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M – Scheme

e-TEXTBOOK
on
ROBOTICS
for
VI Semester DICE

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ROBOTICS

DETAILED SYLLABUS

UNIT-I

BASIC CONFIGURATION OF ROBOTICS & ITS WORKING:

Introduction – definition – basic configuration of robotics and its working – robot components – manipulator – end effectors, drive system, controller, sensors – mechanical arm -degrees of freedom – links and joints – construction of links, types of joint -classification of robots-Cartesian, cylindrical spherical, horizontal articulated (SCARA), vertical articulated -structural characteristics of robots –work envelope and work volume – robot work volumes and comparison – wrist rotations – mechanical transmission, pulleys, belts, gears, harmonic drive – conversation between linear and rotary motion and its devices.

UNIT I - BASIC CONFIGURATION OF ROBOTICS AND ITS WORKING

1.1 INTRODUCTION

Robotics can be described as the current pinnacle of Technical Development. Robotics is a confluence science using the continuing advancements of Mechanical Engineering, Material Science, Sensor Fabrication, Manufacturing Techniques and Advanced Algorithms.

The origin of word 'robot' is in the 'robota' meaning either a slave or a mechanical item that would help its master. A robot therefore carries out the task done by a human being.

The word robot was first introduced by keralcapek in 1921 regarding to checoslavokia in his play RUR-Rossum's universal robot. The word robota means a forced labour. In his play a brilliant scientist named rossum and his son were developed a chemical substance that is similar to protoplasm to make the robot. Their plan was that the robot would obey humankinds and do all physical labour. Rossum continues to make improvements in the design of the robot, eliminating the unnecessary parts they developed a perfect robot which eventually goes out of control and attack human beings.

The term robotics was coined by Issacasimov in 1942 in his science fiction story RunArodno where portrayed. Robots are used not in a negative manner but built with safety measures to assist the human beings.

Laws of Robotics:

1. Zeroth Law: A robot may not harm humanity or through inaction, allow humanity to come to harm.
2. First Law: A robot may not injure a human being or through inaction, allow a human to be harmed
3. Second Law: A robot must obey orders given by humans except when that conflicts with the First Law.

4. Third Law: A Robot must protect its own existence unless that conflicts with the First or Second Laws.

1.2 DEFINITION OF ROBOTICS :

Robotics may be defined as the branch of technology deals with design, construction, operation and application of robotics.

1.2.1 Definition of Robot :

"Robot is a reprogrammable, multifunctional manipulator designed to move materials, parts, tools or special devices through variable programmed motions for the performance of a variety of tasks".

1.3 BASIC CONFIGURATION OF ROBOTICS AND ITS WORKING :

Robot configuration:

a. Polar configuration
b. Cylindrical configuration
c. Cartesian co-ordinate configuration (XYZ)
d. Jointed –arm configuration
    i) Vertical articulated
    ii) Horizontal articulated.

1.4 Robot Components:

The various components of a robot are

1. Base
2. Manipulator
3. End effector
4. Drive system
5. Controller
6. Sensors

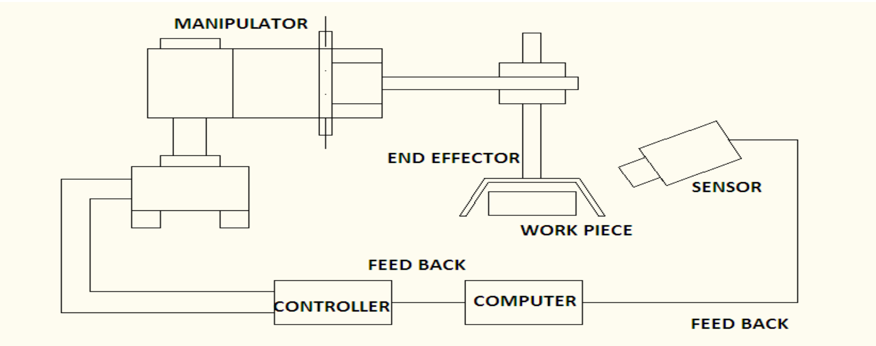


FIG 1.1 Schematic diagram of robot system

1. BASE:

The base may be fixed or mobile

2. MANIPULATOR:

The basic components arm, body, wrist of a robot is known as manipulator. It is a mechanical unit that provides motion similar to human arm. Its primary function is to provide the specific motion that will enable the tooling at the end of the arm for the required work.

The manipulators movement can be divided into two categories as follows:

1. Arm body movement
2. Wrist movement

1. Arm body movement:
    a. Vertical traverse:

       This is the capability to move the wrist up or down to provide the desired vertical attitude.

    b. Radial traverse:

       This involves the extension or retraction (in or out movement) of arm from the vertical centre of the robot.

    c. Rotational traverse:

       This is the rotation of the arm about the vertical axis.

2. Wrist movement:

    a. Wrist Roll:

Also called wrist swivel, this involves rotation of the wrist mechanism about the arm axis.

    b. Wrist pitch:

       Given that the wrist roll is in its centre position, the pitch would involve the up or down rotation of the wrist. Wrist pitch is also sometimes called wrist bend.

    c. Wrist yaw:

       Again, given that the wrist swivel is in the centre position of its range, wrist yaw would involve the right or left rotation of the wrist.

3. END EFFECTOR:

Robot end effector is the gripper or end of arm tooling on the wrist of the robot manipulator arm.

A Robot performs a variety of task for which various tooling and grippers are required. The types of grippers are

a. Mechanical gripper
b. Magnetic gripper
c. Vacuum gripper
d. Hooks, scoops and other miscellaneous

4. DRIVE SYSTEM:

Robot's capacity to move its arm, body, and wrist is provided by the drive system. Drive system determines, speed of movement, strength of robot & dynamic performance of robot. There are three different types of power drives in common use. They are

a. HYDRAULIC DRIVE:

In a hydraulic system, the electric motor pumps fluid from a reserve tank to the hydraulic actuators. Fluid at a high pressure passes through control valves, before its entry into the linear actuators. On the other hand rotary actuators comprising some motors may also be employed.

Advantage of hydraulic drives are, increase in speed and strength. The disadvantages are requirement of more floor space and leakage of oil. Hydraulic drives are used in larger robots such as, unimate 1000 series.

b. ELECTRIC DRIVE:

These drives are clean and quiet with high degree of accuracy and reliability. They also offer a wide range of payload capacity with wide range of cost.

D.C servo motors, brushless D.C motors, reversible A.C servo motors and stepper motors are important electrical servo drives.

Rotational motion is acquired by stepper motor, DC servo motors. Linear motion is acquired by pulley or other translational mechanism.

c. PNEUMATIC DRIVES:

These systems use compressed air to move the robot arm.

The Pneumatic systems may employ a linear actuator or a rotary actuator like vane motors.

The advantages of pneumatic actuators are: simple construction, fast, reliable and relatively inexpensive.

The disadvantages are smaller pay loads delayed response of the robot arm Non servo robots can be built up with pneumatically powered actuators.

5. CONTROLLERS:

The purpose of the controller is to compare the actual output of the plant with the input command and to provide a control signal which will reduce the error to zero or close to zero as possible.

Controllers are the communication and information processing device that initiates, terminates and coordinates the motion and sequence of robot.

Controller accepts the necessary input signals to the robot and provides output to the controller motor or actuator of arm joint. Controllers vary greatly in complexity and design.

They have a very great deal to do functional capabilities of robot that complex work tasks that robot must be able to fulfil

Figure 1.2 shows the block diagram illustrates the various components in controller system. The robot controller computer is the heart of the controller and its solid state memory. The controller computer sometimes interfaced with many microprocessors.

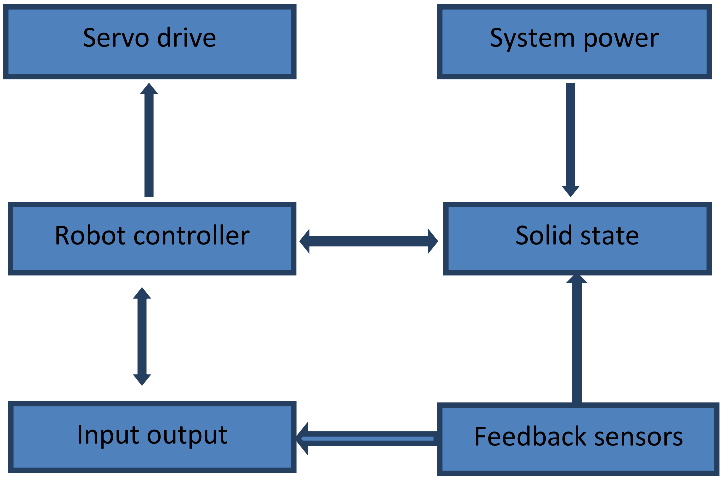


FIG 1.2 Block diagram of Controller

The input output section provides communication between the robot controller computer and the following devices

-feedback devices

-production sensors

-production equipment

-teaching device

-hard copy disc

- Memory storage device

The robot controller computes controls the motion of robot through the device signals from servo drive interface to the actuator of arm joints

6. SENSORS:

The sensors perform the following functions:

(i) To act as feedback devices to direct further actions of the manipulator arm and the end effector(gripper)
(ii) To interact with the body's working environment

Usually there are two basic types of sensors. These are:

i) Tactile sensors:

There are “contact sensors” that must be brought in contact with the object to obtain signals to measure the necessary qualities.

-when the tactile sensors make physical contact with the object, an electrical analog or digital signal is generated and sent to the robot controller. Electrical signals may be obtained through the contacts of micro switches. Signals may also be obtained through mechanical pressures which change resistance of electrical strain gauges or general electrical potentials in piezoelectric crystals.

-Typical contact type robotic sensors include:

(a) Force sensors (b) torque sensors

(c) Touch sensors (d) Position sensors

ii) Non Tactile Sensors:

These are contactless sensors which sense the signals remotely, but only within the specified range of distance from the object

The detect and measure magnetic fields, infrared and ultraviolet light, x rays electrical fields, ultrasonic sound waves or electromagnetic waves

Typical non-contact robotic sensors include:

(a) Proximity sensors;
(b) Electro-optical sensors;
(c) Range imaging sensors

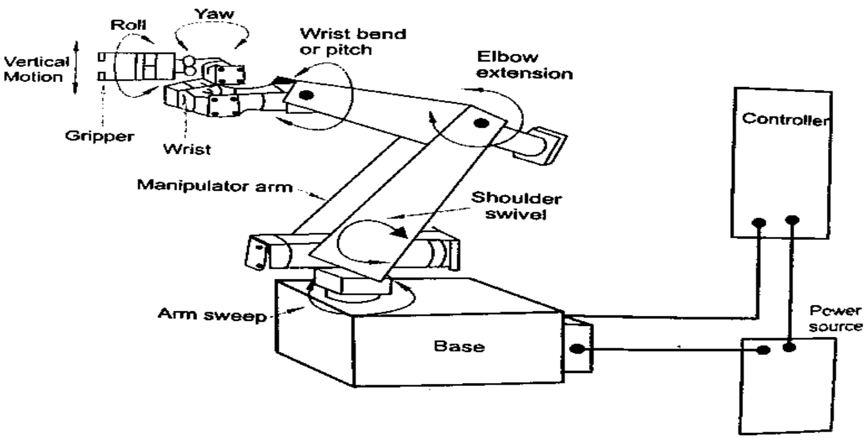


FIG 1.3 Robot with various components

Figure 1.3 shows the various components and degrees of freedom of body, arm and wrist.

A Robot has some specific objective. It may be designed for simply picking up and placing the work piece. It may be employed to interact with and work load a lathe, a milling machine or any equipment, or it may also perform some assembly work. To accomplish the job, a robot must have a suitable manipulator arm with specified coordinate systems to attain a designed reach in the working space. It should have a suitable gripper to match the geometry of the work piece to be handled; a suitable control system with or without servo mechanisms for sending signals to the drives, or permitting storage of programmes and data for desired path planning with adequate speed and good accuracy. The robot may have some sensors to feedback information for modifying the motion or path. The controller is provided with interfacing units connected to external equipment in the outside world.

1.5 MECHANICAL ARM:

Robot Anatomy is concerned with the physical construction of the body arm and wrist of the machine. Most of the robots used in plants are mounted on a base which is fastened to the floor.

The body is attached to the base and the arm assembly is attached to the body. The end of the arm is wrist. The wrist consists of a number of components that allow it to be oriented in a variety of positions.

Relative movements between the various components of the body arm, wrist is provided by a series of joints. These joint movements usually involve either rotating or sliding motions, the body, arm and wrist assembly is sometimes called the manipulator.

The arm and body joints of the manipulator are used to position the end effector, and the wrist joint of the manipulator used to orient the end effector.

1.6 DEGREES OF FREEDOM:

The individual joint motion associated with arm body movement and wrist movement is known as degrees of freedom of robot. We can simply say the number of axis is equal to number of degrees of freedom. A typical industrial robot is equipped with 4 to 6 degrees of freedom.

Degrees of freedom associated with arm and body

The arm and body joints are designed to enable the robot to move its end effector to a desired position within the limits of the robot‘s size and joint movements. For robots of polar, cylindrical and jointed arm configuration, the three degrees of freedom associated with arm and body motions are

1. Vertical traverse – This is the capability to move the wrist up or down to provide the desired vertical attitude.
2. Radial traverse – This involves the extension or retraction (in or out movement) of the arm from the vertical center of the robot.
3. Rotational traverse – this is a rotation of the arm about the vertical axis.

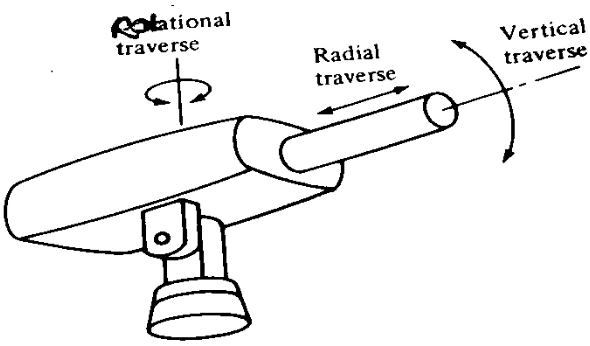


FIG .1.4 shows the various moments of body and arm

1.7 LINKS AND JOINTS:

1.7.1 LINKS

Link is a rigid member that connects various manipulated joints. In a manipulator a link –joint-link chain, the link that is closest to the base is called input link. The link that moves with respect to the movement of the input link is the output link. A rigid link that can be connected, at most with two other links is referred to as a binary link, Shown in fig 1.5.

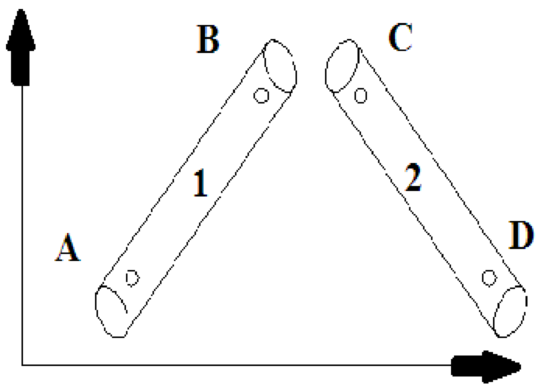


FIG 1.5 shows two rigid binary links

The two rigid binary links, 1 and 2 each with two holes at the ends A, B and C, D respectively to connect with each other or to other link. Two links are connected together by a joint. By putting a pin through holes B and C of links 1 and 2, an open kinematic chain is formed.

The joint formed is called a pin joint also known as revolute or rotary joint. Relative rotary motion between the links is possible and the two links are said to be paired.

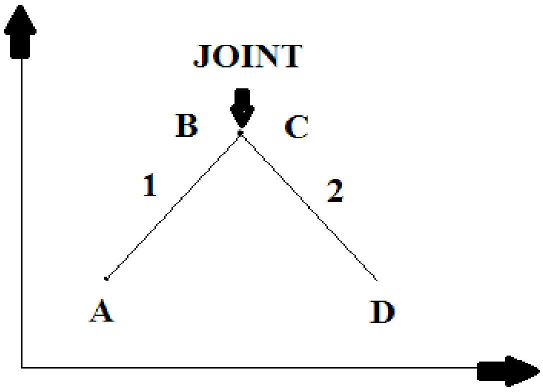


FIG 1.6 Revolute Joint

The above links are represented by straight lines and rotary joint by a small circle.

1.7.2 JOINTS:

The element that connects two links is called as joint. Joint enables the link to move linearly or rotationally.

1.8 TYPES OF JOINT:

1. Linear Joint:

   Linear joints involve a sliding motion of connecting links. The motion can be achieved in a number of ways. (eg by a piston, telescoping mechanism) The axes of the two links are parallel to each other. The linear joint is denoted by L Joint.

2. Orthogonal Joint:

   In this type of joint, the two links are perpendicular to each other but motion between them at the joint is linear sliding type. This is denoted as O joint.

3. Rotational Joint:

   It involves the rotational motion. The input link and output link are parallel but axis of rotation is perpendicular. Rotational joint is represented as R joint.

4. Twisting Joint:

   Twisting joint involves the twisting motion between the input and output link. The input and output link are parallel to each other. The twisting joint is represented as T joint.

5. Revolving joint:

   Revolving joint involves the revolutionary motion. The input link is parallel to axis of rotation. The output link is perpendicular to axis of rotation. Revolving joint is denoted as R Joint.

The different types of joints shown in figure 1.7

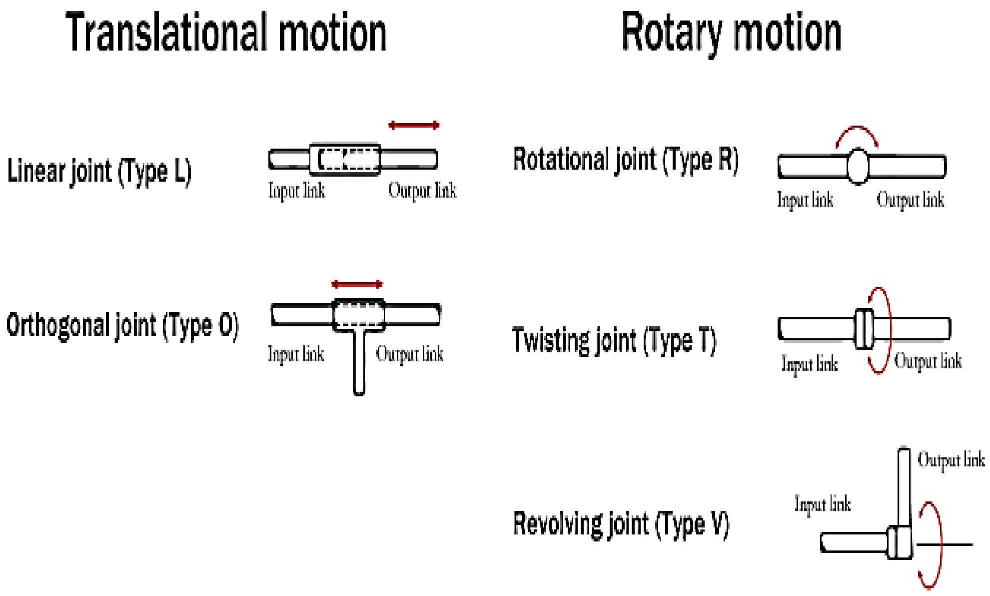


FIG 1.7 Types of Joint.

1.9 CLASSIFICATION OF ROBOT:

The robot manipulator can be classified according to the types of axes movement needed to compute the task. Because we live in a three dimensional world the robot must be able to reach the point in space by moving forward and backward, left and right , up and down. This can be accomplished by classifying the robot manipulator according to the type of the axes movement. They are

1. Cartesian coordinated robot (Box, Gantry, Rectangular)
2. Cylindrical coordinated robot (Post type)
3. Spherical coordinated robot (Polar, Telescopic type)
4. Jointed arm
    (i) Vertical jointed arm
    (ii) Horizontal jointed arm

1.9.1 Cartesian Coordinated Robot :

It consists of three linear axes of motion or coordinates. The first coordinate represents the left and right axis of the motion. The second coordinate represents the forward and backward axis of motion. The third coordinate represents the up and down axis of motion. The work volume formed by this kind of robot is box or cubic.

