime, less in process inventory etc.

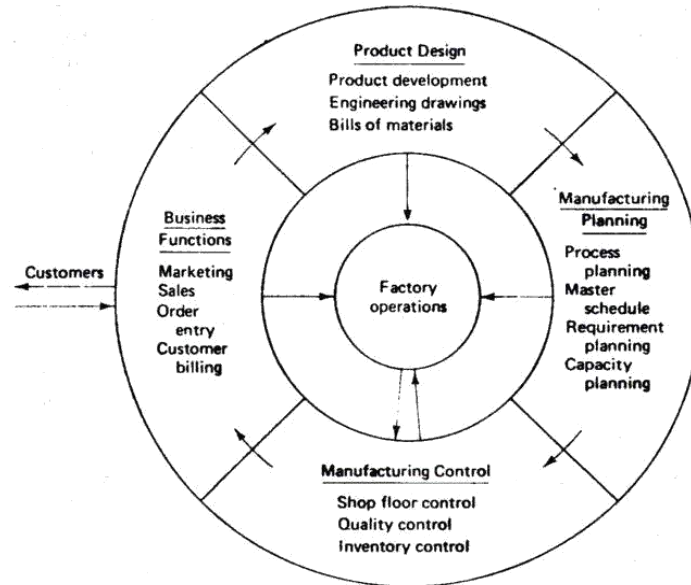
**Diagram**



#### Functions of automation information processing in manufacturing :-

It consisting of four functions :-

**Diagram :**



### 1) Business functions :

- It is the mean of communicating with the customer.
- It is beginning & end of the information processing cycle.
- It included category are sales, marketing, forecasting, order entry, cost accounting, customer billing & soars.

### 2) Product design :-

- The product is to be manufactured to customer specifications.
- It is provided by customer.
- The new product often originate in sales & marketing department.
- This department includes research & development, design engineering, drafting & prototyping.

### 3) Manufacturing Planning :-

- In it the organization that perform manufacturing engineering, industrial engineering & products on planning & control.

### 4) Manufacturing control :

- It is concerned with managing & controlling the physical operation in the factory to implement the manufacturing plan.
- The flow of information is from planning to control as indicated in fig. broadly manufacturing control consist of shop floor control, quality control & inventory control.

### Automated flow line :-

- It consists of several machines or workstations which are linked together by work handling devices that transfer parts between the stations is called automated flow line.

The objective of use of flow line automation are :-

- 1) To reduce Labour cost
- 2) To increase the production rate
- 3) To reduce work in progress
- 4) To minimise distance moved between operations
- 5) To achieve specialization of operations.
- 6) To achieve integration of operations.

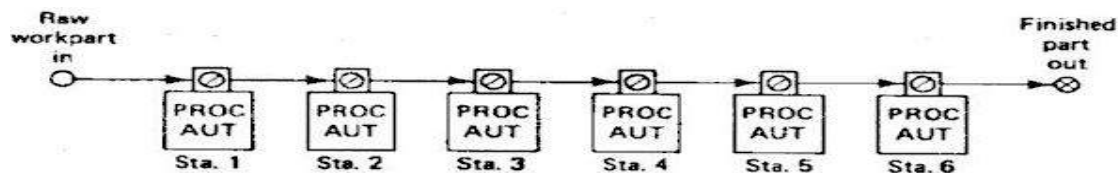
### Types of automated flow line :-

- It is basically divided into two types depending upon the forms in which the work flow can take place as.

#### 1) In – Line type :-

- It consists sequence workstationsing more –or- less straight line arrangement.
- The flow of work can take a few 90° turns either for work piece orientation.
- Factory layout limitation or other reason are also responsible for straight line configuration.

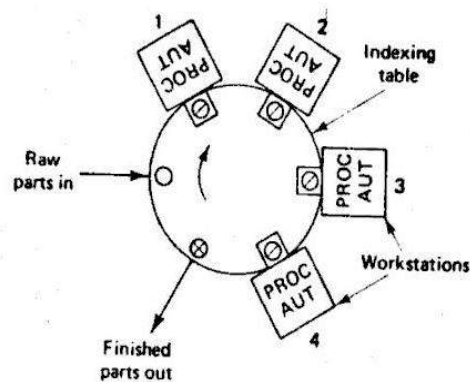
#### Diagram :



#### 2) Rotary types :-

- In this type work parts are indexed around a circular table or dial.
- The workstations are stationary and usually located around the periphery of the dial.
- The parts on the table are positioned at processing station for the operation.

#### Diagram:



### Various methods of work part transports :-

### Method of work part transport :

- 1) Continuous transfer
- 2) Intermission or synchronous transfer
- 3) Asynchronous transfer

#### 1) Continuous transfer :-

- In this method the work part are moved continuously at constant speed
- This requires the work heads to move during processing in order to maintain continuous registration with the work part.

#### 2) Intermittent transfer :-

- In this method the work pieces are transported with an intermittent or discontinuous motion..
- The work stations are fixed in position and parts are moved between stations then registration.
- All work parts are transported at the same time and for this reason it called synchronous transfer system.

#### 3) Asynchronous transfer :-

- In this system each work parts to move to next stations when processing at the current station has been completed.
- In it each parts moves in dependently of other parts.
- Asynchronous transfer systems move flexible than the other two system.
- It is used where there are one or more manually operated stations and cycle time variation station.

### Difference Between Automation and Mechanization

Automation	Mechanization
✓ It is concern with application of electronics and computer based system to operates production	✓ It is concern with machineries to operate production
✓ It operates without human	✓ It operates with the help of human
✓ It has close loop system in which feedback is provided by sensors	✓ No feed back process is available
✓ It is controlled by automatic control system	✓ It involves human efforts for operation

## Different type of transfer mechanisms:

1. Linear transfer mechanism

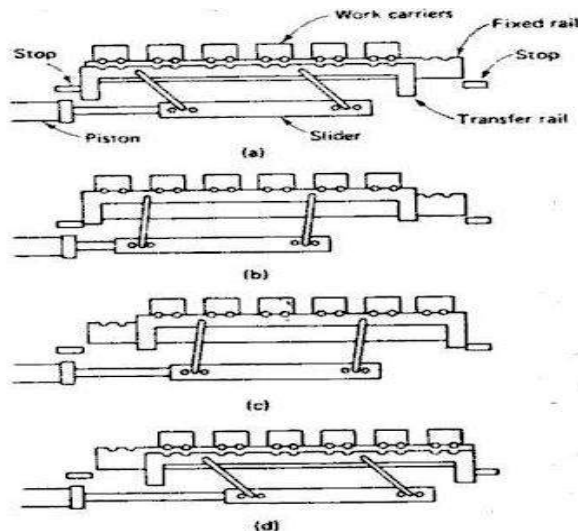
2. Rotary transfer mechanism

### 1. Linear transfer mechanism:

- a) Walking beam systems
- b) Powered roller conveyor system
- c) Chain-drive conveyor system

### ) Walking beam systems:

- ✓ In it the work-parts are lifted up from their workstation locations by a transfer bar and moved one position ahead, to the next station.
- ✓ The transfer bar then lowers the pans into nests which position them more accurately for processing



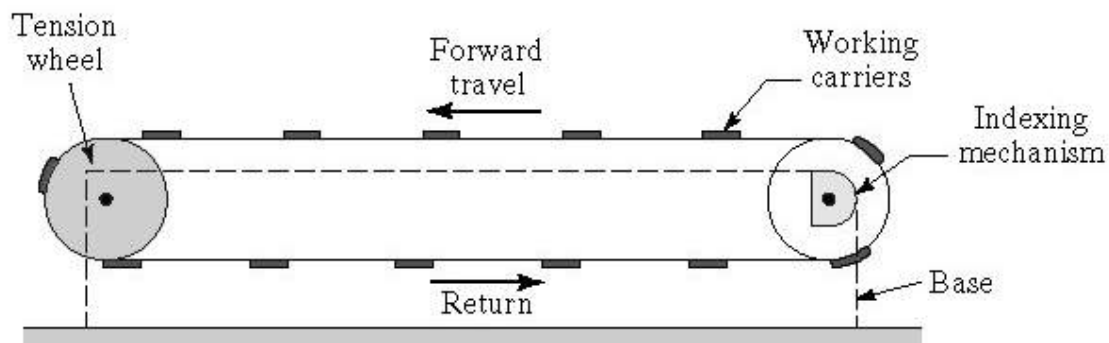
### b) Powered roller conveyor system:

- ✓ This type of system is used in general stock handling systems as well as in automated flow lines.
- ✓ The conveyor can be used to move pans or pallets possessing flat riding surfaces.
- ✓ The rollers can be powered by either of two mechanisms. The first is a belt drive, in which a flat moving belt beneath the rollers provides the rotation of the rollers by friction



### c) Chain-drive conveyor system:

- ✓ In it either a chain or a flexible steel belt is used to transport the work carriers.
- ✓ The chain is driven by pulleys in either an "over-and under" configuration, in which the pulleys turn about a horizontal axis, or an "around-the-corner" configuration, in which the pulleys rotate about a vertical axis.
- ✓ It can be used for continuous, intermittent, or asynchronous movement of work parts. In the asynchronous motion,



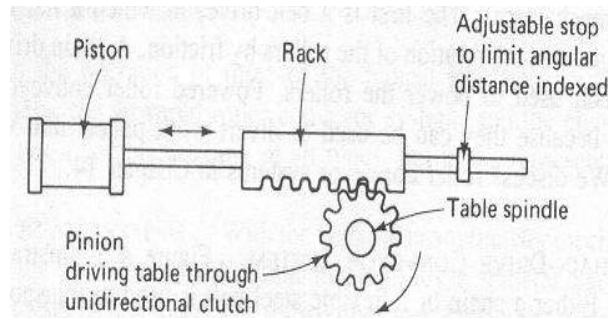
## 2. Rotary transfer mechanisms

- a) Rack and pinion
- b) Ratchet and pawl
- c) Geneva mechanism
- d) CAM Mechanisms

### a) Rack and pinion:

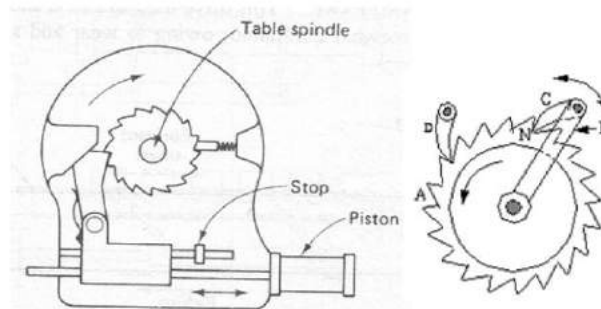
- ✓ This mechanism is simple but is not considered especially suited to the high-speed operation often associated with indexing machines.

- ✓ A piston to drive the rack, which causes the pinion gear and attached indexing table to rotate, A clutch or other device is used to provide rotation in the desired direction.



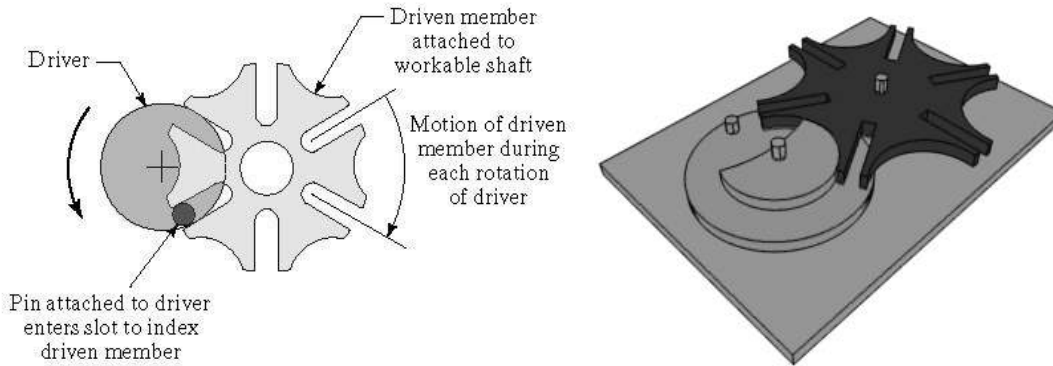
### b) Ratchet and pawl:

- ✓ A ratchet is a device that allows linear or rotary motion in only one direction, while preventing motion in the opposite direction.
- ✓ Ratchets consist of a gearwheel and a pivoting spring loaded finger called a pawl that engages the teeth. the spring for forcing it back with a 'click' into the depression before the next tooth.
- ✓ When the teeth are moving in the other direction, the angle of the pawl causes it to catch against a tooth and stop further motion in that direction



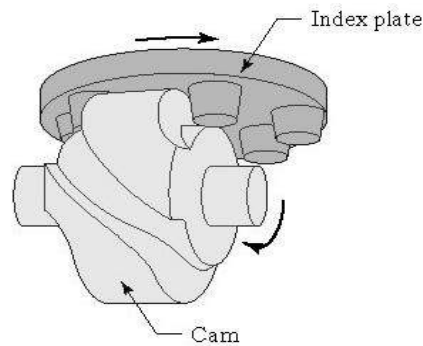
### c) Geneva mechanism:

- ✓ The Geneva mechanism uses a continuously rotating driver to index the table
- ✓ If the driven member has six slots for a six-station dial indexing machine, each turn of the driver will cause the table to advance one-sixth of a turn.



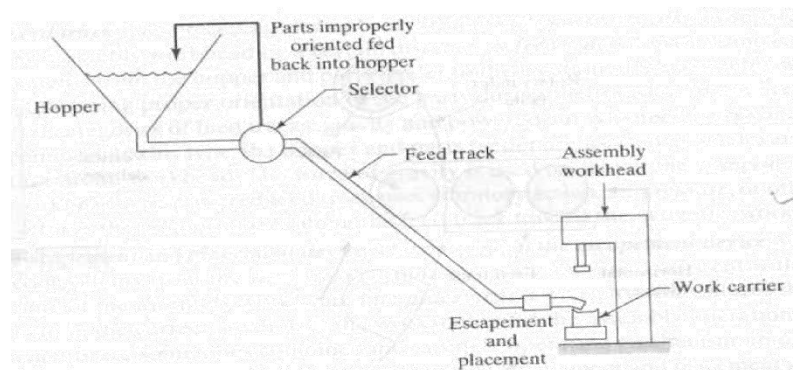
**d) CAM Mechanisms:**

- ✓ Cam mechanism provide probably the most accurate and reliable method of indexing the dial.
- ✓ They are in widespread use in industry despite the fact that the cost is relatively high compared to alternative mechanisms.
- ✓ The cam can be designed to give a variety of velocity and dwell characteristics.



**Elements of the parts delivery system:**

- ✓ The hardware system that delivers components to the work head in an automated assembly system typically consists of the following elements



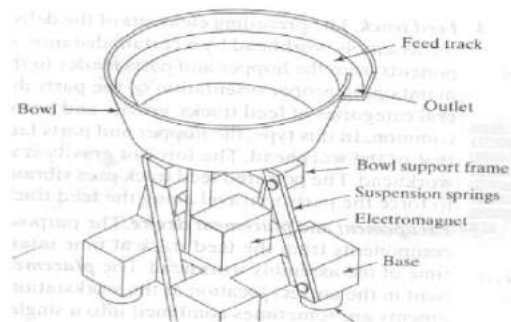
**Hopper:**



- ✓ This is the container into which the components are loaded at the workstation.
- ✓ The components are usually loaded into the hopper in bulk. This means that the parts are randomly oriented initially in the hopper.

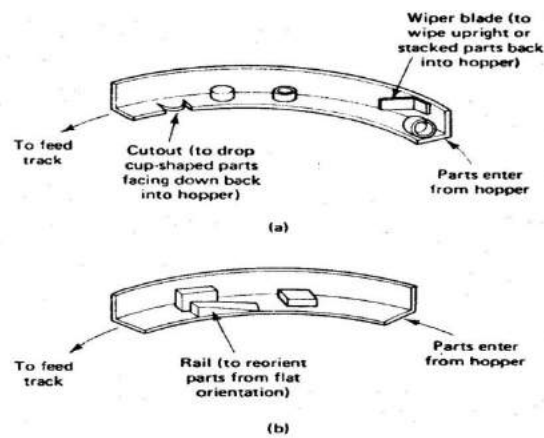
### Parts feeder:

- ✓ This is a mechanism that removes the components from the hopper one at a time for delivery to the assembly work head.
- ✓ The hopper and parts feeder are often combined into one operating mechanism.



### Selector and/or orienter:

- ✓ These elements of the delivery system establish the proper orientation of the components for the assembly work head.
- ✓ A selector is a device that acts as a filter, permitting only parts that are in the correct orientation to pass through. Components that are not properly oriented are rejected back into the hopper.
- ✓ An orientor is a device that allows properly oriented parts to pass through but provides a reorientation of components that are not properly oriented initially.

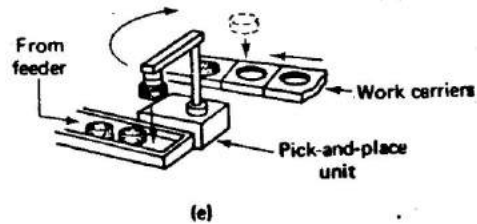
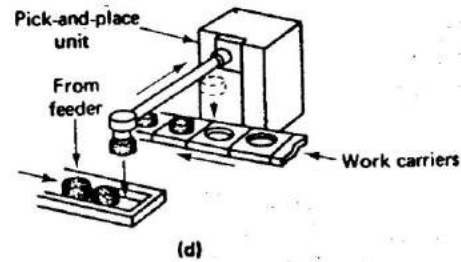
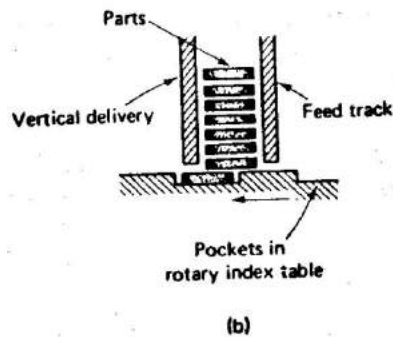
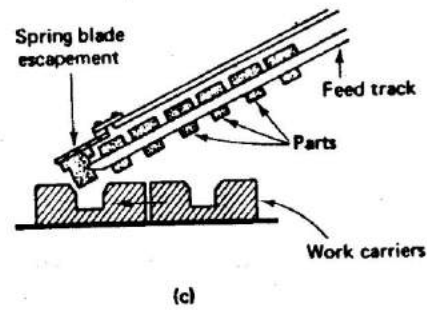
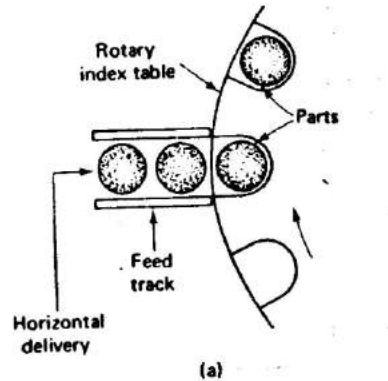


### Feed track:

- ✓ A feed track is used to transfer the components from the hopper and parts feeder to the location of the assembly work head, maintaining proper orientation of the parts during the transfer.

