ROBOTIC TECHNOLOGY

Definition of a Robot

• "A reprogrammable, multifunctional manipulator designed to move material, parts, tools, or specialized devices through various programmed motions for the performance of a variety of tasks" .

Or a simpler version

• *An automatic device that performs functions normally ascribed to humans or a machine in the form of a human.*

Need of Industrial Robots

• Repetitive tasks that robots can do 24/7.

• Robots never get sick or need time off.

• Robots can do tasks considered too dangerous for humans.

• Robots can operate equipment to much higher precision than humans.

• May be cheaper over the long term

• May be able to perform tasks that are impossible for humans

Robots are also used for the following tasks:

• Dirty Tasks

• Repetitive tasks

• Dangerous tasks

• Impossible tasks

• Robots assisting the handicapped.

First, they are hardworking and reliable. They can do dangerous work or work that is very boring or tiring for humans. They can work around the clock without complaining and without needing rest, food or vacations. And robots can go places that humans cannot, such as the surface of Mars, deep under the ocean or inside the radioactive parts of a nuclear power plant.

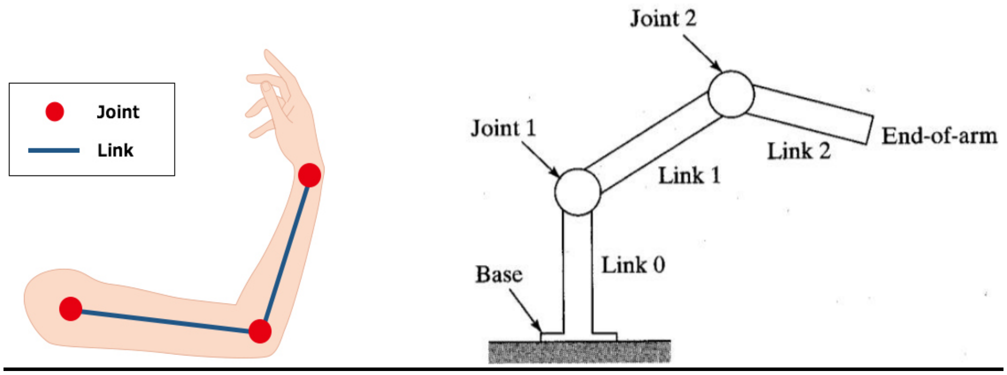
Asimov's Laws of Robotics (1942)

1st law: A robot may not injure a human being, or, through inaction, allow a human being to come to harm

2nd Law: A robot must obey orders given it by human beings, except where such orders would conflict with the First Law.

3rd Law: A robot must protect its own existence as long as such protection does not conflict with the First or Second Law.

ROBOT ANATOMY



Main Components of Industrial Robots:

- Arm or Manipulator
- End effectors
- Drive Mechanism
- Controller
- Custom features: e.g. sensors and transducers

Manipulator consists of joints and links

- Joints provide relative motion
- Links are rigid members between joints
- Various joint types: linear and rotary
- Each joint provides a “degree-of-freedom”
- Body-and-arm – for positioning of objects in the robot's work volume
- Wrist assembly – for orientation of objects

TYPES OF LINKS USED IN ROBOTS:

“A **link** is defined as a single part which can be a **resistant body** or a combination of **resistant bodies** having inflexible connections and having a relative motion with respect to other parts of the machine.

A link is also known as a kinematic link or element.
A **resistant body** is one which does not go under deformation while transmitting the force.”

There are different division of link in robot.

1. **Rigid link**: In this type of link, there will not be any deformation while transmitting the motion. For example, the industrial robotic arm is having rigid links, there will not be any deformation while moving the arm.
2. **Flexible link**: In this type of link, there will be a partial deformation while transmitting the motion. One of the examples of flexible links is belt drives.

3. **Fluid link**: In this type of link, motion is transmitted with the help of fluid pressure. Hydraulic actuators, brakes are an example of a fluid link.

A robot link will be mostly in the form of *solid material*, and it can be classified into two key types :

- *input link* and
- *Output link*.

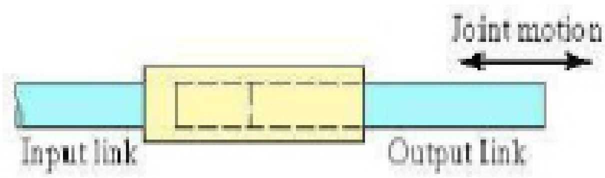
The movement of the input link allows the output link to move at various motions. An input link will be located nearer to the base.

Types of joints used in robots

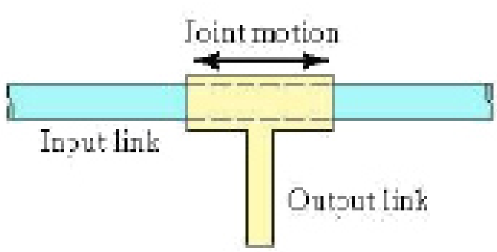
The Robot Joints is the important element in a robot which helps the links to travel in different kind of movements. There are five major types of joints such as:

PRISMATIC JOINTS:

1. **Linear Joint:** Linear joint can be indicated by the letter L –Joint. This type of joints can perform both translational and sliding movements. These motions will be attained by several ways such as telescoping mechanism and piston. The two links should be in parallel axes for achieving the linear movement.

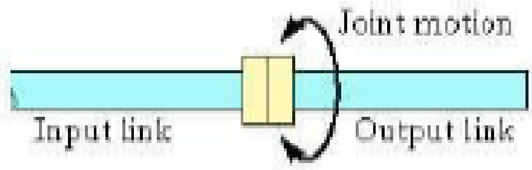


2. **Orthogonal Joint:**The O –joint is a symbol that is denoted for the orthogonal joint. This joint is somewhat similar to the linear joint. The only difference is that the output and input links will be moving at the right angles.