Figure 1.8 shows the XYZ movements of Cartesian coordinated configuration

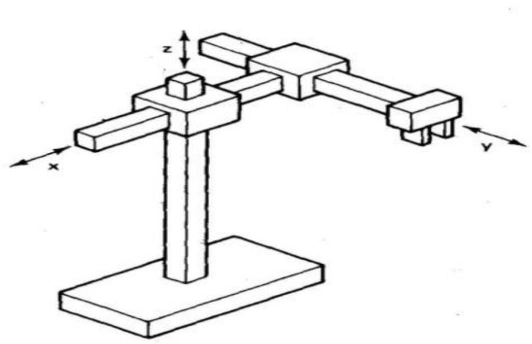


FIG 1.8 Cartesian Co-ordinate Configurations

Advantages:

→ Simple control
→ Easy to visualize
→ High mechanical rigidity
→ Good accuracy
→ Good repeatability

Disadvantages:

→ Limited in movement
→ Need large floor space
→ It can reach only front of itself

Application:

→ Assemble
→ Surface finish
→ Inspection

1.9.2 Cylindrical coordinated robot

A cylindrical or post type coordinated robot manipulator consists of three axes of motion. The first two are linear motions and third coordinate is a rotational one. The robot which has two linear motions and one rotational motion can achieve variable motion. The first coordinate correspond to ø about the base. The second coordinate y is in and out motion. The third coordinate Z is the up and down motion. The overall volume or work envelope is a portion of cylinder. Figure 1.9 shows the movements of cylindrical robot and its work envelope

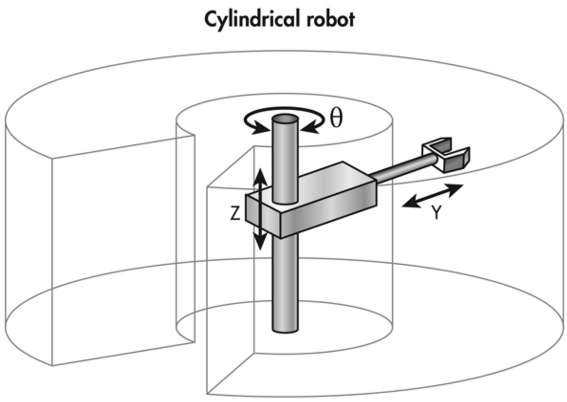


FIG 1.9 Cylindrical Coordinated Robot

Advantages:

→ Rigid Structure

→ Good repeatability

→ Good accuracy

→ Easy to program offline

→ Larger work envelope

Disadvantages:

→ Lower mechanical rigidity

→ More sophistic control system is required.

→ Horizontal motion is circular only

Application:

→ Load and unload

→ Conveyor pallet transfer

→ Material handling

1.9.3 Spherical Coordinated Robot

It has one linear and two rotational robot motions. The first rotational is about the base ø. The robot manipulator has the second rotational β. The third one is the linear motion of the robot manipulator Y. The work volume shape is a section of sphere with upper and lower limit imposed by the rotational movement of the arm.Figure 1.10 illustrates the movement of different joints of spherical coordinated robot.

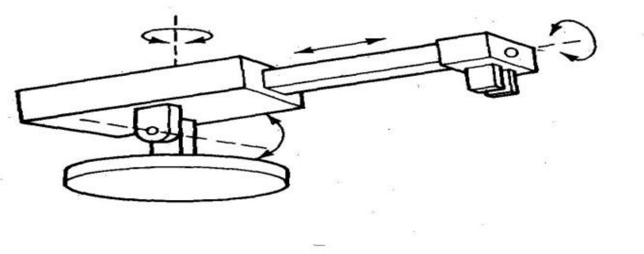


FIG 1.10 Spherical coordinated robot

Advantages:

→ Simple design
→ High pay loads
→ Good precision
→ Easy to program
→ Larger envelope than Cartesian

Disadvantages:

→ Lower mechanical rigidity
→ Limited vertical movement

Application:

→ Forging
→ Injection moulding
→ Machine tool loading
→ Material transfer

1.9.4 Jointed arm coordinated robot:

It has the work envelope of the irregular shape which is divided into two categories as follows.

(i) Vertical articulated robot:

It manipulates three rotary motions to reach the point in space. This manipulator has axis of motion similar to human arm. This robot manipulator has two links shoulder and elbow. The first rotation is about base. The second rotation is about the shoulders. The third rotation is about the elbow. The work envelope formed by this kind of robot is circular in top surface. When viewed inside surface it seems to be scalloped surface. These types of robots are called 'Tear drop'. Figure 1.11 shows the vertical articulated robot.

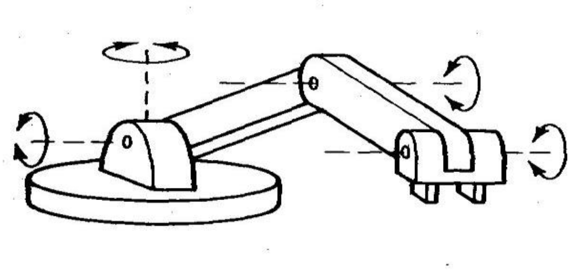


FIG 1.11 Jointed arm coordinated robot:

Advantages:

→ More flexible

→ Flexible reach

→ Versatile configuration

Disadvantages:

→ Poor accuracy

→ Complex programming

→ Most complex manipulator

Application:.

→ Automatic assembly

→ Machine vision

→ In process inspection

→ Painting and welding

(ii) Horizontal articulated Robot:

The horizontal jointed arm robot has generally two rotary and one linear coordinates. These kinds of robots are also called as SCARA (Selective compliance assembly robot arm). This robot has two horizontally jointed arm mounted on a rigid base. The first rotary motion is about the shoulder. The second rotary motion corresponds to the elbow. The third linear movement is about the Z axis. The figure 1.12 shows the different movements of SCARA robot

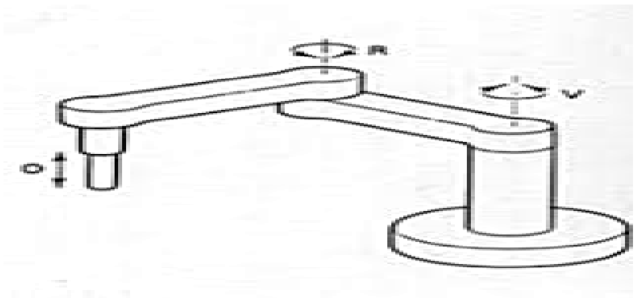


FIG 1.12 SCARA

Advantages:

→ Large work area for floor space

→ Good repeatability

→ High axis is rigid

Disadvantages:

→ Difficult to program offline

→ Complex arm

→ Two ways to reach a point

Application:

→ Industrial (hobbyist)

→ Domestic

→ Persona (military)

→ Medical (Education).

1.10 STRUCTURAL CHARACTERISTICS OF ROBOTS:

Speed of Response and stability

Speed of response: It refers to the capability of the robot to move to the next position in a short amount of time. It is governed by:

1. The distance to be moved
2. The weight of the part to be moved
3. The accuracy required in placement of the part

Stability:

It is defined as a measure of the oscillations which occur in the arm during movement from one position to the other. A robot with good stability will exhibit little or no oscillations either during or at the termination of the arm movement. Poor stability would be indicated by a large amount of oscillation. The stability of a robot can be controlled to a certain extent by incorporating damping elements into the robots design

Mechanical Rigidity:

It is defined as the property of materials to withstand failure in extensional, impact or flexural stresses.

1.10.1 Effect of structure:

The effect of structure depends on following factors.

Precision of movement depends on

1. Spatial resolution
2. Accuracy
3. Repeatability

1. **Spatial resolution**: Spatial resolution of robot is the smallest increment of the movement into which robot can divide its work volume. Spatial resolution depends on the two factors: the system's control resolution and robots mechanical inaccuracies.

   Control resolution: Control resolution is determined by the robot's position control system and its feedback measurement system. It relates to the systems capability to divide the range of the total movement into closely spaced points that can be identified. Thus it would represent the minimum noticeable movement achievable.

   It may be added that the controller can generate pulses of very small duration but the positioning device should be able to respond and change its position accordingly. In such a case, control resolution= range of movement/ 2n .where n= no. of bits devoted to a joint and 2n = no. of addressable points.

   Whereas control resolution controls the resolution for only one link and one motion, spatial resolutions combines the control resolution of all motions and also considered as the mechanical errors in the points and associated links.

   Figure 1.13 illustrates the accuracy and spatial resolution

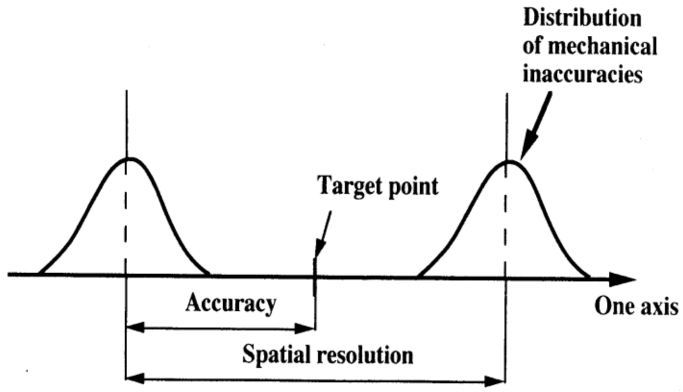


FIG 1.13 Illustration of accuracy and spatial resolution

2. **Accuracy**: Accuracy refers to a robots ability to position its wrist end at a desired target point with in the work volume. The accuracy of a robot can be defined in terms of spatial

resolution. Because the ability to achieve target points depends on how closely the robot can define the control increments for each of its joint motions.

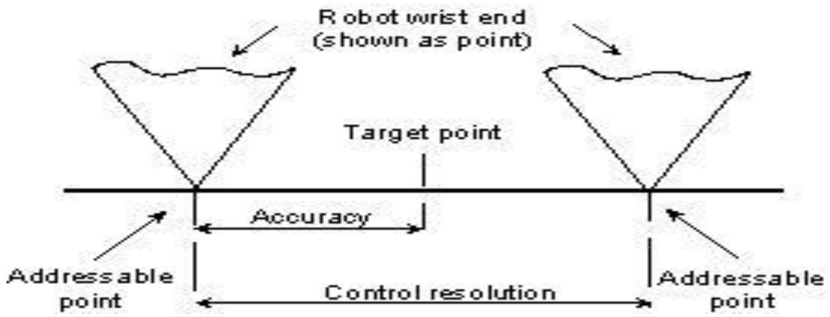


FIG 1.14 Illustration of accuracy and control resolution when mechanical inaccuracies are assumed to be zero

3. **Repeatability**: It is concerned with the robots ability to position an object at a previously taught point in the work envelope. Because of errors present particularly due to mechanical sources the robot will not be able to return to exact programmed points. Figure 1.15 illustrates the repeatability and accuracy

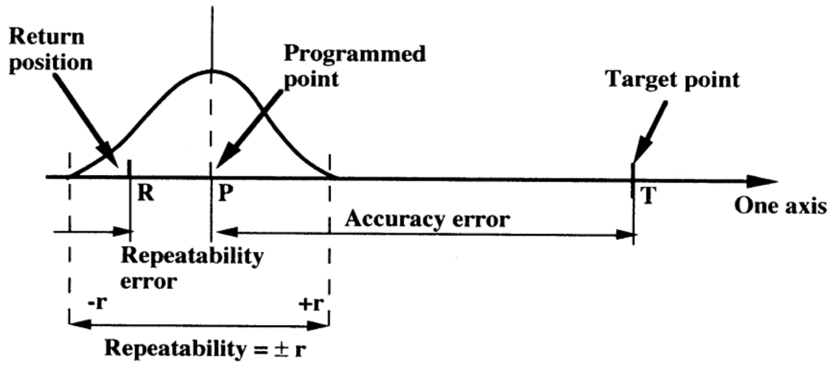


FIG 1.15 Illustration of repeatability and accuracy.

1.11 WORK VOLUME OR WORK SPACE OR WORK ENVELOPE:

The term work volume refers to the space within which the robot can manipulate the wrist end. This depends on

(i) Physical configuration of robot
(ii) Size of arm, body, wrist of robot
(iii) Limits of joint movements of robot

1.12 ROBOT WORK VOLUMES AND COMPARISONS:

1. Cartesian Co-ordinate Robot:

The work envelope of a rectangular Cartesian coordinate Robot is shown in figure 1.16. The elevation view indicates the vertical and horizontal reach obtained due to the rise and fall of the arm on the vertical column and in and out position of the robot arm.

The plan view also shows a rectangle due to the combined action of the sliding of the arm on the horizontal axis and the transverse stroke.

The work envelope of the rectangular coordinate robot is a parallelepiped. Rectangular coordinate robot is very rigid and suitable for pick and place operations in hot environment as in a furnace. It is also suitable manipulator for overhead operations as it covers a large work area.

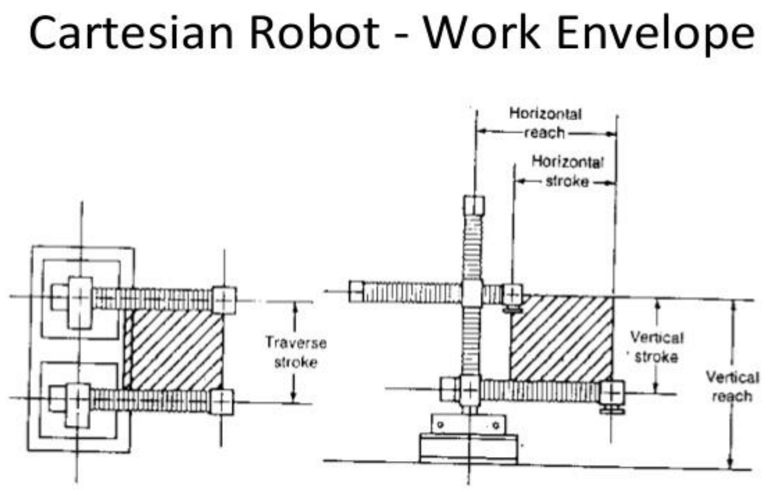


FIG 1.16 Work envelope of Cartesian robot

2. Cylindrical coordinate robot:

The work envelope of the cylindrical coordinate robot is shown in figure 1.17. The elevation view indicates the vertical and horizontal reach. The vertical and horizontal strokes combined to form a rectangular section. The plan view indicates the robot arm pivoted at the centre of the base which can form a portion of a circle by the action of swing. The plan view also shows the horizontal reach. Thus the work envelope of a cylindrical coordinate robot is the portion of the cylinder.

Cylindrical coordinate robot is suitable for handling parts in the machine tools and other manufacturing equipment.

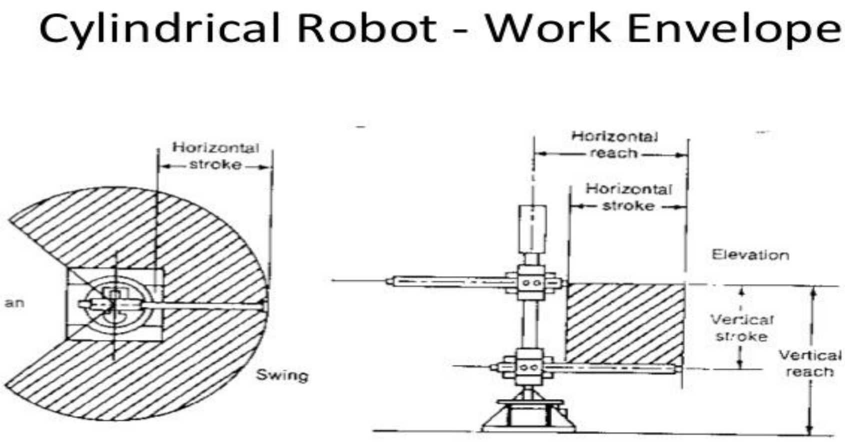


FIG 1.17 Work Envelope of Cylindrical Robot

3. Spherical or Polar Coordinate Robot:

It forms an envelope as shown in the figure 1.18. The elevation view indicates the vertical reach and the horizontal reach. Unlike the cylinder coordinate robot that makes up and down motions on the vertical axis, the polar coordinate robot is pivoted and forms an arc while the horizontal stroke extends from the inner circle to the outer circle in the elevation view. The plan view indicates a swing of robot's arm as it is rotated around its base.

The work envelope of the extension arm of a spherical coordinate robot is the volume swept between two partial spheres.

Spherical coordinate robots are most suitable for transferring parts on machine tools. They are suitable for picking components from the floor.

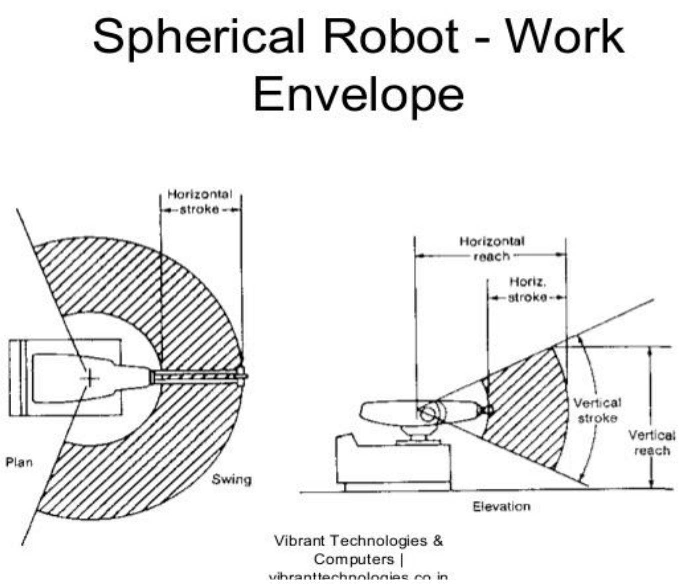


FIG 1.18 Work Envelope of Spherical Robot

4. Jointed arm Coordinate Robot:

The work envelope of a revolute or a jointed arm coordinate robot is shown in figure 1.19. The elevation view indicates a complex work envelope that is swept by the combined motion of the waist elbow and the wrist of the manipulator. The vertical and horizontal reach is also shown in the elevation view. The plan indicates the same swing as shown in the plan view of the cylindrical coordinate robot.

Jointed arm robot is flexible and versatile as it can easily reach up and down and also can swing back. The joints are all rotary. This type of robot is suitable for loading and unloading of components or tools in CNC machines and machining centres, and finds wide application in forging and metal working industries.

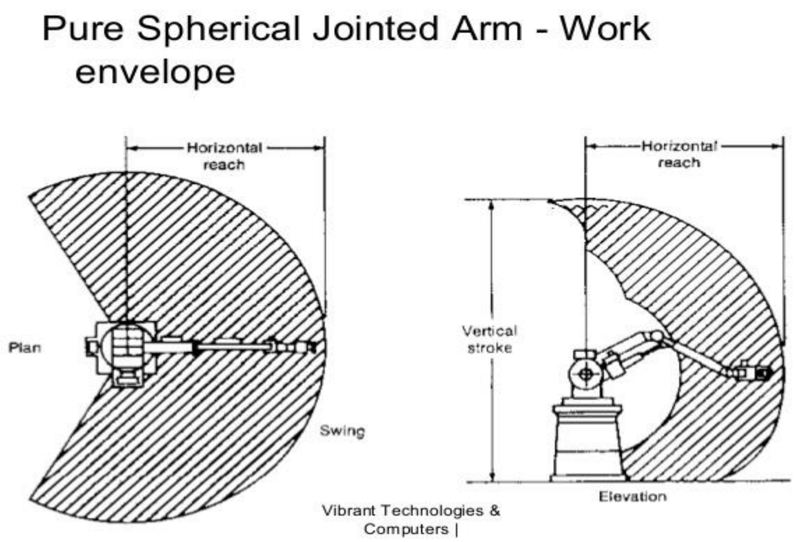


FIG 1.19 Work Envelope of Pure Spherical Jointed Arm

1.13 Wrist Rotations:

a. Wrist roll: Also called wrist swivel, this involves rotation of the wrist mechanism about the arm axis.
b. Wrist pitch: Given that the wrist roll is in its centre position, the pitch would involve the up or down rotation of the wrist. Wrist pitch is also sometimes called wrist bend.
c. Wrist yaw: Again, given that the wrist swivel is in the centre position of its range, wrist yaw would involve the right or left rotation of the wrist.