**Two general categories of feed tracks:**

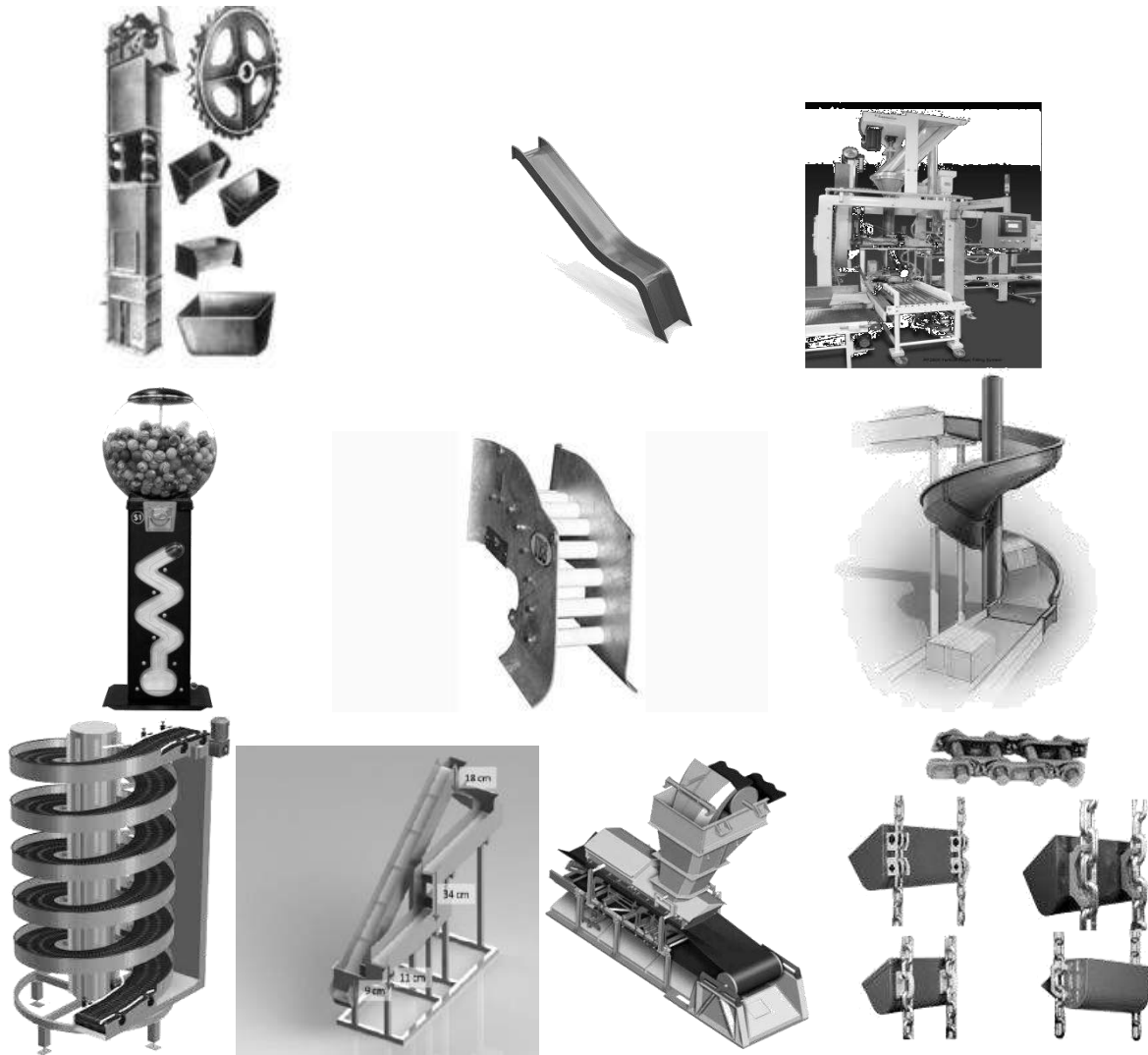
1. **Gravity:** The force of gravity is used to deliver the components to the work head.
2. **Powered:** vibratory action, air pressure, or other means to force the parts to travel along the feed track toward the assembly work head.



**Different Type of Chutes:**

1. Straight slide chutes
2. Roller chutes
3. Spiral chutes
4. Spiral roller chutes
5. A vertical open core chute

6. A zig-zag or curvilinear chute
7. A ladder chute of retarding type
8. Powered chutes
- 9.Chain controlled chute



**Control strategies to control the operation of automatic transfer system as follows:**

1. Sequence control
2. Safety monitoring
3. Quality monitoring
  - a) Instantaneous control
  - b) Memory control

### 1. Sequence control:

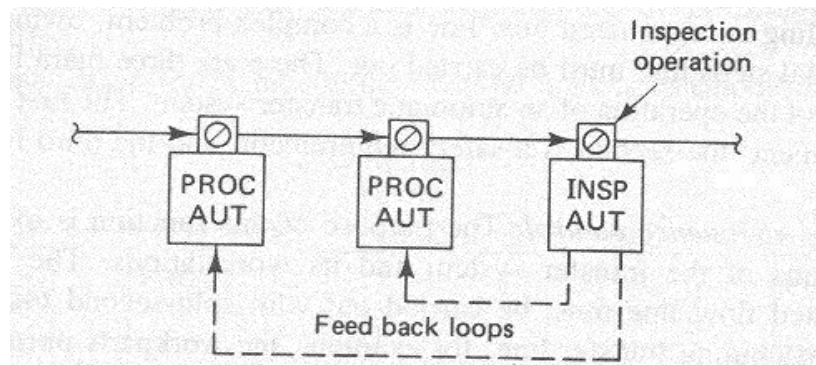
- ✓ The purpose of this function is to coordinate the sequence of actions of the transfer system and its workstations.
- ✓ The various activities of the automated flow line must be carried out with split-second timing and accuracy.

### 2. Safety monitoring:

- ✓ This function ensures that the transfer system does not operate in an unsafe or hazardous condition.
- ✓ Sensing devices may be added to make certain that the cutting tool status is satisfactory to continue to process the work part in the case of a machining-type transfer line.
- ✓ Other checks might include monitoring certain critical steps in the sequence control function to make sure that these steps have all been performed and in the correct order.

### 3. Quality monitoring:

- ✓ The third control function is to monitor certain quality attributes of the work part
- ✓ Its purpose is to identify and possibly reject defective work parts and assemblies.
- ✓ The inspection devices required to perform quality monitoring are sometimes incorporated into existing processing stations or separate stations are included



### There are alternative control strategies

- a) Instantaneous control
- b) Memory control.

#### a) Instantaneous control:

- ✓ This mode of control stops the operation of the flow line immediately when a malfunction is detected.
- ✓ It is relatively simple, inexpensive, and trouble-free.

- ✓ Diagnostic features are often added to the system to aid in identifying the location and cause of the trouble to the operator so that repairs can be quickly made.
- ✓ stopping the machine results in loss of production from the entire line, and this is the system's biggest drawback.

**b) Memory control:**

- ✓ In contrast to instantaneous control, the memory system is designed to keep the machine operating.
- ✓ It works to control quality and/or protect the machine by preventing subsequent stations from processing the particular work part and by segregating the part as defective at the end of the line.
- ✓ The flow line will continue to operate, with the consequence that bad parts will continue to be produced.

**Assembly involves the joining together of two or more separate parts to form a new entity is called assembly or subassembly.**

the assembly of the components can be divided into three major categories.

1. **Mechanical Fastening:** Screws, bolts, nuts etc. Rivets, crimping and other methods Press fits Snap fits –temporary interface of the two parts C-ring. Sewing and stitching –for soft, thin material.
2. **Joining Methods:** Welding, brazing and soldering
3. **Adhesive Bonding:** Thermoplastic, thermosetting (chemical reaction)

**There are various methods used in industry to accomplish the assembly processes. Major methods can be classified:**

1. Manual Single-Station Assembly
2. Manual Assembly Lines
3. Automated Assembly System

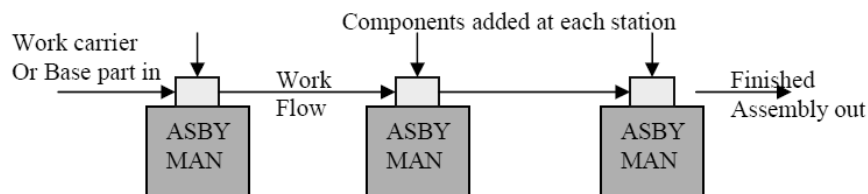
**1. Manual Single-Station Assembly:**

- ✓ It consist of a single workplace to accomplish the product or some major subassembly of the product.
- ✓ It used on a product that is complex and produced in small quantities, one or more workers depending on the size of the product and the production rate.

Such as machine tools, industrial equipment, aircraft, ships and complex consumer products (appliances, car,...)

## 2. Manual Assembly Lines

- ✓ Consist of multiple workstations in which the assembly work is accomplished as the product (subassembly) is passed from station to station along the line.
- ✓ At each workstation one or more human workers perform a portion of the total assembly work on the product, by adding one or more components to the existing subassembly.
- ✓ Manual Assembly Lines Are used in high-production situations where the work to be performed can be divided into small tasks and tasks assigned to the workstations on the line.
- ✓ Key advantage of using manual assembly line is specialization of labour –By giving each worker a limited set of tasks to do repeatedly.



**Automated assembly system refers to the use of mechanized and automated devices to perform various functions like handling and fastening with following strategies**

1. Reduce the amount of assembly required
2. Use modular design
3. Reduce no of fasteners required
4. Reduce the no of component to handle
5. Limiting the no. of unnecessary motion

### **1. Reduce the amount of assembly required:**

It implies the combining the functions of same part that previously accomplished by separate components in product.

### **2. Use modular design:**

It reduces the no. of assembly stations for assembling the complicated assembly products.

### **3. Reduce no of fasteners required:**

It reduces the no of fastener parts to simplify the design

### **4. Reduce the no of component to handle:**

It reduces the no of component that requires for assembly to handle

### **5. Limiting the no. of unnecessary motions:**

Its reduces the unnecessary motion of work part and assembly machines

### Types of automated Assembly flow line:

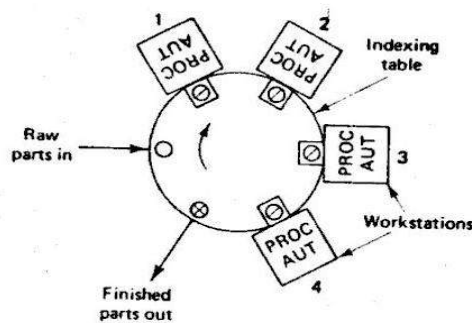
1. Continuous Transfer System
2. Synchronous transfer system
3. Asynchronous transfer system
4. Stationary base part system

### Classification on basis of Physical configuration:

1. Dial- type assembly machines
2. Inline assembly machines
3. Carousel system

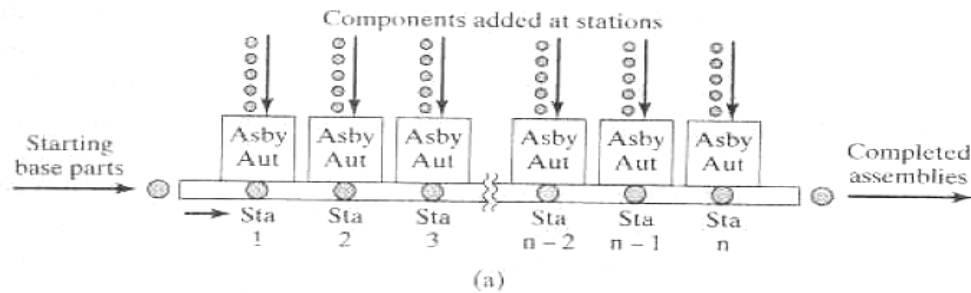
#### 1. Dial- type assembly machines:

- ✓ The base part are indexed around a circular table or dial. The workstations are stationary and usually located around the outside periphery of the dial.



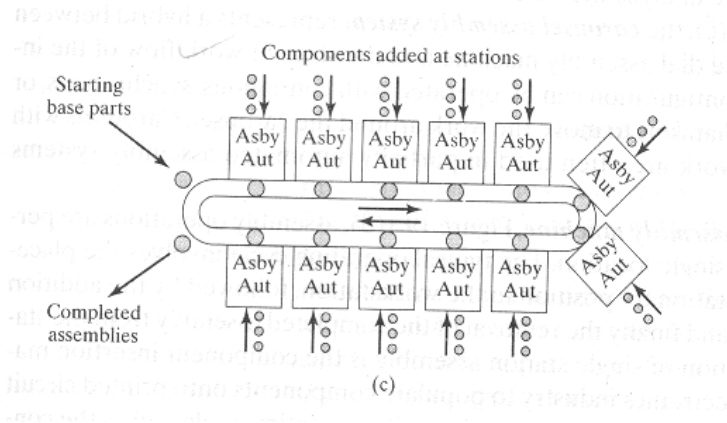
#### 2. Inline assembly machines:

- ✓ The in-line configuration assembly system consists of a sequence of workstations in a more-or-less straight-line



#### 3. Carousel assembly system:

- ✓ It represents a hybrid between the circular flow of work provided by the dial assembly machine and straight work flow of the in-line



### **Assembly line balancing:**

- ✓ It means that arranging the individual processing and assembly task at the work stations so that time required on each station on each station is same
- ✓ It is the concept in which we have to integrate the all work station and balance the time required in such a way that the flow of work part should be smooth

### **Following are the benefit of line balancing:**

1. Allocating Balance work load
2. Increase production rate
3. Reduce idle time of machine
4. Reduce wastage
5. Reduces material handling

### **Different constraints for assembly line balancing:**

1. Precedence Constraint
2. Zoning Constraint
3. Position Constraint

#### **1. Precedence Constraint:**

- ✓ It is refer to as 'technological sequencing requirement'
- ✓ It causes the delay in work progress and line become unbalance

For example: A threaded hole must be dilled before tapped

A nut can be turned and tighten after washer must placed



### **Zoning Constraint:**

- ✓ It is concern with restriction of arrangement of the stations according to the sequence of work
- ✓ It may be positive or negative
- ✓ Positive zoning constraint means that certain work element should be placed nearer to each other
- ✓ Negative zoning constraint indicates that work elements might interfere with one another
- ✓ It is created due lesser space available

### **Position Constraint:**

- ✓ It is concern with physical arrangement of recourses according to the sequence of the work process
- ✓ It creates waiting of work part and causes the delay in production
- ✓ It would be encountered in the assembly of large products such as automobiles or major appliances

### **Probabilities, in analysis of transfer line without storage :-**

There are two approaches as follows :-

- 1) Upper bound approach
- 2) Lower bound approach

#### **1) Upper bound approach :-**

- It provides an estimate of upper limitation the frequency of line stops per cycle.
- In it a break down at a station does not cause the part to be removed from the station.  
For example :- 1) A hydraulic failure at a work station which prevents the feed mechanism from working the cutting tool which has nearly worn out and needs to be changed. 2) The work part is close to being out of tolerance and a tool adjustment is required to correct the condition.

Let  $P_i$  represent the probability that a part will jam at a particular station 'i' where  $i = 1, 2, \dots, n$  each of the  $n$  stations is processing a part each cycle.

Hence the frequency of line stopper cycle is equal to flow line stop per part passing through it in no.

Thus the frequency of line stop per cycle

$$\sum_{i=1}^n P_i$$

If probability  $P_i$  are all equal  $P_1 = P_2 = \dots = P_n = P$

Then  $F = nP$

## 2) Lower bound approach :-

- It gives an estimate of the lower limit on the number of line stop.
- In it the station break down results in destruction or damage of work piece.

For example: A drill or tap break –off in the part during processing. The broken tool must be replaced at the work station and the work part must be removed from the live for subsequent rework or scrap .

Let  $P_i$  be the probability that a part will jam at a particular station ‘i’. Then, considering a given work part as it proceeds the live.

If  $P_1$  is the probability that the part will Jam at station 1 and  $(1-P_1)$  is the probability that the part will not jam at station 1 X available for subsequent processing.

The quantity  $P_2 (1-P_1)$  is the probability that the given part will jama station 2.

Generalizing above statement as,  $P_i (1-P_i - 1), (1-P_i - 2) - - - - (1-P_i - n)$

Where  $i = 1, 2, \dots, N$

Thus the frequency of line stops per cycle as,

$$F = 1 - \prod_{i=1}^n (1 - P_i)$$

If the probability  $P_i$  are all equal  $P_1 \& P_2 = \dots = P_n = P$  then Frequency of line stops per cycle is given as,  $F = 1 - (1-P)^n$

Using lower bound approach, the production rate becomes

$$RP = \frac{1-P}{TP}$$

Where F not only stands for the frequency of line stops but also the frequency of part removal.

If line breakdown F is the scrap rate therefore the term  $(1-P)$  represents the yield of the transfer machine. Hence  $T_p$  is the average cydetime of the machine or production Time.

Prob.1. A 16 station flow line has a cycle time of 15 seconds & it is assumed that all station has roughly equal process time. When ever a station breakdown occurs, the average downtime is 2.0min Given the following breakdown frequencies (Pi) faveachstation find the relative performance when the line is separated into two, three or four stages(S-99)

Station	Pi	Station	Pi
1	0.01	9	0.03
2	0.02	10	0.01
3	0.01	11	0.02
4	0.03	12	0.02
5	0.02	13	0.02
6	0.04	14	0.01
7	0.01	15	0.03
8	0.01	16	0.01

**Soln : Given**

Tc=15 sec.=0.25 min, Td=2min

Frequency of downtime occurrence 4'8given by

$$F = \sum_{i=1}^{16} P_i$$

$$= 0.01 + 0.02 + 0.01 + 0.03 + 0.02 + 0.04 + 0.01 + 0.01 + 0.03 + 0.01 + 0.02 + 0.02 + 0.02 + 0.01 + 0.03 + 0.01 = 0.3$$

The line efficiency will be

$$F = \frac{T_c}{T_c} = \frac{0.25}{0.25 + 0.3} = 0.2941$$

Case 1/Stages : When the line is suspended into two stages.

$$F = \sum_{i=1}^{16} P_i$$

$$= 0.01 + 0.02 + 0.01 + 0.03 + 0.02 + 0.04 + 0.01 + 0.01 = 0.15$$

$$F = \sum_{i=1}^{16} P_i$$

$$= 0.03 + 0.01 + 0.02 + 0.02 + 0.02 + 0.02 + 0.01 + 0.03 + 0.01 = 0.15$$

The resulting stage efficiency

$$E_1 = E_2 = T_c / T_c + F_1 T_d$$

$$= \frac{0.25}{0.25 + 0.15 \times 2} = 0.4545$$

$$\therefore E_\infty = E_{\min} = 45.45\%$$

**Case 2 :** When the line is separated in time stages

Stage	8 Station	F	E
1	1-5	0.09	0.5814
2	6-10	0.10	0.5556
3	11-16	0.11	0.5319

There all three stage line efficiency is Lowest efficiency

$$E_\infty = E_{\min} = 0.5319 = 53.19\%$$

**Case 3 :** When the line is separated into four stages

Stage	8 Station	F	E
1	1-4	0.07	0.6410
2	5-8	0.08	0.6098
3	9-12	0.08	0.6098
4	13-16	0.07	0.6410

$$E_\infty = E_{\min} = 0.6098 = 60.98\%$$

**Various terms of transfer line :-**

### 1) Buffer Storages :-

- It includes in production flow line as storage zones for collection banks of work parts along the line.
- In it the production flow line is intermittent to connect to the production flow line in ventory area.
- It possible connect three, four or even more lines in this manner.
- It is used in asynchronous type of flow line to provide a bank of work part for every station on the live in such a way that line will not need to stop for any break down in transfer flow live.

There are two principal reasons for use of buffer storage zones.

- 1) To reduce the effect of individual station breakdown on the line operation. When breakdown occurs at the individual stations or when preventive maintenance is applied to the machines, production must be halted.