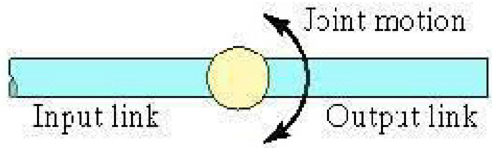


REVOLUTE JOINT:

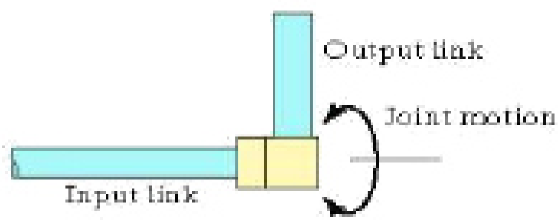
1. **Twisting Joint:** Twisting joint will be referred as V –Joint. This joint makes *twisting motion* among the output and input link. During this process, the output link axis will be vertical to the rotational axis. The output link rotates in relation to the input link.



2. **Rotational Joint:** Rotational joint can also be represented as R –Joint. This type will allow the joints to move in a rotary motion along the axis, which is vertical to the arm axes.

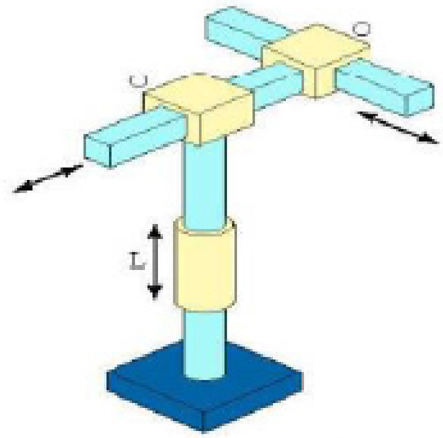


3. **Revolving Joint:**Revolving joint is generally known as V –Joint. Here, the output link axis is perpendicular to the rotational axis, and the input link is parallel to the rotational axes. As like twisting joint, the output link spins about the input link.

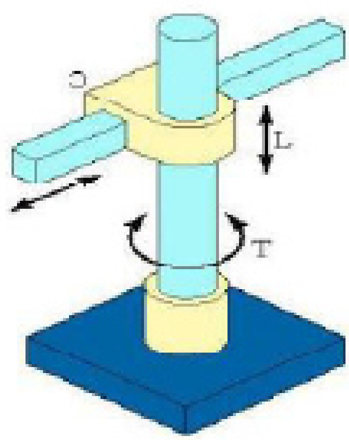


COMMON ROBOT CONFIGURATIONS:

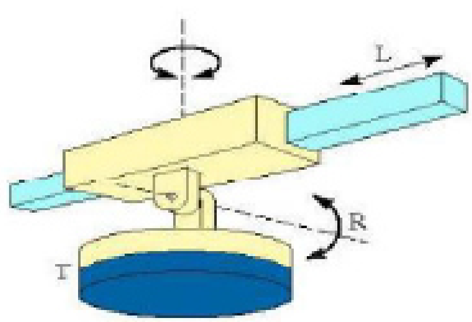
Cartesian coordinate Body-and-Arm Assembly: Consists of three sliding joints, two of which are orthogonal other names include rectilinear robot and x-y-z robot Notation LOO:



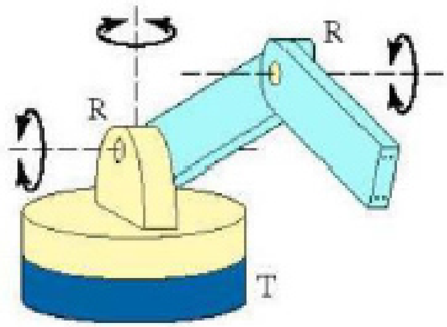
Cylindrical Body-and-Arm Assembly: Consists of a vertical column, relative to which an arm assembly is moved up or down. The arm can be moved in or out relative to the column Notation TLO:



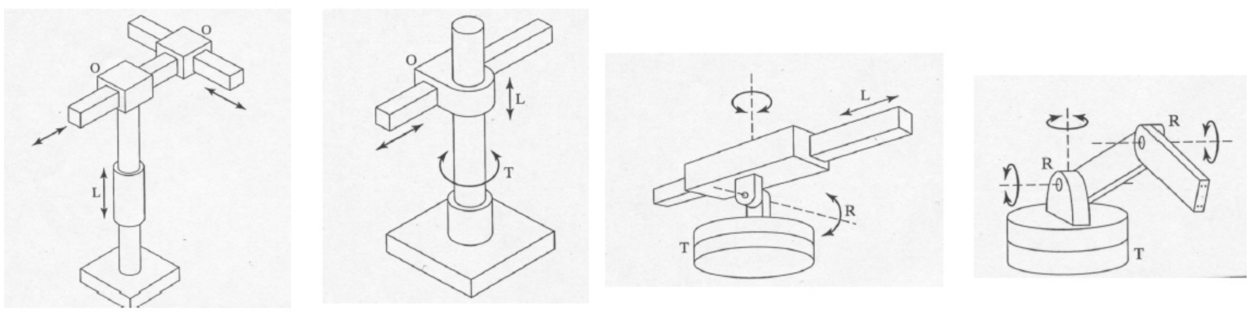
Polar Coordinate Body-and-Arm Assembly: Consists of a sliding arm (L joint) actuated relative to the body, which can rotate about both a vertical axis (T joint) and horizontal axis (R joint) Notation TRL:



Jointed-Arm Robot: Similar in appearance to human arm Rotated base, shoulder joint, elbow joint, wrist joint. Notation TRR:



Comparison of Arm Configurations



WORK VOLUME:

Work volume of a robot: Work volume is the term that refers to the space within which the robot can manipulate its wrist end. The convention of using the wrist end to define the robot's work volume is adopted to avoid the complication of different sizes of end effectors that might be attached to the robot's wrist. The end effector is an addition to the basic robot and should not be counted as part of the robot's working space. Also, the end effector attached to the wrist might not be capable of reaching certain points within the robot's normal work volume because of the particular combination of joint limits of the arm.