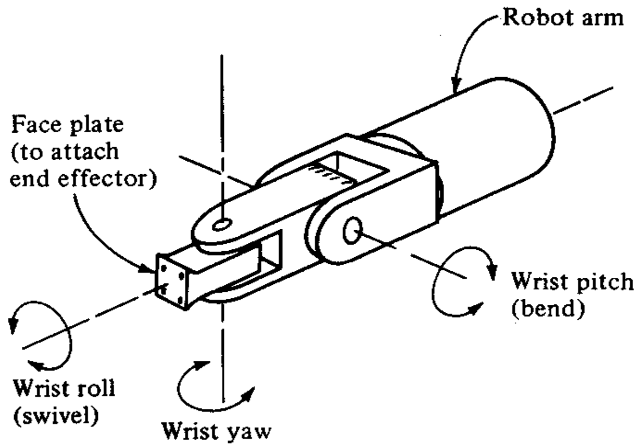


FIG 1.20 Illustrates Wrist Rotations

1.14 MECHANICAL TRANSMISSION:

To actuate links and joints, drives are used. These drives may be hydraulic, pneumatic or electric. It is not possible to apply forces, speed or force, torque at places where it is required. Also it is not possible to use actuator directly at the place of need. These are due to limitations in constructions and design etc. Hence some sort of devices is required to transfer power from actuator to the place of need. This is accomplished by mechanical power transmission. There are number of ways to transfer the power such as pulleys and gears, chains, belts, sprockets etc.

To transfer rotary motion from one shaft to another pulleys and belts, gears, sprockets are used. To transfer rotary motion from one shaft into linear motion slider cranks, powered screws (lead screws), rack and pinion are used.

1.15 PULLEYS AND BELTS:

→ Pulleys and belts are one of the ways for mechanical power transmission system. Because of the physical location of components in many robot manipulators, the gears are not most productive in which the power can be transferred from actuators to load. The better way is through the use of belts. Belts provide low cost way to deliver power. Belts also provide a smooth, quiet running, shock absorbing system to the robot.

→ Belts are not much strong as chain or gear to transmission of power. But belts can be reinforced so that they can be the useful parts of robotic system. The robotic manipulators uses V belt, synchronous belt, flat belts which are described below.

1.16 BELTS ARE CLASSIFIED ACCORDING TO THE POWER TRANSMITTED:

1. Light drives: This type of belt drive is used for transmitting less power with belt of speed up to 10m / Sec. Used in agricultural machines and small machine tools.
2. Medium drives: Speed from 10 m/ sec to 20m/ sec used in machine tools.
3. Heavy drives:
   - → Above 20m / sec speed
   - → Used in compressor, generators

According to the type of belt used, the belt drives are classified as follows:

→ Flat belt drives:

a. Open belt drive
b. Cross belt drive
c. Compound belt drive

The cross section of flat belt is rectangular and they are used where a medium amount of power is to be transmitted from one pulley to another.

Open Belt drive:

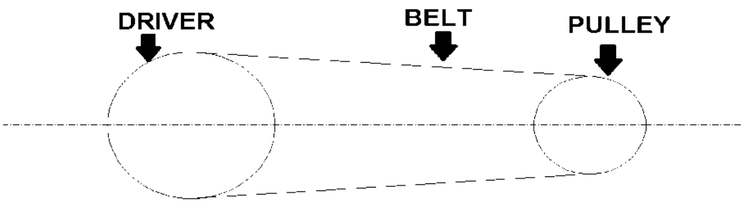


FIG 1.21 Open Belt Drive

As shown in figure 1.21, when two pulleys are arranged in parallel and both are to be rotated in same direction an open belt drive is used.

Cross belt drive:

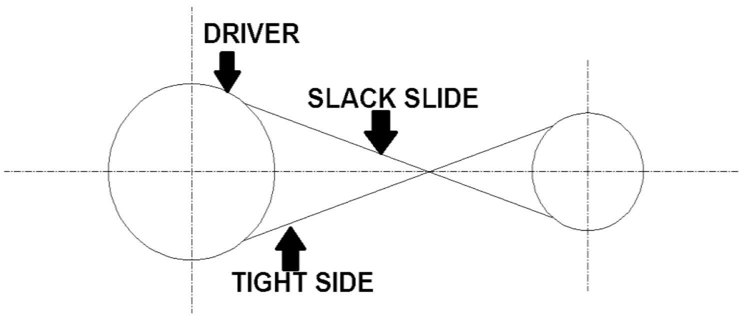


FIG 1.22 Cross Belt Drive

The cross belt drive is used when the shafts are arranged in parallel and rotate in opposite direction as shown in diagram 1.22

Compound Belt Drive:

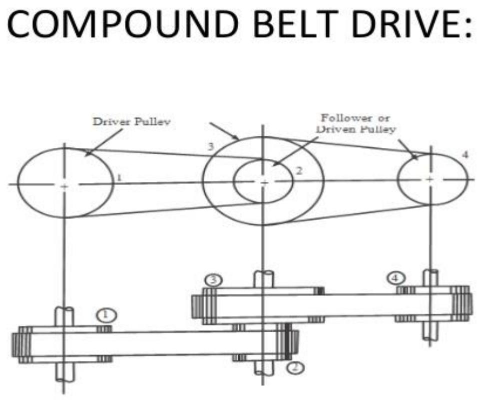


FIG 1.23 Compound Belt Drive

Flat belt drive:

When power is to be transmitted from one shaft through a number of pulleys, then a compound belt drive is used. Flat belt is the most common type of belts used in robotic system. It provides the cheapest way to deliver the power at moderate speeds. Flat belts are used to transfer large amount of power at smaller speeds.

The flat belt is tending to slip between the pulleys. Hence it cannot provide much torque required by many robot manipulators. The flat belt is generally used where short distance between actuator and pulley. For example flat belts can be used in wrist assembly of smallest manipulators

V-Belt drive:

The cross section of V-Belt is trapezoidal and they are used when large amount of power is to be transmitted form one pulley to each other. Figure 1.24 shows Flat and V belt.

The V belt is named for its shape. The belt is made up of rubber and contains a coated jacket which prevents the belt from tearing and wearing from daily operations. The belt contains reinforced cords which provide additional strength to the belt. The cushioned section of v belt conforms to channel of pulley on which it may be mounted.

The belt transfers energy through pulleys or sheaves. These devices allows belt to turn and transfer its energy to other pulleys. The belt runs around the pulley but its dimension will not be distorted because the size of belt has into account of diameter pitch of the pulley.

In robot manipulator the V belts are used to transfer energy from motor to pulleys that connected to base of the manipulator.

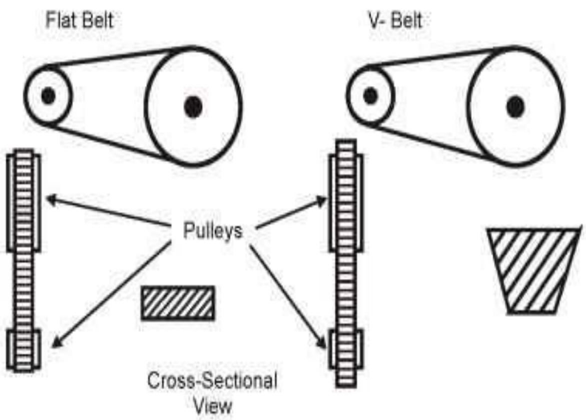


FIG 1.24 Flat and V belt

Synchronous Belt:

Synchronous belt have evenly spaced teeth in its contact surface. These are used with special type of pulleys which have grooves on its surface. The teeth of belts and gears groove must be meshed to transfer energy.

Synchronous belt provides positive grip that are needed by chains or gears in the system. Synchronous belt provides positive contact between pulleys. These are expensive than V belts. These are also referred as timing belts. Synchronous belts are used where constant changing of direction of rotation is needed. These must be used in wrist assembly of manipulator.

1.17 GEARS:

The use of gears in power transmission is most common in robots. Gears are used to transfer power between parallel shafts or intersecting shafts.

The simplest gear is spur gear used to transmit rotary motion between parallel shafts. The worm gear and worm wheel, bevel gears are used to transfer power between intersecting shafts. The use of gears provides various speeds. By use of gears increasing or reduction in speed is possible.

Spur gears:

Spur gears are used to connect two parallel and coplanar shafts. When the spur gears mesh internally they are called internal gears, whereas if the mesh externally they are called external gears. Figure 1.25 shows spur gear.

Internal gear → rotate in same direction

External gear → rotate in opposite direction

FIG 1.25 Spur Gear

Applications:

→ Used in the gear box-automobiles
→ Used in back gear of lathe
→ Watches and clock

Helical gears:

Helical gears are used to connect either parallel or non-parallel and intersecting shafts. The teeth are cut in the form of helical. More power can be transmitted. Figure 1.26 shows Helical gear.

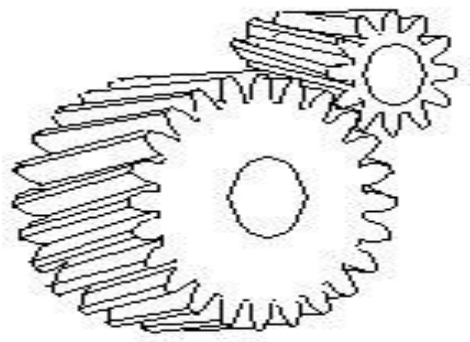


FIG 1.26 Helical Gear

Applications:

→ Used in gear box and final drive automobiles
→ Shaft of IC Engines
→ Timing gears of IC Engines

Bevel Gear:

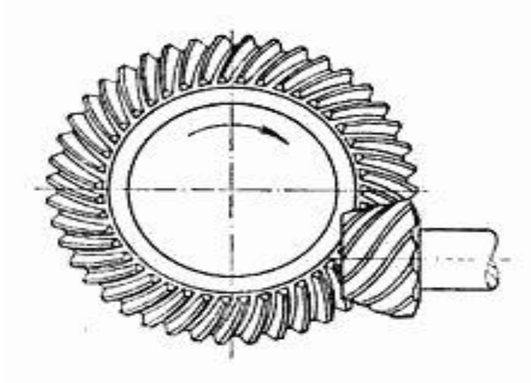


FIG 1.27 Bevel Gear

- → It can have straight, spiral teeth
- → Bevelled gears are used when we wish to transfer work between two perpendicular shaft that are on the same plane.

Applications: Differential automobile drill chuck key worktable of machine tools.

Worm gear:

This gear resembles a screw, with parallel helical teeth and mates with a normal spur gear. They are used for transmission between two non in-intersecting perpendicular axes.

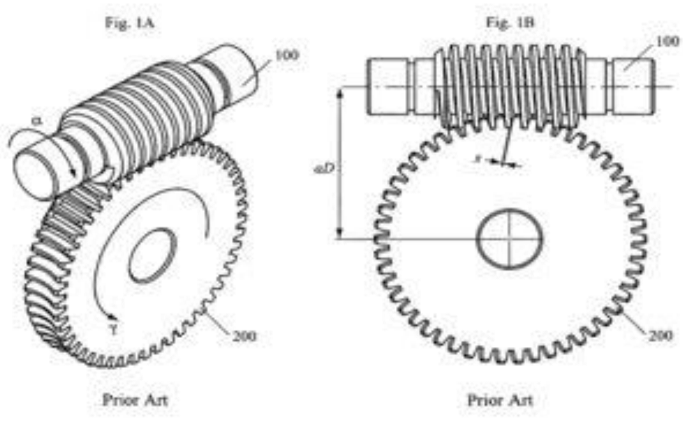


FIG 1.28 Worm Gear

According to types of arrangement, Gears are classified as simple gear train, Compound gear train and planetary wheel.

1.18 HARMONIC DRIVE:

Harmonic drive is a device used for transferring rotary motion from one shaft to another shaft.

Advantages:

1. Various speed ratio is possible with the use of harmonic drive.

2 .Both reduction and increase in speed ratio is possible.

Components: (CWF)

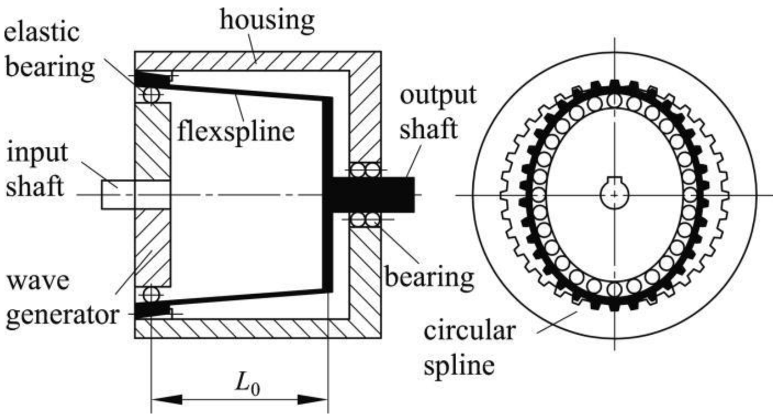


Fig 1.29 Shows Components of Harmonic drive.

Circular spline:

The rigid thick wall, internal spline teeth may either be fixed or rotating element.

Wave Generator:

It is an elliptical shaped ball bearing mechanism having shaft coupling. It is the drive input shaft

Flex spline: Non rigid, thin wall cup is flex spline having fewer teeth than circular spline and also less pitch diameter than circular spline. It is output drive shaft.

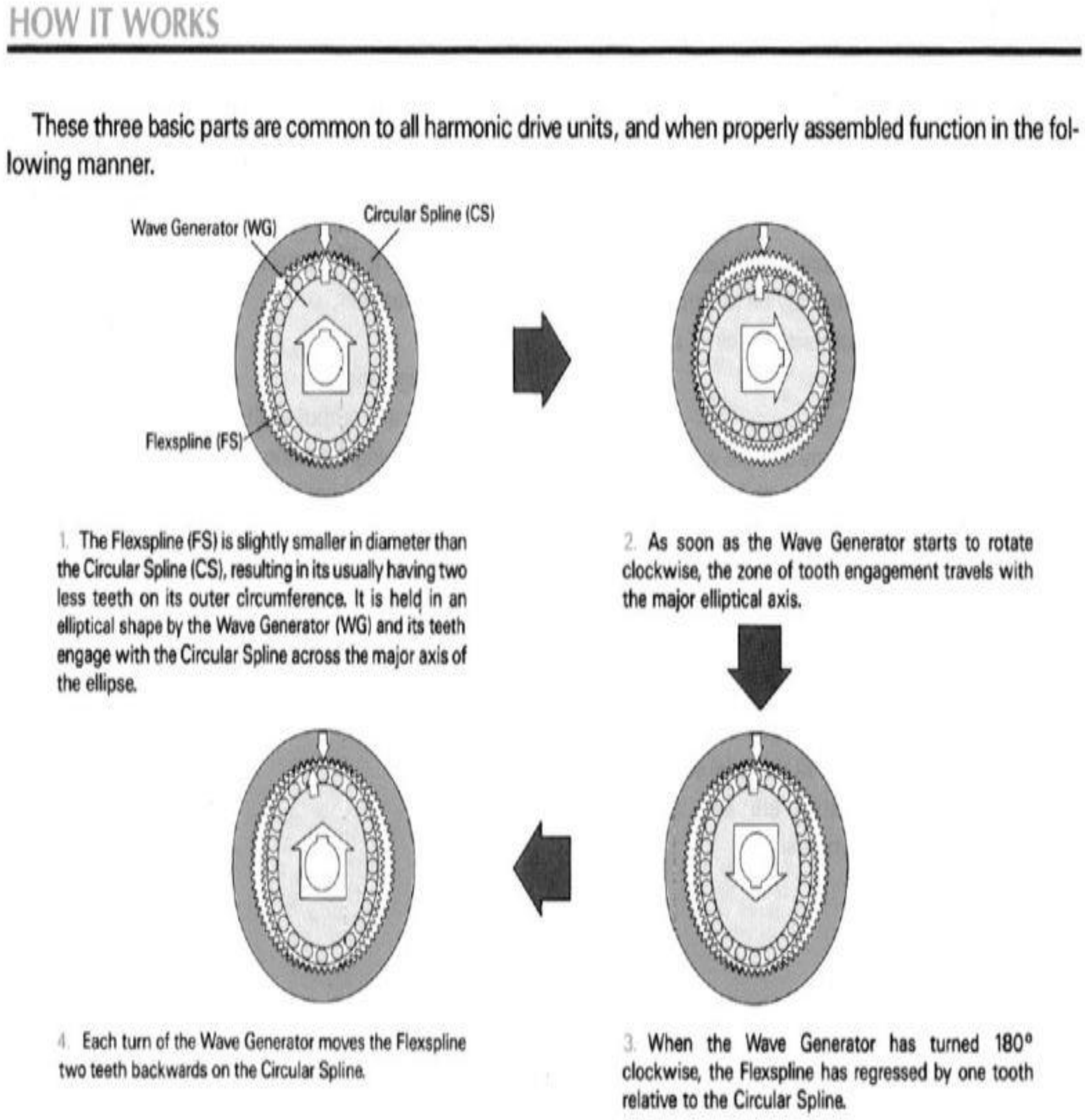
Principle:

Harmonic drive works on the principle of non-rigid body mechanism. This allows three concentric components to have mechanical advantages and speed ratio. Non Rigid Body Mechanics allows a continuous elliptical deflection wave to be induced on the non-rigid external gear that provides continuous rolling in the rigid internal gear.

Working:

Since teeth in the non-rigid flex spline and rigid circular spline are in continuous engagement and since the flex spline has fewer teeth than circular spline the input for one revolution produces relative motion between circular spline and flex spline produce output of reduced speed equal to two teeth. The circular spline is fixed the flex spline is rotating in opposite direction produces reduced speed ratio equal to number or tooth in flex spline divided by two

The relative motion can be easily understood by taking the motion of one single flex spline tooth over one half or input revolution. The tooth is fully engaged when major axis is 90 degree The tooth is engaged with adjacent tooth of flex spline when major axis is at 180°



HOW IT WORKS

These three basic parts are common to all harmonic drive units, and when properly assembled function in the following manner.