To avoid this the buffer storage is used which allows a portion of the line to continue operating while the remaining portion is stopped and under repair.

- 2) To smooth out the effect of variation on cycle times. These variations occur either between stations or, in case of flow lines with one or more manual stations, they can occur from cycle to cycle at the same station.

Diagram:

## II) Line efficiency :

- A synchronous transfer system in which parts are introduced into work station and are processed and transported at regular interval to next stations.
- The Interval time of process & transportation is called cycle time 'Tc' of the flow line.
- From fig it is clear that cycle time plus breakdown time 'Td' is equal to production Time 'Tp'

Diagram :

Let 'F' be the frequency in which the breakdown occurs in flow line which causes downtime 'Td' is called average downtime to diagnose the problem and make repair. Since there may be more than one reason why a line is down hence.

The production on time is as.

$$T_p = T_c + F T_d$$

There are different reasons for breakdown occurs which causes down time are tool failure, part jam, Feed mechanism etc. downtime represents 'Tdj'. The subscript j used for different reasons for break down

Thus, average production time becomes.

$$T_p = T_c + \sum_j F_j T_{dj}$$

One of the important measures of performance for a transfer line is the average production rate. The actual average production rate is based on the average production time 'Tp'.

$$R_p = \frac{1}{T_p}$$

Efficiency E is simply proportion of time the line is up and operating.

$$E = \frac{T_c}{1P} = \frac{T_c}{T_c + F T_d}$$

## 2) Partial automation :-

Partial automated production lines occur for two main reasons.

- 1) Mechanization of a manually operated flow line.
- 2) It is based on economics.

To analyze the performance of a partially automated flow line. The cycle time To will be determined by the slowest station in the line which generally will be one of the manual stations.

Let 'P' be the probability breakdown of work head, the value of 'P' is different for different work stations.

The total line cost CL given by

$$CL = n_o C_o + n_a C_{as} + \text{cat} \text{-----}(1)$$

Where n = Total no. of work stations (i.e. n<sub>a</sub>+n<sub>o</sub>)

n<sub>a</sub> = Total no. of automatic workstations

n<sub>o</sub> = Total no. of manual operate station

C<sub>o</sub> = Operate cost per manual station.

C<sub>as</sub> = Cost per automatic work station

Cat = Cost per minute of the automatic transfer mechanism.

Cpc = cost per work piece

The average production time is as follows.

$$T_p = T_c + FT_d$$

$$T_p = T_c + n_a T_d \text{-----}(2)$$

Now cost per work piece Cpc.

$$Cpc = c_m + CL TP + Cat \text{-----}(3)$$

Put equation no. (1) & (2) in(3)

$$Cpc = C_m + C_{no} c_a + n_a c_{as} + cat (T_c + n_a T_d)$$

#### 4) Starving & Blocking Stations :-

##### Starving :-

If a workstation can not operate continue because work station has no parts to work on This station is called starved part station.

If a break down occurs at a given station in the line. The station after break down station become starved station.

##### Blocking :-

→This occurs when a station is prevented work part passing along the following work stations.

→If a break down occurs, the preceding station are said to be blocked stations, because they are unable to transfer work parts to the station that is down.

##### Explain the terms :-

- 1) Feed rate
- 2) Tolerance Time
- 3) Manufacturing Lead time (MLT)
- 4) Capacity
- 5) Utilization
- 6) Work – in- progress

##### Feed rate : (CFP)

→Fp refer to the reciprocal of the time interval between work parts on the moving flow line.

→Fp measured in work piece per time & given by

$$Fp = \frac{V_c}{S_p}$$

Where,

Vc = convey or speed

Sp = Spacing of work parts.

Along the flow line.

## 2) Tolerance : (Tc)

→It is to control the feed of the line,

→Work parts are come into the line at regular intervals as the work part flow along the line at certain interval it reaches at each work station after certain time. This time period is called tolerance time.

$$Tt = \frac{L_s}{V_c}$$

Where

Ls = Lenth of work station

Vc = flow line or convey or speed

## 3) Manufacturing Lead time (MLT) :-

The manufacturing Lead time (MLT) is time required to process a given product or workpart through the plant.

$$MLT = \sum_{i=1}^{nm} (T_{sui} + QT_{oi} + T_{noi})$$

Where I indicate the operation & sequence in the processin. Where i=1,2 .....n.

Tsu = setup time

To= operation time

Tno= Non-opeation time

nm=No. of machine stations.

Q= No.of proudcts



#### 4) Capacity :-

It is the term which referce as plant capacity, is used to define the maximum out put is able to produce under available operating conditions.

The production capacity for the group of work center ave as,

$$PC = WsWHRp$$

W capacity

W= No. of work centers

H = operating hours per shift

SW = No. of shifts /week

Rp = Production rate  $\left(RP \frac{1}{1P}\right)$  Tp = production time

**3) Utilization :-**(U) utilization is defined as the amount of output produce by production facility relative to its capacity.

$$U = \frac{\text{output}}{\text{capacity}}$$

#### 4) Work in process :(WIP)

It is the amount of product currently located in factory either being processed or is between is processing station.

WIP is the inventory that is in the state of being transformed from raw material to finished product.

$$WIP = \frac{PC \times U}{SW \times H} \times (MLT)$$

Where, PC = plant capacity

U = Utilization

H = Operating hours per shift

SW= No. of shift/week

MLT = Manufacturing Lead time.

Significance of  $E_0 < E < E_\infty$ : –

$E_0$  = Efficiency of line with no buffer storage capacity

$E_{\infty}$  = overall line efficiency

$E$  = Actual line efficiency

The actual  $E$  value lies between  $E_0$  and  $E_{\infty}$

It signifies as,

1) If  $E_{\infty}$  (overall line efficiency) is Larger than  $E_0$  than there is scope for improvement with buffer storage for in erasing line efficiency.

2) If difference between  $E_{\infty}$  &  $E_0$  is larger it very essential to implement buffer storage.

### **Balance Delay :-**

It measures the line in efficiency which results from idle time due to imperfect allocation of work among stations is given as,

$$d = \frac{nT_c - TW_c}{nT_c}$$

Where,  $d$  = Balance delay

$T_c$  = Cycle time

$TW_c$  = Total work content

$n$  = no. of work station

### **Different methods of line balancing :-**

- 1) Manual Methods
- 2) Computerized methods

#### **1) Manual Methods :**

##### **I) Largest Candidate rule :-**

In this method, work elements are arranged in descending orders of  $T_e$ .

##### **II) Kill bridge and wester's Method:-**

It implied work element are selected according to their position in precedence of diagram.

##### **III) Ranked positioned eights methods :-**

It implies calculating RPW (ranked positioned weight value) for each element.

Assignment of elements are done as per RPW values. It takes both  $T_e$  and position in precedence diagram into account.

##### **2) Computerized method :-**

I) Cansoa

II) CALB(computer assembly line balancing)

III) ALPACA (Assembly line planning control activity)

**Line balancing can be achieved**

- a) Changing work head speeds at automatic stations.
- b) Dividing work elements.
- c) Methods analysis
- d) Pre-assembly of components
- e) Parallel stations etc.

**Prob 2 :-**

A 18 station flow line has a cycle time of 20 seconds it is assumed that all stations have roughly equal process time. When ever a station break down occurs, the average down time is 3 min. Given the following break down frequency (Pi) for each station, find the relative performance when the line is separated Two & three stages.

Station	Pi	Station	Pi
1	0.01	10	0.04
2	0.03	11	0.01
3	0.02	12	0.02
4	0.03	13	0.03
5	0.02	14	0.02
6	0.04	15	0.01
7	0.01	16	0.03
8	0.02	17	0.01
9	0.01	18	0.02

**Soln. :** Given  $T_c = 20 \text{ sec.} = 0.33 \text{ min}$ ,  $T_d = 3 \text{ min}$  frequency of down time is given by

F=

$$\sum_{i=1}^{18} P_i$$

$$= 0.01+ 0.03+ 0.02+ 0.03+ 0.02+ 0.04+ 0.01+0.02 +0.01+0.01 +0.04+0.01+ 0.02+0.03+ 0.02+0.01+0.03+0.01+0.02=0.38$$

The line efficiency will be  $E = \frac{T_c}{T_c + FTd} = \frac{0.33}{0.33 + (0.38) \times 3} = 0.22$

**Case 1:** When the line is suspended in two stages.

$$F_1 = \sum_{i=1}^9 P_i$$

$$= 0.01 + 0.03 + 0.02 + 0.03 + 0.02 + 0.04 + 0.01 + 0.02 + 0.01 = 0.19$$

$$F_2 = \sum_{i=1}^9 P_i$$

$$= 0.04 + 0.01 + 0.02 + 0.03 + 0.02 + 0.01 + 0.03 + 0.01 + 0.02$$

$$= 0.19$$

The resulting stage efficiency

$$E = \frac{T_c}{T_c + F_1d} = \frac{0.33}{0.33 + 0.19 \times 3} = 0.3666$$

$$\therefore E_{\infty} = E_{min} = 36.66\%$$

**Case 2 :-** When line is separated in three stages

Stage	Station	F	E
1	1-5	0.15	0.4230
2	6-10	0.15	0.4230
3	11-16	0.12	0.4782

$$\therefore E_{\infty} = E_{min} = 42.30\%$$

**Prob :** A manual assembly line operates with a mechanical conveyer which moves at a speed of 2m/min. The spacing between base parts put-on the line is 1.5m and stations are separated from each other by 2.5m.

There are 14 work elements for assembly as under:-

Element	Time(min)	Preceded
1	0.02	-
2	0.5	-
3	0.2	1
4	0.6	1

5	0.1 or 3	2
6	0.2	3,4
7	0.3	4
8	0.2	5
9	0.4	5
10	0.3	6, 7
11	0.1 or 5	9
12	0.2	8, 10
13	0.1	11
14	0.3	12, 13

a) Determine Feed rate, cycle time and tolerance time for operator.

b) Find the ideal minimum no. of workstations

c) Get the line balancing solution and find balance delay

**Soln.:** Given  $V_c=2\text{m/min}$ ,  $Sp=1.5\text{m}$ ,  $Ls =2.5\text{m}$

a) Feed rate :  $FP \frac{V_c}{SP} = \frac{2}{1.5} = 1.333 \text{ parts/min}$

Tolerance time

$$Tt = \frac{LS}{VC} = \frac{2.5}{2} = 1.25 \text{ min}$$

Cycle time :-

$$T_c \geq T_{ej} \left( \text{part transfer} = \frac{Fp}{VC + TE} \right)$$

Where  $T_{ej}$  = max element station process time  $T_{ej} = 0.6\text{min}$

$T_c = T_{ej} \text{ max} + \text{part transfer time} (SP+LS)$

$$= 0.5 + 0.4 = 1\text{min}$$

b) Minimum no. of theoretical station required.

$$n \times TC \geq T_{wc}$$

c) Line balancing  $n > 3.7/1 = 2.7 \approx 4$

**Diagraph :**

**By Largest candidate rule :-**

**Step 1:-**

Work element.RPW	Te(element time)	Immediate
4	0.06	Predecessors
2	0.5	1
9	0.4	-
7	0.03	5
10	0.3	4
14	0.3	4
1	0.2	12. 13
3	0.2	-
6	0.2	3,4
8	0.2	3,4
12	0.2	5
5	0.1	8,10
11	0.1	2
13	0.1	11

$$d = \frac{nTc - Twc}{nTc} = \frac{4 \times 1 - 3.7}{4 \times 1}$$

Balance delay = d=0.075 or 7.5%

**Prob :** A circular indexing machine performs 10 assembly operations at 10 assembly operations at 10 separate stations. The total cycle time including transfer line between stations is 10 seconds. The stations breakdown with a probability of 0.007 which can be considered equal for all 10 stations. When there work stoppages occurs, it takes an average of 2 minutes to correct the fault. Parts are not normally removed from the machine when these stoppages occurs.

**Compute ;**

- 1) The proportion of down time
- 2) The efficiency
- 3) The average production rate of this circular indexing machine.

**Sol<sup>n</sup> :-**

**Given :-** T<sub>C</sub> = 10 sec. = 1.66 min

$$P_1 = P_2 = \dots\dots\dots P = 0.007$$

$$T_d = 2 \text{ min}$$

Given that parts are not normally removed that means we appear bound approach to fire failure rate

∴ By upper bound approach

$$F = np = 10 \times 0.07 = 0.07$$

1) Proportion downtime

$$D = \frac{FTd}{T_p} = \frac{FTd}{T_c + FTd} = \frac{0.07 \times 2}{1.66 + 0.07 \times 2}$$

$$D = 0.4565 \text{ min of production}$$

downtime

2) Line efficiency

$$E = \frac{T_c}{T_p} = \frac{T_c}{T_c + FTd} = \frac{1.66}{1.66 + 0.07 \times 2}$$

$$E = 0.5434 = 54.34\%$$

3) Average production rate :-

$$R_p = \frac{1}{T_p} = \frac{1}{T_c + FTd} = \frac{1}{1.66 + 0.07 \times 2}$$

$$R_p = 3.26 = 3 \text{ parts /min.}$$

**Prod<sup>n</sup>** :- A 10 station transfer machine is used to produce component. The ideal cycle time  $T_c = 1.2$  min. breakdown occurs with frequency  $F = 0.1$  breakdown /cycle and average down time per line stop  $T_d = 7.0$  min. The scrap rate 5%.

Find :

- 1) Production rate
- 2) No. of Hrs. required to meet a demand of 1000 units.
- 3) Line efficiency

**1) Production rate :-**

**Sol<sup>n</sup>.** :-  $T_p = T_c + FTd = 1 + 0.1 \times 6$  min/piece

**Production rate :-**

$$R_p = \frac{1}{T_p} = \frac{1}{1.6} = 0.625 \text{ pieces /min.}$$

$$= 37.5 \text{ pieces/hr.}$$

Now considering scrap rate of 5%

$$\text{Production rate } R_p = 0.95 \times 37.5 = 35.625 \text{ pieces/hr.}$$

## 2) Number of hours required to produce 1000 units/week

$$= \frac{1000}{35.625}$$

$$3) \text{ Line efficiency } E = \frac{T_c}{T_c + FTd} = \frac{1.0}{1.0 + 0.1 \times 6} = 62.5\%$$

### Prob.:-

A new small electrical appliance is to be assembled on a production flow line. The total job of assembling the product has been divided into minimum rational work elements. The industrial engineering department has developed time standards based on previous similar jobs. This information is given in the table. In the right-hand column are the immediate predecessors for each element as determined by precedence requirements. Production demand will be 100,000 units/yr. A + weeks/yr and 40h./week. This reduces to an output from the line of 60 units/hr. or 1 unit/min. the uptime efficiency of the line will be 96%

Element	Time(min)	Preceded by
1	0.2	-
2	0.4	-
3	0.7	1
4	0.1	1,2
5	0.3	2
6	0.11	3
7	0.32	3
8	0.6	3, 4
9	0.27	6,7,8
10	0.38	5,8



11	0.5	9,10
12	0.12	11

**Calculate :**

(a) total work content

(b) Rp (production rate)

(c) Cycle time

(d) No. of work station

→Construct the precedence diagram

→Use ranked positioned weight method to balance the line.

(a) Total work content

$$\sum_{i=1}^{12} T_e = 4.0 \text{ min}$$

(b) Given the annual demand, the hourly production rate is

$$Rp = \frac{100,000}{(5)(40)} = \frac{100,000}{Tp}$$

= 50 units/hr.

(c) Cycle line

$$T_c = \frac{60(0.96)}{50.0} = \frac{\text{up line efficiency/min}}{Rp}$$

=1.15

**Prob.:** A manually assembly line operates with a mechanized conveyer which never at speed of 2m/min. The space between base part pt on the line is 1.5 m. and station are separated from each other by 2.5m. There are 14 work elements which must be accomplished to complete the assembly.

The element and precedence are as under :

Element	Time(min)	Precedent by
1	0.2	-
2	0.5	-

3	0.2	1
4	0.6	1
5	0.1	2
6	0.2	3, 4
7	0.3	4
8	0.2	5
9	0.4	5
10	0.3	6, 7
11	0.1	9
12	0.2	8,9
13	0.1	11
14	0.3	12, 3

i) Determine feed rate, cycle time, tolerance time for each operator.

ii) Find ideal minimum no. of work station as

iii) Draw precedence diagram

iv) Fine balancing solution using any method.

v) Find balance delay.

Assign elements to station according to RPW avoiding precedence constraint & time cycle violations.

## Unit –II

# Introduction to Numerical Control of Machines

### \* Why NC machines?

- 1) Automation and mass production are associated with advancement in technology.
- 2) In today world of globalization and Industrialization cut throat compition increases for productivity, time & quality to satisfy this all industries are going for automation.
- 3) Automation means special purpose automation m/cs, automatic transfer lines and material handling robots etc. which are controlled by a digital electronics unit.
- 4) In conventional large variety of components and product manufactured by general purpose machine tools & skilled operators who was responsible for many inputs to the machine for example reading drawing, dimensions, material loading, unloading and inspection for quality.
- 5) Although the general purpose machines are very flexible but this flexibility on the cost of time, productivity & quality.
- 6) As the degree of complexity of component increases the tolerances of time and productivity become closer.
- 7) The process was totally dependent on operators, the mistakes on the part of operator due to in attention and tiredness, result in production of defective components.
- 8) To over come these problems of job & batch production several improvements had been made in conventional m/cs by reducing the manual control element
- 9) At the age of second world war the special purpose machine like copying machine had been evolved for producing similar component in mass level. It is also called tracer machines, a model or template called master was used to manufactured first then a tracer or stylus scans the model r template and controls the motion of cutting tool by mean of servo motor, mechanism.
- 10) The main disadvantage of copying machine is time spent on producing the master, as master is made without automation and it has to be produced to high degree of accuracy. Since this operation is very time consuming.
- 11) After copying machine automated lathe machine had been evolved but this type of setup of the required dimensions of the parts are established by micro switches and stoppers. The disadvantage of this setup is to setting of the limit switches and stoppers for every new product.
- 12) So all these problems of automation of medium and small volume production have been overcome by numerically controlled machine tools where the machining opera hens/processes are controlled with the help of coded instructions given to the machine tools.

The simplest definition of numerical control (NC) given by Electronic industries Association(EIA) USA is :

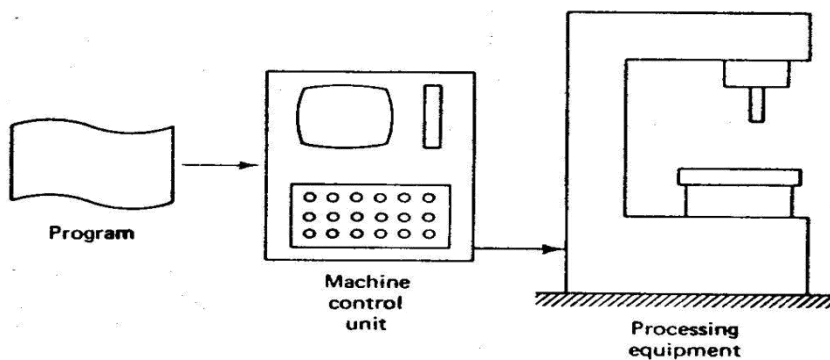
“A system in which the actions are controlled by direct in section of numerical data at some point. The system must automatically interpret at least some portion of this data”.

- 13) This definition elaborated as machine tools controlled by means of a prepared programme, which consists of blocks or series of numbers, alphabets or alpha numerics. These codes define the required position of each machine slide, feed, cuttings speed & depth of cut. In addition the codes are used to control other functions like codeant ON /OFF, tool change, etc. The data for preparing the coded instructions, called part programming.

