FUNDAMENTALS OF ROBOTICS AND AUTOMATION

UNIT 6

6.1 INTRODUCTION TO INDUSTRIAL ROBOTICS

The primary concern of the manufacturing industries since the early 70s was to find ways to increase productivity and reduce the cost of manufacturing products. Since the early 80s, the major industries are looking for the technologies as Numerical Control (NC) systems, Computer Numerical Control (CNC), Computer-Aided Design (CAD), Computer-Aided Manufacturing (CAM), and Computer Integrated Manufacturing (CIM) to optimize the production in all aspects. CIM utilizes CAD, CAM, CNC, and robots to create work cells that perform a series of operations from the design of the part to its complete creation without the use of human labor. The tasks of selecting a piece of raw material, placing the material in a machine, selecting a machine tool, removing the partially completed part, placing the part in another machine, and eventually placing the finished part in a storage bin are performed by one or more robots. Robots are also well suited for doing heavy, dangerous, and repetitive tasks.

Since the robots replaced human workers, organized labor resisted the move by major companies to incorporate these devices on the assembly lines.

Besides this, the cost of initial stages robots was in the hundreds of thousands of dollars, hence, the large scale industries could justify their need. The decrease in productivity and an increase in labor costs, soon or later, the companies are forced to use robots. With the increase in demand for robots, many companies designed and manufactured an enhanced version of robots on a mass scale, hence the cost of robots were dropped quickly. Robots are useful in industry for a variety the different of reasons, few reasons are listed below.

1. Robots never get sick and don't require rest, also they can work for 24×7.

2. The environments or conditions where the human being can't perform the task, the robots can perform the task.

3. Robots don't get bored for the repetitive nature of work and Robots don't get hurt, rewarding is not a problem for a robot.

Definition of Industrial Robot

"A robot is a reprogrammable, multifunctional machine designed to manipulate materials, parts, tools, or specialized devices, through variable programmed motions to perform a variety of tasks."

Or

"An industrial robot is officially defined by as an automatically controlled, reprogrammable, multipurpose programmable manipulator in three or more axes."

6.1.1 Degrees of freedom (DOF) of Robot

The specific defined modes in which a mechanical device or system can move. The number of degrees of freedom is equal to the total number of independent displacements or aspects of motion.

The term is widely used to define the motion capabilities of robots. Robot arms are described by their degrees of freedom.

This number typically refers to the number of single-axis rotational joints in the arm, where a higher number indicates increased flexibility in positioning a tool. A robot with six degrees of freedom is shown in Figure 6.1.

6.1.2 Classification of Robots

Robots can be classified according to various criteria such as their degrees of freedom, kinematical structure, drive technology, workspace geometry, and motion characteristics.

1. **Classification by Degrees of Freedom :**

   A manipulator should have 6 degrees of freedom (DOF) to manipulate an object freely in three-dimensional spaces. A typical Robot with 6 DOF is shown in Figure 6.1. As per this point of view, a robot may be a :

   a) *General-purpose robot:* The robot which has six degrees of freedom.

   b) *Redundant robot:* The robot which has six degrees of freedom. It provides more freedom to move around obstacles and operate in a tightly confined workspace.

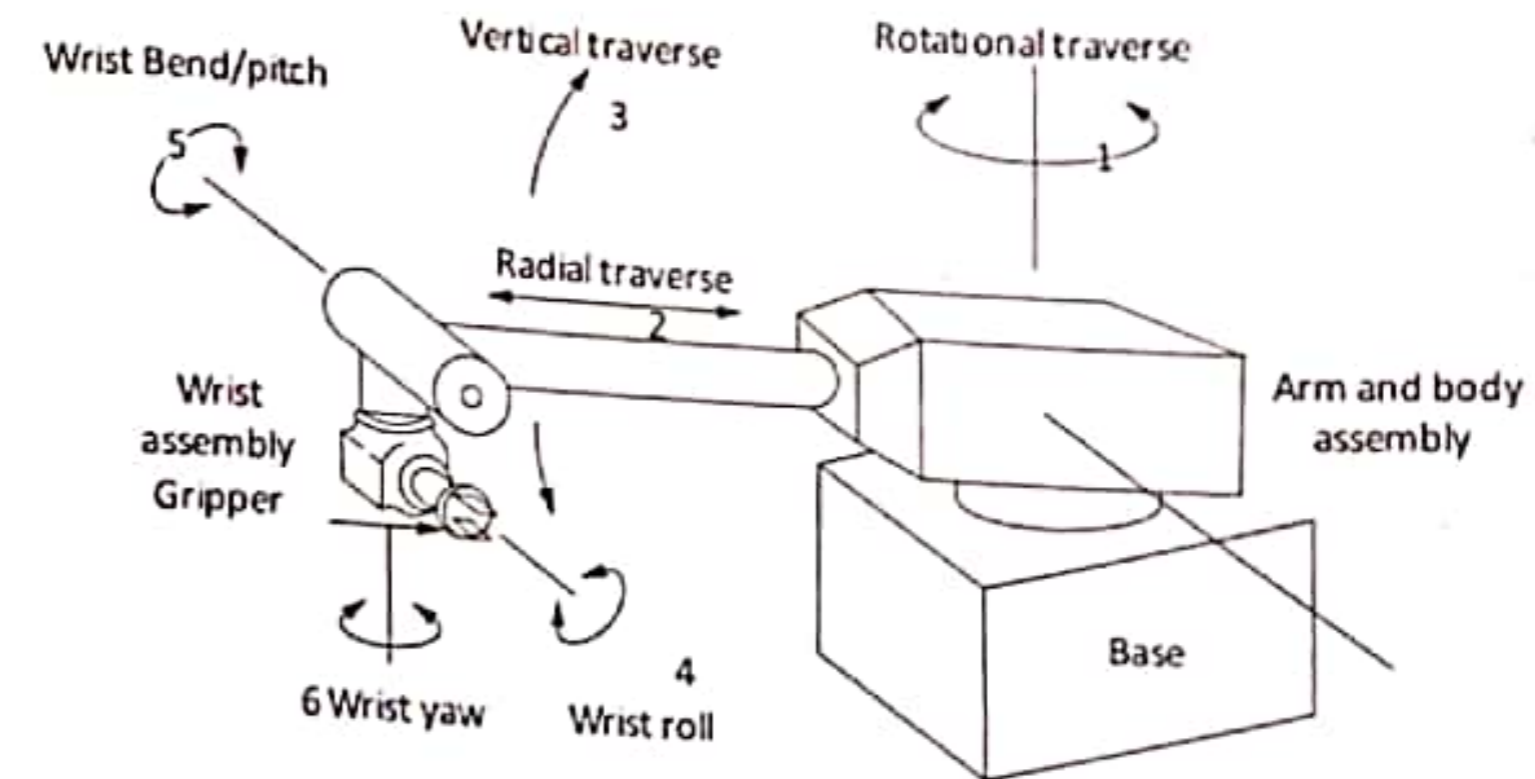   c) *Deficient robot:* The robot which has less than six degrees of freedom.