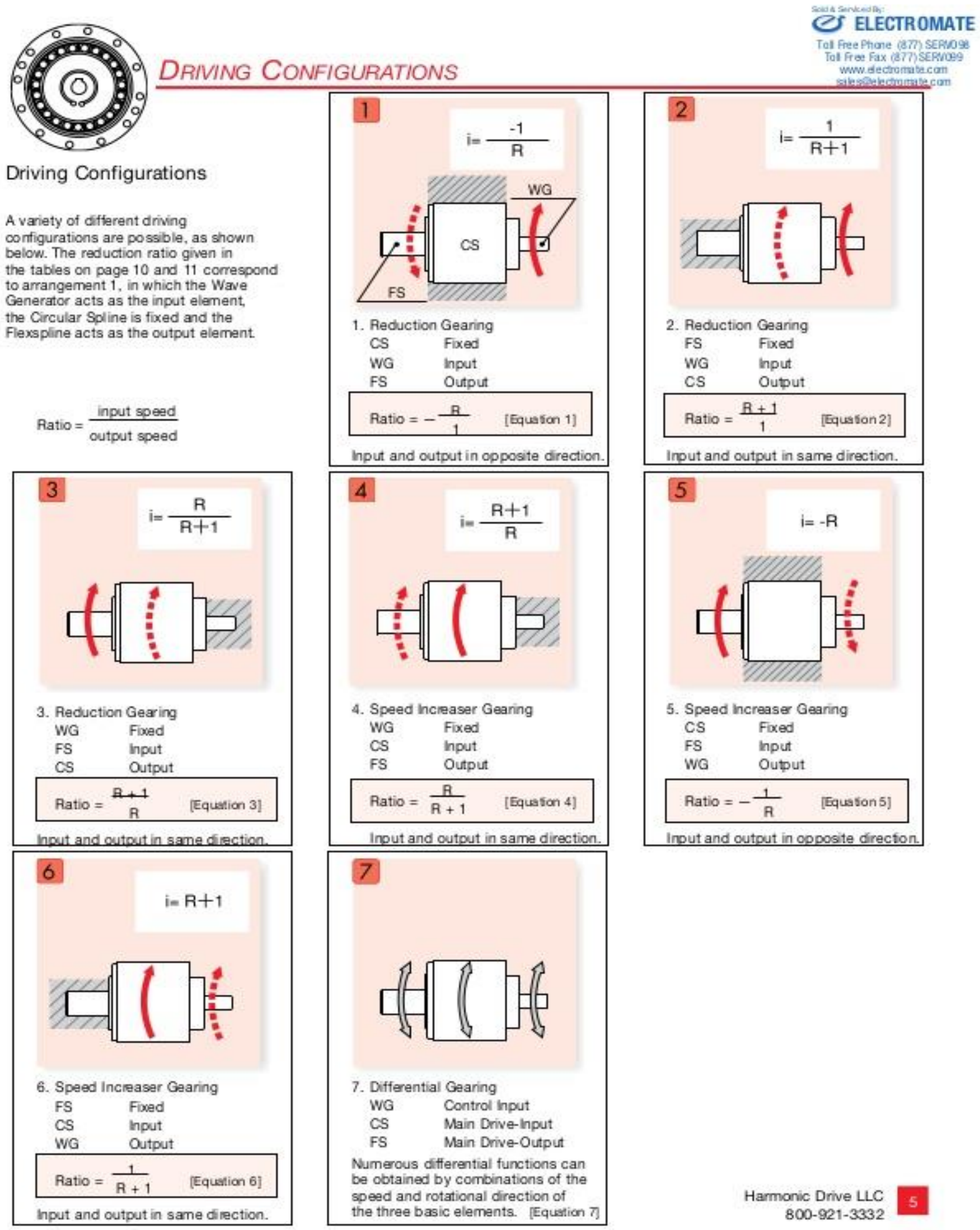
1. The Flexspline (FS) is slightly smaller in diameter than the Circular Spline (CS), resulting in its usually having two less teeth on its outer circumference. It is held in an elliptical shape by the Wave Generator (WG) and its teeth engage with the Circular Spline across the major axis of the ellipse.

2. As soon as the Wave Generator starts to rotate clockwise, the zone of tooth engagement travels with the major elliptical axis.

3. When the Wave Generator has turned 180° clockwise, the Flexspline has regressed by one tooth relative to the Circular Spline.

4. Each turn of the Wave Generator moves the Flexspline two teeth backwards on the Circular Spline.

The variety of different driving configurations are as follows



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DRIVING CONFIGURATIONS

Driving Configurations

A variety of different driving configurations are possible, as shown below. The reduction ratio given in the tables on page 10 and 11 correspond to arrangement 1, in which the Wave Generator acts as the input element, the Circular Spline is fixed and the Flexspline acts as the output element.

$$\text{Ratio} = \frac{\text{input speed}}{\text{output speed}}$$

1 $i = \frac{-1}{R}$ (WG, CS, FS)

1. Reduction Gearing
CS Fixed
WG Input
FS Output

$$\text{Ratio} = -\frac{R}{1} \quad \text{[Equation 1]}$$

Input and output in opposite direction.

2 $i = \frac{1}{R+1}$

2. Reduction Gearing
FS Fixed
WG Input
CS Output

$$\text{Ratio} = \frac{R+1}{1} \quad \text{[Equation 2]}$$

Input and output in same direction.

3 $i = \frac{R}{R+1}$

3. Reduction Gearing
WG Fixed
FS Input
CS Output

$$\text{Ratio} = \frac{R+1}{R} \quad \text{[Equation 3]}$$

Input and output in same direction.

4 $i = \frac{R+1}{R}$

4. Speed Increaser Gearing
WG Fixed
CS Input
FS Output

$$\text{Ratio} = \frac{R}{R+1} \quad \text{[Equation 4]}$$

Input and output in same direction.

5 $i = -R$

5. Speed Increaser Gearing
CS Fixed
FS Input
WG Output

$$\text{Ratio} = -\frac{1}{R} \quad \text{[Equation 5]}$$

Input and output in opposite direction.

6 $i = R+1$

6. Speed Increaser Gearing
FS Fixed
CS Input
WG Output

$$\text{Ratio} = \frac{1}{R+1} \quad \text{[Equation 6]}$$

Input and output in same direction.

7

7. Differential Gearing
WG Control Input
CS Main Drive-Input
FS Main Drive-Output

Numerous differential functions can be obtained by combinations of the speed and rotational direction of the three basic elements. [Equation 7]

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Advantages:

→ Zero black lash

→ High reduction ratio with single stage

→ Compact and light weight

→ High torque capability

→ Coaxial input and output shaft.

1.19 CONVERSION OF ROTARY MOTION INTO LINEAR MOTION:

It is concerned with the rotary motion with torque as input and linear motion with force as output. These can be accomplished by lead screws, rack and pinion, cranks and slides as follows.

1.19.1 Lead screws:

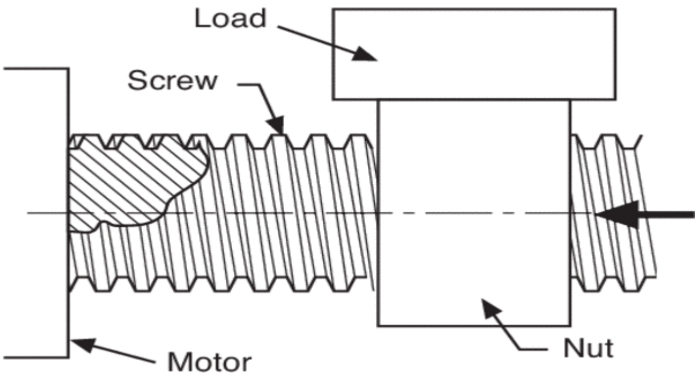


FIG 1.30 Lead Screw

The figure 1.30 shows lead screws driving a pay load along single axis. In this configuration, the screws are fixed with its end, free to rotate as the screw is turned, the nut with pay load typically moves along the surface with very low frictional components.

A rotary displacement of input shaft ø is converted into linear displacement of payload X.

1.19.2 Rack and Pinion:

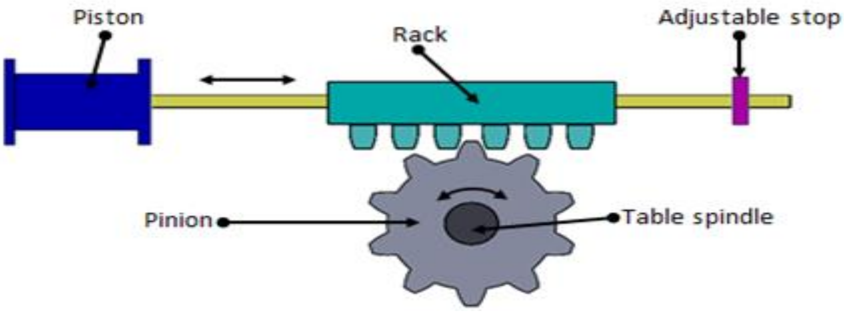


FIG 1.31 Rack and Pinion

The figure 1.31 illustrates rack and pinion arrangement to convert rotary motion into linear motion. The pinion is the small gear wheel, the rack is linear member having geared teeth on one side. The transfer of motion mechanism can be represented as

$$X=2x\ 22/7\ r$$

The linear distance travelled is proportional to rotational movement of input shaft with constant proportionality equal to the circumference of pinion. The linear distance travelled is equal to rotational distance travelled by the pinion.

→ The linear drives are used in Cartesian robots and polar robots to obtain a linear movement.

1.19.3 Slider crank:

Its mechanism is a cost effective method for converting rotary motion into linear motion. The fig illustrates a representation of a crank driving a linear load. Figure 1.32 shows slider crank.

In this construction, the crank portion is the wheel the rotates about its center and has a rod of fixed length mounted to a point on its circumference. The other end of the connecting rod is attached to the linear load. At both its locations on the disk and linear stage, the connecting rod is free to rotate. As the disk travels from 0 to 180 degree in the clockwise direction, the linear load moves a distance equal to 2r.

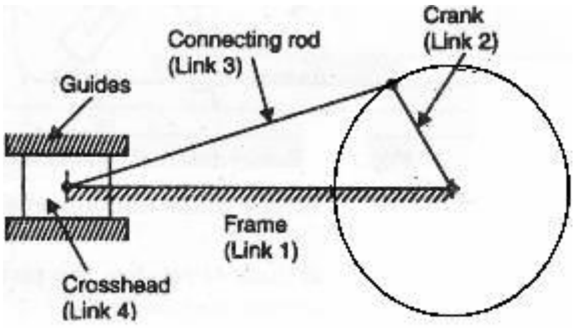


FIG 1.32 Slider Crank.

= = = = = = =

Model Questions

PART-A (2 MARKS)

1. Define robot

2. List out the types of robot configuration system?

3. Name the important parts of harmonic drive.

4. What is meant by work volume?

5. What is meant by accuracy of a robot?

6. What is meant by precision of a robot?

7. Define repeatability of a robot.

8. What is end effector?

9. What is EOT?

10. Name any two types of sensors used in robotics.

11. What is meant by degree of freedom?

12. What is meant by link, state the types of links?

13. What is meant by mechanical transmission?

14. List out the advantages of Cartesian coordinate configuration

15. List the types of drive systems used in robot

16. What are joints?

17. Classify types of belt drive

18. List the types of gear drive

PART- B (3 MARKS)

1. What are the different components of a robot?

2. Draw the different types of joints.

3. Describe degrees of freedom associated with wrist

4. Define i) Accuracy ii) Repeatability.

5. Briefly explain DOF associated with arm and body

6. Draw DOF associated with arm and body.

7. Draw Cartesian configuration robot.

8. Draw the work envelop of cylindrical coordinate robot.

9. Write short notes on SCARA.

10. Define accuracy and repeatability.

11. Write short notes on harmonic drives

12. Write any one device used to convert rotary motion in to linear motion.

13. List any two advantages and disadvantages of cylindrical coordinate robot.

14. Mention any two advantages and disadvantages of spherical coordinate robot.

PART-C (10Marks)

1. Explain various components of a robot with a neat diagram.

2. Explain rectangular and cylindrical coordinate robot with neat diagram.

3. What are the structural characteristics of a robot? Explain.

4. Explain cylindrical and spherical coordinate robot with its work envelope.

5. With neat diagram explain harmonic drives.

6. Explain DOF associated with Arm, body and wrist.

7 Explain the different types of robot joints with neat diagram.

8. Explain any three configuration of robot with a neat diagram.

9. Explain any two devices used to convert rotary to linear motion.

10. Explain any two mechanical transmission elements with diagram.

11. Explain Cartesian coordinate robot with neat diagram. Mention its advantages and disadvantages

12. Explain polar coordinate robot with neat diagram. Mention its advantages and disadvantages.

UNIT-II

ROBOT CONTROLLER, SERVO SYSTEMS

Robot controller – level of controller – open loop and closed loop controller –servo systems – – robot path control – point to point – continuous path control – sensor based path control – controller programming – actuators – dc servo motors – stepper motors – hydraulic and pneumatic drives - feedback devices – potentiometers – optical encoders – dc tachometers.

2.1 ROBOT CONTROLLER:

The controller is a communication and information processing device that initiates, terminates, and coordinates the motion and sequences of a robot. It accepts the necessary inputs to the robot and provides the output drive signals to a controlling motor or actuator to correspond with the robot movements and outside world.

Controllers vary greatly in complexity and design. They have great deal to do with the functional capabilities of a robot and therefore complexity of tasks that robots must be able to fulfil.

The heart of the controller is the computer and its solid- state memory. In many robot controllers, the computer includes a network of microprocessors.

The input and output section of a control system must provide a communication interface between the robot controller and the following parts.

- Feedback sensors
- Production sensors
- Production machine tools
- Teaching devices
- Program storage devices
- Hard copy devices
- Other computer- device hardware

ELEMENTS OF ROBOT CONTROLLER:

The computer controls the motion of the robot arm by means of drive signals that pass through the drive interface to the actuators on the arm. Figure 2.1 illustrates General robot controller elements.

The elements needed in the controller are:

- Joint servo controllers
- Joint power amplifiers

- Mathematical processor
- Executive processor
- Program memory
- Input device

The number of joint servo controllers and joint power amplifiers would correspond to the number of joints in the manipulator.

Motion commands are executed by the controllers using two ways. Operator input and program memory

1. Operator input or program memory – In this method operator inputs, commands to the system using an input device such as teach pendant or a CRT terminal, or Commands are down loaded to the system from program memory under control of executive processor.
2. The set of commands have been previously programmed into memory using the operator input devices.
3. For each motion command, the executive processor informs mathematical processer about the coordinate transformation calculations that must be made. When the transformation computations are completed, the executive processor downloads the result to the joint controllers as position commands. Each joint then drives its corresponding joint actuator by means of the power amplifier.

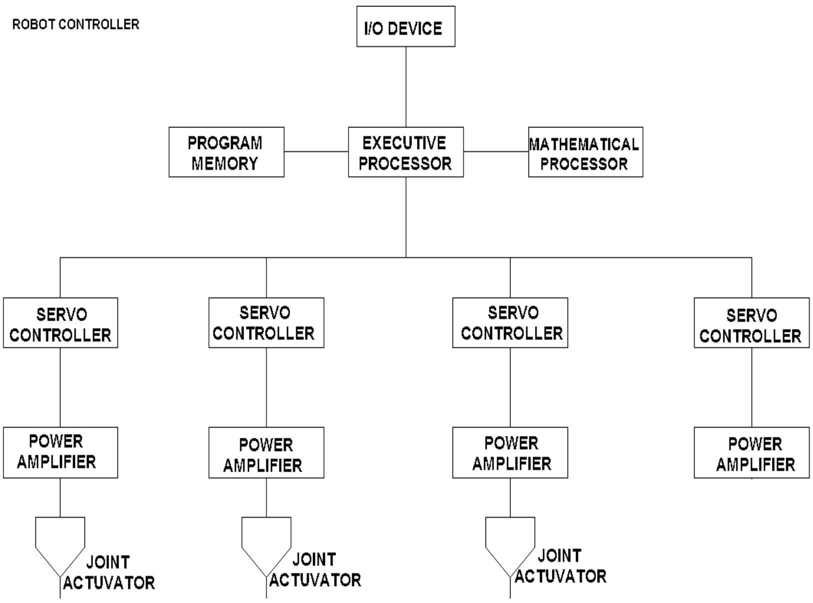


Fig 2.1 General Robot controller Elements

Microprocessor are typically utilised in several components of a modern robot controller. These components include the mathematical processor, the executive processor, the servo controllers, and the input device. Each of the control boards make use of common data buses and address buses.

The microprocessors communicate with each other by sending messages into common areas in the system memory. This architecture provides several advantages in the design of the controller. These advantages include

- Expansion of system to more joints
- Information flow between joint control elements,
- Sharing of feedback information among the various joints,
- Providing information to develop algorithms for improving individual joint dynamics.

2.2 LEVEL OF CONTROLLER:

A controller is a device introduced in the system to modify the error signal and to produce a control signal. The manner in which the controller produces the control signal is called control action. The absolute control actions can be classified into on-off controllers, proportional controllers, Derivative controllers and Integral type. By combining oneor more control actions the following types of controllers are devised.

1. On – off controller
2. Proportional controller
3. Integral controller
4. Proportional plus integral controller (P-I)
5. Proportional plus derivative controller (P-D)
6. Proportional plus Integral plus derivative controller (P I D)

1. **On-off Control:** In On-off controller the control element provides only two level of control full-on or full-off.

   If the error present at the controller is e (t) and the control signal which is produced by the controller is m(t), then the On-off controller is represented by

   $$m(t) = M1 \; for \;\; e(t) > 0$$
   $$= \; M2 \;\; for \; e(t) < 0$$

   In most of the controllers M1or M2will be equal to zero.

2. **Proportional control:** The proportional controller is a device that produces a control signal, m (t) which is proportional to the input error signal e (t).

   $$m(t) \propto e(t)$$
   $$m(t) = K_p \, e(t)$$

   K_p - proportional gain or constant.

   $M(s)/E(s) = K_p$

Features

- Provides smoother control
- Control signal proportional to the error
- Acts as an amplifier with gain Kp

3. **Integral control:** The integral controller is a device that produces a control signal m(t) which is proportional to integral of the input error signal, e(t).

$$m(t)\ \alpha \int e(t)\,dt$$

$$m\,(t) = Ki\int e(t)\,dt$$

k_i →integrator gain

Taking Laplace transform

M(s) = Ki s E(s)

M(s) / E(s) = Ki s

Features

- For a large signal the signal increases rapidly.
- At zero error, output of the controller remains constant.

4. **Proportional plus integral control:** The proportional- plus – integral controller produces an output signal consisting of two terms. One proportional to error signal and the other proportional to the integral of error signal.

Sometimes it is necessary to combine control actions. A proportional controller is incapable of counteracting a load on the system with an error. An integral controller can provide zero error but usually provides slow response. PI control overcomes this disadvantage.

$$m(t)\ \alpha[e(t) + \int e(t)\,dt]$$

$$m(t) = K_p e(t) + \frac{K_p}{T_i}\int e(t)dt$$

T_1 Integral time and *Kp* Proportional Gain.

Features

- Slow response
- Provides zero error
- Combined control action

5. **Proportional plus Derivative control:** The proportional- plus – derivative controller produces output signal consisting of two terms- one proportional to error signal and the other proportional to the derivate of the error signal.

$$m(t)\ \alpha\ [e(t) + \frac{d}{dt}e(t)]$$

$$m(t) = K_p e(t) + K_p T_d \frac{de(t)}{dt}$$

Kp proportional gain and T_d – Derivative time.

Features

- Control signal proportional to rate of change of error signal
- Faster response

6. **Proportional plus integral plus derivative control**: The combination of proportional control action, Integral control action and derivative control action is called PID control action. The combined action has the advantages of each of the three individual actions. It can be presented by

$$m(t) \;\alpha\; [\, e(t) + \int e(t)dt \; + \frac{de(t)}{dt}]$$

$$m(t) = K_p e(t) + \frac{K_p}{T_i}\int e(t)dt + K_p T_d \frac{de(t)}{dt}$$

Transfer function, $M(s)/E(s) = K_p + \frac{Kp}{Ti}s + K_p T_d s$

K p – Proportional gain

Ti - Integral time

Td - Derivative time

Features

- Most general and commonly used controller.
- Quick response
- Good control system stability
- Low steady state error

2.3 OPEN LOOP CONTROLLER

- Any physical system which does not automatically correct the variation in its output is called an open loop system. Figure 2.2 shows the block diagram of open loop system

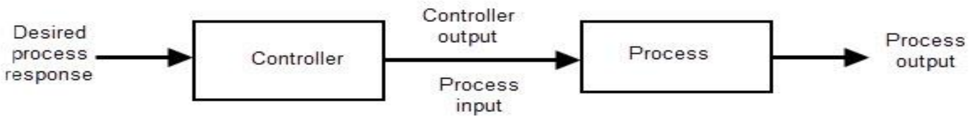


Fig 2.2 Open loop controller

- An Open-loop system, is a non-feedback system, in which, output signal has no effect on the input.

- In other words, in an open-loop control system the output is neither measured nor "fed back" for comparison with the input.
- An open-loop system is expected to follow its input command or set point regardless of the final result.
- In an open loop system the changes in output are corrected by changing the input manually.