### NC machines :

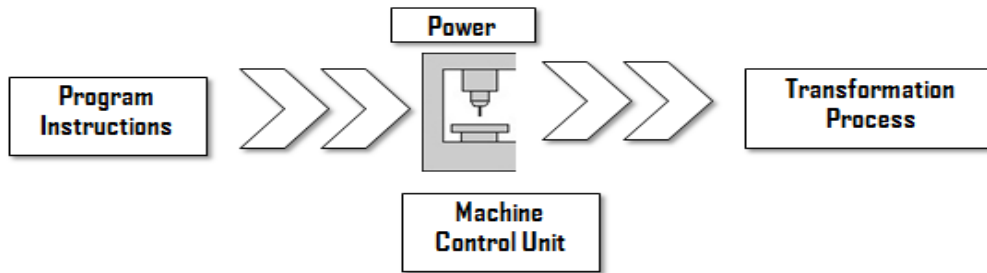
#### What is the concept of NC machines?

- 1) Combining control system with coded programmed and machine tools is formed Numerical controlled machine tools (NC machines)
- 2) NC machines having variety of complexities & capabilities. Conventionally NC control units added to machine tools which were used to control the position of work piece and relative motion of cutting tool. But the operator was required to select the cutting tolls, speed & feeds etc.



- 3) But As time passes the capabilities of machines tools improved and in addition to maintaining cutting tools & work piece relationship, the material removal was also controlled by the numerical control system.
- 4) NC machines consisting of following types of components.
  - 1) Program of instruction (paper tape or magnetic tape)
  - 2) Machine control Unit.
  - 3) Machine tool or processing equipment.

**Diagram:**



**NC Machine System**

- 1) **Program of instruction:** The instructions to NC machines are fed through an external medium i.e. paper tape or magnetic tape. The information coded on the paper tape and magnetic tap inform of coded punter with specific position. Which defines, cutting tool position with respect to the work piece.
- 2) **Machines control Unit :-** The information read through an external medium i.e., paper tap or magnetic tape processed and decoded in for m of digital signals which converts these digital signals into analog signals and control the motion of cutting tool with respect to work piece. This read information stored into the memory of the control system called “buffer storage” and is processed by the machine is working on one instructions block, the next block read from the tape and stored in the memory of machine control system.
- 3) **Machine tool or processing unit :-** Since the part cannot be produced without a tape being run through the control unit these type of NC machines called tape controlled machines. The machine tool. reads the digital signals inform of analog and transmit inform of mechanical motion for producing components. The tape has to be run repeatedly to be produced. Also if there is minor change inhering of component, the tape has to be discarded and new tape with changed programme has to be produced.

**CNC Machines:**

**\*What is the concept of CNC machines?**

- 1) In case of computer is used to perform all basic NC functions to control the machine tolls this type of machine tool system is called CNC machine (computer numerical controlled machine)
- 2) The complete part program to produce a component is input and stored in the computer memory and the information for each operation is fed to the machine tools i.e. motors, etc.

- 3) The programs can be stored in memory of the computer and used in future.

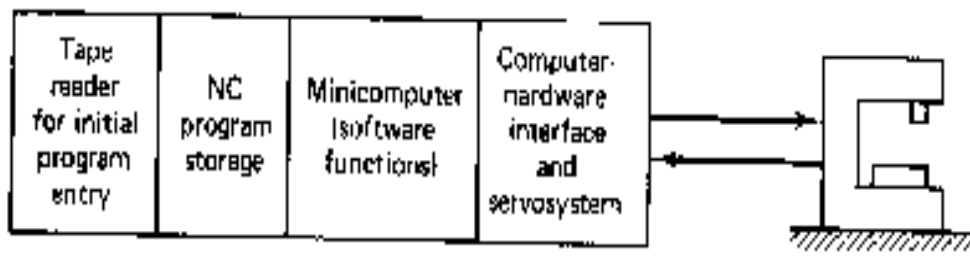
### Some of important features available for CNC m/c:-

- 1) The part program can be input to the controller unit through keyboard
- 2) The part program can be input to the computer memory can be used again and again.
- 3) The part program can be edited and optimized at m/c tool itself if there is any change in the design of the component the part program can be changed according to the requirements.
- 4) The input information can be reproduced by developing sub program favor putative operations. For example, for making holes on pitch circle etc. Subroutines can be retrieved and used any number of times within a part program only certain parameters have to be specified.
- 5) The CNC machines have the facility for providing the part program without actually running it on the machine tool. Each operation we can execute actual running of machine tool with we can see the video of operation on monitor screen.
- 6) CNC control unit allows compensation for any changes the dimension of cutting tool. Because according to part program particular type & size of cutting tool in mind. But in actual use that cutting may not available. So in this regard CNC can provide compensation to made difference between the programmed cutter and the actual cutter used.
- 7) CNC machines system, useful to the management also like control system can provide the information such as number of components produced, time per component time for setting up a job, time for which a particular toll has been use, time for which machine has not been working and fault diagnosis etc.

### CNC machine consist of following component;-

- 1) Program instruction
- 2) Machine control unit
- 3) Machine tool or processing equipment.

### Diagram:-



**CNC Machine system**

- 1) Program instruction: The program of CNC machine in two type's manual part programming & APT manual part programming use in special coded instructions for different machining operation 'G' code & 'H' code form. After the completion of part program it is allow to execute without actual operation and check where her it is correct or not in control unit of CNC machine.
- 2) Machine Control Unit (MCU):- The machine control unit through which reading of the part programming and convert these coded instruction to the main operation instruction in digital mode and transmit the coded digital signal of instruction to the machine tool. MCU also provides the actual working interface of the actual operation without machine tool running which can be helpful to find out defects an part programming. MCU work as a management unit of CNC machine tool for managing various operational activities and store the information like program and sort of instruction for future use.

### **Direct Numerical control (DNC machine):-**

#### **What is the concept of DNC machines?**

- 1) Direct Numerical control (DNC) machine is a new generation manufacturing system in which large number of machines is controlled by a computer through the direct connections.
- 2) All machines linked to a main frame computer which sends information to individual machines when required.
- 3) The part programming for all the components, which are to be manufactured on DNC system, are stored in the memory of the computer.
- 4) There are two types of system configuration for linking the computer with machine tool.

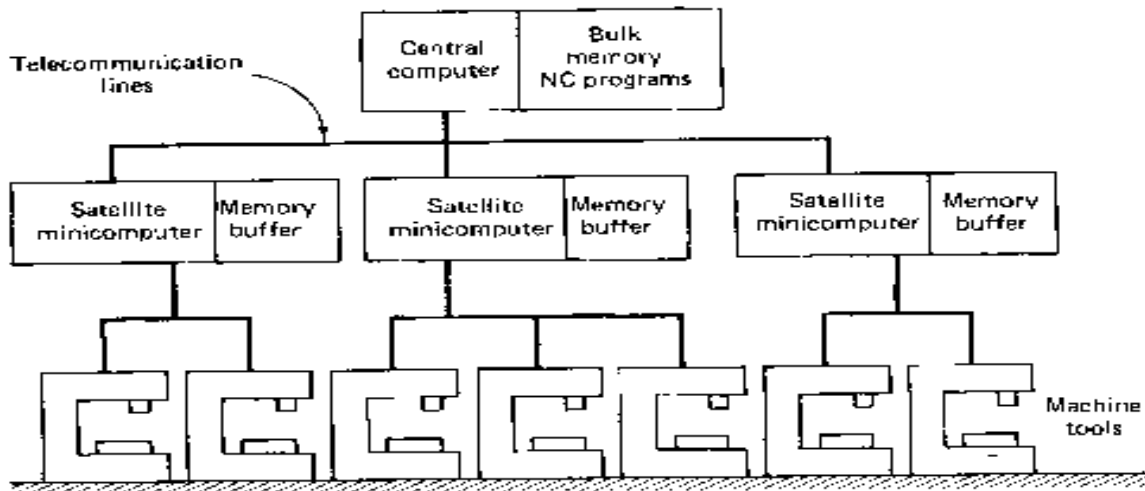
The 1<sup>st</sup> configuration in which main computer is directly linked to the machine but in this type there can be delay in communicating the instruction in between computers. 2<sup>nd</sup> configuration the main computer is connected to machine tool through a minim computer called satellite computer. The main computer stores the part programmes for all the components to be mechanical on a particular machine. The satellite computer receives and stores the part program. The satellite computer controls the machines tool operation. The advantage of this system is that the machine can be used independent of the main computer as the main computer is not actively involved in operation of machine tool.

Advantage DNC machine that we can give the instruction of complier manufacturing unit from very long distance.

#### **There are various components of DNC machines as follows :-**

- 1) Central main frame satellite computer with bulk memory.
- 2) Satellite minicomputer with memory buffer
- 3) Tele communication lines
- 4) Machine tolls.

## Diagram:



- 1) **Central Computer:-** It is the master computer which consist or execute the part program and transmit the command or instruction directly or through satellite to mini subsystem through the telecommunication system.  
The control computer consists of main Bulk memory for storing different part program and sort of instruction.
- 2) **Satellite mini computers:-** Satellite mini computers are the sub systems which are linked to their machine tool. There computer taking signals in form of instruction from the central computer directly or through satellite these instruction transmit to the machine tool for operation. These computers having. Buffer memory for storing the program and instruct.
- 3) **Telecommunication lines:-** Telecom.- communication lines through which the central mainframe computer linked with satellite minicomputer directly or through satellite.
- 4) **Machine tool:-** Machine tools receives the digital signal from minicomputers inform of instruction and convert that digital signals into the analog signals and perform different machining operations.

## Advantages of CNC machines:

### \*What are the advantages of CNC M/C?

There are following advantages of CNC machine:-

- 1) **Reducing Lead Time :-** It is the time there receipt of a design drawing by production department and manufacturer getting ready to start production including the time needed for planning, design or Jigs & Fixtures etc. is called lead time.  
Since special Jigs and fixtures are often entirely eliminated CNC machines, the whole of the time needed for their design and manufacturing saved.  
CNC machine can start production within a short period of the work being planned and material being available.
- 2) **Elimination of operator Errors: -** The machine is controlled by program of instructions stored in memory. The program is checked before goes on machine so no errors will



occur in job Fatigue boredom or in attention by a operator will not effect the quality or duration of the machining.

- 3) **Operator Activity:-** The operator is relieved of tasks readily performed like pre-setting of tools, setting of components and preparation of planning so man factor totally eliminated in CNC systems.
- 4) **Lower Labour cost:-** CNC machine requires lower operation time hence one operator can run two or more machines or multiple parallel machines at a time resulting reduced of labour cost.
- 5) **Smaller Batches:-** In CNC machines pre-setting of tools and work piece is minimum 80 we can produce different design of product with smaller batches.
- 6) **Longer tool Life :-** Tools can be used at optimum speed and feed because this functions are controlled by part program so we can get Longer tool life.
- 7) **Elimination of special Jigs & Fixtures:-** Special Jig & Fixtures are often not used on CNC and cost and storage space required for it totally eliminated because CNC having all these facilities in built.
- 8) **Flexibility in changes of component Design:-** The modification or changes in component design can be readily accommodated by re programming.
- 9) **Reduced inspection:-** The time spent on inspection and in waiting for inspection to being greatly reduced. Normally it is required to inspect only 1<sup>st</sup> component in place of inspection in batch wise.
- 10) **Less scrap:-** Since the operator error eliminated results the proper planning of raw material use and tool setting which avoids raw material & tools wastage. Which result into less scrap.
- 11) **Accurate costing & scheduling:-** In CNC machine the time fell in machining is predictable, consist and result in greater accuracy of costing & scheduling and more predictable output.

### **Disadvantages of CNC machines**

#### **Explain various disadvantages of CNC m/c<sup>3</sup>**

There are four main disadvantages of CNC m/c are as follows:-

**1) Higher Investment Cost:** - CNC machine tools represent a more sophisticated and complex technology. This technology costs more to buy than its non CNC counterpart, higher cost requires manufacturing management, erection & operation.

**2) Higher Maintenance Cost:** - CNC machines are more sophisticated and complex then maintenance problem occur more frequency and it required skilled manpower for maintenance which cost is very high.

**3) Costlier CNC personnel:-** Certain aspects of CNC machine operations requires a higher skill level than conversional operations. Part program & CNC maintenance with required skill are in short supply. Hence cost of CNC personnel hiring is very high.

**4) Planned Support facility:-** CNC operations is done which required a vast planned support facility for different planning of work, time, cost & material which much costlier as compaire to conversional one.

### **Classification of CNC machines.**

**\*What are different type of control system ?**

**Ans :** I) Based on the motion type point to point, straight line & contouring system.

**a) Point to Point control system :-**

1) point to point control is one where accurate positional slides only to place the machine slides in fixed position & the machine tool slide is required to reach a particular fixed to co-ordinate point in the shortest possible time.

2) The machining operating are performed at specific points and there is no machining while the machine table/slide move from one point to the next. No machining takes place until the machine slides have reached the programmed co-ordinate point and slide movement ceases. Since there is no machining when the machine slides move from one point to other point.

3) Here path of movement of tool is not important but care must be taken to ensure that the costing tool should not hit the work piece while moving from one position to the next.

4) The movement along different axis may be sequential or simultaneous. The sequential or simultaneous movement reducing machining time.

5) Point to point system is suitable for drilling, boring, tapping, punch presses and jig boring machines.

**Diagraph :**

**Point - to – point system**

**b) Straight line control system :-**

1. It is extension of point to point control system in which special provision for machining along a straight line as in case of milling, turning & facing.
2. In this control system controlled feed provides along the axis in line motion.
3. In this control system it is capable of calculating and displacing the slides simultaneously at suitable feed rates to reach the desired points.

**Diagraph :**

## **Straight line system**

### **C) Continuous path or contouring control system**

1. The contouring system is a high technology and most versatile control system. The control system generates continuous motion of tool and work piece along different co-ordinate axis.
2. This system enables the machining of profile, contours and curved surfaces.
3. This system designed for continuous path machining hence in it we can perform point to point & straight line machining also
4. In this system the machine tool, tool & work piece movement control simultaneously relative positions and velocities at every point throughout the operation.

**Diagraph :**

## **Contouring System**

**\*Explain the open loop & close loop control system :**

II) Based on Feedback control

a) Open-loop control System :

**Diagraph**

## **Open loop control system**

### **Block diagram of an open-loop system.**

- 1) Machine tool control in which there is no provision to compare the actual position of cutting tool or work piece are called open-loop systems.
- 2) Programmed instructions are fed into the controller through an input device. These instructions are then converted to electrical pulses (signals) by the controller and sent to the servo amplifier to energize the servo motors.
- 3) The primary drawback there is not monitoring of the actual displacement of the machine slide.
- 4) For these reasons the open-loop system is generally used in point-to-point systems. Where the accuracy requirements are not critical.
- 5) In open-loop control system the actual displacement of the slide may vary with change in external conditions and wear of components of the drive mechanism. Since there is no provision of feedback in the control system periodical adjustments are required to compensate for the changes due to various factors.

### **b) Closed-loop control system :**

#### **Diagram :**

- 1) In a closed-loop control system i.e. actual displacement of the machine slide, is compared with the input signal. The closed loop control systems are characterized by the presence of feedback devices in the system.
- 2) In the closed-loop control system the displacement can be achieved by a very high degree of accuracy because a measuring or monitoring device is used to determine the displacement of the slide.

- 3) The feedback from the monitoring device is then compared with the input. Signal and slide position is regulated by the servo system until it agrees with desired position a closed loop control system with a provision for feed back for the displacement of position of machining slide. In order to measure the speed of the motor and compare the actual speed with the programmed speed, a velocity feed backs system is added to the system.

### **III) Based on the number of axes 2,3,4, & 5 axes CNC machines**

- 1) **2 & 3 lathes will be coming under 2 axes machines.** There will be two axes along which motion takes place. The saddle will be moving

## UNIT III

# ROBOTICS

**Q.1 : Define Industrial Robot and its anatomy.**

**OR Define robot and various types of joints used in robot with neat sketches.**

**Ans. :** An industrial robot is reprogrammable, multifunctional manipulator designed to move materials, parts, tools or special devices through variable programmed motions for the performance of variety of tasks.

**Robot anatomy :-** The manipulator or an industrial robot is constructed by a series of joints and links. Robot anatomy deals with the types and sizes of the joints and links and other aspects of the manipulator's physical constructions.

**Joints and links :-** A joint of industrial robot provides relative motion between two parts of the body, connected to each joint are two links. One of them is input link and the other is output link. Links are considered to be the rigid components of the robot. The purpose of the joint is to provide controlled relative movement between the input link and the output link.

Nearly all industrial robots have mechanical joints that can be classified into five types. They include two types that provide linear motion and three types that provide rotary motion. These joints are illustrated in figure (1) and summarized as follows :-

1. **This joint is also referred as 'L' type :-** The relative movement between the input link and the output link is a linear sliding motion, with the axis of the two links being parallel.
2. **Orthogonal joint :-** This is also linear sliding motion, but the input and output links are perpendicular to each other during the move. This is O type joint.
3. **Rotational joint:-** This type provides rotational relative motion of the joints, with the axis of rotation perpendicular to the axes of both links. This is a R type joint.
4. **Twisting joint :-** This joint also involves a rotary motion, but the axis of rotation is parallel to the axes of links. This is known as T-type joint.
5. **Revolving joint :-** In this type, the axis of the input link is parallel to the axis of rotation of the joint, and the axis of the output link is parallel to the axis of rotation of the joint, and the axis of the output link perpendicular to the axis of rotation. This joint is also referred as V type joint (V from the "v" in revolving).

Link 'O' is the connection between the stationary base of robot and the first joint. Hence, the link 'O' is input to joint 1. The output link of joint 1 is link 1. Then the link 1 is output to joint 2, and so on. This jointlink numbering scheme is pictured in figure(2).

Fig.1 (a) Two of linear joint- type L;(b)Two forms of orthogonal joint-type O;  
 (C)Rotational joint -type R;(d)Twisting joint-type T;  
 (e)Rotational joint-type V.

To establish the position of the object, the body-and –arm must be capable of moving the object in any of the following three directions :-

- 1) Vertical motion (z-axis motion)
- 2) Radial motion (in-and-out or y-axis motion).
- 3) Right-to-left motion (x-axis motion or swivel about a vertical axis on the base).

After the object is positioned correctly, it has to be oriented to proper direction, which is achieved by Gripper/Wrist. There are three of freedom provides to the Gripper/Wrist.

1. **Roll** :- This DOF (degree of freedom) can be accomplished by a T-type to rotate the object about the arm axis.
2. **Pitch** :- This involves the up-and-down rotation of the object, typically done by means of a R-type joint.
3. **Yaw** :- This involves using an R-type joint.

**Q.2. : What are the basic elements of industrial robot ? [W-02]**

**Ans. :** All industrial robots are made up of three elements :

- 1) Manipulator
- 2) Power supply, and
- 3) Controller.

**1) Manipulator** :- It is the most obvious part of the robot consisting of an end effector and sensor. The movement of the manipulator can be described in relation to its coordinate system which may be cylindrical, spherical, Cartesian or anthropometric.

The main parts of manipulator are as under :

**(i)End effector** : An end effector is a special device attached to the manipulator's wrist to perform a specific task. End effectors may be tools or grippers. Tools are used when certain operations like processing, etc. are to be performed as spot welding, spray painting etc. whereas grippers are used to grasp the object.

**(ii) Sensor** : It is a device which responds to a physical phenomenon or to a change in physical phenomenon. Sensors are used in robots for sensing the environment. Different types of external sensors can be incorporated.