Figure 6.1 A Robot Showing Six Degrees of Freedom in Robot Motion

2. *Classification by Kinematic Structure :*

   According to kinematic structure robots can be classified as

   a) *Serial Robot or Open- loop Manipulator:* A robot is said to be a serial robot or an open-loop manipulator if its kinematic structure takes the form of an open-loop chain.

   b) *Parallel Manipulator:* In general, a parallel manipulator has the advantages of high stiffness, higher payload capacity, and lower inertia to the manipulation problem than serial manipulator, at the price of a smaller workspace and more complex mechanism.

   c) *Hybrid Manipulator:* If it consists of both open and closed-loop chains. Many industrial robots employ this type of robot construction.

3. *Classification by Drive Technology :*

   Manipulators can also be classified by their drive technology. The three popular drive technologies are

   a) *Electric:* Most manipulators use either electric DC servomotor or stepper motors because relatively easy to control.

   b) *Hydraulic:* Used for high speed and high load carrying capabilities. The major disadvantage associated with this is leakage of oils.

   c) *Pneumatic:* Used for high speed and high load carrying capabilities. The pneumatic drive is clean and fast but it is difficult to control because air is a compressible fluid.

4. **Classification by Workspace Geometry :**

The workspace of a manipulator can be defined as the volume of space that the end-effector can reach. The workspace can be of two types: A reachable workspace is the volume of space within which every point can be reached by the end effector at least one orientation.

a) *Cartesian robot:* In this, the kinematic structure of a robot arm is made of three mutually perpendicular prismatic joints. Three Cartesian co-ordinates associated with the three prismatic joints can conveniently describe the wrist center position of a Cartesian robot (Figure 6.2(a)). The regional workspace of a Cartesian robot is a rectangular box.

b) *Cylindrical Robot:* A robot arm is called a cylindrical robot if either the first or the second joint of a Cartesian robot is replaced by a revolute joint. The wrist center position of a cylindrical robot can be described by a set of the cylindrical coordinate system associated with the three joint variables. Two concentric cylinders of finite length confine the workspace of a cylindrical robot (Figure 6.2(b)).

c) *Spherical Robot:* The spherical has two rotary joints and one prismatic joint, in other words, two rotary axes and one linear axis (Figure 6.2(c)). Spherical robots have an arm that forms a spherical coordinate system. The workspace of a spherical robot is confined by two concentric spheres.

d) *Articulated Robot:* A robot arm is said to be an articulated robot if all three joints are revolute (Figure 6.2(d)). The workspace of an articulated robot is very complex, typically a crescent-shaped cross-section. Puma robot is an articulated robot.

e) *The SCARA (Selective Compliance Assembly Robot Arm) Robot:* It is a special type of robot consisting of two revolute joints followed by a prismatic joint (Figure 6.2(e)). All the three joint axes are parallel to each other and usually point towards the direction of gravity. The wrist has one degree of freedom and hence the entire robot has 4 degrees of freedom. This type of robot is useful for assembling parts on a plane. The classification of robots as per the workspace geometry are shown in Figures 6.2.
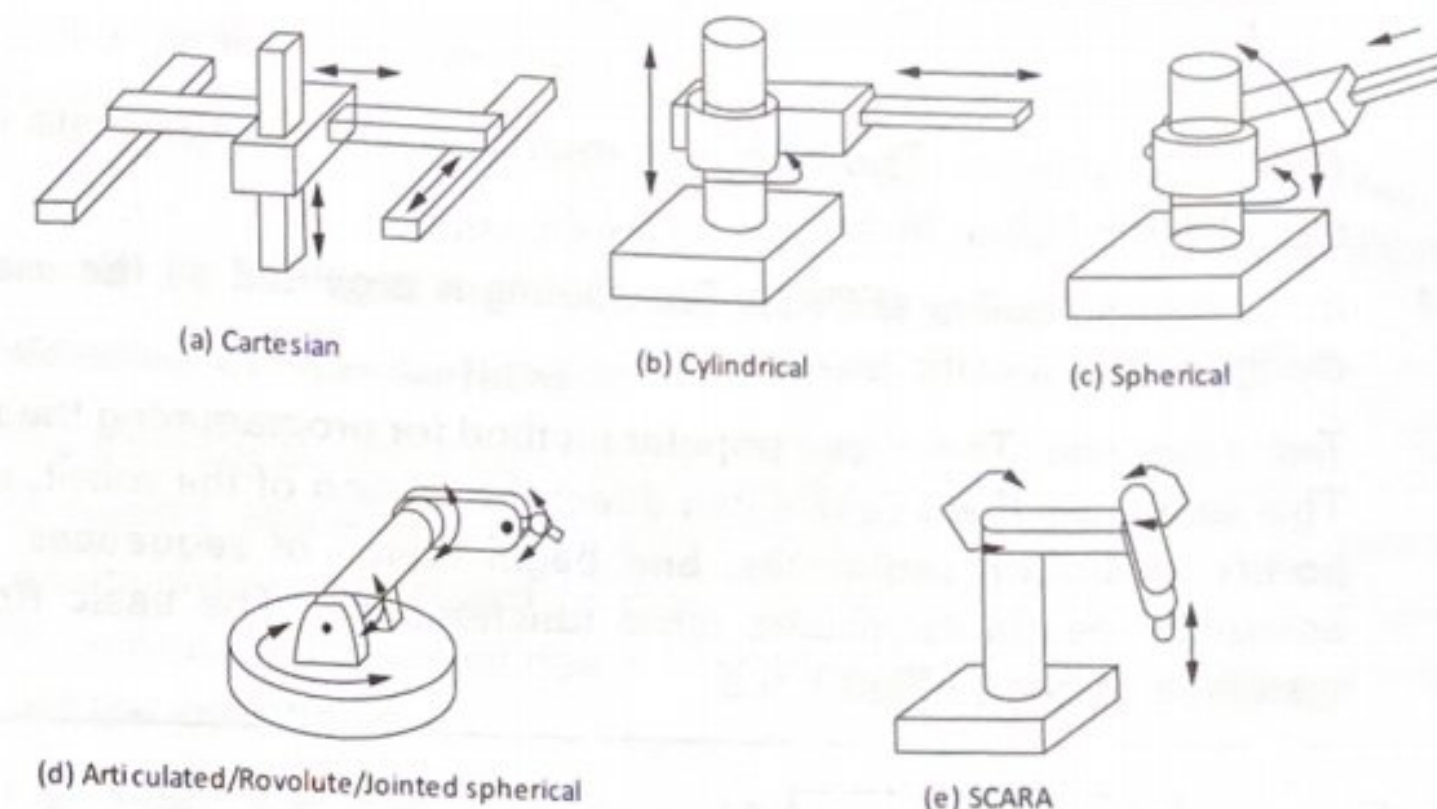
(a) Cartesian   (b) Cylindrical   (c) Spherical