The main characteristics of an "Open-loop system"

- There is no comparison between actual and desired values.
- An open-loop system has no self-regulation or control action over the o/p value.
- Each input setting determines a fixed operating position for the controller.

Advantages of Open loop control System:

- The open loop systems are very simple in design and easy to design.
- These are cheaper in cost than other type of control systems.
- Maintenance of open loop control system is very simple.
- These are stable for some extent of time.
- These types of systems are convenient to use.

Disadvantages of Open loop control System:

The non-feedback system doesn't facilitate the automation of process.

- Open loop systems are inaccurate in nature.
- As their output is affected by some of the external system disturbances, the non-feedback systems are unreliable.
- It cannot correct the output deviations automatically.

2.3.1 CLOSED LOOP CONTROLLER:

Closed loop system is an Automatic control system in which an operation is regulated by feedback. Control system in which the output has effect upon the input quantity is called as closed loop controller. Here the control action is dependent on the output.

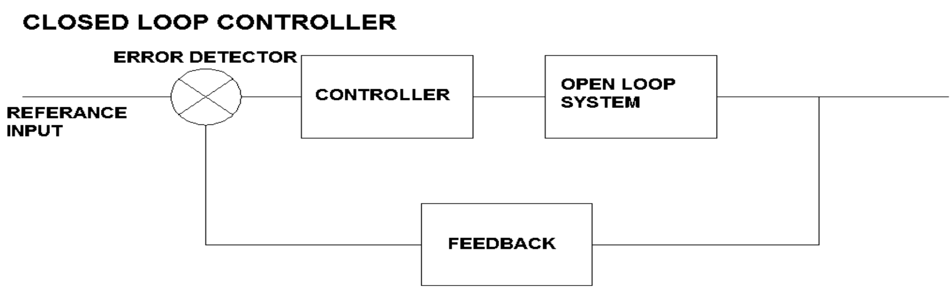


Fig 2.3 Closed Loop Control

Closed-loop control systems are also called “feedback control systems”. Feedback systems have a part of their output signal “fed back” to the input for comparison with the desired set point condition. This type of feedback signal can result either in positive feedback or negative feedback. Figure 2.3 shows the block diagram of closed loop system.

In a closed-loop system, a controller is used to bring the output of the system back to the desired response by

- Comparing the output of the system
- Converting the error into a control action
- Reducing the error

The main characteristics of Closed-loop Control

- To reduce errors by automatically adjusting the systems input.
- To improve stability of an unstable system.
- To enhance robustness against external disturbances to the process.
- To produce a reliable and repeatable performance.

Advantages of closed loop control.

- Higher positional accuracy
- Higher speed
- Higher torque
- Flexible program control
- Ease of changing programmed points

Disadvantages of closed loop control

- Large capital investment
- Sophisticated programs
- High –Skill maintenance.

Comparison of closed and open loop system.

Open loop system	Closed loop system
No feedback is used	Feedback is used
An open loop system is inaccurate	A closed loop system is accurate. Due to feedback
Simple and easy system.	Complex system.
More affected by noise	Less affected by noise

Open loop system	Closed loop system
External disturbance are not corrected automatically.	External disturbance are corrected automatically.
Gain is not affected.	Gain is changed because of feedback in the system.
Generally stable in operation	Stability depends on system components.

2.4 SERVO SYSTEMS:

A servo mechanism is a control system used to detect and correct errors.

A block diagram of a simple closed loop servo system is given in figure 2.4(a).The system includes an input comparator, which is responsible for the comparison of the command input signals from the controller's microprocessor and the feedback pulses from the actuator.

The servo amplifier is response for amplifying the difference between the command pulses and feedback pulses. The resultant pulses are feedback to the actuator.

The actuator is the drive system such as electric motor, a hydraulic cylinder, or a hydraulic motor.

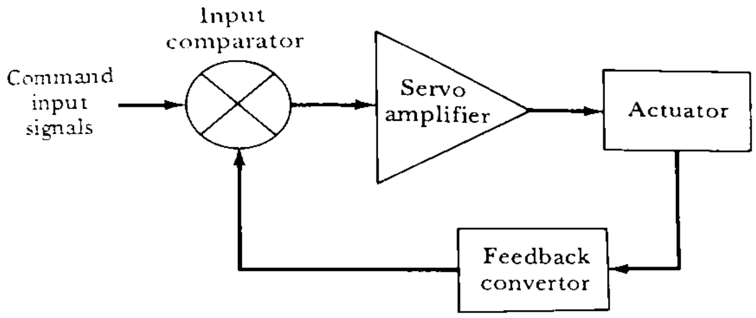


Fig 2.4 (a) Closed Loop servo system

Figure 2.4 (b) illustrates an expanded servo system loop for measuring the velocity and the position of an axis. In this block diagram, several different components are included in the overall servo system in order to generate the feedback data required.

The input of the servo system shown in figure 2.4(b) is from the robot controller's axis control circuitry. Positional data that has already been programmed is sent to the input position comparator circuitry.

The amplifier that follows the position comparator increases the strength of the compared signal and sends it to the speed comparison circuitry.

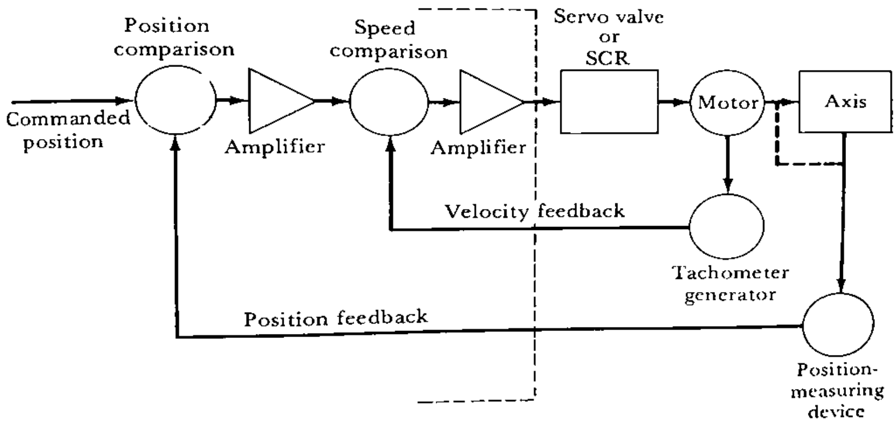


Fig 2.4(b).Expanded Servo System.

In the speed comparison circuitry, the feedback signal of the velocity of the axis is compared with the programmed speed. If there is any difference in the programmed speed and the actual speed, the servo will correct the velocity of the axis.

The speed comparison circuitry then feeds an amplifier circuit. Again, the amplifier only conditions the signal to control the servo mechanism.

The servo control device in figure 2.4(b) can be a hydraulic servo valve or an electronic control such as Silicon Controlled Rectifier. The pulses from the amplifier are sent to the servo control circuitry. The servo control circuitry directs the motor to rotate. The motor then moves the axis.

Two feedback components are used in the servo operation are,

1. Velocity Measuring device.
2. Position measuring device.

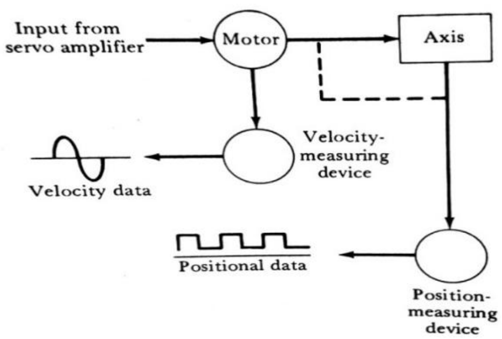


Fig 2.4 (c) Wave forms for velocity and position devices

The tachometer generator converts the velocity of the actuator into electric pulses. These pulses are feedback to the controller.

The position measuring device is an encoder that converts angular position into positional feedback signals.

Both of these transducers convert feedback signals into electric pulses. These pulses are feedback to the robot's controller's axis control circuitry and they are compared with the programmed data. If any errors, between these two signal, that are detected and corrected by the servo system. The waveforms of velocity and positional data are shown in fig 2.4(c).

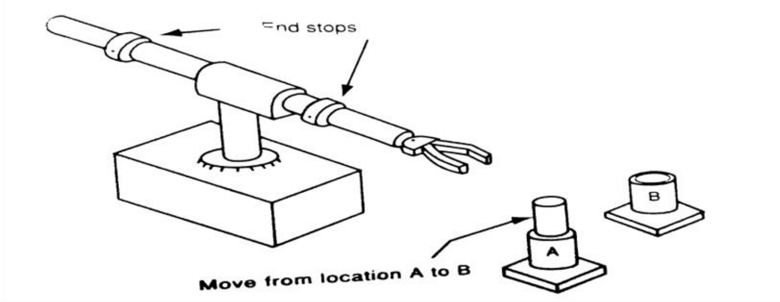
2.5 ROBOT PATH CONTROL

Robot path control can control the path and end on any specified position without collision or sudden movement. Robot path control plays an important role to reach thedesired location as fast as possible. Commercially available industrial robots can be classified into four categories according to their path control system.

- Limited sequence robot.
- Play back robots with Point to point control
- Play back robot with Continuous path control.
- Intelligent robot.

Limited sequence Robot

- Limited sequence robot does not use servo control to indicate relative position of the joint.
- It is controlled by limit switches and mechanical stops.
- In this method of control the individual joints, can only be moved to their extreme limits of travel. This has the effect of severely limiting the number of distinct joints. Therefore this control is intended for simple motion cycle, such as pick and place operation where each axis is normally limited to two end points.
- There is no feedback system.
- Pick and place robots are simplest of all robots. They normally perform in industry. A pick and place robots can be used to unload a conveyor or used for simple press loading applications. Pick and place robots have lowest level of control but are least expensive. Easiest to maintain. These types of robots are normally pneumatically actuated. Repairing of this robot is simple and fast. Figure 2.5 shows pick and place operation



Figs 2.5 pick and place robot

2.6 PLAY BACK ROBOTS WITH POINT TO POINT CONTROL:

- Point to point control can move from one specified point to another but cannot stop at arbitrary points not previously designated by the robot.
- Point to point robots driven by servos is controlled by potentiometers which are used to stop the robot arm at a specified point.
- Point to point robot can be programmed to move from any point with in work envelope to any other point with in work envelope.
- Point to point motion involves the movement of the robotic system through a number of discrete points.
- The programmer can use combination of robot axes to position the end effector at a desired point. These positions are recorded and stored in memory. During the playback mode, the robot move through the points recorded in memory.

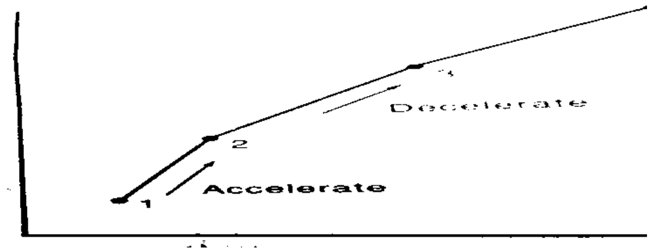


Fig 2.6 point to point motion

- Point to point robot can move more than one axis at a time.
- To programme point to point robot, the programmer uses Teach pendant.
- Point to point robot can move to any point within its work envelope, not only in straight-line between two points but also in arc form (Combined horizontal and vertical movement).fig 2.6 shows point to point motion of robot path control.
- Point – to - point robots are easy to program and have a higher load carrying capacity and a much larger work envelope

Application:

- Loading and unloading, Spot welding, assembly, grinding, inspection, palletizing and de palletizing.

CONTROLLED PATH:

- Controlled path is specialized control method with more precise control.
- The controlled path robot ensures that the robot describe the right segment between two points.
- Controlled path is a calculated method.
- **Programming control path robot is same as that of programming for point to point except that the points must be calculated.**
- Controlled path robots can generate straight lines, circles, interpolated curves and path with high accuracy. Path can be specified in geometric or algebraic terms. Only start and end coordinates and path definitions are required for control.
- Applications of controlled path robot are arc welding, drilling, polishing, and assembly.

2.7 PLAY BACK ROBOT WITH CONTINUOUS PATH CONTROL:

- Continuous path motion is an extension of point to point method.
- It is capable of performing motion cycle in which the path followed by the robot is controlled.
- Continuous path involves the utilisation of more points and its path can be arc, circle or a straight line
- Continuous path program can have several thousand points.

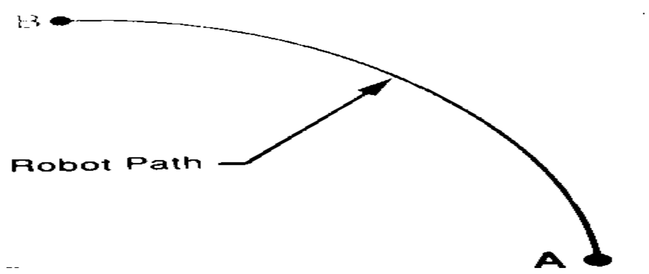


Fig 2.7 Continuous Path Control

- Continuous path motion is concerned with control of path movement rather than with end point positioning.
- It is capable of producing smooth movements. Figure 2.7 shows continuous path control.
- The continuous path robot are programmed differently, the manipulator of a continuous path robot is programmed by grabbing hold of the robot arm. And actually leading the

arm through the path that we wish the robot to remember. The robot remembers not only exact path but also the speed at which the manipulator is moved.

- The difference between continuous path control and point to point control is the controller's ability to remember thousands of points in the continuous points, whereas point to point control is limited to several hundred of points of memory.
- Continuous path robots have greater repeatability than point- to- point, but lower load carrying capacity.

INTELLIGENT ROBOTS:

- These robots interact with its environment.
- The intelligent robot can alter the program cycle according to the condition that occurs in workplace.
- They can make logical decisions based on sensor feedback systems. The robots have capacity to communicate with the human and work environment.
- The intelligent robots are programmed to a high level language.

2.8 SENSOR BASED PATH CONTROL

The use of sensor based path control in robotics is to determine the position and other information about various objects in the work cell Figure 2.8(a) shows servo system with position and velocity sensors.

In addition to positional data about particular object, the other information required to properly execute in the work cycle might include the object orientation, colour, size and other characteristics. Robots require Extensive information about their environment in order to function effectively.

Sensor based path control is a closed loop and more intelligent control with sensors to provide overall feedback control**.** Robotic sensors are used to estimate robots condition and environment .Sensor signals are passed to a controller to enable appropriate behaviour.

- Sensor based path controlled robots are directed by a controller that memorizes a sequence of arm and end effector positions.
- Sensor based path control follow a programmed contour surface.
- Hundreds or thousands of points can be stored in the computer and the velocity and acceleration along the path can be controlled.
- Sensor based path control with different types of sensors includes force control and visual servoing. Robots are made intelligent with visual sensor. Vision camera can detect parts and coordinate the part position for the robot and adapt its actions to the information it receives.

* Sensor based path control provides shortest or optimal path between two points.
* Sensor based path control has servo control for several positions that have been taught.

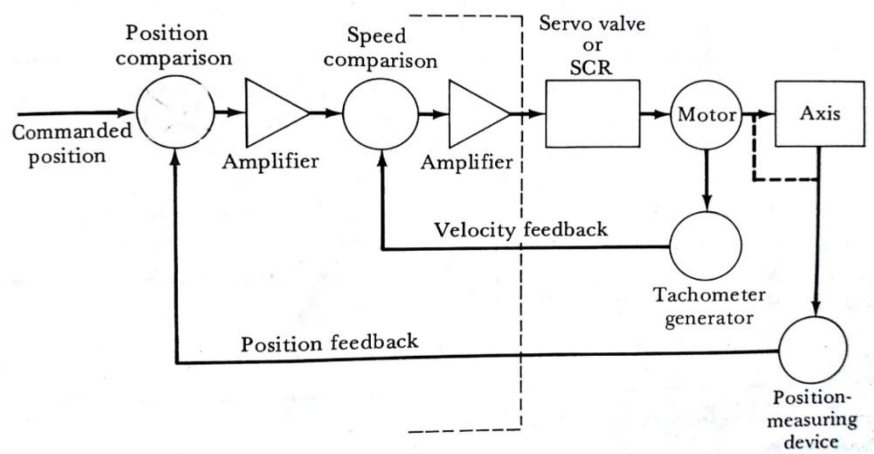


Fig 2.8(a) Servo system with position and velocity sensors.

* It is capable of performing motion cycle in which the path followed by the robot is controlled.
* In sensor based path control, program cycle can be altered according to the conditions that occur in workplace. A lot of sensors can be added to increase robots adaptability.

Figure 2.8 (a) shows Servo system with two feedback components

1. Velocity Measuring device.
2. Position measuring device.

The tachometer generator converts the velocity of the actuator into electric pulses. These pulses are feedback to the controller.

The position measuring device is an encoder that converts angular position into positional feedback signals.

Both of these transducers convert feedback signals into electric pulses. These pulses are feedback to the robot's controller's axis control circuitry and they are compared with the programmed data. If any errors, between these two signal, that are detected and corrected by the servo system.

High technology robots are servo controlled systems; they accept more sophisticated sensors and complex programming in order to have better perspective on their operation and provide safest workspace. Figure 2.8 (b) shows High tech robot utilising visual sensors.

The intelligent control robot is capable of performing some of the functions and task carried out by human being. It can also detect changes in the work environment by means of sensors.

Also intelligent robot is equipped with variety of sensors and sensor apparatus providing visual and tactile capabilities to respond instantly to various situations and provide good control during the process.

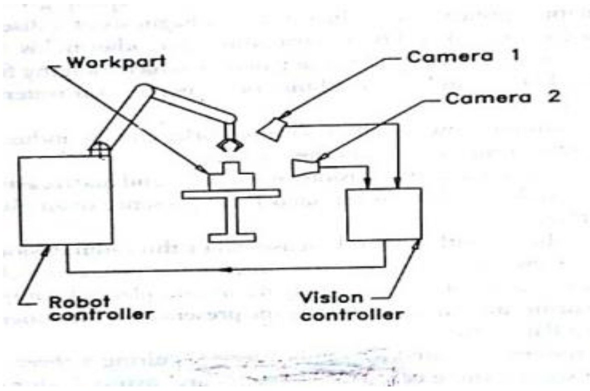


Fig 2.8(b) High-tech robot utilising visual sensors

Intelligent robot observes and evaluates the immediate environment by perception and pattern recognition. Because its operation is so complex, powerful computers are required to control its movement and more sophisticated sensing devices to respond its action**.**

2.9 CONTROLLER PROGRAMMING:

Many automated systems today are controlled by computers with multiple processors to perform logical decision and to permit high level machine communication with other pieces of equipment.

The robotic controller has two basic programs

- Control program
- User program.

1. CONTROL PROGRAM:

The control program controls the basic operation of the robotic system. It is developed by the manufacturer, and it gives the controller the necessary routines for the robot's general operation. This program cannot be altered by the user without damage to the robotic operating system.

2. USER PROGRAM:

The user's programme is the one that the user writes to meet his or her application. They contain information about axis velocity data, location geometry and other information.

Special user programs are often used in fully automated production environment to program the flow of information between intelligent devices and standard programs. Such programs are written for specific applications

Programming Methods: Robot is programmed by entering the programming commands into a controller memory.

- Manual
- Teach pendant
- Walk through
- Computer terminal

Manual programming

Manual programming is used for robots with point–to-point open loop controllers. This method is associated with limited sequence pick-and place robots.

Teach pendant programming

Teach pendant programming is used today for entering commands into computer memory. It involves the use of teach pendant (hand held device)

Walk through programming

Walk through is used for play back robots with continuous path control, irregular motion patterns, and for roughly locating the tool center point for some robots.

Computer terminal programming

Computer terminal programming can be done off line or online (at the robot's cell). Final testing or play back of the program is done at the job site.

2.10 ACTUATORS:

Actuators are the devices which provide actual motive force for the robot joints. They commonly get their power from one of the three sources; compressed air, pressurised fluid and electricity and they are called pneumatic and hydraulic, and electric actuators respectively.

Actuators are the muscles of robots. The action of the individual joints must be controlled in order to perform desired task. The robot's capacity to move its body, arm and wrist is provided by the drive system used to power the robot.