**(2) Power supply** :- Movement of the manipulator arm requires energy which is supplied by the energy source. Depending upon the load and applications, it can be electrical, hydraulic or pneumatic. For smaller loads electrical sources and for large loads hydraulic sources are used. When accuracy requirement is less pneumatic sources could be used.

**(3) Controller** : It may be referred to as the brain of the robot and is based on or controlled by a computer or a system of computers. Its major functions are to store, sequence and to position the data in memory, to initiate and stop motions of manipulator, as per set instructions given to interact with the environment. The controller has two components – hardware and software. These controller could be classified as

- (i)Simple step classified as
- (ii)Pneumatic logic system
- (iii)Electronic sequencer
- (iv)Microcomputer
- (v)Minicomputer

**Q.3 : Explain the following terms for robot**

- 1) Degree of freedom
- 2) Work volume
- 3) Accuracy & repeatability
- 4) Control resolution
- 5) Spatial resolution.

**Ans :** **1) Degree of freedom** :- DOF is defined as the no. of variables required for complete robot definition of robot motion.

A joint of industrial robot provides relative motion between two parts of the body. Each joint provides the robot, which is called degree of freedom of motion.

**2) Work Volume** :- The work volume of the manipulator is defined as the envelope or space within which the robot can manipulate the end of its wrist. It is sometimes referred to by the term work envelope. Work volume is determined by the number and types of joints in the manipulator (body-and-arm and wrist), the physical size of the joints and links, and the ranges of the various joints.

The shape of the work volume depends largely on the type of robot configuration.

**3) Accuracy** :- Accuracy is a measure of the robot's ability to position the end of its wrist at a desired location in the work volume.

It is given by

$$\begin{aligned} \text{Accuracy} &= \frac{CR}{2} + 2\sigma \\ &= \frac{CR}{2} + 3\sigma = \frac{SR}{2} \end{aligned}$$

Where CR=Control resolution .  
SR=Spatial resolution, and  
 $\sigma$  =Standard deviation of mechanical error.

**Repeatability** :- Repeatability is a measure of the robot's ability to position its end-of-wrist at a previously attained point in the work volume.

It is given by

$$\text{Repeatability} = \pm 2 (\text{Std. dev. of mech. Error}) = \pm \sigma$$

Where,  $\sigma$  = Standard deviation of mechanical error.

**4) Control Resolution (CR)** :- Control resolution is defined as the distance between adjacent addressable points. It refers to the capability of robot's controller and positioning system to divide the range of joint into closely spaced points, that can be identified by the controller, called addressable points.

No. of addressable points are  $2^n$ .

Control resolution is given by

$$CR = \frac{\text{Joint range}}{2^n}$$

Control resolution , accuracy and repeatability are illustrated in fig.



5) **Spatial Resolution (SR)** :- Spatial resolution combines the control with the mechanical errors in the joint and associated links. The spatial resolution is defined in terms of the standard deviation as

$$SR = CR + 6\sigma$$

Where CR = Control resolution  
 $\sigma$  = Standard deviation of mechanical error.

**Q.4 : What do you mean by work volume of a robot ? Explain how work volume depends on type of robot configuration.**

**Ans. :** An end effector is defined as the special device that attaches to the manipulator's wrist to enable the robot to accomplish a specific task.

Tools and grippers are the two general categories of end effectors used in robotics. Tools are used in applications where the robot must perform some processing operation on the workpart. The robot, therefore, manipulates the tool relative to a stationary or slowly moving object (e.g. workpart, subassembly, etc.). Examples of the tools used as end effectors by robots to perform processing applications include the followings :

- Spot welding gun,
- Arc welding tool,
- Spray painting gun,
- Rotating spindle for drilling, routing, grinding, etc.,
- Assembly tool (e.g.; automatic screwdriver),
- Heating torch,
- Water-jet cutting tool.

Grippers are end effectors used to grasp and manipulate object during the work cycle. The objects are usually workparts that are moved from one location to another in the cell. Machine loading and unloading applications fall into this category. Other objects that can be handled by grippers include tools. The gripper can act as a fast change tool holder for quickly fastening and unfastening the various tools used during the cycle.

Examples of grippers used as end effectors in industrial robot applications include the following :

- ★ Mechanical grippers, in which the part is held between mechanical fingers and the fingers are mechanically actuated,
- ★ Vacuum grippers, in which suction cups are used to hold flat objects,
- ★ Magnetized devices, for holding ferrous parts,
- ★ Adhesive devices, where an adhesive substance is used to hold a flexible material such as fabrics.

A mechanical gripper design is illustrated in figure.

**Fig. Robot mechanical gripper**

**Q.6 : Explain 'Sensors' in robots with specific application.**

**OR What is the purpose of sensors in robotic system ? State their types with applications ?**

**Ans. :** Sensor is a device which responds to a physical phenomenon or to a change in a physical phenomenon. Industrial robots are classified as :

i) Internal sensors, ii) External sensor.

Sensors internal to the robot are used for controlling position and velocity of the various joints. These sensors form a feedback control loop with the robot controller. To control the speed of the robot arm, tachometers of various types are used.

Sensors external to the robot are used to coordinate the operation of the robot with the other equipment in the cell. The term "workcell control" is used in reference to these sensor applications. External sensors such as limit switches that determine whether a part has been positioned properly in a fixture, or to indicate that a part is ready to be picked up at a conveyor.

Other sensors and their specific applications are as follows :

- 1) **Tactile sensors** :- These sensors are used to determine whether contact is made between the sensor and another object. Tactile sensors can be divided into two types :
  - i) **Touch sensors** :- These are used to indicate that the contact has been made with the object.
  - ii) **Force sensors** :- These are used to indicate the magnitude of the force with the object, which is useful in gripper to determine the magnitude of force to grasp.
- 2) **Proximity sensors** :- These indicate when an object is close to the sensor. When this type of sensor is used to indicate the actual distance of the object, it is called a range sensor.
- 3) **Machine vision and optical sensors** :- Optical sensors such as photocells and other photometric devices can be utilized to detect the presence or absence of objects, and are often used for proximity detection. Machine vision is used in robotics for inspections, parts identifications, guidance and others.
- 4) **Miscellaneous sensors** :- These are the other types of sensors, including devices for measuring temperature, fluid pressure, fluid flow, electrical, voltage, current and various other physical properties.

**Q.7. : Elaborate the factors on which the accuracy and repeatability of a robot depends.**

**Ans. :** Accuracy of a robot refers to its capability to position its wrist end at a given target point within its work volume. Thus accuracy depends on :

i) **Spatial resolution** : The robot's ability to reach a particular point in space depends upon its ability to divide its joint movements into small increments.

ii) Mechanical inaccuracies like deflection of components, gear inaccuracies, etc.

Repeatability is robot's ability to position its wrist end back to a point in space that was achieved initially. Repeatability depends on :

i) Mechanical inaccuracies in robot's arm.

ii) Mechanical inaccuracies in wrist components.

iii) Load carrying capacity of the robot.

iv) Weight of the object to be carried.

**Q.8 : With the help of line sketches explain the various robot configurations.**

**OR Sketch common robot configuration stating their advantages and applications.**

**OR Using line sketches, explain "Degree of Freedom" of robots and robot configuration.**

**Ans. :** Common robot configurations are as follows :

**1) Polar configuration** :- This robot configuration has a TRL notation. A sliding arm (type L joint) is actuated relative to the body, which can rotate about both a vertical axis (L-type joint) and a horizontal axis (R-type joint). This configuration is pictured in figure.

## 2) Cylindrical Configuration :

Fig. Cylindrical body and arm assembly (TLO)

This robot configuration consists of a vertical column, relative to which an arm assembly can be moved up and down. The end-of-arm can be moved in and out relative to the axis of the column. This configuration can be realized structurally in several ways. The possibilities include TLO and LVL. The first among these constructions is illustrated in figure.

3) **Cartesian coordinate robot** :- Other names for this configuration include configuration include rectilinear robot and x-y-z robot. As shown in Figure, it is composed of three sliding joints, two of which are orthogonal. The sketch in the figure shows a LLO notation. Another possible notation is OLO.

Fig. Cartesian coordinate body- and – arm assembly (LLO)

4) **Jointed-arm robot** :- This robot has the general configuration of a human arm. Its arm has a shoulder joint and an elbow joint, and arm can be swiveled about base. Possible configurations for this type include RTT and VVR. The TRR type is pictured in Fig.

Fig. Jointed –arm body & arm assembly (TRR)

5) **SCARA** :- SCARA is an acronym for Selective Compliance Assembly Robot Arm. This is similar to the jointed –arm robot except that the shoulder and elbow rotational axes are vertical. This means that the arm can be constructed to be very rigid in the

vertical direction, but compliant in the horizontal direction. This permits the robot to perform insertion tasks (for assembly) in a vertical direction, where some side-to-side adjustments may be needed to meet the two parts properly. One possible notation for a SCARA would be VRO, as indicated in figure.

**Fig. SCARA body-and-arm  
Assembly (VRO)**

**Q.9. : Explain the circumstances and various considerations for justifying applications of a robot.**

**OR Explain various robot characteristics in context to their increasing use in industry.**

**Ans. :** There are several capabilities and price ranges available for industrial robots, that some of the factors are required to be considered before selecting a proper robot. They are as follows :-

- a)Complexity of operation
- b)Degree of disorder
- c)Production rate
- d)Production volume
- e)Long-term potential
- f)Acceptance(amongst working people).

Considering these, one has to be concerned with cost, number and types of axes of motion, power drive, logic memory, programming, maintenance, environment, physical size and weight, cycle rate, etc. In addition, robot characteristics should also be considered.

The Robot characteristics are as follows :

**1)Work envelope** :- Industrial robots have arms that move in several directions to perform work. The robot's work envelop is set of points described by the maximum reach of the robot and effector (or working tool) in all direction.

**2)End effector (Hand)** :- It is the device attached to the robot arm tool-mounting plate in order to interface with its tool or other work environment. End effectors include grippers, tools, welding torch, or any type of device or fixture attached to the robot arm to accomplish the actual work.

**3)Pay load** :- A robot's pay load is its ability to carry, both continuously and satisfactorily, a specified maximum weight, usually defined in kilograms or pounds.

**4)Velocity** :- It is maximum speed at which the tip of its arm is capable of moving at full arm extension, usually, expressed in mm/sec. or inches/sec.

**5)Accuracy** :-The accuracy of a robot is its ability to position its end effector, when commanded, at the specified point, without having attained that position previously.

**6)Repeatability** :-A robot's repeatability is its ability to return consistently and accurately to a predefined and previously attained position.

**7)Stability** :- The of a robot refers to the amount of overshoot and oscillation that occurs in the robot motion as it attempts to reach a certain location. More oscillations in the motion indicates less stability. Hence, the robots with greater stability are inherently slower in their response.

**Q.10: Discuss the factors affecting Robot Economy.**

**Ans. :** Implementation of robot through considered for enhancement of productivity, quality or even for worker safety. But economy using in the robots plays a vital role while selecting a robot. In order to considering this, two factors must be considered, i.e. 1) Cost factors; and 2) Saving/Benefits factors,

**Cost factors :**

1. Robot cost-Denoted as R
2. Cost of Robot Gripper Mechanism –Say G.
3. Cost of Sensors-Say N
4. Cost of layout changes necessary for robot installation –Say L
5. Cost of feeders – Say S
6. Maintenance cost, generally 10% of Robot cost-Say M.

**Saving/Benefits factors :**

1. Labour Replacement –Say B
2. Quality Improvement –Say Q
3. Increase in Productivity – Say P
4. Indirect Savings e.g, reduced scrap, reduced accidents, etc. if quantified, they can be denoted as I.

Using the above factors, we can determine the total cost as,

$$C=R+G+N+L+S+M$$

and total savings can be calculated from

$$A = B + Q + P + I$$

Now, to justify the installation of robots, A has to be shown equal to or greater than C, involves most of the one time amounts. A includes annual savings. So, either pay-back period or return- on investment can be computed to justify the initial high investment.

**Q.11.: Bring out the evolution of industrial Robots.**

**Ans. :** In early 17<sup>th</sup> century, industry revolution brought out the first programmable loom. It is controlled by punch cards and was developed in France. Thereafter and card programmable loom were developed for mass production and other applications. During 18<sup>th</sup> century, motor operated crane with a gripper, programmable lathe, etc. were in use. Real development started in 19<sup>th</sup> century when a programmable point spraying machine spray guns and electro mechanical sequence controller was developed. Development in Robotics can be given as follows :

- |                  |   |  |
|------------------|---|--|
| <b>Year</b>      | - | Cybernetics was introduced by Norbert-Weiner           |
| <b>Year 1956</b> | - | Development of artificial intelligence                 |
| <b>Year 1957</b> | - | Pick and place robot was developed                     |
| <b>Year 1959</b> | - | First commercial robot sold by Planet Corporation, USA |

In 1983, first man carrying computer controlled walking machine was made and thereafter, two-legged walking machine was designed by Shimoyana. Other robots developed were (1) Robot controlled by a general purpose computer; (2) Computer integrated assembly robot; (3) Three-legged waling machine; (4) Programmable universal machine for assembly robot(the PUMA robot).

Thus, evolution for more sophisticated and intelligent robot is still in progress.

**Q.12. : How the robots could be classified ?**

**Ans. :** Robots could be classified as under :

**(1) Depending upon physical configuration :** In this robots are classified as :

**(i) Cartesian robot :** In this robot consists of three sliding joints out of which one is linear and

other two are orthogonal.

**(ii)Cylindrical robot :-** In this robot consists of a vertical column relative to which an arm assembly moves up and down.

**(iii)Polar robot :** In this sliding arm of the body can rotate about both vertical and horizontal

axis.

**(iv)Jointed arm robot :** It has a structure swiveled about the base with shoulder joint, elbow

joint, etc.

**(2)Depending upon the motion characteristics :** In this robots are classified as per motion

performed by them.

**These are ;**

(i)Point-to-point robots.

(ii)Continuous path robots.

**(3)Depending upon the level of sophistication :** In this robots are classified as :

(i)First generation robots which are simple programmable robots being used widely.

(ii)Second generation robots with the capability of sensing the environment by acquiring the

data.

(iii)Third generation robots or Intelligent robots which can handle all types of tasks.

**(4) Depending upon the manipulator functions : In this robots are classified as :**

(i)Pick and place robots used for material handling.

(ii)Special purpose robots for performing various functions like spray painting, spot welding, etc.

(iii)Universal robots.

**(5)Depending upon the type of control used : In this the robots could be classified as :**

(i)Servo controlled robots

(ii)Non-servo controlled robots.

**(6)Depending upon the type of input : In this the robots could be classified as :**

(i)Manual manipulator robot

(ii)Numerically controlled robot

(iii)Intelligent robot

(iv)Playback robot

(v)Fixed sequence robot

(vi)Variable sequence robot,

**Q.13.: Write a short note on basic motions of robot.**

**OR Describe six degrees of freedom of robot.**

**Ans. :** To perform a task the robot arm must be capable of moving the end effector through a sequence of positions. There are basically six motions also called degrees of freedom of the robot which provides a robot the ability to perform the task. The six basic motions consists of three arm-and-body motions and three wrist motions, which are summarised as below.

**Arm and body motions :**

**(1)Vertical transverse :** These are up-and-down motions of the arm, caused by pivoting the entire arm about a horizontal axis or moving the arm along a vertical side.

**(2)Radial transverse :** This is in-and-out movement of the arm.

**(3)Rotational transverse :** This is swiveling of the robot arm about the vertical axis.

**Wrist motions :**

**1)Wrist swivel:** It is the rotation of the wrist.

**2)Wrist bend :** It is the up or down movement of the wrist.

**3)Wrist yaw :** It is right or left swivel of the wrist.

**Q.14: What are the motion systems followed by robots ?**

**OR Name the systems through which path of robot could be controlled.**

**Ans. :** The system through which robot motions could be obtained are as follows.

**1)PTP or point –to-point system :** In this, robot's movement is controlled from one point location in the space to another. The path traversed by the robot in moving from one point to the other is not considered. Each point is programmed into robot's memory and then played back during the entire work cycle.

**Example :** Such robots are used in spot welding, pick and place activities, machine loading and unloading, etc.

**2)Continuous path system :** In this the whole path to be traversed by the robot is taken into the account. In this the robots are programmed to follow a closed spaced locus of points describing a path.

**Example :** Such robots are used in seam welding process, paint spraying, grasping the objects moving on conveyors, etc.

**Q.15.: Write specific notes on –**

**1)Robot programming languages**

**2)Maintenance and safety in robots.**

**Ans. :** **1)Robot programming languages :-** There are a variety of commercially available robot languages. It includes VAL-II (by Unimation-Westinghouse), AML(IBM-Corp.) RAIL (Automation Inc.), HELP (General Electrical), ARL, HARL, IRL, MCL, LM, PLAW, SIGLEA, ROLE etc. The basic components of a robot language are :

**i)Instructions** which determine the action of robot.

**ii) Tools** which construct sequence of procedures for a task.

**iii) Media** to transfer a sequence of codes into other departments which accumulate these data.

**i) VAL(Vice ARM Language ):-** An interactive version of AL-VAL and its associated hardware has been adopted to all animate robots which previously used on ole form of point control. VAL-II newer version is also available.

**ii) AML (A Manufacturing Language) :-** It is represented by IBM with its robots. IBM automated parts assembly system (AUTOPASS) language attempts to eliminate the need to issue detailed instruction to a robot. The program automatically determines the motion paths and grip points from geometric database.

**iii)ARL(Assembly Robot Language):-** It is basically used to control high-level complicated tasks such as assembly and inspection.

**iv) HARL (Hitachi Assembly Robot Language) :-** It is suitable for point-to-point assembly and handling tasks. There are 18 motion typical instructions available to carry out programming. By this, motion control data are programmed and location data are taught so as to make locational information of motion statements.

**v) IRL (Intuitive Robot Language):-** It is developed by the Swiss company Microbo, affiliated to the large watch-making companies, for its range of high precision assembly robots.

**vi) MCL:-** MCL is an extension of APT, and aims at programming flexible units, i.e. of a set of machines served by one or more robots.

**vii) PLAW (Programming Language For ARC Welding):-** This is particularly well suited to intelligent welding, i.e. which involves use of sensors such as limit switches, optical sensors, etc.

**viii) ROL (Robot Language):-** ROL is a research and development product, ROL aims at designing a complete commercial system for computerized control (including hardware and software ) adaptable to any robot.

**ix) AL (Arm Language) :-** It is the outcome of research at the Stanford University into programming robots and the use of WAVE language.

**x) LM (Language de-Manipulation):-** Developed in the IMAGE Robotics Laboratory at the General University in 1979. It adopts most of the main concepts of AL but is used on a microcomputer (68000).

**xi) SIGLA (Sigma Language):-** First commercial language available with a robot. It resembles some NC languages, but also allow control of several arms, with loops and tests on the sensors.

## **2) Maintenance and Safety in Robots :-**

**Maintenance in robots :-** In robots, three types of component usually requires special attention, They are :

**1) Electrical Components, 2) Electromechanical Components, and 3) Mechanical Components.**

Each of these components of robots requires separate planning and due attention so as to maintain the robot. Electronic component and due attention so as to maintain the robot. Electronic component (Microprocessor) needs air-conditioned environment so as to protect it from dust, dirt, humidity which may affect its working. Electronic components are replaced when they fail to work.

Electromechanical components, such as servomotors, feedback device, power supply units etc, require to have a preventive maintenance schedule to carry out maintenance activities periodically.