(d) Articulated/Rovolute/Jointed spherical   (e) SCARA

Figure 6.2 Classification of Robots by Workspace Geometry

5. **Classification by Motion Characteristics :**

Robot manipulators can also be classified according to their nature of motion.

a) *Planar:* A manipulator is called a planar manipulator if its mechanism is a planar mechanism. Planar manipulators are useful for manipulating an object on a plane surface.

b) *Spherical:* A rigid body is said to be under a spherical motion if all the particles in the body describe curves that lie on concentric spheres. A mechanism is said to be a spherical mechanism if all the moving links perform spherical motion about a common stationary point.

c) *Spatial Manipulator:* A rigid body is said to perform a spatial motion if its motion cannot be characterized as planar or spherical motion. A manipulator is called a spatial manipulator if at least one of the moving links in the mechanism has a general spatial motion. Planar and spherical mechanisms can be considered as special cases of spatial mechanisms.

6.1.3 Basic Components of a Robotic System

The basic components of a robotic system are shown in Figure 6.3 and briefly illustrated below.

1. *Structure:* The mechanical structure (links, base, etc.). This requires a great deal of mass to provide enough structural rigidity to ensure minimum accuracy under varied payloads.

2. *Actuators:* The motors, cylinders, etc. that drive the robot joints. This might also include mechanisms for transmission, locking, etc.

3. *Control Computer:* This computer interfaces with the user, and in turn controls the robot joints.

4. *End of Arm Tooling (EOAT):* The tooling is provided by the user and designed for specific tasks.

5. *Teach pendant:* This is one popular method for programming the robot. This small handheld device can direct the motion of the robot, record points in motion sequences, and begin replay of sequences. More advanced pendants include more functionality. The basic Robotic system is shown in Figure 6.3.
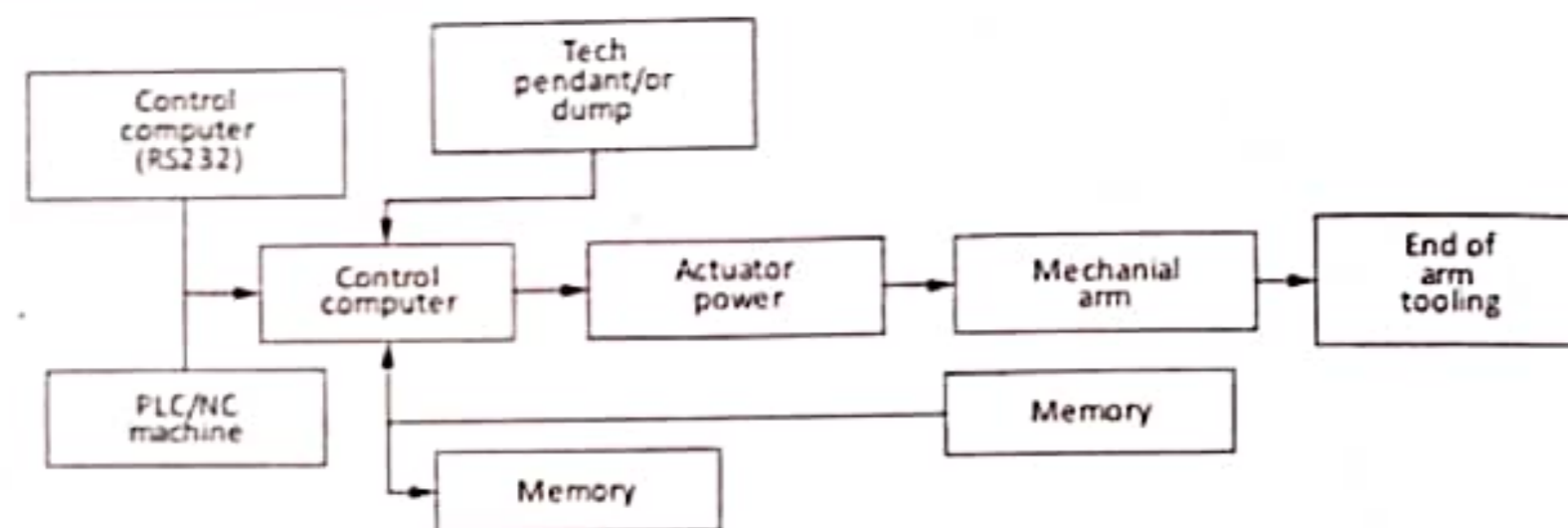

Figure 6.3 Basic Components of Robotic System
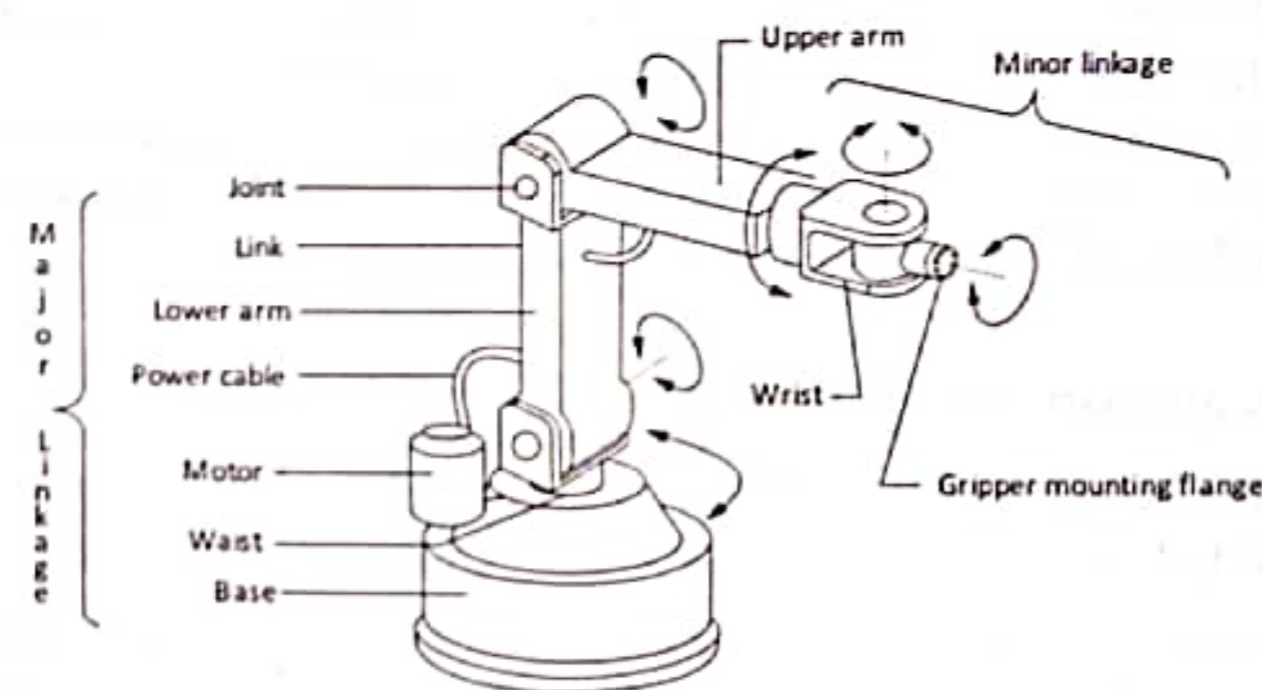
6.1.4 Manipulator