Spatial region within which the end of the robot's wrist can be manipulated and is Determined by

– Physical configurations

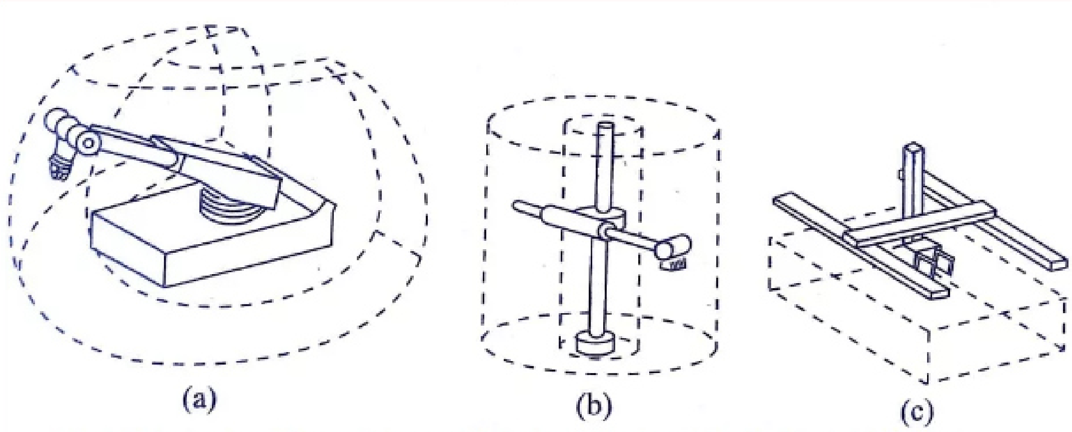
– Size

– Number of axes

– The robot mounted position (overhead gantry, wall-mounted, floor mounted, on tracks)

– Limits of arm and joint configurations

– The addition of an end-effectors can move or offset the entire work volume



Work Volumes for Different Types of Robots : **(a) Polor, (b) Cylindrical, (c) Cartesian**

Various shapes of work volume of robots:

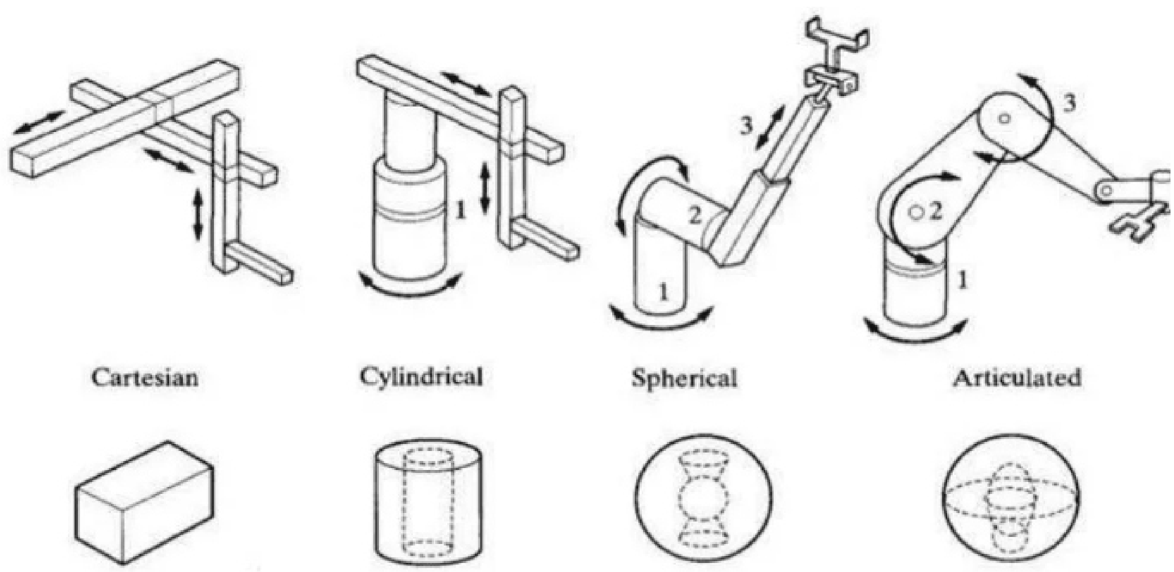
• Polar coordinates – Partial Sphere

• Cylindrical coordinates – Cylindrical

• Cartesian - Rectangular

• Jointed arm – Irregular

The influence of the physical configuration on the shape of the work volume is illustrated in fig. A polar robot has a work volume that is a partial sphere, a cylindrical robot has a cylindrical work volume.



Degrees of Freedom in Mechanisms: How many degrees of freedom (DOF) are needed to position and orient an object in space?