Mechanical components are more prone to breakdown. These components such as arm assembly gripping devices, various fans, etc. required to be maintained through PM plans.

**Safety in robots :-** It is not always possible to have an alert operator to identify the situation of crisis and to turn the robot work cycle. Off. Hence a more automatic and reliable means of protecting the cell and people who might into the work zone is called safety monitoring.

Safety monitoring also known as hazard monitoring) is a workcell control function in which sensors are used to monitor the status and activities of the cell and to detect the unsafe conditions. Various sensors like limit switches, temperature, pressure sensors, photo-detectors, machine vision systems can be used to implement safety



monitoring system. The safety monitoring system is programmed to respond to the various hazard situations in different ways, they are :

(a) Complete stoppage of the work cell operations, (b) Warning buzzers, (c) Special programmed functions to allow the robot to recover from a particular unsafe event. This is also known as error detection and recovery.

**Q.16.: Write a short note on**

**(i) Robot programming and methods of programming.**

**(ii) Design considerations for industrial robot.**

**Ans. :** **(i) Robot programming and methods of programming :** A robot program is determining the path in the space to be followed by the manipulator. Programming is deciding upon the work plan and path followed along with the peripheral actions that support the work cycle. Robot programming could be done by entering the commands into the controller memory.

The programming of robots could be done by :

**(1) Manual programming :** It is usually associated with limited sequence robots. The end points of the motions of these robots could be controlled by setting limit switches and mechanical stops. The order in which each joint is to operate to get a complete cycle is determined and the motion is regulated.

**(2) Walk-through programming :-** In this the programmer manually moves the robot arm through the path to be traversed. Each movement gets recorded in the memory for subsequent playback of action during production. The speeds with which the movements are performed could be controlled independently. In this main concern is on getting position sequence correct than cycle time. It is used in spray painting, are welding robots, etc.

**(3) Lead-through programming :-** Lead through programming is also called "teach showing". It involves use of teach pendant which is a hand-operated device with switches and levers to control robot's physical movements. Each motion gets recorded in controller memory for future playback.

**(4) Computer like programming languages :** It involves use of computer like programming languages for feeding the commands in the memory to follow a particular path during the production.

**(5) Offline programming :** It involves preparation of the robot program. Off-line, i.e., the program for future work is prepared while robot is engaged in doing a work. The main advantage of this is that production time of robots is not lost due to delays in teaching the robot the path to be followed. It results in higher utilization of the robot and equipments in use.

**(ii) Design consideration for industrial robot :-** Designing of robot involves integrating all possible movements required by different components to perform the desired task. The various design considerations that are taken into the account are :

**(a) System specification :** It includes range, speed, work envelope, load capacity, etc.

**(b) System performance :** It includes system velocity, acceleration, repeatability, resolution, accuracy, life, etc.

**(c) System configuration :** It includes number of degrees of freedom, drive used, joint travel, etc.

**Q.17.: Explain 'lead through programming of robots'.**

**OR Explain 'lead through programming stating typical applications.**

**Ans. :** Lead through programming is also called as "Teach by showing". In this operator moves the robot arm through the desired motion path. Then, program is entered into

controlled memory. Lead through teach procedure can be performed by following two methods :

1) Powered lead through

2) Manual lead through

1) **Powered lead through** :- Powered lead through is commonly used as the programming method for playback robots with point-to-point control. It involves the use of a teach pendant (hand-held control box) which has toggle switches or contact buttons for controlling the movement of the manipulator joints. Using the toggle switches or buttons, the programmer power drives the robot arm to the desired positions in sequence, and records the positions into memory. During subsequent playback, the robot moves through the sequence of positions under its own power.

2) **Manual leadthrough** :- Manual leadthrough is convenient for programming playback robots with continuous path control in which the continuous path is an irregular motion pattern such as spray painting. In this method, operator physically grasp the end-of-arm or tool attached to the arm and manually move through the motion sequence, recording the path into memory. Because the robot arm itself may have significant mass and would therefore be difficult to move, a special programming device often replaces the actual robot for the teach procedure. The motions are recorded as a series of closely spaced points. During playback, the path is recreated by controlling the actual robot arm through the same sequence of points.

**Q.18. : Explain Robot Drives and Control Systems.**

**OR Discuss the drives employed in robots.**

**Ans. : Drive systems:-** Common drive systems used in robotics are :-

i) Electrical, ii) Pneumatic, and iii)Hydraulic drive systems.

**i)Electrical** :- They make use of electric motors as joint actuators(e.g. dc servomotors, stepper motors, etc.) They are becoming more prevalent in commercially available robots. They are readily adaptable to computer control systems. Accuracy is another feature of electric drives.

**ii)Pneumatic** :- Pneumatic drives make use of linear pistons or rotary vane actuators to provide motion to various links. These drives are typically reserved for smaller robots used in simple material transfer applications.

**iii)Hydraulic** :- Hydraulic drives also use linear pistons or rotary vane type of devices for positioning and movement. These as well as electric drives are used for more sophisticated robot applications, as compared to the pneumatic drives. This drive can work at greater speed and carry out heavier tasks, while accuracy is slightly lower.

**Control Systems** :- A microprocessor-based controller is commonly used today in robotics as the control system hardware. The controller is organized in a hierarchical structure as indicated in figure so that each joint has its own feedback control system, and a supervisory controller coordinates the combined actuations of the joints and sequences the motions according to the sequence of the robot program.

According to the level of sophistication of the robot controller, it can be classified into one of the following four categories :

1. **Limited –sequence robot** :- This is the most elementary control type and can be utilized only for simple motion cycles, such as pick-and-place operations. It is usually implemented by setting limits or mechanical stops are set to actuate joints in a predefined sequence. Feedback loops are sometimes used to indicate positioning control. However , there is no servo control to accomplish precise positioning of the joint. Many pneumatically driven robots are limited – sequence robots.
2. **Playback robot with point-to-point control** :- In these systems, the controller has a memory for recording not only the sequence of the motions in a given work cycle, but also the locations that are associated with each element of the motion cycle. These locations and their sequence are programmed into memory, and played back during the operation. In point-to-point (PTP) control, individual positions of the robot arm are recorded into memory. Feedback control is used during the motion cycle to ascertain that the individual joints have achieved the desired locations defined in the program.
3. **Playback robot with continuous-path control** :- The number of individual locations that can be recorded into memory is far greater than for point-point. This means that the points constituting the motion cycle can be spaced very closely together, which permits the robot to accomplish a smooth continuous motion. Servo control is used to maintain continuous control over the position and speed of the manipulator. This type of robot can take on point-to-point job also.
4. **Intelligent robots** :- It has some characteristics that make a robot appear intelligent, include the capacity to interact with its environment, make decisions when things go wrong during the work cycle, communicate with human beings, make computations during the motion cycle, and operate in response to advanced sensor inputs such as machine vision. In addition, these robots possess the playback capability for either PTP or continuous-path control. These features require a relatively high level of computer control and an advanced programming language in order to input the decision making logic and other “intelligence” into memory.

**Q.19. : Describe in short work cell layout in context to robots.**

**Ans. :** Cell is defined as compartments assigned to various facilities. Industrial applications of robots always involve other pieces of equipment such as machine tools, conveyors, sensors, fixtures, etc. alongwith robots. Each equipment performs a specific function in the cell, and for the cell to perform properly all these functions must be sequenced and co-ordinated with the actions of the robot. Thus workcell layout is required to provide the sequencing and co-ordination of cell components. Variation functional parameters required in designing a robot station are :

- i) Axes of motion
- ii) Movement of arm and wrist
- iii)Weight carrying capacity
- iv)Type of control
- v)Memory

- vi)Maximum operating temperature
  - vii)Programming method
  - viii)Accuracy and repeatability etc.
- Work cell layouts could be classified as :
- 1)Robot centred cell
  - 2)In-line robot cell
  - 3)Mobile robot cell.
- 1)Robot centred cell :**

In this robot is located at the approximate centre and other pieces of equipment are arranged around it. This type of layout is suitable for robots serving number of processing machines. This type of layout is usually employed in loading and unloading activities.

**2) In-line robot Cell:** In this type of layout one or more robots are located along a line, i.e. along a conveyor or other material transport system. Each robot is to perform some processing of assembly operation on the part. This type of layout is preferable for assembling of automotive car body.

**3)Mobile Robot Cell :-** In this type of layout, robot is mobile i.e. moves to perform operations at various work-stations. A transport mechanism like floor mounted or overhead rail is used for the movement of robot. This arrangement is suitable when several workstations are to be served by a single robot and these workstations could be located around the robot.

**Q.20 : What are the areas of applications of Robotics ?**

**Ans. :** Robot applications are basically :

**i)Industrial applications :** These includes

**a)Material handling**

**b)Processing operations** like welding, spray painting, casting, heat treatment, finishing operations.

c) Assembly and inspection.

**ii) Non-industrial applications :-** This includes space applications agriculture applications, ocean exploration, defence, house-hold jobs, etc.

**Q.21 :** **Discuss various considerations in selection of robot for material handling applications.**

**Ans. :** Material handling means moving materials or parts from one location to other. Material handling includes :

**i) Material transfer**

**ii) Machine loading and unloading.**

The various considerations for selecting the robot for material handling applications are as follows :

**i) Material transfer** means picking the part at one location and placing it at the other location. Thus for such application a robot with only two or four joints could be used.

**ii) In complex case of palletizing** where the parts are to be transferred into pallets, the robot is required to be taught by each position in palletizing and hence lead-through programming is required.

**iii) In case of machine loading and unloading**, robots may be used for loading or unloading only and for both purposes. The work cell consists of two or more machines and hence robot centered cell is preferred. If distances to be travelled between two machines are large, mobile robot cell could be used.

Thus in case of material handling, robots are equipped with a gripper type and effector or handle specific part or parts.

**Q.22 :** **Explain how would you select robot for :**

**i) Spot welding**

**ii) Arc welding**

**iii) Spray painting.**

**OR Suggest a suitable robot for applications in welding and painting activities. Sketch the robot and describe its characteristics for the above applications.**

**OR Suggest a suitable robotic system for application in any one processing operation.**

**Ans. :** **1) Spot welding :-** Spot welding is a metal joining process in which two sheet metal parts are fused together at localized point of contact. Because of its widespread use in the automobile industry for ca body fabrication, spot welding represents one of the most important application of industrial robots today. The use of industrial robots in this application has dramatically improved the consistency with which the welds are made. Jointed arm and polar coordinate robots are the most commonly used for spot welding application in automobile. In –line robot cell-layout with 20 to 30 robots are typical.

**Fig. Spot welding robot**

**Characteristics of spot welding applications :**

- i) Playback robots with point-to-point control are used.
- ii) Must be programmed using powered leadthrough method.
- iii) Sufficient payload capacity to hold the heavy welding gun.
- iv) Five or six axes are generally needed to achieve the positioning and orientation required.

**2) Arc welding :-** The hot, smoky and bright environment is not suitable for humans without special protective clothing and appliances. Jointed arm robots and Cartesian coordinates are used in arc welding applications. The welding workstations should consist of welding tool, power source wire feed system and a workpart manipulator. Programming for arc welding is costly. Therefore, most applications require a large batch size to justify the robot cell.

**Characteristics of arc welding applications :**

- i) Playback robots with continuous path control are used.
- ii) Must be programmed using one of the lead through methods.
- iii) The robot should have five or six axes to define orientation.

**Fig. Arc Welding**

**3) Spray painting :** Spray painting is the most common example of a more general class of robot applications called spray coating. The spray coating process makes use of spray gun directed at the object to be coated. The robot applications include spray coating of appliances, automobile car bodies, engines, and other parts, spray staining of wood products and spraying of porcelain coating bathroom fixtures. Jointed arm robots are most common anatomy for this application.

**Characteristics of spray painting application :-**

- i) Playback robots with continuous path-control are used to accomplish the smooth motion sequences required in spray painting.
- ii) The most convenient programming method is manual leadthrough.
- iii) The robot must possess a long reach in order to access the axes of the workpart to be coated in the application.

**Spray painting robot**

- Q.23 :** Suggest a suitable robotic system, explaining its characteristics for application in
- i) heat treatment activities,**
  - ii) Tool transfer tool bank to spindle of machining centre.**
- i) Heat treatment activities :-** Heat treatment activities include loading and unloading parts in furnaces or bath. It requires to control span of moving member to load and unload the parts after a specified time. Thereafter, suitable robot system for heat treatment activities is low technology robot. Its characteristics are as follows :
- Work envelope – Rectangle
  - Repeatability – Medium
  - Accuracy – Medium
  - Speed-Low speed operation
  - Drive – DC Motor Drive
  - Control- Limited sequence type control
- ii) Tool transfer tool bank to spindle of machining center :-** Suitable robot system for tool transfer tool bank to spindle of machining center is low technology robot. It may be limited sequence type i.e. programmed using limit switches and other sensors. Its characteristics are as follows :
- Work envelope - Cylindrical
  - Repeatability - High
  - Accuracy - Low
  - Speed - High speed operation of tool change.
  - DOF - 3 DOR
  - Drive - Pneumatic drive
  - Control - Limited sequence type control
- Q.24. :** Explain how would you select robot for following applications :
- i) Continuous arc welding**
  - ii) Water jet cutting application**
  - iii) Assembling a small toy made of 5-6 parts.**
- Ans. :** For selection of a robot for particular application, the factors that are taken into the consideration are
- 1) Work envelope
  - 2) Accuracy and Repeatability
  - 3) Pay load
  - 4) Speed
  - 5) Degree of freedom
  - 6) Type of drive and control
  - 7) Type of sensors.
- Thus, the robots required for following processing are as follows :
- i) Continuous arc welding :** For answer refer “Arc Welding” in Q.22.
- ii) Water jet cutting applications :** Water jet cutting is a process in which a pressurized stream of water is forced through a small nozzle at very high speeds to cut the fabrics, cardboards, plastic sheets, etc. precisely. Thus the basic requirements for water jet cutting by robot are :
- a) End effector which directs the water jet nozzle over a desired cutting path.
  - b) Continuous path control is required.
- Characteristics required are :**
- Work - Rectangle

Accuracy	-	High
Speed	-	High speed operation
Control	-	Continuous path control.
Drive	-	Electrical (DC motor)
Robot	-	Joined arm robot

**iii) Assembling a small toy made of 5-6 parts :** Assembly means addition of components to build the product. The assembly could be done by fastening two or more components together or using adhesives or by welding, brasing, etc.

The assembling of a toy having 5-6 parts requires following characteristics :

Work envelop	-	Cylindrical
Accuracy	-	High
Repeatability	-	Playback robot with point to point control
Drive	-	D.C. motor drive
Speed	-	Medium speed operation

The robots thus required are jointed arm robots with end effectors performing multiple functions including handling of more than one part geometry, gripping and assembly tool.

**Q.25 :** Write short notes on

**i)Circumstances and considerations for justifying the application of robots**

**ii)Interlocks**

**iii)Cybernetics.**

**Ans.** **i)Circumstances and considerations for justifying the application of robots :** Work environment is the most important characteristic that should be considered for the selection of robots. The circumstances and considerations that have promoted substitution of a robot for human labour are:

**a)Hazardous work environment :** When the work environment is unsafe, unhealthy, uncomfortable and hazardous, then robots are used. The include high temperature zones, very low temperature zones like laboratories section with temperature below 0°C.

**b)Repetitive work cycle :** If sequence of operations are same for processing of an element requiring high accuracy and repeatability, robots are preferred as in case of human factor accuracy gets reduced due to fatigue factor.

**c)Difficult handling for human beings :-** Parts or tools that are too heavy to be carried by human beings easily require robots.

**d)Multi shift operations :-** In manual operations requiring 2 or 3 shifts, roots could be used to substitute the human labour. This results in much faster financial paybacks.

**e)Infrequent change-overs :-** In case of batch or job shop productions change over of production techniques require a lot of time moreover it results in large non-productive times or both human and machine. Hence robots could be used which could be reprogrammed quickly.

**f) high accuracy in part positioning and orientation could be done by robots in lesser time.**

**ii)Interlocks :** Interlocks are the means of interfacing the robot with external devices to regulate the sequence of program and to co-ordinate the activities in the cell. The interface permits control signals to flow back and forth between robot controller and external devices. The interlocks are of two types : input interlocks and output interlocks.



Input interlocks are signals that originate at any external device like sensor, limit switch, etc, and are transmitted to robot controller. Whereas output interlocks are signals that sent from the robot controller to the external devices. The input interlocks interpret the regular execution of the program, whereas output interlocks controls and co-ordinate the operation of external devices with that of robot.

**iii)Cybernetics** : Cybernetics could be defined as that filed of knowledge which deals with the science of communications for the purpose of control. Cybernetics is closely connected with the control of operations with non-automatic performance of the controls may be managed manually but with automatic operations, the controls are either mechanical or electrical. The stages of cybernetics are :

- a)Receipt of signal indicating a significant deviation from the standards of correct performance.
- b)The evaluation of the signal and determination of the connective action to betaken.
- c)The feedback of information regarding this corrective action to a device which controls the performance of the operation.
- d)The corrective adjustment of the process by the device to restore satisfactory performance.



## UNIT IV

# AUTOMATED MATERIAL HANDLING AND STORAGE

**Q.1 :** List out various MH equipments.

**Ans. :** Various material handling equipments used in industry are as follows :

**1)Hand trucks :** It includes wheelbarrows, trollies, two wheeled trucks, four wheeled trucks, hand-lift or manually operated forklift trucks.

**2)Powered trucks :-** It includes walk i.e. truck in which operator works with vehicle for steering, riding trucks, forklift trucks, slider loaders, tractor, trailer trains and industrial crane trucks.

**3)Cranes, monorails and hoists :-** It includes Jib cranes, gantry cranes, bridge cranes, overhead monorails, hand and powered hoists.

**4)Conveyors :-** It includes gravity conveyors (chutes rollers) and powered conveyors (rollers, belts, chain, overhead, in-floor tow and cart-on-truck)

**5)AGVS:-** It includes driverless trains, pallet trucks and unit load carriers.

**6)Other handling equipments :-** It includes industrial robot, dial indexing tables, transfer mechanisms in automated flow lines, elevators, part feeders, pipelines, containers such as pallets, bins, tote pans, highway tractor trailers, railway trains, cargo aircrafts, ships , barges and other marine vessels.

**Q.2. :** Discuss the various factors considered in analysis of automatics material handling system. What are material handling analysis technique ?

**Ans. :** The various factors which are considered which are considered in analysis of material handling system are :

**i)Material composition and movement conditions :** In this, the materials are characterized by :

<b>Property</b>		<b>Description</b>
Physical form	-	Solid, liquid or gas
Size	-	Length, width and height
Weight	-	Weight per piece, weight per volume
Shape	-	Long and flat, round, square
Risk of damage	-	Fragile, brittle, sturdy.
Safety risk	-	Explosive, toxic, corrosive.
Condition	-	Hot, wet, dirty, sticky.

Thus physical form, size, weight etc. give whether the material to be moved in bulk or as individual pieces. Moreover for moving liquid in bulk pipelines are preferred. Also various safety conditions, risk of damage etc. are to be taken in account to check whether material handling system is appropriate or not.

**ii) The quantity of the materials to be moved :-** It implies for large quantity of materials to be handled a dedicated handling system whereas if the quantity of materials to be moved is small a shared handling system is preferred.

**iii)Rate of flow required**

**iv)Scheduling of the moves :** It implies timing of the material should be such that urgent required materials are moved continuously. Seasonality is also an important factor as it is not justified to use automated handling for seasonal products which remains idle in other part of year.