Figure 6.4 Typical Robotic Manipulator with Links and Joints

A robot manipulator is an electronically controlled mechanism, consisting of multiple segments, that performs tasks by interacting with its environment. They are also commonly referred as robotic arms. The manipulator consists of a series of rigid members, called links, and are connected at joints (Figure 6.4). Its primary function is to provide the specific motion that will enable the tooling at the end to do the required work.

Working of Manipulator :

The actuator accomplishes the motion of joints. The manipulator bends, slides, or rotates about the joints which is referred as degrees of freedom. The manipulator is composed of three divisions. The first one is major linkages (Positioning), the second one is minor linkages (wrist components-orientation), and the end effector.

The minor linkages (wrist Assembly-orientation) are for wrist movements, which are designed to orient the end-effector properly. Normally wrist is provided with 3 Degrees of Freedom (DOF), wrist movements suchas Wrist roll, Wrist pitch, Wrist Yaw can be observed in Figure 6.4.

6.1.5 End-Effector

In robotics, the end effector is a device at the end of a robotic arm and designed to interact with the environment. The exact nature of this device depends on the application of the robot.

The end- effector is mounted on the wrist which enables the robot to perform specified tasks. Various types of end-effectors are designed for the same robot to make it more flexible and versatile. The End-effectors are categorized into two major types, those are grippers and tools.

Grippers

Grippers are generally used to grasp and hold an object and placed at the desired location.

1. *Mechanical Grippers:* Mechanical gripper is an end-effector that uses a mechanical finger or clamp actuated mechanically to grasp objects to make contact with the object. These are again inside and outside grippers to hold the solid and hollow type of objects (Figure 6.5 (a)).

2. *Vacuum Grippers:* In this type of grippers, the suction cups are used to create a vacuum to hold/adhere the objects to the grippers (Figure 6.5 (b)).

3. *Magnetic grippers*: The magnetic grippers are used for handling ferrous materials. The magnetic grippers employ the effect of the magnetic field to contact with ferrous metal (Figure 6.5 (c)). There are two types of magnetic grippers, first one is Electromagnetic and the second one is a permanent magnetic type.

4. *Special purpose*: The other type of grippers employed in robotic material handling applications includes:

   a) *Adhesive Grippers*: An adhesive substance (say sticky tape) performs the grasping actions. These grippers can be used to handle fabrics and other lightweight materials.
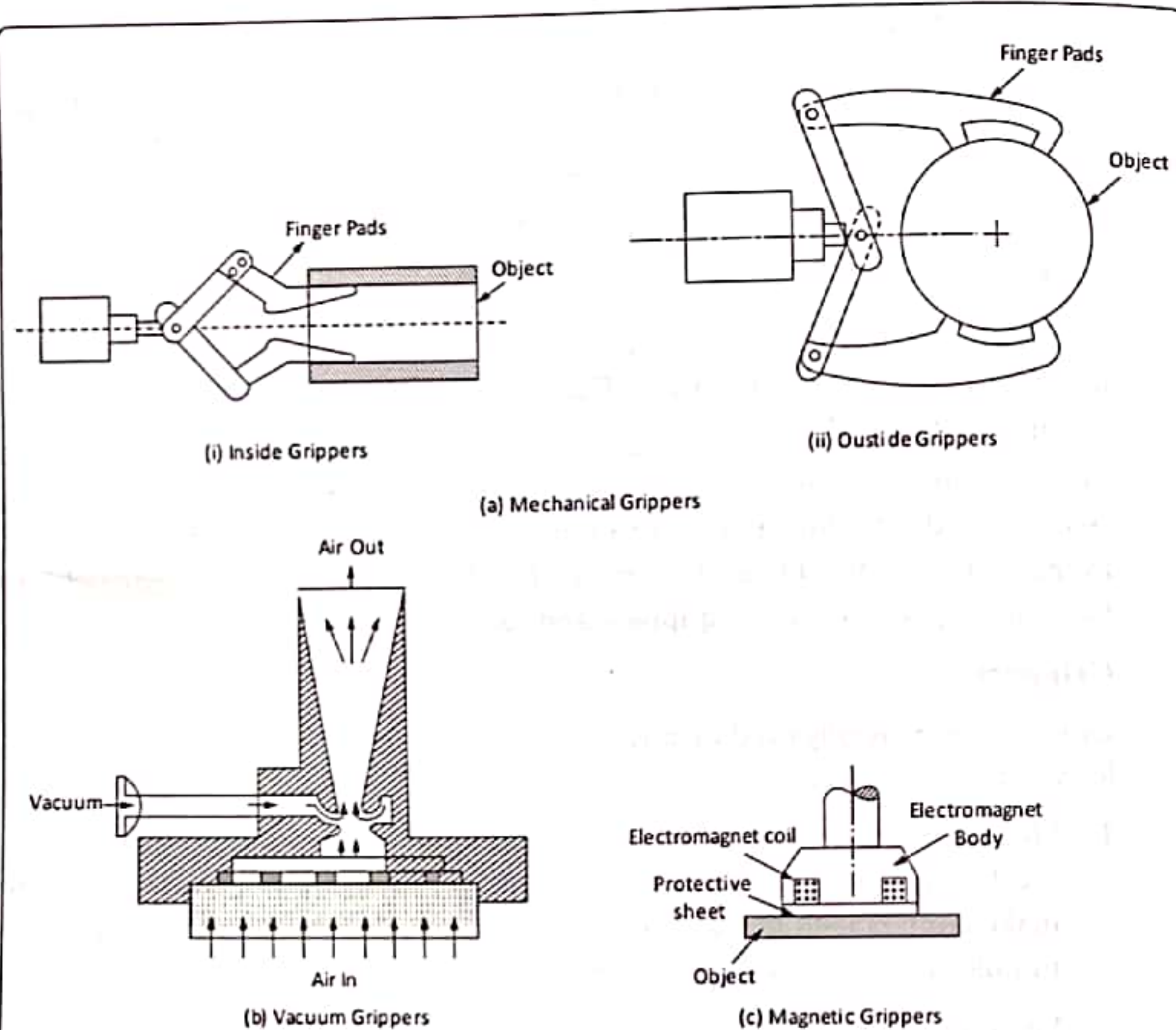

(i) Inside Grippers   (ii) Ouside Grippers

(a) Mechanical Grippers

(b) Vacuum Grippers   (c) Magnetic Grippers

Figure 6.5 Different Types of Robot Grippers

b) *Piercing Grippers*: The component to be handled is pierced; this type is used where a slightly damaged component is accepted.

c) *Hooks scoops & ladles and other miscellaneous devices*: Hooks can be used as end-effector to handle containers of parts and to load and unload parts from the conveyers.