Desired Degrees of Freedom

- 3 Dimensional Case
  - 3 DOF for positioning (x, y, z)
  - 3 DOF for orientation (pitch, yaw, roll)
- 2 Dimensional Case (Planar case)
  - 2 DOF for positioning (x, y)
  - 1 DOF for orientation (tilt)

Mechanism Types: Two different category

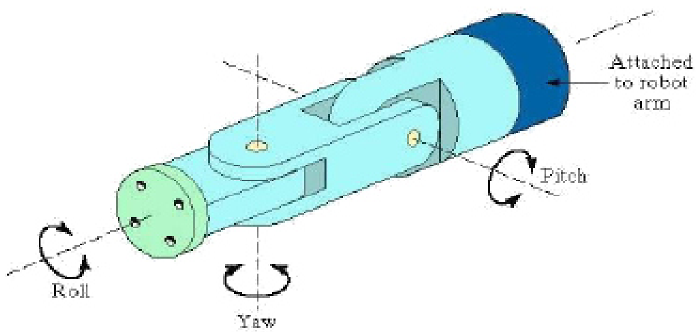
 Arm: Two to three degrees of freedom

 Wrist: One to three degrees of freedom

ROBOT WRIST CONFIGURATIONS

Wrist assembly is attached to end-of-arm. End effectors is attached to wrist assembly. Function of wrist assembly is to orient end effectors. Body-and-arm determines global position of end effectors Two or three degrees of freedom:

- Roll
- Pitch
- Yaw



Gripper Configurations: typically have 3 degrees of freedom

– *Roll* involves rotating the wrist about the arm axis

– *Pitch* up-down rotation of the wrist

– *Yaw* left-right rotation of the wrist

End effectors is mounted on the wrist.

END EFFECTORS

The special tooling for a robot that enables it to perform a specific task Two types:

- *Grippers – to grasp and manipulate objects (e.g., parts) during work cycle*
- *Tools – to perform a process, e.g., spot welding, spray painting, Device attached to the robot's wrist to perform a specific task*

GRIPPERS: Grippers grasp and manipulate objects during the work cycle. Typically the objects grasped are work parts that need to be loaded or unloaded from one station to another. It may be custom-designed to suit the physical specifications of the work parts they have to grasp. Grippers are described in detail in table below.

Type	comment
Mechanical gripper	Two or more fingers that can be actuated by robot controller to open and close on a work part.
Vacuum gripper	Suction cups are used to hold flat objects.
Magnetised devices	Making use of the principles of magnetism, these are used for holding ferrous work parts.
Adhesive devices	Deploying adhesive substances these hold flexible materials, such as fabric.
Simple mechanical devices	For example, hooks and scoops.
Dual grippers	Mechanical gripper with two gripping devices in one end effector for machine loading and unloading. Reduces cycle time per part by gripping two work parts at the same time.
Interchangeable fingers	Mechanical gripper whereby, to accommodate different work part sizes, different fingers may be attached.
Sensory feedback fingers	Mechanical gripper with sensory feedback capabilities in the fingers to aid locating the work part and to determine correct grip force to apply (for fragile work parts).
Multiple fingered grippers	Mechanical gripper with the general anatomy of the human hand.
Standard grippers	Mechanical grippers that are commercially available, thus reducing the need to custom-design a gripper for each separate robot application.

TOOLS: The robot end effecter may also use tools. Tools are used to perform processing operations on the work part. Typically the robot uses the tool relative to a stationary or slowly moving object. In this way the process is carried out.

– Spot Welding gun

– Arc Welding tools

– Spray painting gun

– Drilling Spindle

– Grinders, Wire brushes

– Heating torches

MECHANICAL GRIPPERS: Mechanical grippers are used to pick up, move, place, or hold parts in an automated system. They can be used in harsh or dangerous

VACUUM GRIPPERS: for non-ferrous components with flat and smooth surfaces, grippers can be built using standard vacuum cups or pads made of rubber-like materials. Not suitable for components with curved surfaces or with holes.

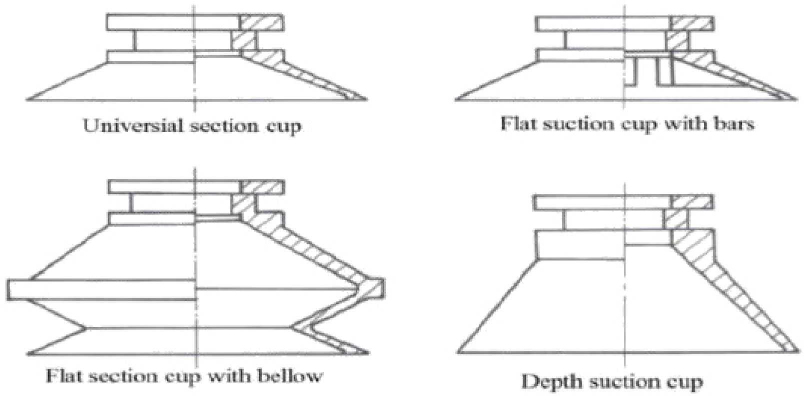


Figure 3 Different types of suction cups, picture taken from [5] page 204

Fig 2.4 Suction Cups

VACUUM GRIPPERS: Vacuum-grippers become in suction cups, the suctions cups is made of rubber. The suction cups are connected through tubes with under pressure devices for picking up items and for releasing items air is pumped out into the suction cups. The under pressure can be created with the following devices:

The vacuum grippers use suction cups (vacuum cups) as pick up devices. There are different types of suction cups and the cups are generally made of polyurethane or rubber and can be used at temperatures between -50 and 200 °C. The suction cup can be categorized into four different types; universal suction cups, flat suction cups with bars, suction cups with bellow and depth suction cups as shown in figure 3.

The universal suction cups are used for flat or slightly arched surfaces. Universal suction cups are one of the cheapest suction cups in the market but there are several disadvantages with this type of suction cups. When the under pressure is too high, the suction cup decreases a lot which leads to a greater wear. The flat suction cups with bars are suitable for flat or flexible items that need assistance when lifted. These types of suction cups provides a small movement under load and maintains the area that the under pressure is acting on, this reduces the wear of the flat suction cup with bars, this leads to a faster and safer movement. Suction cups with bellows are usually used for curved surfaces, for example when separation is needed or when a smaller item is being gripped and needs a shorter movement. This type of suction cups can be used in several areas but they allow a lot of movement at gripping and low stability with small under pressure. The depth suction cup can be used for surfaces that are very irregular and curved or when an item needs to be lifted over an edge. [5] Items with rough surfaces (surface roughness ≤ 5 μm for some types of suction cups) or items that are made of porous material will have difficulty with vacuum grippers. An item with holes, slots and gaps on the surfaces is not recommended to be handled with vacuum grippers. The air in the suction is sucked out with one of the techniques described earlier, if the material is porous or has holes on its surface; it will be difficult to suck out the air. In such cases the leakage of air can be reduced if smaller suction cups are used. Figure 4 shows different types of suction cups.