**v) The route by which the materials are to be moved :** It implies longer the distance to be moved, costlier is the handling. Also various conditions like humidity, temperature, whether path is straight line or has turns, traffic congestion etc. determines the type of handling required.

**vi) Miscellaneous factors :** It includes number of workstations, number of loading and unloading stations, whether manual or automatic loading and unloading is being done etc.

**Material handling analysis technique :** Several techniques have been developed to represent material flow. Many tabular and graphical techniques have been developed for visualizing the moves of materials. The techniques being used are :

**1) From-To-chart :** It is quite similar to mileage chart on a road map.

From	To			
	1	2	3	4
1	0	9	5	6
2	0	0	0	0
3	0	6	0	2
4	0	0	0	0

**From –To-Chart showing number of deliveries required between different stations in a layout.**

From	To			
	1	2	2	4
1	0	200	500	70
2	--	0	--	--
3	--	400	0	300
4	--	--	--	0

**From –To-Chart showing distance between different stations.**

Left hand corners depicts origination points from where tips are made whereas h horizontal row depicts destination points. The chart is used to represent various parameters of material flow which includes number of deliveries between points, distances between the work stations, volume of product flowing between various locations etc.

**(ii) Flow diagram :** It provides information about the movement of materials, corresponding origination and destination points of moves. Origination and destination points are represented as nodes and material flow is depicted by arrows. Nodes represent productions department between which parts are to be moved. Material flow rate is indicated near arrow tips.

**Q.3 :** Briefly discuss automated material handling system and its significance in FMS.

**Ans :** Material handling is very important to any organization because starting from the time raw material enters the factory gate and goes out of the factory gate in the form of finished products, it is handled at all stages in between, no matter it is in stores or on the shop floor. It has been estimated that average material handling cost is roughly 50 to 60% of the total production cost and the ratio between the weight of handled material to produce an item and the weight of finished item may vary between 40 to 50. A component may be handled even 50 times or more before it changes to finished product. It thus becomes clear that cost of production of an item can be lowered considerably by making a saving in the material handling cost.

Thus automated material handling employs use of modern machineries with continuous feedback so that the handling of the materials could be performed safely, efficiently, (at low cost), in a timely manner, accurately (right materials in the right quantities to the right location) and without damage to the materials. Manual handling could be reduced by use of hand trucks, powered trucks, cranes, hoists, conveyors, AGVS(Automated Guided Vehicle Systems), robots etc.

**Significance in FMS :** In FMS, automatic material handling system is necessary to provide for flexibility of the FMS operations. The flexibility could be provided by :

- i) Quick transfer of work from staying area to individual workstations in the system.
- ii) At the workstation materials are transferred from vehicle platform into the work area of the station for processing without damaging of the materials.
- iii) At the completion of processing the finished work is dispatched quickly to the next area and hence the change over in products could be done without wastage of time due to mixing of products.

**Q.4 :** Explain various guiding principles of material handling which are used to reduce material handling cost.

**Ans. :** Material handling costs in large scale products could be reduced by using mechanical devices like conveyor belts, chutes etc. Principles that have been developed to provide guidance in design of material handling system are-

**1)Unit load principle** – It implies materials to be moved should be aggregated into a larger unit size which are then placed on pallet or other standard sized container for handling. The materials are referred to as unit load.

**2)Avoid partial loads** – It involves unit loads should be tried to transport rather than partial loads.

**3)Shortest distance principle-** It involves movement of materials over shortest possible distance. This generally depends on plant layout design.

**4)Straight-line flow rule** – The material handling path should be a straight-line from point of organization to destination. This rule complies with that of shortest distance.

**5)Gravity principle-** Gravity should be used to assist the movement to extent possible keeping in consideration safety and risks of product damage.

**6)Minimum terminal time-** It involves that movement of load consists of move time alongwith time required for loading, unloading and other activities which do not involve in actual transport of material. Minimize these non-move times.

**7)Carry loads both ways-** It involves handling system should be designed to carry loads in both directions as return trips with empty loads are wasteful.

**8)Mechanization principle-** It involves manual handling should be avoided and handling process should be mechanized wherever possible to increase efficiency and economy.

**9)Part orientation principles** – It involves orientation of work part should be established and maintained throughout the handling process.

**10)System principles-** It involves integrating material handling systems with other systems including receiving, storage, production, assembly, inspection, packaging, shipping, transportation so that movement of items could be identified alongwith their orientation and destination.

**Q.5 :** **How are the material handling equipments classified ? Discuss.**

**Ans. :** Material handling equipments may either be of general purpose or of special purpose use. The equipments are basically selected so as to allow continuous production flow, reduce handling problems thus wastage time and capital required in handling reducing industrial accidents etc.

These are classified in following manner –

1)Lifting and lowering devices with vertical movement

a)Block and tackle b)Hoist c)Crane d)Hand and power winches.

2)Transporting devices (horizontal movement)-

a)Hand and power trucks b)Tractors and trailers

c)Pipe line

3)Devices which lift and transport (combination devices)-

The material handling equipments can be then classified in the following manner.

**Q.6 :** Write a short note on material handling equipments. Explain various guiding principles to reduce material handling costs in an organization.

**Ans.:** A wide variety of material handling equipment is in the market, some equipments are of general purpose use and others are of special purpose use. The choice of a particular equipment depends upon the specific requirements or the conditions of an industry. Naturally, the best equipment will be one which allows smooth and continuous production flow, involves less accidents, reduces production cycle time, promotes better working conditions incurs less fatigue to the operators and brings down the total material handling costs.

A wide range of material handling equipments are available suitable to most of the industrial requirements. Such equipments though need a high capital investment, prove very paying in long run. They

(1) minimize the total handling time,

(2) promote the total handling time,

(3) eliminate idle time of workers and machines which would be there, otherwise, while waiting for the materials for necessary operations,

(4) make it possible to move the material fast,

(5) decrease fatigue incurred by the workers

(6) add to safety,

(7) locate and stock materials better and in less space, and

(8) operations can be automated to increase production.

Every material handling equipment possesses certain characteristics with respect to

Example : (1) Industrial trucks (2) Cranes (3) Hoist (4) Monorail (5) Conveyers (6) Slides & chutes (7) Lifts (8) Tractors and Trailors

**Q.7 :** Give advantages of material handling devices.

**Ans.:** Advantages of material handling devices are –

i) Minimise total material handling cost.

ii) Promote easier, safe and effective handling,

iii) Eliminate idle time of workers and machine, by supplying material at right time,

iv) Make material handling movements faster.

v) Decrease fatigue incurred by the workers.

**Q.8 : What is a conveyor system ? Name are the types of conveyors used in material handling.**

**Ans. :** A conveyor system is used to move the materials in large quantities between specific locations over a fixed path. Most conveyor systems are powered to move the loads along the pathways, other conveyors use gravity to cause the load to travel from one elevation in the system to a lower elevation. Conveyors thus comprise of following attributes –

**(i)**These are fixed –in-position to establish the paths.

**(ii)**They can either be floor-mounted or overhead.

**(iii)**They are always limited to one-directional flow of materials.

**(iv)**They generally move discrete loads, but certain types can be used to move bulk or continuous loads.

**(v)**They can be used for either deliver only or delivery plus storage of items.

**Types of conveyors used :**

**(i)**Roller conveyors.

**(ii)**Skate-wheel conveyors.

**(iii)**Belt conveyors

**(iv)**Chain conveyors

**(v)**Slat conveyors

**(vi)**Overhead trolley conveyors

**(vii)**In floor two line conveyors

**(viii)**Cart-on-track conveyors

**Q.9 : Describe in short about various types of conveyors used in automatic material handling.**

**Ans. :** The various types of conveyors being used are :

**(i)Roller conveyors:** This is the most common type of conveyors system being used. It consists of series of rollers that are perpendicular to the direction of the travel. The rollers are contained in a fixed frame which elevates the pathway above the floor level from several inches to several feet. These are either powered or gravity type. The powered types are driven by belt, chain mechanism etc. and the gravity types are arranged so that the pathway is along a downward slope sufficient to overcome rolling friction. Examples :used in steel plants to carry billets from one shop to other.

**(ii) Skate-wheel conveyors :** These are quite similar in operation to the roller conveyors, but instead of rollers skate wheels rotating on shafts connected to the frame are used to roll the pallet along the pathway. Skate wheel conveyors are used to carry relatively lesser loads as the contact between the loads and conveyors are much more concentrated.

**(iii)Belt-conveyors :** In this belt, is used to move the materials. Materials are placed on the belt surface and travel along the moving pathway. The belt is usually made in a continuous loop so that half of its length could be used for delivering materials and the other half is the return run. The belt moves on series of rollers and at the end of the conveyor where the belt loops back driver rolls are situated. Belts used are flat belts for pallets, parts, etc. and troughed belts for bulky materials.

**(iv)Chain conveyors :** Chain conveyors are made of loops of endless chain in an over-and-under configuration around powered sprockets at the end of the pathway. There may be one or more chains operating in parallel to form conveyor. The loads generally move along the top of the chain but in some cases a pushed bar is projected up between two parallel chains to push or pull the load along a track.

**(v)Overhead trolley conveyors:** These are wheeled carriage running on an overhead rail from which loads could be suspended. The chain or cable is attached to drive wheel that supplies power to the system. A trolley conveyor comprises of multiple equi-spaced trolleys, equally spaced along the rail system by means of this chain or cable. Hooks, baskets, electro-magnets etc. are suspended from the trolley to carry loads. Overhead trolley conveyors are used in industries to move parts and assemblies between major production departments.

**(vi)Slat conveyors :-** Slat conveyors use individual platform called slats that are connected to a continuously moving chain. Loads are placed on the flat surface of the slats and are transported along with them. Straight line flows are common in slat conveyor systems. In this conveyor path can have turns in its continuous loop.

**(vii) In floor towline conveyors :** This conveyors make use of wheeled carts powered by means of moving chains or cables. The power mechanism is located in trenches in the floor. The chain or cable is known as towline and hence conveyor system is in floor towline conveyor. The carts use hardened steel pins called dowels that project below the floor surface into the trench to engage the chain for towing. To disengage the cart the pin is pulled out of the trench. These conveyors are used for moving unit loads in plants and warehouses.

**(viii)Cart-on-track conveyors :** These conveyor system use individual carts riding on a two-railed track contained in a frame that places the track a few feet above floor level. These carts are driven by means of a rotating tube that runs between two rails. A drive wheel at the bottom of the cart, is driven by the spinning or rotating tube which drives forward the cart. The cart speed is controlled by regulating the angle of contact between the drive wheel and the spinning tube. When drive wheel is perpendicular to the tube the cart does not move but if this angle is increased towards  $45^{\circ}$  the speed increases. The most important advantage of this system is achieving high accuracies of position.

**Q.10: What is an AGVS ? Explain its applications and utility in FMS ? OR Explain the different types of AGVS alongwith their applications. OR Write a short note in AGVS.**

**Ans. :** An automated or automatic guided vehicle system (AGVS) is a materials handling system that uses independently operated, self-propelled vehicles that are guided along defined pathways in the floor. The vehicles are powered by means of on board batteries that allow operation for several hours (8 to 16 hours is typically) between recharging. The definition of the pathways is generally paint on the floor surface. Guidance is achieved by sensors on the vehicles that can follow the guide wires or paint.

There are a number of different types of AGVS, all of which operate according to the preceding description. The types can be classified as follows :

**1)Driverless trains :-** This type consists of a towing vehicle (which is the AGV) that pulls one or more trailers to form a train. It was the first type of AGVS to be introduced and is still popular. It is useful in applications where heavy payloads must be moved large distances in warehouses or factories with intermediate pickup and drop-off points along the route.

**2)AGVS pallet trucks :-** Automated guided pallet tucks are used to move palletized loads along predetermined routes. The capacity of an AGVS pallet truck ranges up to 6000 lb, and some trucks are capable of handling two pallets rather than one. A more recent introduction related to the pallet tuck is the forklift AGV. This vehicle can achieve significant vertical movement of its forks to reach loads on shelves.



**3)AGVS unit load carriers :-** This type of AGVS is used to move unit loads from one station to another station. They are often equipped for automation loading and unloading by means of powered rollers, moving belts, mechanized lift platforms, or other devices. Variations of the unit load carrier include light-load AGVS and assembly line AGVS. Light-load guided vehicles are designed to move small loads (single parts, small baskets or tote pans of parts, etc.) through plants of limited size engaged in light manufacturing. The assembly line AGVS is designed to carry a partially completed subassembly through a sequence of assembly workstations to build the product.

**Applications :-** AGVS has wide applications in coming high-tech scenario. However, its application can be grouped into following five categories:

**1.Driverless train operations :-** These applications involve the movement of large quantities of materials over relatively large distance. For example the moves are within large warehouse or factory building, or between buildings in a large storage depot. For the movement of trains consisting of 5 to 10 trailers, this becomes an efficient handling method.

**2.Storage/Distribution systems :-** Unit loads carriers and pallet trucks are typically used in these applications. These storage and distribution operations involve the movement of materials in unit loads (sometimes individual items are moved) from or to specific locations. The applications often interface AGVS with some other automated handling or storage system, such as an automated storage/retrieval system(AS/RS) in a distribution center. The AGVS delivers incoming items or unit loads (contained on pallets) from the receiving dock to the AS/RS, which places the items in storage, and AS/RS retrieves individual pallet loads or items from storage and transfers them to vehicles for delivery to the shipping dock. When the rates of incoming loads and the outgoing loads are in balance, this mode of operation permits loads to be carried in both directions by the AGVS vehicles, thereby increasing the handling system efficiency.

This type of storage/distribution operation can also be applied in light manufacturing and assembly operations in which work-in-progress is stored in a central storage area and distributed to individual workstations for assembling or processing. Electronics assembly is an example of these types of applications. Components are "kitted" at the storage area and delivered in tote pans or trays by the guided vehicles to the assembly workstations in the plant.

**3.Assembly –line operations :-** AGV systems are being used in a growing number of assembly-line applications, based on a trend that began in Europe. In these applications, the production rate is relatively low(perhaps 4 to 5 min per station in the line) and there are a variety of difficult models made on the production line. Unit loads carriers and light-load guided vehicles are the type of AGVS used in these assembly lines.

**4.Flexible manufacturing systems:-** In this application, the guided vehicles are used as the materials handling system in the FMS. The vehicles deliver work from the staging area (where work is placed on pallet fixtures usually manually) to the individual workstations in the system. At a workstation, the work is transferred from the vehicle platform into the work area of the station (usually, the table of a machine tool) for processing. At the completion of processing by that station, a vehicle returns to pick up the work and transport it to the next area. AGV system provide a versatile material handling system to complement the flexibility of the FMS operations.

**5. Miscellaneous applications :-** Other application of automated guided vehicle systems include nonmanufacturing and no warehousing applications, such as mail delivery in office buildings and hospital material handling operations. Hospital guided vehicles transport meal trays, linen medical and laboratory supplies, and other materials, between various departments in the building. These applications typically required movement of the vehicles between different floors of the hospital, and hospital AGV systems have the capability to summon and use elevators for this purpose.

**Q.11. Write specific note on AGVS guidance and routing,**

**OR How is an AVGS guided ?**

**OR Discuss “the vehicle guidance and routing is performed to separate on AGVS”.**

**What is accuracy obtainable ?**

**Ans. :** The term guidance system refers to the method by which the AGVS pathway are defined and the vehicle control systems that follow the pathways. There are two principal methods currently in use to define the pathways along the floor:

i)Guide wires and

ii)Paint strips.

The guide wire system is the more common in warehouse and factory applications.

In the guide wired method the wires are usually embedded in a small channel cut into the surface of the floor. The channel is typically about 1/8 inch wide and 1/2 inch deep. After the guide wires are installed, the channel slot is filled so as to eliminate the discontinuity in the floor surface. An alternative but less permanent way to install the guide wires is to tape them to the floor. A frequency generator provides the guidance signal carried in the wire. The signal is of relatively low voltage (less than 40 V), low current (less than 400 mA) and has a frequency in the range 1 to 15 kHz. This signal level creates a magnetic field along the pathway that is followed by sensors on-board each vehicle. The operation of a typical system is illustrated in figure. Two sensors (coils) are mounted on the vehicle on either side of the guide wire. When the vehicle is moving along a course such that the guide wire is directly between the two coils, the intensity of the magnetic field measured by each coil will be equal. If the vehicle strays to one side or the other, or if the guide wire path curves, the magnetic field intensity at the two sensors will be different. This difference is used to control the steering motor, which makes the required changes in vehicle direction to equalize the two sensor signals, thereby tracking the defined pathway.

**Fig. Operation of a typical sensor that uses two coils to track the magnetic field of the guide wire.**

Paint strips are used to define the vehicle pathways, the vehicle possesses an optical sensor system that is capable of tracking the paint. The strips can be taped, sprayed, or painted on the floor. One system uses a 1-in, wide paint strip containing

fluorescent particles that reflect an ultraviolet (UV) light source on the vehicle. An onboard sensor detects the reflected light in the strip and controls the steering mechanism to follow it. The paint guidance systems are useful in environments, where electrical noise would render the guide wires system unreliable or when the installation of guide wires in the floor surface would not be appropriate. One problem with the paint strip guidance method is that the paint strip must be maintained (kept clean and unscratched.).

Routing in an AGVS is concerned with the problem of selecting among alternative pathways available to a vehicle in its travel to a defined destination point in the system. Vehicles in the system must decide which path to take to reach a defined destination point. There are two methods used in commercial AGV systems to permit the vehicle to decide which path to take :

- 1) Frequency select method.
- 2) Path switch select method.

In the frequency select method, the guide wires leading into the two separate paths at the branch have different frequencies. This method requires a separate frequency generator for each frequency that is used in the guide path layout. This usually means that two or three generators are needed in the system. Additional channels must often be cut into the floor with the frequency select method to provide for bypass channels, where only the main channel needs to be powered for vehicle tracking.

The path switch select method uses a single frequency throughout the guide path layout. To accomplish routing by the path switch select method. The guide path layout must be divided into blocks that can be independently turned on and off by means of controls mounted on the floor near their respective blocks. These control units are operated by the vehicles as they move in the various blocks.

**Q.12: Explain the following with respect to AGV-**

**i) Dead reckoning.**

**ii) Vehicle's acquisition distance.**

**Ans. :** **i) Dead reckoning :** Dead reckoning refers to the capacity of the vehicle to travel along the route that does not follow the defined pathway in the floor. It employs use of microprocessor on the vehicle which computes the number of wheel rotations and the operation of the steering motor required to move along the desired path. Dead reckoning is used where guide wires cannot be installed and also where departure from the path for positioning at load/unload station is required. At the completion of the dead-reckoning phenomenon the vehicle returns to the desired position for resuming normal guidance control.

**ii) Vehicle's Acquisition Distance :** It is the distance beyond which if the vehicle departs along the guided path it automatically stops. It is basically a safety feature used in the operation of most guidance system for stopping the vehicle if it accidentally strays more than a few inches from the guide path. Moreover, in event of vehicle is off the guide path it is capable of locking onto the wire or paint strip if moved within few inches of it. This distance is vehicle's acquisition distance.

**Q.13. Write a short note on system management in AGVS ? OR What are the various dispatching methods in AGVS?**

**Ans. :** Managing of an AGVS deals principally with the problem of dispatching vehicles to the points in the system where they are needed in a timely and efficient manner. The system management is a combine-guidance, routing, traffic control and dispatching

efforts which are needed to allow the AGVS perform its function effectively. These methods are used in combination to maximize responsiveness and effectiveness of the overall system.