- *Scoops type* are used for handling liquids type of materials (chemicals and molten metals) or powder type (food materials and granular form)

- *Other type* grippers include inflatable devices, in which an inflatable bladder or diaphragm is expanded to grasp the object.

Tools

The robots are required to manipulate a tool to operate on a workpiece. In such applications, the end- effecter is a tool itself, few of the tools are listed below.

1. spot-welding tools.
2. arc-welding tools.
3. spray-painting nozzles.
4. rotating spindles for drilling.
5. rotating spindles for grinding.

6.1.6 Applications of Industrial Robots

Robots are used in a wide range of industrial applications. The earliest applications were in materials handling, spot welding, and spray painting. Robots were initially applied to jobs which were hot, heavy, and hazardous such as die-casting, forging, and spot welding.

Few of the applications of the Robots are listed below.

1. Welding Applications.
2. Spray Painting Applications.
3. Assembly Operations.
4. Palletizing and Material Handling.
5. Dispensing Operations.
6. Laboratory Applications.
7. Water Jet Cutting.
8. Work Cell.

Disadvantages of Robots

1. Unemployment (major problem).
2. Economic problem (salary).
3. Dissatisfaction and anger among workers.
4. Lack of capability to respond in emergencies.
5. Lack of decision making power.
6. Limitations (DOFs, Skill, sensors, real-time response, etc.).
7. High initial cost.
8. Need for peripherals, training, and programming.

6.1.7 Role of Robots in CIMS

The role or objective of introducing Robotics in CIM is to remove all the barriers between the following functions performed in the industry is to

1. Encourage marketing
2. Order entry
3. Accounting
4. Design
5. Manufacturing
6. Quality control
7. Shipping and all the other departments to work closely together throughout the process.

6.2 AUTOMATED GUIDED VEHICLES (AGVs)

Automated Guided Vehicles (AGVs) are vehicles that are equipped with automatic guidance systems and are capable of following prescribed paths. Unlike traditional robots, AGVs are not manipulators, they are driverless vehicles that are programmed to follow a guided path. In automated factories and facilities, AGVs move pallets and containers. In offices, they may be used to deliver and pick up the mail. They are even used to transport patrons around in airports. The main benefit of AGVs is that they reduce labor costs. However, in material handling facilities there is another benefit. Material handling has always been dangerous. Injuries may occur due to lack of driver attention, fast driving or personnel not paying attention. Obstacle

detection is therefore a key to allow AGVs to interact with personnel safely while optimizing vehicle speeds. An Automated Guided Vehicle installation consists of several building blocks that together form the complete system. A simple AGV system is shown in Figure 6.6.
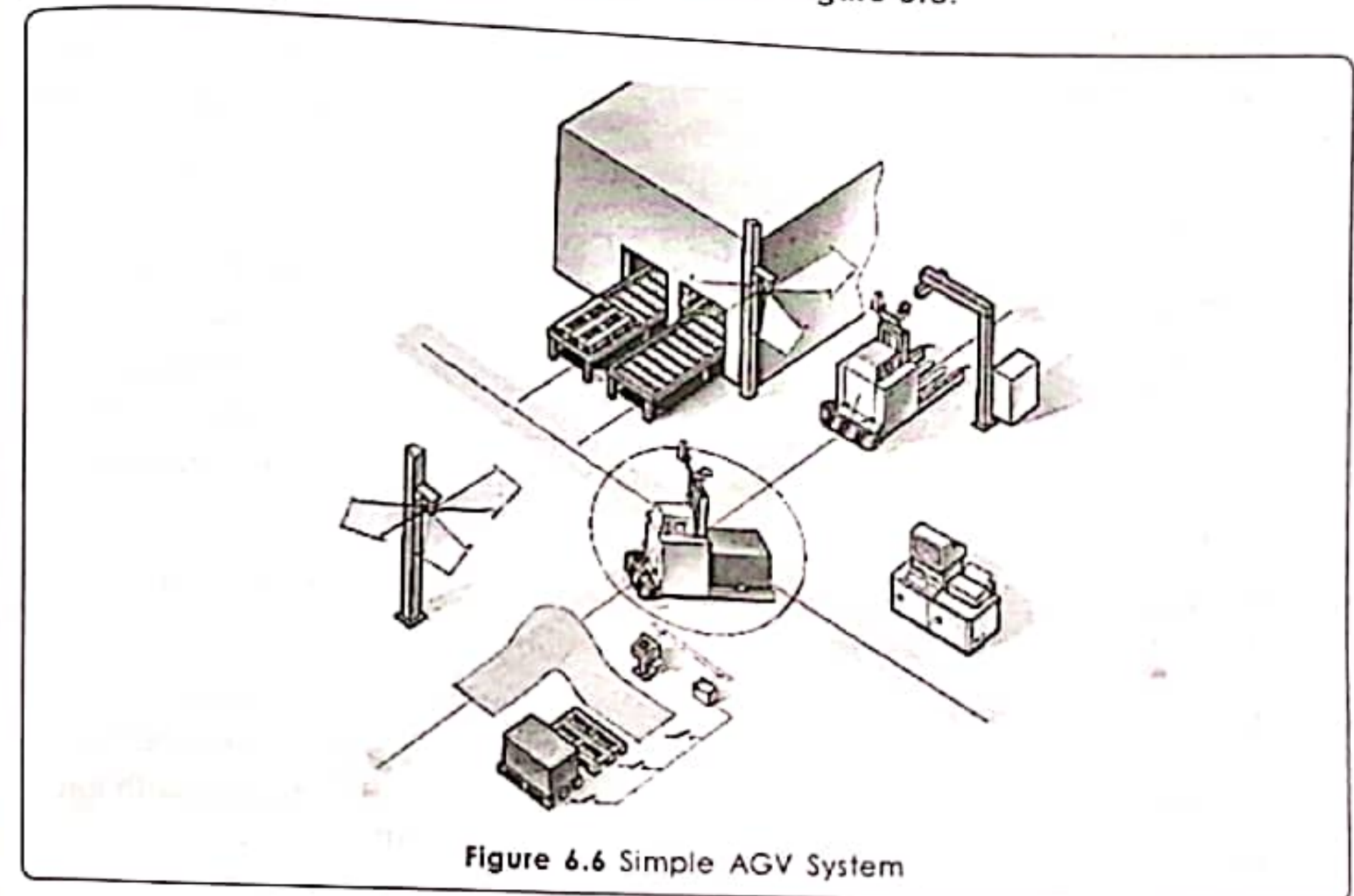

Figure 6.6 Simple AGV System

6.2.1 Components of AGV System

Components of the AGV system are listed and illustrated below.