MAGNETIC GRIPPER: used to grip ferrous materials. Magnetic gripper uses a magnetic head to attract ferrous materials like steel plates. The magnetic head is simply constructed with a ferromagnetic core and conducting coils. Magnetic grippers are most commonly used in a robot as end effectors for grasping the *ferrous* materials. It is another type of handling the work parts other than the mechanical grippers and vacuum grippers. Types of magnetic grippers: The magnetic grippers can be classified into *two common types*, namely:

- **ELECTROMAGNETS:**

Electromagnetic grippers include a *controller unit* and a *DC power* for handling the materials. This type of grippers is easy to control, and very effective in releasing the part at the end of the operation than the permanent magnets. If the work part gripped is to be released, the polarity level is minimized by the controller unit before the electromagnet is turned off. This process will certainly help in *removing the magnetism* on the work parts. As a result, a best way of releasing the materials is possible in this gripper.

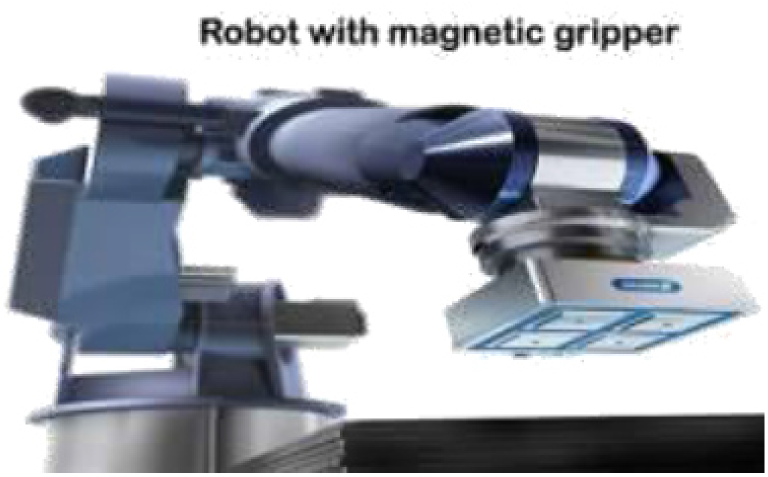


Fig 2.5 Magnetic Gripper

- **PERMANENT MAGNETS:**

The permanent magnets do not require any sort of external power as like the electromagnets for handling the materials. After this gripper grasps a work part, an additional device called as *stripper push – off pin* will be required to separate the work part from the magnet. This device is incorporated at the sides of the gripper. The advantage of this permanent magnet gripper is that it can be used in hazardous applications like *explosion-proof apparatus* because of no electrical circuit. Moreover, there is no possibility of *spark production* as well.

BENEFITS:

This gripper only requires *one surface* to grasp the materials. The grasping of materials is done *very quickly*. It does not require *separate designs* for handling different size of materials. It is capable of grasping materials with *holes*, which is unfeasible in the vacuum grippers.

DRAWBACKS:

The gripped work part has the chance of *slipping out* when it is moving quickly. Sometimes *oil* in the surface can reduce the strength of the gripper. The *machining chips* may stick to the gripper during unloading.

SENSORS IN ROBOTICS

Two basic categories of sensors used in industrial robots:

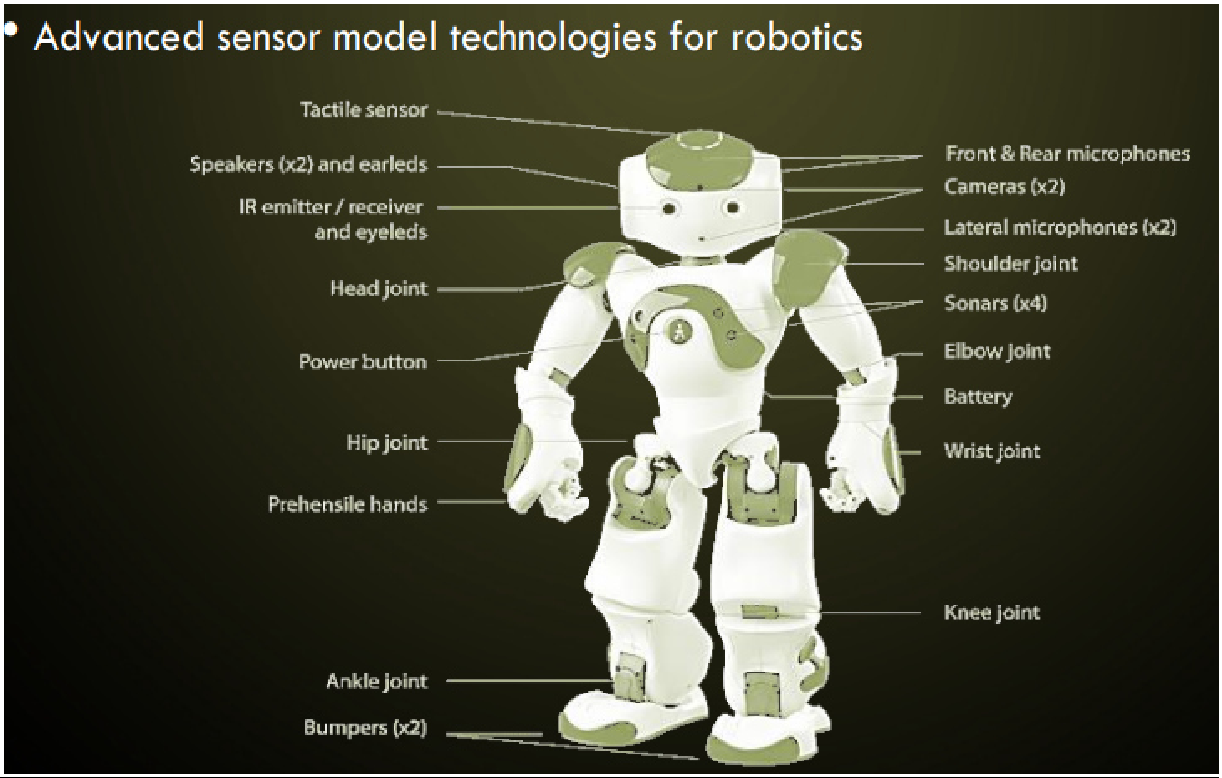
1. Internal - used to control position and velocity of the manipulator joints