At the joints, actuators provide required force or torque for the movement of the links. The movements of all the links combined together form the arm end or wrist motion.

TYPES OF ACTUATORS

PNEUMATIC ACTUATORS:

Pneumatic actuators are generally found in relatively low cost manipulators with low load carrying capacity. When used with non-servo controllers, they usually require mechanical stops to ensure accurate positioning

An advantage of the pneumatic actuator is its light weight, particularly when operating pressures are moderate .Because of the light weight, pneumatics are often used to power end effectors even when other power sources are used for the manipulator's joint

Pneumatic actuators are good choice for moderate to low load applications, that do not require great precision.

HYDRAULIC ACTUATORS:

Hydraulic drives are either linear piston actuators or a rotary vane configuration. Hydraulic drive provide large amount of power for a given actuator.

The high power – to – weight ratio makes the hydraulic actuator an attractive choice for moving moderate to high loads at reasonable speeds and moderate noise level.

Hydraulic motor usually provide a more efficient way of using energy to achieve a better performance, but they are more expensive and generally less accurate.

Hydraulic systems are susceptible to leakage, which may reduce efficiency or require frequent cleaning and maintenance.

ELECTRIC ACTUATORS

In all electric robots, the drive actuators, as well as the controller, are electrically powered. Most electric robots use servo motors for axes motion, but a few open loop robot systems utilize stepper motors. The majority of robots presently are equipped with DC servomotor

The electric motor is a device that converts electric energy into mechanical energy. Through this conversion process, the manipulator's axes can be moved to the desired location.

Electric robot do not require a hydraulic power unit, they conserve floor space and decrease factory noise .Direct drive motors provide very quick response. No energy conservation is required because the electric power is applied directly to the drive actuators on the axes.

Electric motors are becoming more and more the actuators of choice in the design of robot. They provide excellent controllability with a minimum of maintenance required.

The disadvantages of electric drives are that the payload capability is limited to three hundred pounds or less, and the operations in explosive environment possess problems.

2.11 DC SERVOMOTORS:

Servo motors are used as actuators in automatic control system. DC servo motor which employ DC supply.

PRINCIPLE

A rotational movement is produced in a rotor when an electric current flows through the windings of the armature setting up a magnetic field opposing the field set up by the permanent magnet**.**

CONSTRUCTION

The main components of the DC servomotor are the rotor and the stator. The rotor includes the armature and the commutator assembly and the stator includes the permanent magnet and brush assembly.

OPERATION

When current flows through the windings of the armature it sets up a magnetic field opposing the field setup by the magnets. This produces a torque on the rotor. As the rotor rotates, the brush and commutator assemblies switch the current to the armature so that the field remains opposed to the one set up by the magnets.

In this way the torque produced by the rotor is constant throughout the rotation. Since the field strength of the rotor is a function of the current through it.

$$T_m(t) = K_m I_a(t)$$

Where T_m is the Torque of the motor,

I_a is the current through the armature

$K_m$is the motor's torque constant.

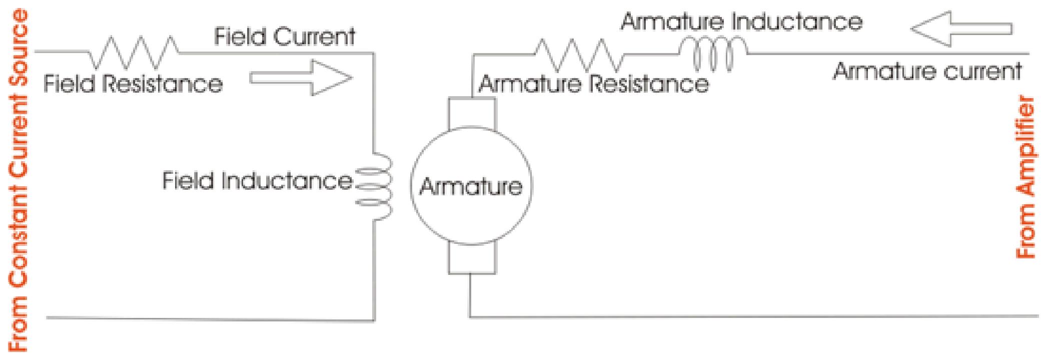


Fig 2.9 Armature control DC Servo motor

Another effect associated with DC servomotor is the back- emf. Spinning the armature in the presence of magnetic field produces an opposing voltage across the armature terminals. This voltage is proportional to the angular velocity of the rotor.

$$e_b(t) = K_b w(t)$$

$e_b(t)$ - Back-emf Voltage

w - Angular Velocity.

K_b - voltage constant of the motor.

The effect of the back-emf is to act as viscous damping for the motor. If we were to supply a voltage across the motor terminals of V_{in} and the resistance of armature were Ra then the current through the armature would be V_{in} / R_a. This current produces a torque on the rotor and causes the motor to spin. As the armature spins, it generates back-emf $e_b(t)$.This voltage must be subtracted from V_{in} in order to calculate the armature current.

The actual armature current is

$$I_a(t) = \frac{V_{in}(t) - e_b(t)}{Ra}$$

As the motor velocity increases, and the back-emf voltage increases accordingly, the current available to the armature decreases. The decreasing current reduces the torque generated by the rotor. As the torque decreases the acceleration of the rotor decreases as well. At the point at which $e_b = V_{In}$ the motor maintain steady state velocity. Figure 2.10 shows block diagram of DC motor.

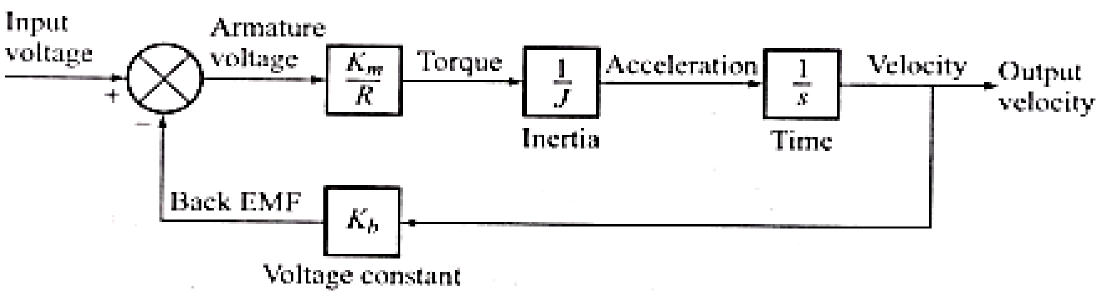


Fig 2.10 Block diagram of DC Motor

Features

- High acceleration
- Uniform torque
- Good response for better control

Advantages of DC servomotor

- Their output is high when compared with that of a 50 Hz motor of the same size.
- Linear characteristics of a servomotor can be achieved easily
- Speed is controlled easily from zero to full speed in both directions.
- It has a capacity of delivering about more than 3 times of their rated torque for a short time period.

Applications:

- PM motors are commonly used in printers and disk drives, tape drives ,word processor, etc.,
- Used for manufacturing position equipment's such as an industrial robots
- Used in numerical control milling machine.

2.12 STEPPER MOTOR

Stepper motor can also be known as step motors or stepping motors. Because stepper motors can move in accurate discrete angular increments in steps, in reaction to electrical input pulses applied. They are ideal for applications that require controlled, precise movements in an open loop system.

In many low –technology robot stepper motor is used as manipulators drive system. Stepper motor operates through pulses supplied to the motor. Each pulse causes the motor to rotate in a clockwise and anti-clock direction and each pulse causes certain degrees of rotation.

The stepper motor used as drive system for the manipulator must be very accurate so that the manipulators axes can be positioned accurately.

The amount of rotation produced by stepper motor directly corresponds to number of electric pulses while the motor's speed is proportional to frequency of pulses. A stepper motor can only take one step at a time, and each step taken is of same size. The number of degrees that the motor rotates depends on motor size.

When a train of pulses is applied, it gets turned through a certain angle. The angle through which the stepper motor shaft turns for each pulse is referred as the step angle, which is generally expressed in degrees.

Permanent Magnet Stepper Motor: Permanent magnet motor is one type of stepper motor. These types of stepper motor use a permanent magnet (PM) in the rotor and operate on the attraction or repulsion between the rotor PM and the stator electromagnets.

Construction Permanent Magnet Stepper Motor:

It consists of slotted periphery on which stator coils are wound. It has projected poles on the slotted structure where the wound windings can be two or three or four-phase.

The end terminals of all these windings are brought out and connected to the DC excitation via solid state switches in the drive circuit.

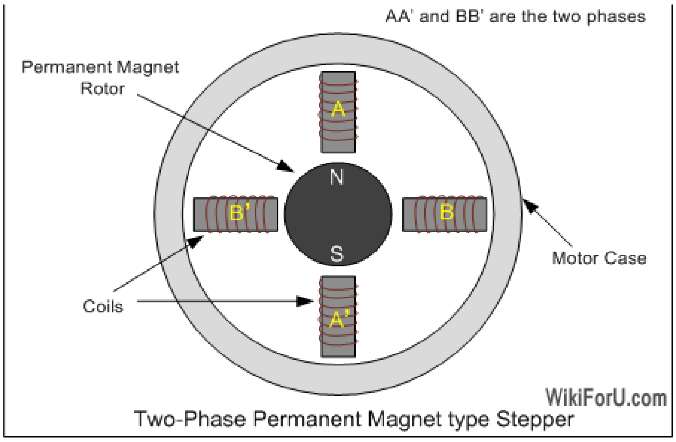


Fig 2.11.Construction of permanent magnet stepper motor.

The rotor is made up of a permanent magnet material like a ferrite that can be in the shape of either cylindrical or salient pole, but usually it is of smooth cylindrical type.

The rotor designed to have an even number of permanent magnetic poles with alternate North and South polarities. Figure 2.11.construction of permanent magnet stepper motor.

Working of Permanent Magnet Stepper Motor:

The operation of this motor works on the principle either unlike poles attract each other or like poles repel each other. When the stator windings are excited with a DC supply, it produces magnetic flux and establishes the North and South poles.

Due to the force of attraction and repulsion between permanent magnet rotor poles and stator poles, the rotor starts moving up to the position for which pulses are given to the stator.

Consider a 2-phase stepper motor with two permanent magnetic rotor poles as shown in the figure 2.11 (b)

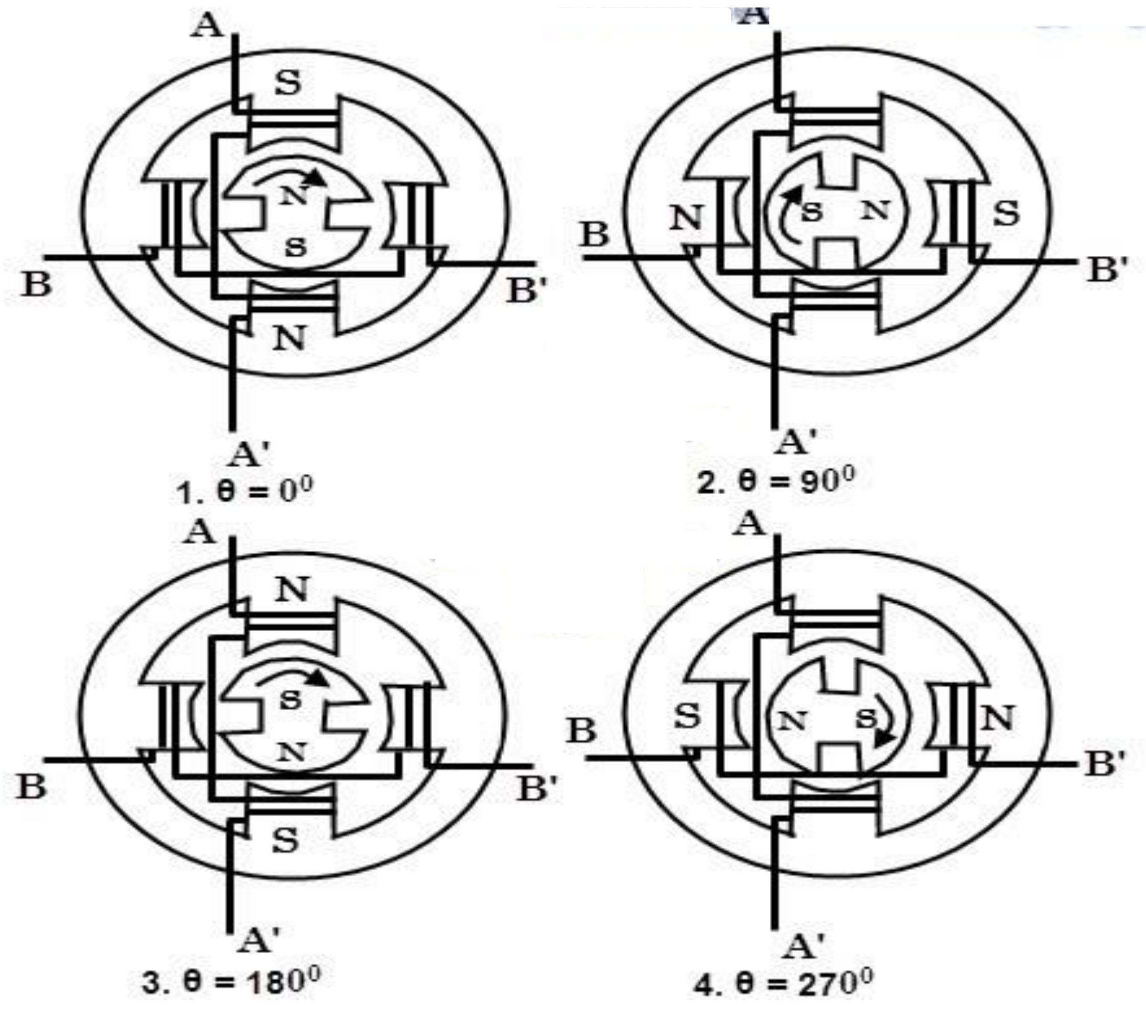


FIG – 2.12 Stepper Motor Operations

When phase A is connected with a positive voltage with respect to A', current flows through the stator winding, thereby establish North and South poles. Due to the force of attraction, the rotor poles align with stator pole such that the magnetic pole axis of rotor adjusts with that of stator as shown in figure 2.12.

When the excitation is switched to B phase and switching off phase A, the rotor further adjusts to magnetic axis of phase B, and thus rotates through 90 degrees in clockwise direction.

Next, if the phase A' connected with positive voltage respect to A, the formation of stator poles causes the rotor to move through another 90 degrees in clockwise direction.

In the same way, when excitation is switched to B' phase and switching off A', the rotor rotates through another 90 degrees in the same direction.

Next, if the phase A is excited with positive voltage with respect to A', the rotor comes to the original position thus making a 360 degrees complete revolution.

This implies that, whenever the stator is excited, the rotor tends to rotate through 90 degrees in clockwise direction.

RESOLUTION OF STEPPER MOTOR:

Resolution is determined by the number of stator poles in the stepper motor.

Step angle $A_s=360/n_s$

Where n_s - Number of poles.

Number of stator poles $n_s= 360/A_s$

Resolution $R_s= A_s/360$

Pulse- - single pulse of electrical signal is necessary for the rotor to rotate by one step. For one rotation number of pulse,

$N_p= 360/A_s$

Advantages :

- Low cost & Ruggedness
- Simplicity of construction
- Can operate in an open loop control system
- Low maintenance
- Will work in any environment
- Can be used in robotics in a wide scale.
- High reliability
- The motor has full torque at standstill (if the windings are energized)

Application:

- Used in computer peripheral
- X,Y plotter, CNC machines, process entry system

- Position information of robot joint axes can be obtained by counting the pulses sent to the motor

2.13 HYDRAULIC AND PNEUMATIC DRIVES:

Pneumatic and hydraulic actuators are both powered by moving fluids. In the first case the fluid is compressed air and in the second case the fluid is usually pressurised oil. The operation of these actuators is generally similar except in their ability to contain the pressure of the fluid.

Elements of hydraulic system and functions

1. Reservoir or tank -Stores and supply hydraulic oil to the system in a closed circuit
2. Hydraulic pump - Receives oil from the reservoir and pressurises the oil in accordance with its capacity.
3. Electric motor - Receives electric current from mains and provides rotational movement to the pump
4. Valves - control the direction of flow, regulate the pressure and provide safety to the system.
5. Hoses and pipes – provide connection between the various elements transporting the high pressure oil.

Cylinder and Piston:

The simplest fluid power device is the cylinder, which could be used to actuate a linear joint by means of a moving piston. This type of cylinder is called single ended cylinder as the piston comes out of the cylinder at one end. Figure 2.13 shows Cylinder and piston.

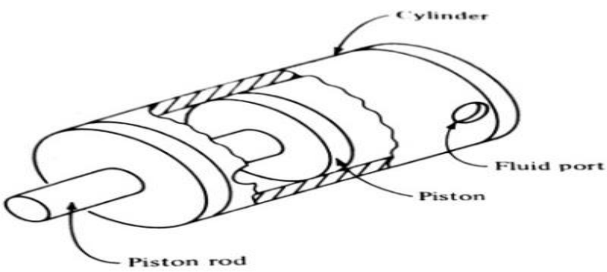


Fig 2.13 Cylinder and piston

The velocity and the force of the actuator with respect to the input power is given below.

$$V(t) = f(t)/A$$

$$F(t) = P(t)\,A$$

Where V (t) is the velocity of the piston

f (t) is the fluid flow rate.

F (t) is the force.

P (t) is the pressure of the fluid.

A is the area of piston.

HYDRAULIC MOTOR:

Hydraulic actuator is the hydraulic motor which is given its name because it is a rotational actuator. The hydraulic motor resembles hydraulic pump.

The major difference is that a pump applies pressure to the hydraulic fluid, while motor receives pressure from the fluid. This pressure causes the rotation of the motor. The Rotating motor then develops a torque providing a continuous Rotational motion.

CONSTRUCTION AND WORKING OF HYDRAULIC MOTOR:

The motor has two parts the inlet port and the outlet port. The direction of the flow of the fluid determines the direction in which the motor will turn.

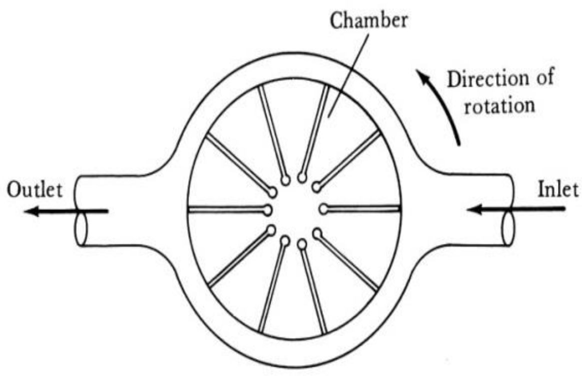


Fig 2.14 Hydraulic motor

Figure 2.14 shows the direction of flow of the Fluid entering the motor from the right hand side, which causes the motor to turn in a counter clockwise direction.

The outlet fluid leaves through the outlet port. If positions of the inlet port and the outlet port were changed, the motor would rotate in a clockwise direction.

GEAR MOTOR:

Torque in the gear motor is developed through pressure of the fluid that is applied to the surface of the gear teeth. The gear teeth of the motor mesh and rotate together.

The drive shaft to which the load is applied is connected to only one of the gears. The motor can rotate in either direction by reversal of the fluid through the motor.

Gear motors operate in the range of 2400 revolutions per minute, and at a pressure of 2000 pounds per square inch. Figure 2.15 shows direction of rotation of gear motors.