Guidance refers to the fixation of the pathway, routing is concerned with the selection with the selection of most appropriate pathway from given number of pathways to travel to a defined point, traffic control prevents collisions between the vehicles travelling along the same guide path.

Dispatching is the most important function of AGVS. The dispatching methods are :

- i) On board control panel.
- ii) Remote call stations,
- iii) Central computer control.

**i) Onboard control panel :** It is the simplest method of vehicle control, programming etc. Most commercial vehicles have the capacity to be dispatched by means of this control panel to a given station in AGVS layout. It employs manual control and hence provides flexibility and responsiveness to changing demands of the handling system.

**ii) Remote call stations :** These are used to adjust to the changing demand pattern in the system. These provides for stopping a vehicle at a given station and programming next sequence at the remote call panel. The simplest form of this call station is press button mounted near the load/unload station. It provides for a load transfer operation and the vehicle might be dispatched to the desired location by means of the on-board control panel. Remote call stations are thus more automated approach allowing automatic loading and unloading operations at call stations.

**iii) Central computer control :-** It is used to accomplish automatic dispatching of the vehicles according to a preplanned schedule of pickup and deliveries in the layout in response to the calls from the issue commands to the vehicles in the system concerning their destinations and operations. In this method a central computer system is used which posses real-time information about the location of each vehicle in the system so that it can take appropriate decisions concerning which vehicles to dispatch at what locations. The feedbacks are obtained continuously from the vehicles and hence an accurate controlling is obtained.

**Q.14: What is AS/Rs ? Explain different AS/Rs.**

**OR Explain different systems of automated storage and retrieval.**

**Ans. :** An automated storage/retrieval system(AS/RS) is defined as a combination of equipments and controls, which handles, stores, and retrieves materials with precision, accuracy and speed under a defined degree of automation.

Different automated storage/retrieval systems includes :

- 1) Unit load/AS/RS :-** This is typically a large automated system designed to handle unit loads stored on pallets or other standard containers. The system is computer-controller and the S/R machines are automated and designed to handle the unit load containers.
- 2) Miniload AS/Rs :-** This storage system is used to handle small loads (individual parts or supplies) that are contained in bins or drawers within the storage system. The S/R machine is designed to retrieve the bin and deliver it to a P & D station(usually manually operated) at the end of the aisle so that the individual items can be withdrawn from the bin. The bin or drawer is then returned to its

location in the system. The miniload AS/RS system is generally smaller than the unit load AS/RS and is often enclosed for security of the item stored.

- 3) **Man-on board AS/RS** :- The man-on-board (also called manboard) storage/retrieval system represents an alternative approach to the problem of storing and retrieving individual items in the system. The man-on-board system permits the individual items to be picked directly at their storage locations. This offers an opportunity to reduce the transaction time of the system.
- 4) **Automated item retrieval system** :- These system are also designed for retrieval of individual items or small unit loads such as cases of product in a distribution warehouse. However, in this system, the items are stored in single-file lanes rather than in bins or drawers. When an item (or case) is to be retrieved, it is released from its lane onto a conveyor for delivery to the pickup station. The supply of items in each lane is generally replenished from the rear of the retrieval system so that there is flow-through of the items, thus permitting first-in/first-out inventory control.
- 5) **Deep-lane AS/RS**:- The deep –lane AS/RS is a high density unit load storage system that is appropriated when large quantities are to be stored but the number of separate types of material is relatively small. Instead of storing each unit load so that it can be accessed directly from the aisle (as in the conventional unit load system), the deep-lane system stores up to 10 or so loads in a single rack, one load behind the next. Each rack is designed for “flow-through”, with an input on one side an output on the other side. Loads are picked from one side and output on the other side. Loads are picked from one side of the rack system by a special S/R- type machine designed for retrieval, and another special machine is used on the entry side of the rack system for input of loads.

**Q.15: Explain the major components of an automated storage and retrieval system.  
OR does a typical AS/RS works ?**

**Ans. :** Basic components of an AS/RS are :

- 1)Storage components of an AS/RS are :
- 2)Storage/Retrieval (S/R) machine,
- 3)Storage modules (e.g., pallets for unit loads),
- 4)Pickup-and-deposit stations.

**1)Storage structure** :- The storage structure is the fabricated steel framework that supports the loads contained in the AS/RS. The structure must possess sufficient strength and rigidity so that it is not affect significantly due to the loads in storage or other forces on the framework.

The storage structure may also be used to support the roof and siding of the building in which the AS/RS resides. When used for this purpose, there is often a tax advantage because the building (or portions of it) can be depreciated as equipment rather than as building property.

**2)Storage /Retrieval (S/R) machine**:- The S/R machine (sometimes called a crane) is used to accomplish a storage transaction, delivering loads from the input station into storage, or retrieving loads from storage and delivering them to the output station. To perform these transactions, the storage/retrieval machine must be capable of horizontal and vertical to align its carriage (which carries the load) with the storage compartment in the storage structure, and it must also pull the load from or push the load into the storage compartment.

The carriage consists of some form of shuttle mechanism to deposit loads into and extract loads from their storage compartments. The carriage and shuttle are positioned and actuated automatically in the usual AS/RS.

To accomplish the desired motions of the S/R machine, three drive systems are required : Horizontal, vertical and shuttle. The horizontal drive is capable of speed up to 500 ft/min along the aisle on modern S/R machines. The vertical or lift speed is limited to 100 ft/min. These speeds determine the time required for the carriage to travel from the P & D station to a particular location in the storage aisle. Acceleration and deceleration of the S/R machine often have a significant effect in determining travel time over shorter distance.

**3)Storage modules :-** The storage modules are the containers of the stored material. Examples of storage modules include pallets, steel wire baskets and containers, tote pans, storage bins, and special drawers (used in miniload AS/RS systems). These modules are generally made to standard base size that can be handled automatically by the carriage shuttle of the S/R machine. The standard size also permits it to be stored in the storage compartments of the AS/RS structure. The storage modules slide into racks in the compartment that permit convenient entry and extraction of the load by the shuttle.

**4)Pickup-and-deposit station :-** The pickup-and-deposit stations are used to transfer to and from the AS/RS/ They are generally located at the end of the aisles for access by the S/R machines and the external handling system that brings and deposit stations may be located at opposite ends of the storage aisle or combined at the same location. This depends on the origination point of the incoming loads and the destination of the output loads. The P & D stations must be designed so that they are compatible with both the S/R machine shuttle and the external handling system. Some of the common methods used to transfer loads out of the AS/RS at the P and D station include manual load/unload, forklift truck, conveyor systems (e.g. roller, cart-on-track, chain), and AGVS.

**Q.16: State the reasons that justify the installation of an automated storage system for work-in-process ?**

**Ans. :** The objectives satisfied by the installation of an automated storage system are :

- i) Increase in the storage capacity.
- ii) Increase in the floor space utilization.
- iii) Recovery of space manufacturing facilities.
- iv) Improvement in security and reduced pilferage.
- v) Reduced labour cost in storage operations.
- vi) Increased labour productivity in storage operations.
- vii) Improved control over /inventories.
- viii) Improved safety in storage functions.
- ix) Improved customer services.
- x) Increased stock rotation.

**Q.17: Explain performs criteria of an automated storage system includes :**

- i)Storage capacity**
- ii)System throughput**
- iii)Utilization**
- iv)Uptime reliability.**

**Ans. :** **i)Storage capacity :-** It is total maximum number of individual loads that are expected to be stored. The capacity of the storage system should be greater than the actual

maximum number of loads that will be held, to provide available empty spaces for materials being centred into the system and to allow for variations in minimum storage requirements.

**ii) Systems throughput :-** It is the number of loads per hour that the storage system can (a) receive and place into storage and (b) retrieve and deliver to the output station. The system should be designated to handle maximum throughput.

**iii) Utilization :-** It is the percent of time that the system is in use as compared to the time it is available for. It is desirable to design storage system for relatively high utilization. If the average utilization runs too high, there tends to be no allowance for rush periods or breakdowns of the system. If average utilization is too low the system needs to be over designed.

**iv) The uptime reliability :** It is percentage of time that the system is capable of operating compared to the normally scheduled time of system operations. Malfunctioning of the equipment both mechanical and electronic cause down time that prevents the system from operating. It is appropriate to design a storage system in such a way that the malfunction of one component or section does not cause entire system to be down.

**Q.18: Define AS/RS and explain for the same :**

- i) S/R machine,
- ii) Storage modules,
- iii) Aisle transfer car.

**Ans. :** For part (i) and (ii) Refer Q.15.

**iii) Aisle transfer cars :** Aisle is the passage between various stations. If the number of loads is quite large and the activity per aisle is relatively low, aisle transfer cars are used to move storage and retrieval machines back and forth between aisles to perform their storage and retrieval functions. The aisle transfer car consists of rigid frame that accepts the storage and retrieval (S/R) machine and moves it between storage aisles. The car rides on a track along the end of the aisles of automatic storage and retrieval system.

**Q.19: What is storage transaction ?**

**Ans. :** System throughput could be defined as the number of loads per hour that the storage system can :

- i) Receive and place into storage.
- ii) Retrieve and deliver to the output station.

These two activities can be done separately or combined into one cycle. The cycles are referred as storage transactions. In many factory and warehouse operations, there will be certain periods of the day when the rate of input/output transactions required of the system will be greater than at other times. The system should be designed to handle the maximum rate.

**Q.20: Sketch and explain any AS/RS system.**

**Ans. :** Unit load AS/RS

This typically a large automated system designed to handle unit loads stored on pallets or other standard containers. The system is computer-controlled and the S/R machines are automated and designed to handle unit load containers.

In this a conveyor is used to move the parts between various workstations. The storage and retrieval machines, also called cranes, are used to accomplish a storage and retrieval machines, also called cranes, are used to accomplish a storage transaction, delivering loads from the conveyor to the output station. The machine moves in the aisle or the passage between the workstations and the loads are usually transferred in form of bulk.

**Q.21.: What do you mean by :**

**i)Full-empty bin detectors**

**ii)Sizing stations**

**iii)Load identification stations ?**

**Ans. :** **i)Full –empty bin detectors :** These are used by the S/R machine carriage to determine the presence or the absence of a load in a given storage compartment. These may be optical or sonar sensors. If load is present, signals are reflected back or otherwise. These devices are useful to avoid attempts to enter a load into a compartment that is already full, or to unload a compartment that is empty.

**ii)Sizing stations :-** It serves to protect the system by assuring that oversized loads are not entered into the AS/RS. Entering of oversized load may cause load to jam or fall to the ground. The sizing station inspects the length, width and height of the load. If any dimension exceeds the maximum allowable size, the load is moved to a siding for special treatment or resizing.

**iii)Load identification stations :-** These are used to enter the proper identification data about the load into the computer system to keep track of the location of the load in AS/RS. It can be manual or automatic. Manual method involves operator reading the identification number and entering them into the system. Whereas an automated identification involves use of scanners of read bar codes on the various loads.

**Q.22: Explain the caroused storage system and its application.**

**Ans. :** **Carousel Storage System. :-** A carousel storage system is a series of bins or baskets fastened to carriers that are connected together and revolve around a long, oval track system. The track system is similar to a trolley conveyor system. Its purpose is to position bins at a load/unload station at the end of the oval. The operation is similar to the powered overhead rack system used by dry cleaners to deliver finished garments to the front of the store.

The typical operation of the storage carousel is mechanized rather than automated. The load/unload station is manned by a human worker, who activates the powered carousel to deliver bin to the station. One or more parts are removed from the bin, and the cycle is repeated.

**Carousel storage applications :-** The carousel storage system provides for a relatively high throughput rate. It is applicable in the following types of applications :

**1.Storage and retrieval operations :-** In certain operations, individual items must be selected from the group of items stored in the bin or basket. Sometimes called “pick and load” operations, this type of procedures is common for order picking of service parts or other items in a wholesale firm, tools in a toolroom, raw materials from a stockroom, and work-in-process in a factory. In small assembly operations such as electronics, carousels are used to accomplish kitting of parts that will be transported to the assembly workstations.



**2.Transport and accumulation :-** These are applications in which the carousel is used to transport and/or sort materials as they are stored. Examples are :

i) Progressive assembly operations, where the workstations are located around the periphery of a continuously moving carousel and the workers have access to the individual storage bins of the carousel. They remove work from the bins to complete their own respective assembly tasks, then place their work into another bin for the next operation at some other workstation.

ii)Sorting and consolidation of items. Each bin is defined for collecting the items of a particular type or customer. When the bin is full, the collected load is removed for shipment or other disposition.

**3.Unique applications :-** These involve specialized used of carousel storage systems. Examples include electrical testing of components, where the carousel is used to store the item during testing for a specified period of time; and drawer or cabinet storage, in which standard drawer-type cabinets are mounted on the carousel.

## UNIT V

# AUTOMATED INSPECTION AND GROUP TECHNOLOGY

**Q.1 : Define Write a short note on automated inspection.  
OR What is the principle of automated inspection ?**

**Ans. :** Automated inspection is defined as the automation of one or more of the steps involved in the inspection procedure. Basically the only way to achieve 100% quality is to use 100% inspection. When inspection and testing are carried out manually, the time consumed is very large and hence the sample size is kept very small as compared to the size of the population. The sample size may only represent 1% or fewer of the number of the parts in high production run, and hence the sample size is kept very small as compared to the size of the population. The sample size is kept very small as compared to the size of the population. The sample size may only represent 1% or fewer of the number of the parts in high production run, and hence there is a risk that defective parts will slip through. Automated inspection and hence only good quality parts are allowed to pass through the inspection procedure.

Automated inspection could be done by automated presentation of parts by an automated handling system with manual actual inspection process e.g., visually detecting any cracks on the surface or by manual loading of parts into an automatic inspection machine or completely automated inspection system in which the parts presentation and inspection both are performed automatically.

**Q.2. : What are the types of automated inspection ? Describe in short about 100% inspection.**

**Ans. :** The types of automated inspection are :

- i) Off-line inspection
- ii) Off-line inspection
- iii) Distributed inspection
- iv) Final inspection.

100% inspection means inspecting each and every part being produced. The basic principle of 100% quality is that the only way to achieve 100% quality is to use 100% inspection. The best way to achieve 100% inspection is by automating the inspections as manual inspection will take a lot of time. The full potential of automated inspection is achieved when it is integrated into the manufacturing process, when a 1000% inspection procedure is adopted, and when the results of the procedure lead to some positive action relative to the process. The positive actions can be of two forms :

i) Feedback data to the preceding manufacturing processes that are responsible for quality characteristics being evaluated in the inspection operation. If the measurement from the automated inspection indicates that the process is beginning to drift towards the higher side of the tolerance, the corrections could be done in input parameters to bring the output back to nominal value.

ii) Sortation of parts as per the quality level, i.e. acceptable or unacceptable quality. The qualities may be acceptable, reworkable and scrap. The sortation procedure may be an integral part of inspection or is performed separately.

- Q.3 : What do you mean by on-line off-line inspection ?**  
**OR Differentiate between the off-line and on-line inspection.**  
**OR Write a short note on**  
**i)Off-line inspection**  
**ii)On-line inspection.**
- Ans. : i)Off-line inspection :-** The three types are illustrated in figure

An off-line inspection is performed away from the manufacturing process, and there is generally a delay between processing and inspection. Most manual inspections fall in this category. Factors that tend to promote the use of off-line inspection includes; when the process capability is well within the specified design tolerance; for high-production runs with short cycle times; under stable processing conditions with relatively small risk of significance assignable variations in the output; and when the cost of inspection is high relative to the cost of a few defective parts. Since it is typically performed manually, off-line inspection is that the parts have already been made by the time any poor quality is detected.

**ii)On-line inspection :-** On-line procedure is done in two ways :  
 a)On-line/In process  
 b)On-line /Post –process.

**a)On-line/In-process inspection :-** This is achieved by performing the inspection procedure during the manufacturing operation. In-process inspection is possible to influence the operation, that is making the current part, thereby correcting a potential quality problem before the part is completed. When on-line /in-process inspection is performed manually, it means that the worker, who is performing the manufacturing process is also performing the inspection procedure. Technologically, automated on-line /in-process inspection is usually difficult and expensive to implement. As an alternative, on-line/post –process procedures are used.

**b)On-line/Post-process inspection:-** This is accomplished immediately following the production process. On-line/post-process inspection can be performed as either a manual or an automated manufacturing process and the results can immediately influence the product in operation.

- Q.4 : Write short notes on**  
**i)Distributed inspection**  
**ii)Final inspection**  
**iii)Sensors for inspection.**

**Ans. : i)Distributed inspection :-** This implies installing several inspection stations along the line of flow of work in a factory placed at critical points in the manufacturing sequence. A distributed inspection system thus identifies any defective product as soon as possible to permit the action to be taken to either correct the process or sort out the defects from the line or both. This inspection prevents further cost from being added to the defective products. This is usually employed for assembled

products which are made of many components and any defect in any component can make the whole assembly suffer.

**ii)Final inspection :-** It implies one comprehensive inspection testing procedure on the product immediately before shipment to the customer. The basic principle behind this approach is that it is more efficient and less expensive from an inspection view-point, to perform all of the inspection tasks at one location rather than distributing them throughout the plant. Final inspection thus logically gives greatest protection against the poor quality.

**iii)Sensors for inspection :-** Sensors are the devices used to detect any physical changes that have occurred. Modern automated inspection procedures are typically carried by sensors. These sensors could be controlled and communicated by digital computers. There are number of sensor technologies available for automated inspection. They are as follows :

**a)Contact inspection methods :-** These involve use of a mechanical probe or other device that makes contact with the object being inspected. These methods are generally concerned with some physical dimensions of the part and are used in mechanical manufacturing industries. The various methods employed in this are :

- 1) Co-ordinate measuring machines (CMM).
- 2) Flexible inspection system.
- 3) Inspection probes.

**b) Non-contact inspection methods:** These methods do not involve direct contact with the product. In this the sensor is located at a certain distance from the object or measure the desired features. These implies lower inspection times and no loss of quality of product due to contact with checking gauge or device. These are:

- 1) Optical inspection methods like machine vision.
- 2)Non-optical inspection methods like electrical field technique, radiation techniques and ultrasonics.

**Q.5 : Describe CMM (Co-ordinate measuring machines).**

**OR Explain the method of controlling and operating a CMM.**

**OR Explain different types of configurations of CMM.**

**Ans. : CMM :-** A coordinate measuring machine (CMM) consists of a contact probe and a means of positioning the probe in three-dimensional space relative to the surface and features of a workpart. The probe is not merely positioned relative to the part; its location can be accurately and precisely recorded to obtain dimensional data concerning the part geometry.

The different types & configuration of CMM for achieving the motion of probe are :

**i)Cantilever construction :-** In the cantilever configuration, the probe is attached to a vertical quill that moves in a z-axis direction relative to a horizontal arm that overhangs the worktable. The quill can also be moved along the length of the arm to achieve y-axis motion, and the arm can be moved relative to the worktable to achieve x-axis motion. The advantages of this construction are the convenient access to the worktable and its relatively small floor space requirements. Its disadvantage is lower rigidity than some of the other CMM construction.

**ii) Bridge construction** :- The bridge configuration is the most common type used in industry. Instead of a cantilevered arm to achieve the y-axis movement of the probe, the arm is supported on both ends like a bridge. This construction provides greater inherent rigidity, and its advocates claim that this makes the bridge construction more accurate than the cantilevered CMM.

**iii) Column construction** : This construction is similar to the construction of a machine tool. Instead of achieving the relative motion exclusively by moving the probe, the column-type CMM obtains x-axis and y-axis relative motion by moving the worktable. The probe quill is moved vertically along a rigid column to obtain the z-axis motion.