Internal sensors are used to monitor and control the various joints of the robot. They form a feedback control loop with the robot controller. Examples of internal sensors include potentiometers and optical encoders, while tachometers of various types can be deployed to control the speed of the robot arm.

2. External - used to coordinate the operation of the robot with other equipment in the work cell

These are external to the robot itself. They are used when we wish to control the operations of the robot with other pieces of equipment in the robotic work cell. External sensors can be relatively simple devices, such as limit switches that determine whether a part has been positioned properly or whether a part is ready to be picked up from an unloading bay.

Sensor Type	Description
Tactile sensors	Used to determine whether contact is made between sensor and another object. Two types: touch sensors which indicate when contact is made and force sensors which indicate the magnitude of the force with the object.
Proximity sensors	Used to determine how close an object is to the sensor. Also called a range sensor.
Optical sensors	Photocells and other photometric devices that are used to detect the presence or absence of objects. Often used in conjunction to proximity sensors.
Machine vision	Used in robotics for inspection, parts identification, guidance and other uses.
Miscellaneous category	temperature, fluid pressure, fluid flow, electrical voltage, current and other physical properties.



DRIVE SYSTEMS FOR ROBOTS:

- **Electric Drive system:** Uses electric motors to actuate individual joints, Preferred drive system in today's robots, Electric motor (stepper, servo, less strength, better accuracy and repeatability
- **Hydraulic Drive system:** Uses hydraulic pistons and rotary vane actuators, Noted for their high power and lift capacity, Hydraulic (mechanical, high strength)
- **Pneumatic Drive system:** Typically limited to smaller robots and simple material transfer applications, Pneumatic (quick, less strength)

Hydraulic Drive system

– High strength and high speed

– Large robots, Takes floor space

– Mechanical Simplicity

– Used usually for heavy payloads

Electric Motor (Servo/Stepper) Drive system

– High accuracy and repeatability

– Low cost

– Less floor space

– Easy maintenance

Pneumatic Drive system

– Smaller units, quick assembly

– High cycle rate

– Easy maintenance

ROBOT APPLICATIONS:

Areas of Application of Robots

• Outer Space

• Military

• Industry

• Health Service

• Agriculture

• Underwater

• Security and Surveillance

Industrial Application

An industrial robot is a robot system used for manufacturing. Industrial robots are automated, programmable and capable of movement on three or more axis. Typical applications of robots include welding, painting, assembly, disassembly, pick and place for printed circuit boards, packaging and labeling, palletizing , product inspection, and testing; all accomplished with high endurance, speed, and precision. They can assist in material handling. Some of the applications of robots in Industry are:

• Loading and Unloading: Robots are extensively being utilized for the loading and unloading of machines and parts in industries, thus substituting human labor and other mechanical methods. Robots possess the benefit of duplicating the designed tasks, performing accurately, and being compatible with the nearby equipment.

• Arc Welding: The surroundings of arc welding are unsafe for the fitness of human beings, and achievement of quality welds is difficult by manual operations. Therefore, since smooth movements provide superior welds, the use of robots for such operations is growing very rapidly. Utilization of industrial robots for arc welding is economical, and the welds are of an excellent quality.

• Repetitive work cycle: A second characteristic that tends to promote the use of robotics is a repetitive work cycle. If the sequence of elements in the cycle is the same, and the elements consist of relatively simple motions, a robot is usually capable of performing the work cycle with greater consistency and repeatability than a human worker. Greater consistency and repeatability are usually manifested as higher product quality than can he achieved in a manual operation.

• Spot Welding: Robots perform spot welding very accurately, with recurring operations, and are extensively being used in automotive industry. They can extend to places which normally would be difficult to reach by manual welding.

• Painting: It is a difficult and unhealthy operation, where hazardous fumes are released that are extremely dangerous for human beings, and in which a danger of explosion exists in the areas of operation. Furthermore, manual painting results are not consistent due to unpredictable speed of movement of the components involved in this process.

• Investment Casting: Investment casting requires duplication, accuracy, and uniformity in production, all of which can be achieved with employment of industrial robots.

• Integration of Parts: The integration of parts in various sub systems of production is an important application where robots can function more efficiently and with extra speed, thus assisting in the increase of production rate. Presently, robots are being used for tightening of bolts and nuts, placing of components in circuit boards, and a variety of other similar tasks. Logic devices are used for identification and rectification of defects or inconsistencies.

• Hazardous work environment for humans: When the work environment is unsafe, unhealthful, hazardous, uncomfortable, or otherwise unpleasant for humans, there is reason to consider an industrial robot for the work.

Material Handling Robot Applications

- Packing Products. A common material handling task is packing products for shipment or further processing. ...
- Part Transfer. ...
- Loading and Unloading Conveyors. ...
- Holding Material in Place. ...
- Palletizing and Depalletizing.