1. **The Vehicle** of AGV can take many forms :

   a) *Traction Motor(s) to provide movement.*

   b) *Traction batteries to provide power:* Battery technology is developing quickly. Different battery types provide different cost/benefits and performance cycles. Batteries may be Lead-Gel, wet NiCd, or one of the various forms of Lithium. E.g. LiFePo4 (Lithium Iron Phosphate), is one of the new battery types suitable for AGVs.

   c) *Industrial PC or Onboard controller:* This device receives the instructions from the central control processor and manages the on-board systems of the AGV.

   d) *Payload interface:* This may be a fork, platform, and conveyor which lifts the deck and may be configured to engage with external devices and systems.

2. **Safety Systems :** All AGVs include appropriate safety systems to ensure that hazards are avoided, and collisions with people and surroundings are eliminated. Safety systems may be in contact with bumpers and/or contactless sensors and scanners.

3. **Battery Charging System :** On-board batteries require charging, charging systems may be designed to charge the batteries on-board. The AGV will come to the charging point whenever necessary for charging. This also involves either automatic or manual battery exchange for applications where true 24/7 operation is required.

4. **Communication System :** The fixed infrastructure of the AGV installation will communicate over a physical network. The main controller communicates with peripheral devices via Ethernet. The peripheral devices may communicate with other devices using common protocols such as Modbus, CAN, and OPC. Some devices communicate via digital I/O. The vehicles will usually communicate with the control system using WiFi.

5. **Navigation System :** The vehicles require a navigation system that provides the ability for the vehicle to identify its position.

6. **Traffic Management System :** The central controller provides the traffic management system that organizes and controls the movement of the AGVs around the area of operation. The system ensures that AGVs interact with each other to avoid collisions and blockages, and interfaces with external components such as lifts, doors, conveyor systems, and other devices.

7. **Job Control System :** The central control system not only organizes the movement of the AGVs around the facility, but it must also collect the job initiation commands and manage the uplift and discharge of the payloads by the AGV system. The process of matching the job requests to the route may be initiated manually through (e.g. a touch-screen or bar-code scanner or may be generated automatically via interface to a WMS/ERP system).

8. **External Components :** Many AGV installations engage with external components such as buffer conveyors which aid the overall process. The interfaces receive and generate the appropriate commands for the AGV control system.

6.2.2 Types of AGVs

There are three basic types of AGVs listed below

1. Driverless Trains   2. Pallet Trucks   3. Unit Load Carrier.

1. **Driverless Trains :** It consists of a towing vehicle that pulls one or more trailers to form a train. This type is applicable in moving heavy payloads over large distances in warehouses or factories with or without an intermediate pickup and drop off points along the route. It consists of 5-10 trailers.

2. **Pallet Trucks :** Pallet trucks are used to loading and unloading along predetermined routes. The capacity of an AGV pallet truck ranges up to several thousand kilograms and some are capable of handling two pallets.

3. **Unit Load Carrier :** These are used to move unit loads from one station to another. It is also used for automatic loading and unloading of pallets using rollers. Load capacity ranges up to 250 kg or less and these vehicles are designed to move small loads. The Driver less, Pallet trucks, and Unit load carrier AGVs are shown in Figure 6.7 (a), (b), and (c) respectively.
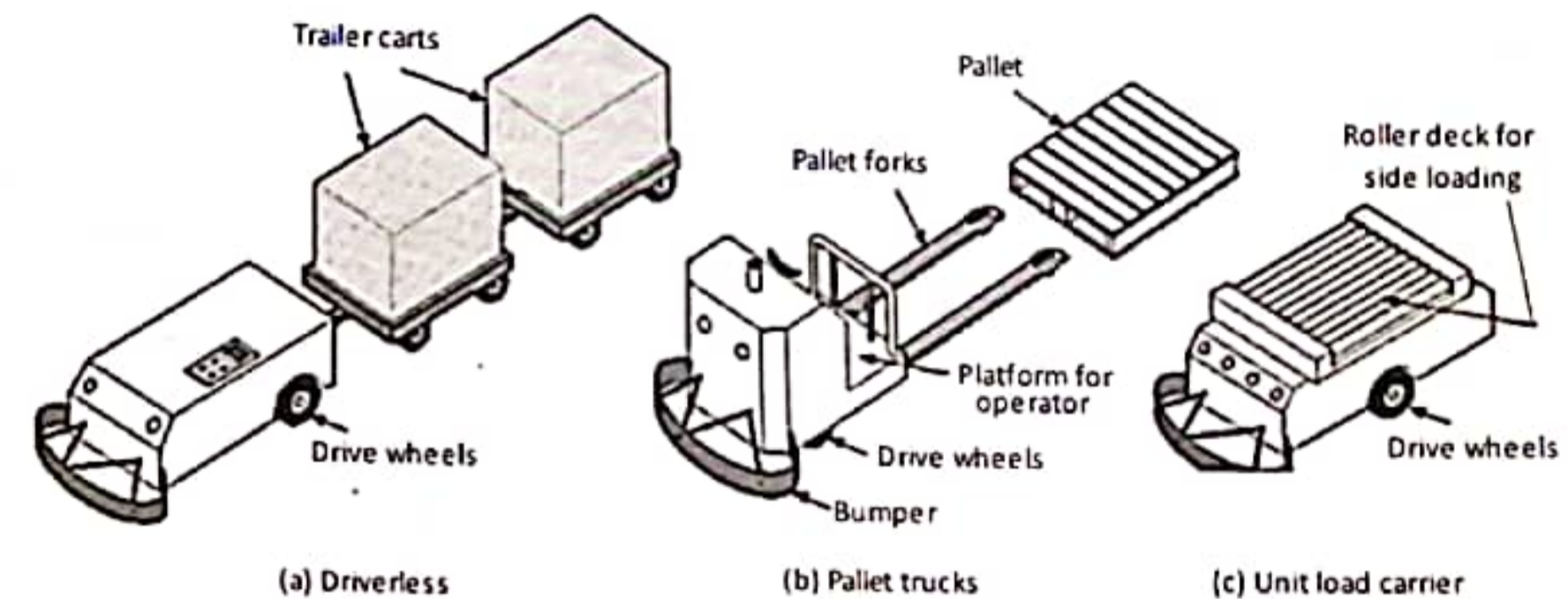

Figure 6.7 Types of AGVs

6.3 AUTOMATED STORAGE AND RETRIEVAL SYSTEMS (ASRS)

In a large manufacturing industry, the volume of items and components are so large that it becomes extremely unreliable and time consuming to use manual storage and retrieval system. Therefore, in such cases, it is advisable to use the automated storage and retrieval system.