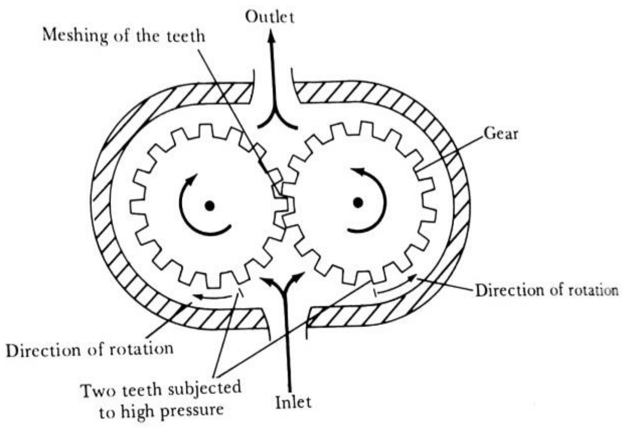


Fig 2.15 Gear Motor

Features of hydraulic Actuators

- Provide high power in small light components
- Long life and reliability
- Can operate safely and continuous.
- Can be easily built using readily available standard elements
- Operation is noisy.
- Unclean area due to possibility of leak.

Advantages

- Precise motion control over wide range of speeds and loads
- Greater strength.

Disadvantages

- Expensive& Noisy
- High maintenance
- Not suited for clean- air environments.

Application of Hydraulic Actuators

- Used to drive the spray coating robots
- Useful in material handling robot system
- Useful in gripper mechanisms

PNEUMATIC ACTUATORS:

The principles of pneumatic actuators match with that of hydraulic actuators. The working fluid in this system is compressed air.

Pneumatic cylinders are used to actuate the linear joints and pneumatic motors are used to drive revolute joints. The pressure of air used in this varies from 6-10 MPa.

TYPES OF PNEUMATIC ACTUATORS:

Pneumatic actuators are of two types. Linear Actuators – pneumatic cylinders and rotary actuators and rotary actuators- piston motor or vane motor.

A typical double acting cylinder is symbolically shown in figure 2.16 (a)

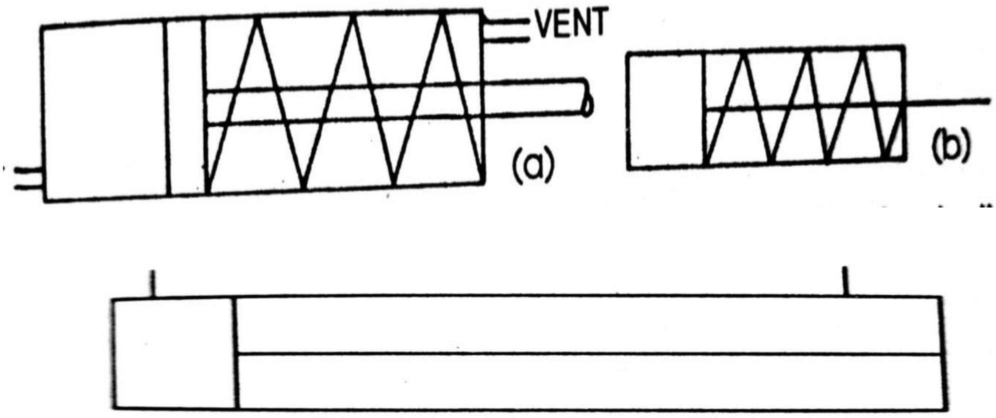


Fig 2.16 (a) Double acting cylinder.

ROTARY ACTUATORS:

Rotary actuators are similar to the hydraulic rotary actuators. There are two types of rotary actuators. Low speed piston motor and variable vane motor. Piston motors are of radial type and shown in figure 2.16(b)

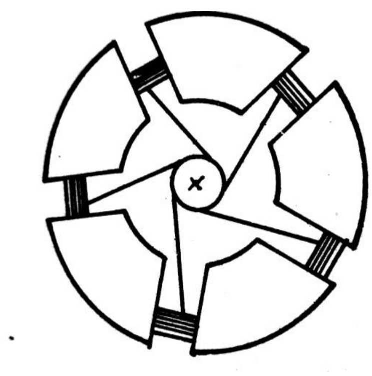


Fig 2.16 (b) piston motor

Vane motors are bidirectional and can rotate in either clockwise or counter clockwise directions. The speed depends on the volume of air induced in and the torque depends on the pressure of the air.

Figure shows 2.16 (c) vane motor.

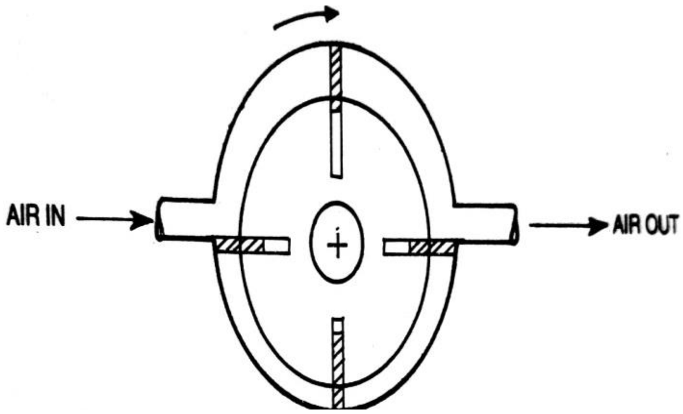


Fig 2.16 (c) vane motor

A typical pneumatic system is illustrated in figure 2.16 (d).to show the use of different pneumatic elements.

Compressor: A pump which compresses air, raising it to a higher pressure, and delivers it to the pneumatic system.

Directional Valve: controls flow of pressurised air from the source to the selected port.

Air Filter : used to remove dirt from the air.

FRL Unit – A combination filter-regulator- lubricator removes dirt and water. The regulator controls the air pressure to the actuators. FRL includes a pressure gauge to indicate the operating pressure.

Pressure Regulators:

Pressure regulators are used to deliver air at a constant pressure to the pneumatic actuators.

Driers:

Compressed air after passing through the after cooler is retained in the receiver. Though after cooler removes most of the moisture from the air. Air driers are used for removing virtually all moisture

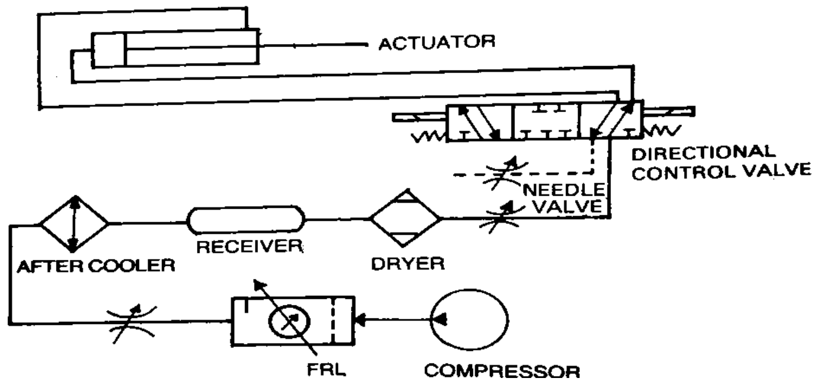


Fig 2.16 (d) A typical pneumatic system.

.**The pneumatic actuators are characterised by the following feature:**

- Lowest power to weight ratio.
- Less leakage of air.
- Uses low pressure compressed air, hence less actuation force.
- Useful in pick and place robots.
- Simple and low cost components.
- Reliable and easily available components.
- The exact position of the actuators can be controlled by servo control Valve.

Advantages

1. Pneumatic systems are more economical than hydraulic systems
2. Easy installation
3. Less costly than hydraulic drives
4. Good speed and accuracy.

Disadvantages

1. Precision is less than electric drives
2. It is noisy in operation.

2.14 FEEDBACK DEVICES:

Position and velocity sensors are used in robotics as feedback devices. Position sensors provide the necessary means of determining whether the joints have moved to correct linear or rotational locations in order to achieve the required position and orientation of the end effector.

2.14.1 POTENTIOMETER:

- The simplest device that can be used to measure position is the potentiometer or pot. This is used to measure angular position of a revolute joint or linear position of prismatic joint.
- Potentiometer is an analog transducer, which converts linear or angular displacement in to voltage.
- It is a variable resistance with two fixed terminals and movable wiper. Figure 2.17(a) shows potentiometer and its symbol.
- It is a type of error detector which is used in servo application

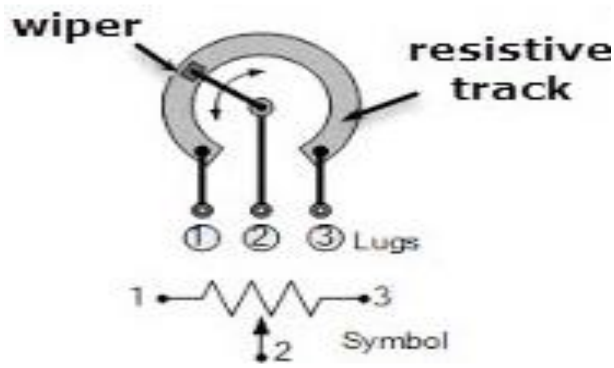


Fig 2.17(a) construction of potentiometer and symbol

Figure 2.17(b) illustrates a typical rotary potentiometer. A voltage is applied across the resistive element. The voltage between the wiper and ground (reference) is proportional to the ratio of resistance on one side of the wiper to the total resistance of the resistive element. Essentially The pot acts as a voltage divider network. That is the voltage across the resistive element is divided in to two parts by a wiper. Measuring this voltage gives the position of the wiper.

The function of rotary potentiometer is given by the following function

$$V_o(t) = K_p\, \theta(t)$$

Vo(t) - Output voltage

Kp - Voltage constant of the pot

$\theta(t)$ - Position of the wiper in radians

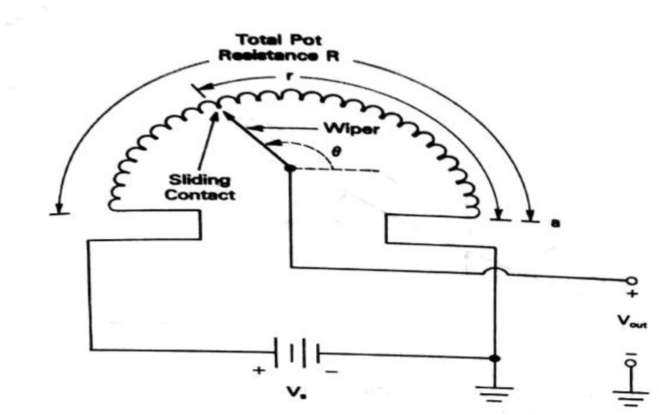
In order to calculate V_O, pot requires excitation voltage,

$$V_o = V_s \times \theta(act) / \theta(tot)$$

V_s - Excitation Voltage

$\boldsymbol{\theta(tot)}$ - Total travel of the wiper

$\boldsymbol{\theta(act)}$ - Actual position of the wiper



Rotary potentiometer- output proportional to θ

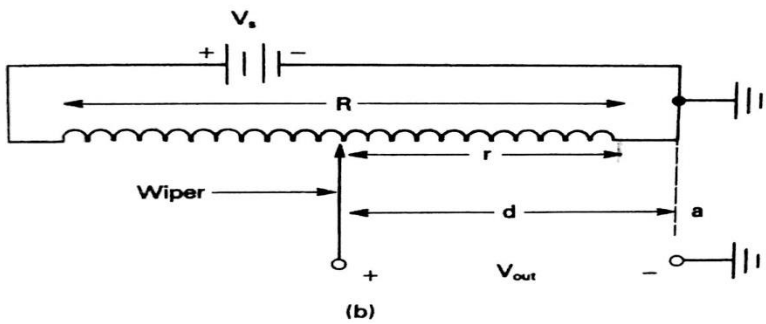
Fig 2.17(b) potentiometer to measure angular position of Revolute joint

Linear potentiometer converts linear displacement into voltage. Figure 2.17(c) shows potentiometer to measure linear position of prismatic joint.

The function of linear potentiometer can be represented by the following function

$$V_o(t) = K_p d$$

V o (t) - Output voltage
K p - Voltage constant of the pot in volts per inches.
d - Position of the wiper in inches.



Linear potentiometer – output proportional to d

Fig 2.17(c).Potentiometer to measure linear position of prismatic joint

By applying a DC voltage (Vs) across the entire R .The voltage V out is proportional to the linear distance (d) of the wiper contact from the reference point a.

Mathematically, if the resistance of the coil between the wiper and the reference is r, then

V out = r /R x Vs.[By the voltage division rule]

R - Total resistance of the potentiometer Ω

r- Resistance between the wiper (movable contact) and ground Ω

Vs. - Excitation voltage of the potentiometer. V

V out - Output voltage

Limitation of wire wound potentiometer

- Output voltage will deviate from the true value in an unpredictable manner, due to corrosion built-up in the wiper and wiper contact.(due to wear and dirt in a typical factory environment where robot is used)
- They cannot be used for small displacement which may be linear or angular.
- Due to its very low sensitivity, high gain amplifier of high cost is required.

Application

- **Audio control** - Low-power potentiometers, both linear and rotary, are used to control audio equipment, changing loudness, frequency attenuation, and other characteristics of audio signals.
- **Motion control-**Potentiometers can be used as position feedback devices in order to create "closed loop" control, such as in a servomechanism.
- **Displacement Transducers-**Potentiometers are also very widely used as a part of displacement transducers.

2.14.2 OPTICAL ENCODER:

Optical position encoder is a device that provides a digital output as a result of linear / angular displacement

The optical encoder is made up of three basic components.

i. Light source
ii. The disc has alternating opaque and transparent sensors, which are etched by means of a photographic process on a plastic disc or slots are cut on a metallic disc.
iii. The sensor - a photodiode or a phototransistor

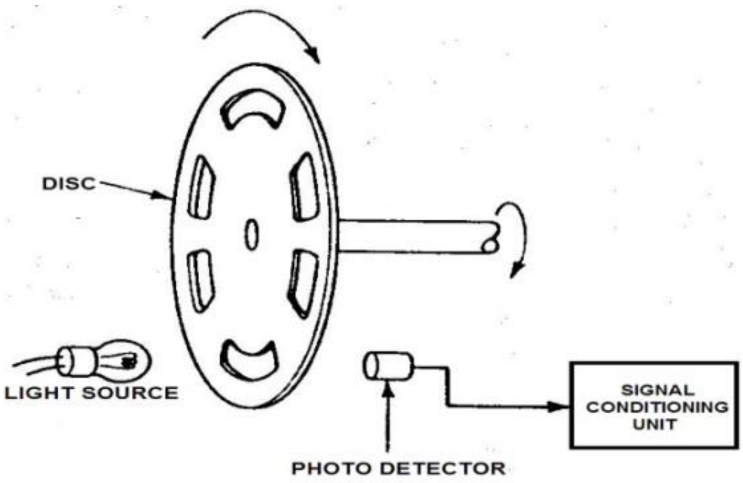


Fig 2.18 shows Basic Principle of Optical Encoder

It has a shaft mechanically coupled to an input driver which rotates a disc rigidly fixed to it. A succession of opaque and clear segments is marked on the surface of the disc. Light from infrared emitting diodes reaches the infrared receivers through the transparent slits of the rotating disc.

Finally a signal conditioning electronics detects the light and dark signals are converts these signals into a usable form of pulses or digital code.

Encoders are classified into two basic types.

Types of Encoder

1. Incremental encoder

2. Absolute encoder

1. Incremental Encoder:

In a simple incremental encoder, a disc is encoded with alternating transparent and opaque (light and dark) stripes aligned radially. A photo transmitter (Light Source) is located on one side and a photo receiver (photo cell) on the other side of a disc.

As the disc rotates , the light beam from the transmitter is alternatively passed and broken which is detected by the receiver, whose output is a pulse train having frequency proportional to the speed of rotation of the disc .

There are usually two sets of photo transmitter and receivers aligned 90° out of phase to provide directional information. Figure 2.19 shows typical incremental encoder.

The most common type of incremental encoder uses, two output channels (A and B) to sense position. Using two code tracks with sectors positioned 90° out of phase the two output channels of the quadrature encoder indicate both position and direction of rotation. If channel A leads B, for example, the disk is rotating in a clockwise direction. If B leads A, then the disk is rotating in a counter clockwise direction.

Therefore, by monitoring both the number of pulses and the relative phase of signals A and B, you can track both the position and direction of rotation.

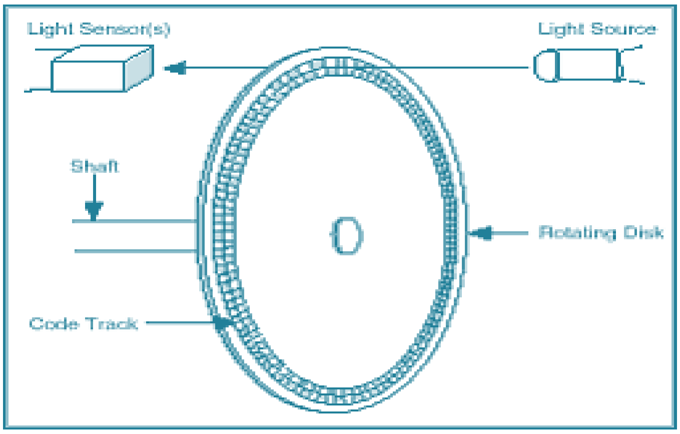


Fig 2.19 Incremental encoder.

By counting number of pulses and by adding or subtracting based on the direction [up-down pulse counter can be used] it is possible to use the encoder for position information with respect to known position.

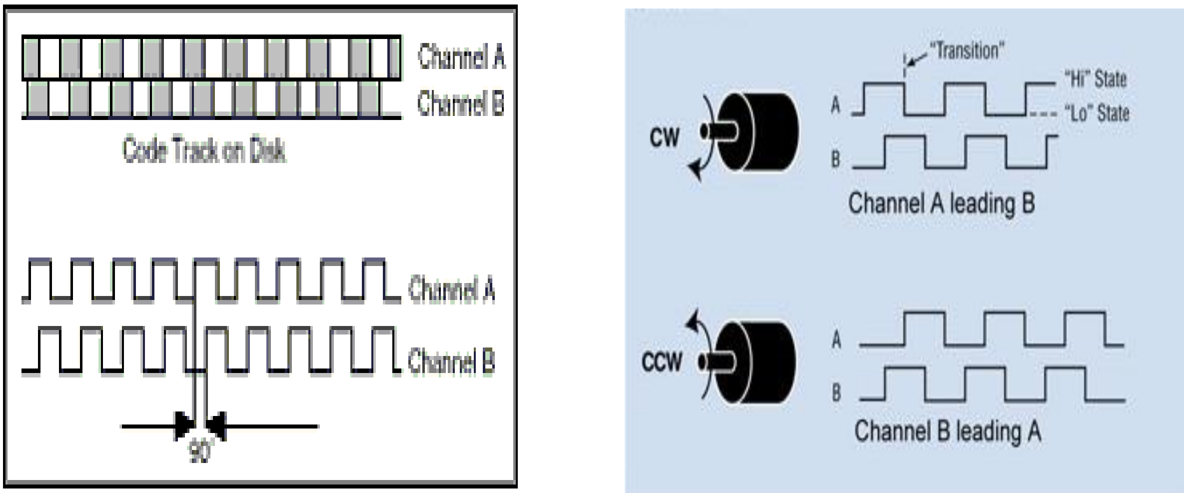


Fig 2.20. Shows code tracks on a disk and directional information.

2. Absolute Encoder :

Absolute encoder is one in which position can be known in absolute terms (Not with respect to starting position) .It generates parallel output of digital code.

It employs same basic construction as incremental encoder except that there are more tracks of stripes and a corresponding number of photo transmitters and photo receivers .The stripes are usually aligned to provide a binary number proportional to shaft angle and the angle can be read directly from the encoder without any counting.