Material handling robots can automate some of the most tedious, dull, and unsafe tasks in a production line and is one of the easiest ways to add automation. Material handling robots enhance the efficiency of your production line and increase customer satisfaction by providing quality products in a timely manner. The term material handling encompasses a wide variety of product movements. Part selection and transferring, palletizing, packing, and machine loading are just a few of the applications that are considered material handling. When picking material handling equipment for your facility, you should consider payload and speed requirements, end-of-arm tooling or grippers needed, facility layout and floor-space, the type of material being handled and any additional possible production problems.

• Part transfer, a dull and tedious process, can also be injury-inducing to human workers. By adding robots to this job, human workers are kept free of the hazardous environment.

• Packaging robots are extremely flexible and easy to integrate into a workspace. Some of the advantages of packaging robots include reduced part package time, ability to lift larger packages and labor cost reduction . With the right end of arm tooling, a robot can complete any packaging process. There is a large variety of robot sizes, mounting options, payload and reach available to choose from.

• Palletizing robots can be seen in many industries including food processing, manufacturing, and shipping.

• Machine loading robots not only increase production speeds, it also protects workers from injury.

Die casting: The robot unloads parts from the die casting machine. Peripheral operations sometimes performed by the robot include dipping the parts into a water bath for cooling.

Plastic molding: Plastic molding is a robot application similar to die casting. The robot is used to unload molded parts from the injection molding machine.

Machining operations: The robot is used to load raw blanks into the machine tool and unload finished parts from the machine. The change in shape and size of the part before and after machining often presents a problem in end effector design; and dual grippers are often used to deal with this issue.

Forging: The robot is typically used to load the raw hot billet into the die, hold it during the forging blows, and remove it from the forge hammer. The hammering action and the risk of damage to the die or end effector are significant technical problems. Forging and related processes are difficult as robot applications because of the severe conditions under which the robot must operate

Press working: Human operators work at considerable risk in sheet-metal press working operations because of the action of the press. Robots are used as substitutes for the human workers to reduce the danger. In these applications, the robot loads the blank into the press, the stamping operation is performed, and the part fails out the back of the machine into a container. In high production runs, press working operations can be mechanized by using sheet metal coils instead of individual blanks.

These operations require neither humans nor robots to participate directly in the process Hear treating: These are often relatively simple operations in which the robot loads and/or unloads parts from a furnace

ROBOTS IN ASSEMBLY

Assembly robots are used for lean industrial processes and have expanded production capabilities in the manufacturing world. An assembly line robot can dramatically increase production speed and consistency. They also save workers from tedious and dull assembly line jobs. End of arm tooling can be customized for each assembly robot to cater to the manufacturing requirements. Additional options, like robotic vision, can also be incorporated to improve efficiency and accuracy of part orientation or sorting identifiers.

Applications: Applications for robotic assembly include automotive components, like pumps, motors and gearboxes. Computers and consumer electronics are another excellent area, as are medical devices and household appliances. Assembly robots are ideal for tasks demanding speed and precision like applying sealants and adhesives. Not only can they put together parts that are too small or intricate for a human, but they work quickly and accurately without tiring or making mistakes. They are good in applications where cleanliness is paramount, like pharmaceuticals and medical device assembly, and they aren't prone to debilitating injuries, like carpal tunnel syndrome, that come with repetitive work.

APPLICATION OF ROBOTS IN INSPECTION

Robot-based inspections systems are an application whose time has come. As vision systems become increasingly powerful and flexible, more end-users will consider inspection tasks being integrated into robotic work cells. Robot makers and integrators can offer end-users some valuable advice on having vision systems do more than just guide the robot.

“Robotic inspection systems are performing flaw detection on parts, ensuring complete part assembly, and measuring parts,”. “The vision system must be able to both find and inspect the part accurately. Most importantly, integrators have to make sure of getting very good positional accuracy and communicating that back to the robot quickly.”

Parts or No Parts?: Inspection systems are called upon to determine part presence. “Integrators start by looking to see if certain things are present or not present on an assembly,” “Inspection systems could be looking at an engine to confirm that it has been completely assembled. For example, at the end of the production line, car makers want to confirm that an oil filter has been put on the engine or determine if a certain bolt has been tightened down completely.” The robotic form of “go/no go” inspection utilizes a camera mounted on the robot’s arm, which is moved around to check the presence of different features on a part.

Measure Up: Robots are also used to measure items. “Inspection systems are measuring components but as tolerances of the measurements get tighter and tighter, these tolerances become harder to satisfy,”. “Lighting and part presentation to the robot becomes more critical. When moving from verifying a part’s presence to actually measuring it, integrators are adding complexity to the inspection system.”

Error-Proofing: “Robotic flaw detection is looking at surface finishes or finding precise dimensions,”. “End-users must define what is a good part and what is a bad part. If you ask several line operators to define what is a good part and what is a bad part and they do not all give the same answer, the inspection system will also struggle with finding a good answer.”

Inspections to Come: As vision systems become more flexible and powerful, inspection systems will be able to better deal with environmental factors such as coping with the robot’s changing dimensions as it warms during operation. "In the next few years, inspection systems will be more accurate and will have better thermal compensation techniques. When the robot heats up, a millimeter expansion creates a significant change in inspection reporting results." Shafi also sees more three-dimensional vision packages offered in the market.