An automated storage and retrieval system (ASRS) can be defined as a storage system under which a defined degree of automation is to be implemented to ensure precision accuracy and speed in performing storage and retrieval operations. This automated storage and mechanized systems eliminate human intervention in performing basic sets of operations.

6.3.1 Objectives of ASRS

1. Increasing the storage capacity.

2. Increasing the stock rotation.

3. Utilization of maximum floor space.

4. Recovering the space for manufacturing facilities.

5. Customer service to be improved.

6. Control over inventories to be improved.

7. Ensuring safety in storage function.

8. Increasing the labor productivity in storage function.

9. Reducing labor cost in the storage operation.

10. Reducing pilferage and improving security.

An ASRS consists of one or more storage aisles that are serviced by a storage and retrieval (SR) machine. The stored materials are held by storage racks of aisles. The SR machines are used to deliver and retrieve materials in and out of inventory.
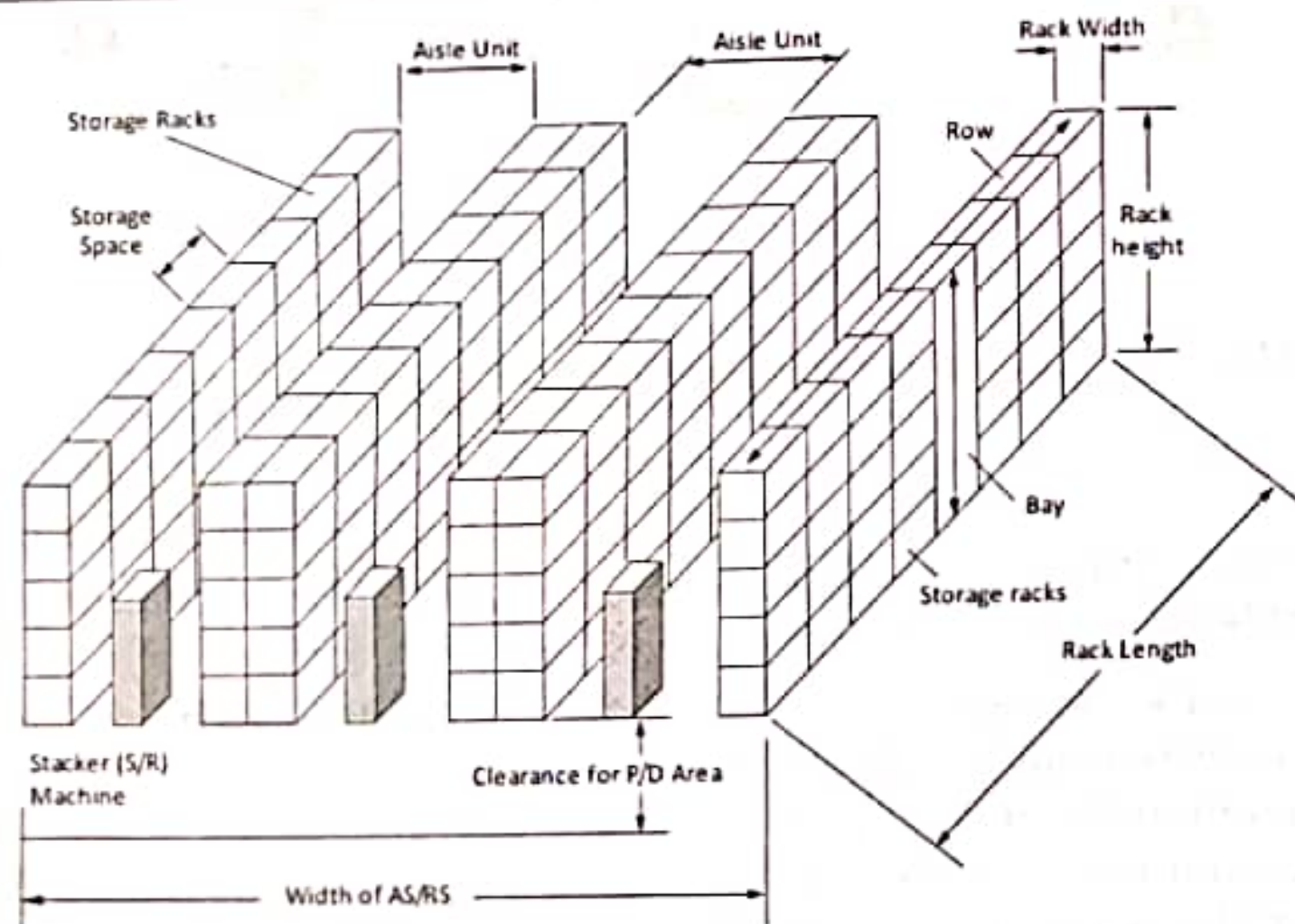

Figure 6.8 Simple AS/RS System with the Terms Used

There are one or more input and output stations in each ASRS aisle for delivering the material into the storage system or moving it out of the system. In ASRS terminology, the input and output stations are called pickup-and-deposit (P&D) stations. The Figure 6.8 shows a simple ASRS system with the terms used.

6.3.2 ASRS Components

1. Storage Racks or Storage Structure.
2. Transport Devices (AGV, Conveyor, etc).
3. Pick-Up and Delivery (P and D) Stations.
4. Storage and Retrieval Machines (Stacker Crane).
5. Computer Control System.

1. **Storage Racks or Storage Structure :** The automated storage and retrieval system contains several rows of storage racks for storing the material or items. The storage structure of the automated storage and retrieval system is much taller (can be as tall as 30 meters) than that of the conventional storage and retrieval systems.

2. **Transport Devices (AGV, Conveyor, etc.) :** The storage structure, where the material or items are storedis linked to the shop floor by transport devices such as automated guided vehicles or conveyors. The incoming material/items are first sorted and loaded to pallets. The loaded pallets are then passed through weighing and sizing stations to ensure that they are within the load and size limits.

3. **Pick-Up and Delivery (P and D) Stations :** The input and output stations are called pick-up and delivery (P and D) stations. The automated guided vehicles transport the pallets or conveyors received at P and D. The details of the pallet contents are communicated to the central computer. The central computer assigns the storage location in storage racks to the pallet.