ROBOT PROGRAMMING

According to the *consistent* performance by the robots in industries, the robot programming can be divided in two common types such as:

1. Leadthrough Programming Method
2. Textual Robot Languages

1. **Leadthrough Programming Method:** During this programming method, the traveling of robots is based on the desired movements, and it is stored in the external controller memory. There are two modes of a control system in this method such as a *run mode* and *teach mode*. The program is taught in the teach mode, and it is executed in the run mode. The lead through programming method can be done by two methods namely:
   a) Powered Leadthrough Method
   b) Manual Leadthrough Method

a) Powered Leadthrough Method: The powered leadthrough is the *common* programming method in the industries. A *teach pendant* is incorporated in this method for controlling the motors available in the joints. It is also used to operate the robot wrist and arm through a sequence of points. The playback of an operation is done by recording these points. The control of complex geometric moves is *difficult* to perform in the teach pendant. As a result, this method is good for *point to point* movements. Some of the key applications are spot welding, machine loading & unloading, and part transfer process.

b) Manual Leadthrough Method: In this method, the robot's end effector is moved physically by the programmer at the desired movements. Sometimes, it may be difficult to move large robot arm manually. To get rid of it a teach button is implemented in the wrist for special programming. The manual leadthrough method is also known as Walk Through method. It is mainly used to perform continuous path movements. This method is best for spray painting and arc welding operations.

2. Textual Robot Languages: In 1973, WAVE language was developed, and it is the first textual robot language as well. It is used to interface the machine vision system with the robot. Then AL language was introduced in 1974 for controlling multiple robot arms during arm coordination. VAL was invented in 1979, and it is the common textual robot language. Later, this language was dated in 1984, and called as VAL II. The IBM Corporation has established their two own languages such as AML and AUTOPASS, which is used for the assembly operations. Other important textual robot languages are Manufacturing Control Language (MCL), RAIL, and Automatic Programmed Tooling (APT) languages.

ROBOT PROGRAMMING METHODS

There are three basic methods for programming industrial robots but currently over 90% are programmed using the each method.

1. **Teach Method:** The logic for the program can be generated either using a menu based system or simply using a text editor but the main characteristic of this method is the means by which the robot is taught the positional data. A teach pendant with controls to drive the robot in a number of different co-ordinate systems is used to manually drive the robot to the desired locations. These locations are then stored with names that can be used within the robot program. The co-ordinate systems available on a standard jointed arm robot are :-

   JointCo-ordinates: The robot joints are driven independently in either direction.

   Global Co-ordinates: The tool centre point of the robot can be driven along the X, Y or Z axes of the robots global axis system. Rotations of the tool around these axes can also be performed

   Tool Co-ordinates: Similar to the global co-ordinate system but the axes of this one are attached to the tool centre point of the robot and therefore move with it. This system is especially useful when the tool is near to the workpiece.

   Workpiece Co-ordinates: With many robots it is possible to set up a co-ordinate system at any point within the working area. These can be especially useful where small adjustments to the program are required as it is easier to make them along a major axis of the coordinate system than along a general line. The effect of this is similar to moving the position and orientation of the global co-ordinate system. This method of programming is very simple to use where simple movements are required. It does have the disadvantage that the robot can be out of production for a long time during reprogramming. While this is not a problem where robots do the sa e task for their entire life, this is becoming less common and some robotic welding syste s are performing tasks only a few times before being reprogrammed.

2. **Lead Through:** This system of programming was initially popular but has now almost disappeared. It is still however used by many paint spraying robots. The robot is programmed by being physically moved through the task by an operator. This is exceedingly difficult where large robots are being used and sometimes a smaller version of the robot is u ed for this purpose. Any hesitations or inaccuracies that are introduced into the progr m c nnot be edited out easily without reprogramming the whole task. The robot con roller simply records the joint positions at a fixed time interval and then plays this back.
3. **Off-line Programming:** Similar to the way in which CAD systems are being used to generate NC programs for milling machines it is also possible to program robots from CAD data. The CAD models of the components are used along with moves of the robots being used and the fixturing required. The program structure is built up in much the same way as for teach programming but intelligent tools are available which allow the CAD data to be used to generate sequences of location and process information. At present there are only a few companies using this technology as it is still in its infancy but its use is increasing each year. The benefits of this form of programming are:-
   - Reduced down time for programming.
   - Programming tools make programming easier.
   - Enables concurrent engineering and reduces product lead time.
   - Assists cell design and allows process optimization

ADVANTAGES

• Increased efficiency Industrial robots can complete certain tasks faster and more efficiently than humans as they are designed and built to perform them with higher accuracy. This combined with the fact they are used to automate processes which previously might have taken significantly more time and resource results in the use of industrial robots to increase the efficiency of production lines.

• Improved quality Given their higher levels of accuracy, industrial robots can be used to produce higher quality products which result in the reduction of time required for quality control and ensures that standards of quality are adhered to.

• Improved working environment Some tasks are deemed as too dangerous or laborious and repetitive for humans to carry out and so instead robots can perform these tasks instead. Working conditions, therefore, can be vastly improved as well as the safety within factories and production plants by introducing industrial robots.

• Increased profitability The results of introducing industrial robots can only ensure higher profitability levels with lower cost per product as by increasing the efficiency of your process, reducing the resource and time required to complete it whilst also achieving higher quality products, introducing industrial robots save money in the long run.

• Longer working hours As human breaks in the working day are required, distractions happen and attention spans slow. Whereas robots can work 24/7 and keep working at 100% efficiency. On average a 40% increase in the output of a production line occurs when one key person is replaced by a robot who operates the same working hours, simply because of stamina. Also, robots don't take holidays or have unexpected absences.

DISADVANTAGES

• Capital cost Implementing industrial robots can incur a high capital cost however, they do prove highly effective and bring a positive ROI. This is why, prior to decisions being made, we always recommend consideration is given to both the investment required and also the ROI you expect to achieve in implementing robots. Often the advice we give is to take out asset finance and the ROI of the robot more than pays for the interest on the asset finance.

• Expertise The initial set up of industrial robots requires a lot of training and expertise as with any other type of technology, this is because they are excellent for performing many tasks. Good automation companies provide a support package of their expertise which is an extremely important factor. However, to minimize reliance on automation companies, training can be given to engineers to allow them to program the robots – though the assistance of experienced automation companies is still required for the original integration of the robot.