4. **Storage and Retrieval Machine (Stacker Crane) :** The pallet is moved from P and D station to the storage rack by storage and retrieval cranes. Whenever there is a request for the item to the central computer, the computer searches its memory for the storage location and directs the stacker crane to retrieve the pallet. An SR machine is capable of both horizontal and vertical movement. A rail system along the floor guides the machine and a parallel rail at the top (up to 30m) of the storage structure is maintained for alignment.

5. **Computer Control System :** The computer control unit performs two functions in ASRS, the first one is to control the operation of the system and the second one is to store the material movement and inventory data.

6.3.3 Advantages of ASRS

An effective automated storage and retrieval system provides several benefits.

1. An efficient ASRS system helps companies cut expenses by minimizing the number of unnecessary parts and products in storage and improving the organization of the contents of a warehouse. Due to automated processes, it also allows for more storage space due to high-density storage, narrower aisles, etc.

2. Automation reduces labor costs while lowering workforce requirements and increasing safety.

3. Modelling and managing the logical representation of the physical storage facilities (e.g. racking, etc.). For example, if certain products are often sold together or more popular than others, those products can be grouped or placed near the delivery area to speed up the process of picking, packing, and shipping to customers.

4. Enabling seamless links to order processing and logistics management to pick, pack, and ship the product out of the facility.

5. Tracking the product information where those were stocked, the supplier information, and the time duration of storage. By analyzing such data, companies can control inventory levels and maximize the use of warehouse space. Furthermore, firms should be more prepared to meet the market demands and supplies of the market, especially during special circumstances such as a peak season on a particular month. Through the reports generated by an ASRS system, the firms are also able to gather important data for the analysis.

SUMMARY

1. **Definition of Industrial Robot:** A robot is a reprogrammable, multifunctional machine designed to manipulate materials, parts, tools, or specialized devices, through variable programmed motions for the performance of a variety of tasks.

2. **Degrees of freedom,** in a mechanics context, are specific, defined modes in which a mechanical device or system can move. The number of degrees of freedom is equal to the total number of independent displacements or aspects of motion.

3. Robots can be classified according to various criteria such as their degrees of freedom, kinematical structure, drive technology, work-shop geometry, and motion characteristics.

4. **Basic Components of a Robotic System:** Structure, Actuators, Control Computer, End of Arm Tooling (EOAT), Teach pendant.

5. A robot manipulator is an electronically controlled mechanism, consisting of multiple segments, that performs tasks by interacting with its environment.

6. In robotics, an end effector is a device at the end of a robotic arm, designed to interact

7. with the environment. The exact nature of this device depends on the application of the robot.

8. **Grippers:** Grippers are generally used to grasp and hold an object and place it at the desired location. These are Mechanical, Vacuum, Magnetic, Special purpose grippers.

9. **Automated Guided Vehicles (AGVs):** Automated Guided Vehicles (AGVs) are vehicles that are equipped with automatic guidance systems and are capable of following prescribed paths. Unlike traditional robots, AGVs are not manipulators, they are driverless vehicles that are programmed to follow a guide path.

10. **Types of AGVs:** There are three basic types of AGVs i) Driverless Trains ii) Pallet Trucks iii) Unit Load Carrier

11. **Automated Storage and Retrieval Systems (AS/RS):** An AS/RS can be defined as a storage system under which a defined degree of automation is to be implemented to ensure precision accuracy and speed in performing storage and retrieval operations.

EXERCISE

PART - A Questions

(1 Mark)

1. Define robot.
2. State any one reason for the robot.
3. List any two types of robots based on drive technology.
4. What is the full form of SCARA Robot?
5. What is an articulated robot?
6. What is the full form of the DOF?
7. Mention the workspace geometry of the cartesian robot.
8. State the kinematic structure of the cartesian robot.
9. Mention the workspace geometry of the cylindrical robot.
10. State the kinematic structure of the cylindrical robot.
11. How do you convert the cartesian robot to a cylindrical robot?
12. Mention the workspace geometry of the Spherical robot.
13. State the kinematic structure of the spherical robot.
14. How do you convert the cartesian robot to a spherical robot?
15. State the kinematic structure of the articulated robot.
16. Mention the workspace geometry of a cartesian robot.
17. List any two basic components of a Robot.
18. What EOAT stands for?
19. List any two types of grippers used for a Robot.
20. Mention any two special-purpose grippers used for a Robot.
21. Mention the use of the actuator of a Robot.
22. Write the function of the actuator in Robots.
23. What is the robot control unit?
24. Write the function of the manipulator of a Robot.
25. Write the function of the end-effector of a Robot.

26. What is End of arm tooling in Robots?
27. What is the Teach pendant of a Robot?
28. Write any two roles of the robot in Robot?
29. What is a special-purpose robot?
30. List any two special-purpose robots.
31. What AGV stands for?
32. Write the use of AGVs.
33. List any two types of AGVs.
34. What ASRS stands for?
35. Write the function of ASRS.
36. List any two components of ASRS.
37. Write the use of pallets used along with AGVs.

PART - B Questions

(3 Marks)

1. Mention any three disadvantages of the use of Robots in industry.
2. List any three criteria for classifying robots.
3. What is 'degrees of freedom' of Robots?
4. Write the various elements of a robot.
5. List any three roles of Robots in CIMS
6. Classify the Robots as per the Degrees of Freedom.
7. Classify the Robots as per Drive Technology.
8. Classify the Robots as per Motion Characteristics.
9. Draw a simple figure of Cartesian workspace geometry Robot.
10. Draw a simple figure of Cylindrical workspace geometry Robot.
11. Draw a simple figure of a Spherical workspace geometry Robot.
12. Draw a simple figure of Articulated workspace geometry Robot.
13. Briefly explain the Robot manipulator.
14. List the various components of a robot.
15. Draw a neat sketch of the Vacuum grippers of a Robot.

16. Draw a neat sketch of the magnetic grippers of a Robot.

17. Write a short note on the end effector of a robot.

18. List the types of AGVs.

19. What do you understand about the ASRS system?

20. What is the use of Pallet Trucks in ASRS?

PART - C Questions   (5 Marks)

1.   Briefly explain the components of the AGV System.

2.   List the objectives of the ASRS system.

3.   Briefly explain the components of the ASRS system.

4.   Write a short note on Pick-Up and Delivery (P and D) Stations of ASRS.

5.   Write the advantages of the ASRS system.

6.   Classify the Robots as per the Workspace Geometry.

7.   Draw a neat sketch of a Robot showing Six Degrees of freedom in motion.

8.   Briefly illustrate the basic components of Robots.

9.   List any five applications of the Robots in industry.

10. List any five limitations of the Robots in the industry.