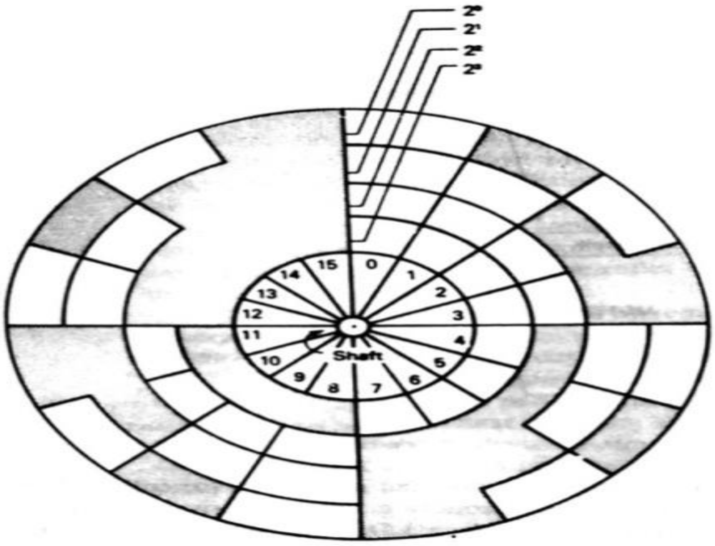


Fig 2.21 Absolute encoder

As shown in figure 2.21, the absolute encoder consists of four tracks& 16 sector binary coded disk. The first track might have 2 stripes, the second track 4 stripes, third track 8 stripes and so on. It can be seen from figure 2.21 that the resolution of the disk is 22.5° (360/16) since one complete disk revolution is 360° and there are 16 sectors.

If the shaded areas are assumed to represent a binary 1 and clear areas a binary 0, the outputs of each of the four light sensors would represent a 4 bit sequence of ones and zero. For example, if sector 11 is in the region of the LEDS, the output of the photo receiver will be 1011 or 11

For example, A 3-bit encoder is shown in figure 2.22. The binary code at each of the eight (0-7) radial positions is generated by a unique combination of ON's and OFF's of photo cell. The resulting code is shown in table 1 (1 represents ON and 0 represents OFF).

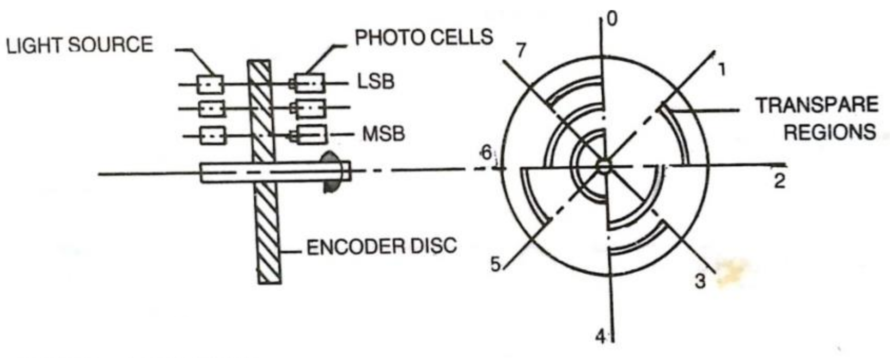


Fig 2.22 3-bit Absolute encoder.

Decimal Number	Binary code
0	000
1	001
2	010
3	011
4	100
5	101
6	110
7	111

Table 1

The resolution of the encoder depends on the number of tracks (n).

Resolution = 2^n

Application of Encoder

- Linear measurment
- Motor feedback
- Packaging and Material handling

2.14.3 DC TACHOMETER

A tacho generator is an electromechanical device designed to produce an output voltage which is proportional to its shaft speed. It is also termed as tachometer

DC Tachometer is specially designed device used to give velocity information to the controller. It is an analog tachometer**. It works as a transducer which converts angular velocity in to an electrical voltage**

A tachometer is a DC generator with linear characteristics. It gives the voltage and speed characteristics linear over the entire operating range. Figure 2.23 (a) shows basic principle of DC tachometer.

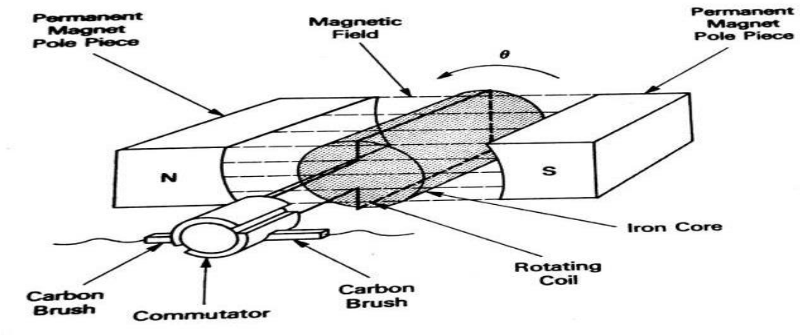


Fig 2.23 (a) Basic principle of DC Tachometer

PRINCIPLE OF OPERATION:

When a wire (coil) is made to move in a magnetic field, voltage is induced across the wire (coil) that is proportional to the velocity. When the wires of plane and the field are perpendicular to each other, it results in maximum output voltage.

CONSTRUCTION:

DC Tachometer consist of small armature (rotor) which is coupled to the machine whose speed is to be measured. Stator consist of a permanent magnet.

The armature consist of a copper (or aluminium) coil is wound on a cylindrical piece of iron. At the ends of the coil are connected to a commutator which is a segmented ring.

The brush/commutator assembly will act as a rectifying element by reversing the coil connection for each half of a complete revolution to produce a pulsating DC voltage. Figure 2.23 (b) illustrates construction of DC tachometer.

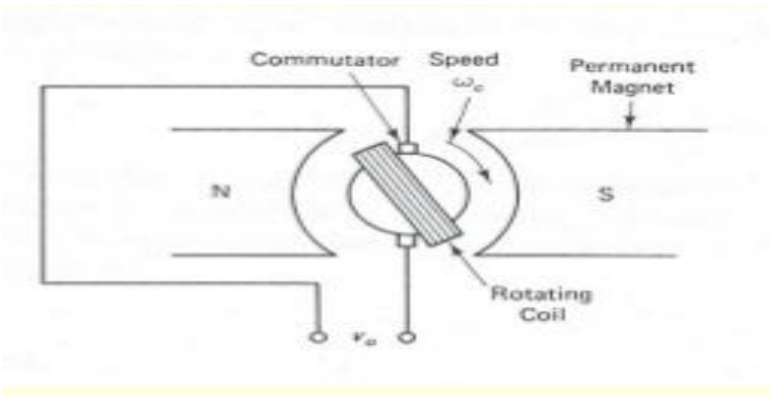


Fig. 2.23(b) illustrates construction of DC tachometer.

WORKING OF DC TACHOMETER:

Operating principle of DC Tachometer is same as that of a DC generator

The input fed to the tachometer is the speed of the shaft and the output from the tachometer is the generator voltage proportional to the angular velocity of the shaft.

As the armature revolves in a field of permanent magnet,It cuts the magnetic lines of force due to which EMF generated in the armature.This EMF is measured with the help moving coil voltmeter having uniform scale and calibrated directly in terms of speed.

The sign of the output voltage depends on the direction of rotation of the shaft.The d.c tachometer issmall in size as does not supply any load.Figure 2.24 shows working of DC tachometer.

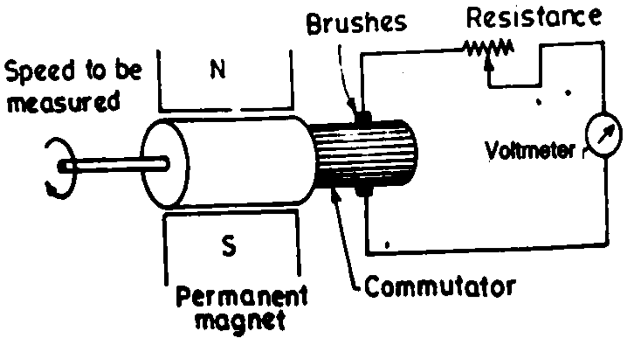


Fig 2.24 Working of DC tachometer**.**

Hence output voltage generated by the tachometer is,

$$V_{out} = K_{t}(t)\ W$$

Kt(t) = Constant

W =Angular velocity in radians per second.

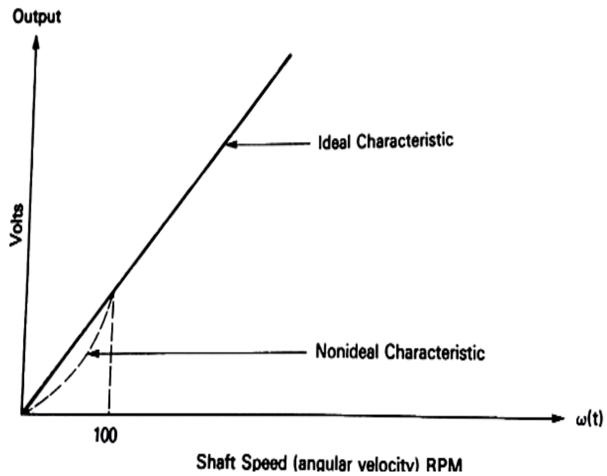


Fig 2.25 Voltage vs. Speed Characteristics

Direct current tachometers provide a voltage output proportional to the armature rotation. Hence they are analog devices. There is a digital equivalent of tachometer which provides pulse train output proportional to the angular velocity.

Advantages :

1 .Direction of rotation is directly indicated by output voltage

2. Output voltage can be measured with conventional type DC voltmeter.

Disadvantages :

Brushes of small tachometer generators often produce maintenance problem, as their contact resistance may vary and produce appreciable error. Thus the commutator and the brush assembly require periodic maintenance.

Application:

- It may be used along with potentiometer to estimate velocity.
- It is employed in speed control system to obtain speed feedback.

Model Questions

PART -A

1.What is a controller?

2.LIst out the the level of controllers

3.What is open loop system?

4.List the advantages of open loop system

5.Mention the disadvantages of open loop system

6.What is a sevo system?

7.What is closed loop system?

8.Define Actuators?

9.List the advantages of pneumatic actutors.

10.What is stepper motor?

11.Mention the advantages of steppermotor.

12 State any two feedback devices.

13.What is an encoder?

14.List the basic types of encoder.

15.What is DC tachometer?

16.Mention the use of DC Tachometer.

17.List the advantages of closed loop system.

PART B

1.State the function of robot controller

2.Write short notes on closed loop system.

3.Compare open loop system and closed lop system

4.Differentiateopen loop and closed loop controller.

5. Write Brief note on servo system.

6. What is Limited sequence path control?

7. What is point to point robot path control?

8. What is actuator ? List out the tpes of Actuators.

9.Write short notes on hydraulic actuator

10. Write short note on electric actators

11. Whatis optical encoer? Classify types of optical encoder.

12.Write short note on any one hydraulic system.

13. Write the basic principle of optcal encoder.

14.List out the types of Robot path control.

15.What is intelligent robot?

16.Discuss the need for feedback devices.

PART-C

1. Explain the elements of robot controller with a neat digram.

2.With neat diagram explain hydraulic and pneumatic drives.

3. Explaiin servo system wth neat diagram.

4. Explain Robot path control in detail.

5. Explain point to point and continous path control with necessary diagram.

6.Explain the working of DC Servo motor.

7.Describe the construction and working principle of stepper motor .State its advantage and diadvantage.

8.Explain the operation of potentiometer sensor with a neat diagram.

9. Explain any one feedback device with neat digram.

10. Explain the working principle of optical encoder with a neat diagram.

11.Explain the working principle DC tachometer with a neat sketch.

12.What is feedback device? Discuss any one feedback device in detail.

UNIT III

ROBOT MOTION ANALYSIS AND VISION SYSTEM

Robot motion analysis – robot kinematics – robot dynamics – end effectors – grippers and tools – gripper design – mechanical gripper – vacuum gripper – magnetic grippers – sensors – transducers – tactile sensors – proximity sensors and range sensors – force and moment sensors and its applications and problems – photoelectric sensors – vision system – image processing and analysis – robotic applications – robot operation aids – teach pendant – MDI and computer control.

3.1 ROBOT MOTION ANALYSIS:

A robot consists of number of links and joints. An Industrial robot has 5 to 6 joints. In order to move the end of arm to a particular point in space, the joints are to be moved in such a way that the end point is reached by the end of arm. The end point and the path by which it is to be achieved is to be controlled. For this motion analysis of the joints are studied and necessary instructions are given to the controller through program.

3.2. ROBOT KINEMATICS

Robot kinematics is the study of motion of links and joints in manipulator of robot without involvement of any forces. In order to develop the controlling motion of manipulator, it is necessary to develop techniques for representing position of arm.

The manipulator is represented by two basic elements.

1. Joints and
2. Links

Each joint representing one degree of freedom. The joints may have rotational –R, Linear –L, Revolving –V, Twisting –T motions with adjacent link. Links are rigid members that connect the joints. Joints are labelled as Jn as shown in figure 3.1 where n-number of joint at the base.

Links are labelled as Ln where n- number one link closest to base. Position of arm is represented by two spaces as joint space Pj and world space Pw.

RR & LL notation

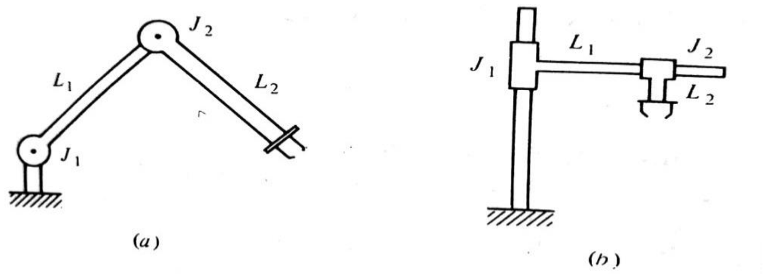


Fig 3.1 Two different 2 jointed manipulators (a) two rotational joints (RR) (b) two linear joints (LL)

3.2.2 POSITION REPRESENTATION:

Arm position of robot is generally represented in two ways as joint space Pj and world space Pw. Kinematics of RR robot is difficult to analyse than LL robot. The figure 3.2 illustrates geometric representation of RR manipulator.

Position representation by Pj = (ø1, ø2) & Pw =(x,y)

In order to control motion of manipulator we must represent position of arm. Position of arm can be represented in joint space which is indicated as P(ø1,ø2)

The second method of representing position of arm is world space p(x,y). These are limited only in 2 dimensional. But these can also be represented in 3D in world space as p(x,y,z) coordinates. When position is represented in world space it is useful for robot to communicate with other machines which has no knowledge about robot kinematics. For these worlds space representation is used.

In order to use both type of spaces, we must be able to transform from one space to another. Going from joint space to world space is called forward transformation and from world space to joint space is called as reverse transformation.

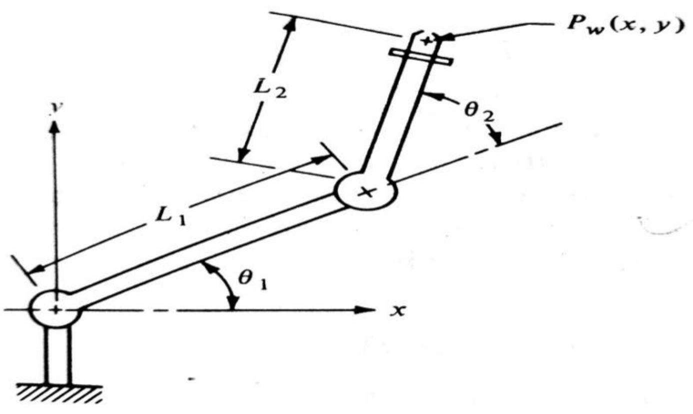


Fig 3.2 A Two Dimensional Two Degrees of Freedom Manipulator (type RR)

Forward Transformation:

The transformation from joint space to world space is called forward transformation.

Reverse transformation:

The transformation from the world space to joint is called as reverse transformation.

Forward transformation of a two degrees of freedom:

We can determine the position of the end of the arm is world space by defining a vector for with one and another for link 2

$r_1 = (L_1 \text{Cos}\theta_1$, L1 sin $\theta_2)$

$r_2 =$ (L2 Cos($\theta_1+\theta_2$), L2 sin ($\theta_1+\theta_2$)

Vector addition of 1 & 2 yields the coordinates. X and y of the end of arm is world space.

X= $L_1\cos\theta_1+L_2\cos(\theta_1+\theta_2)$

Y= $L1\sin\theta_1+L_2\sin(\theta_1+\theta_2)$

Reverse Transformation:

In many situations the reverse transformation is very useful to compute the joint angles required to move its end of arm,when the world space co-ordinates are known. For the two link manipulator, there are two possible configurations for reaching the point (x,y). Fig 3.3 shows two possible configurations to achieve position(x,y).

$\cos(A+B) = cosAcosB + sinAsinB$

Sin (A+B)=sin A cos B + Sin B cos A

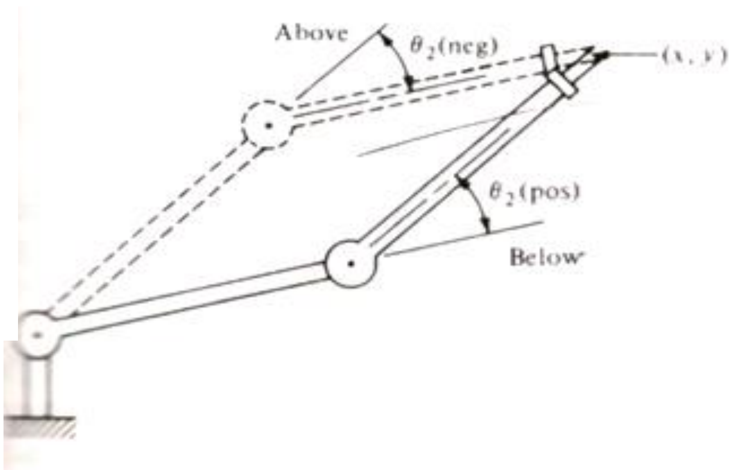


Fig 3.3 The arm at point P(x,y) indicating two possible configurations to achieve the position

Rewriting equations:

$x = L_1 cos\theta 1 + L_2$ Cosθ1 cosθ_2-L2sinϑ_1 sinϑ_2

Y= L_1sinθ_1 + L_2 sin $\theta_1$cosθ_2 + L_2cos$\theta_1$sin θ_1

Squaring on both sides and adding two equations

$$\cos\theta_{2=}\frac{x^2 + y^2 - L_1{}^2 - L_2{}^2}{2L_1L_2}$$

By knowing the link lengths L1 and L2, the joint angle can be calculated to place the arm at position(x, y) in world space.

Three degrees of freedom in two dimensions

The two jointed arm are capable for very simple tasks. Where three jointed arm is capable of positioning and orienting end of arm or tool in space. The third degree of freedom refers to wrist joint. Ψ represents orientation angle of wrist. Then we have coordinates as

X= L1 cosθ1 +L2 cos (θ1+θ2) +L3cos (θ1+θ2+θ3)

Y=L1sinθ1+L2sin (θ1+θ2)+L3sin (θ1+θ2+θ3)

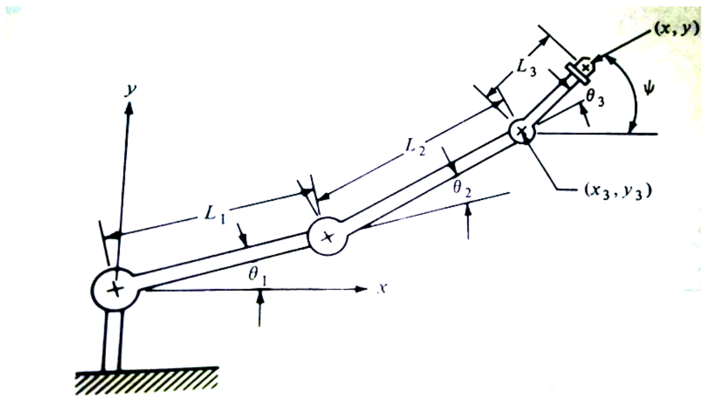


Fig 3.4 The two dimensional three degrees of freedom manipulator with orientations (type RR:R)

Ψ= (θ1+θ2+θ3)

We can use the results that we have already obtained for the 2- degree of freedom manipulator, to do the reverse transformation for the 3- degree of freedom when defining the position of the end of the arm , we will use x, y and Ψ. Given the three values, we can solve for the joint angles (θ1,θ2,θ3). Figure 3.4 shows 3 degrees of freedom manipulator.

X3 = x – L3 cos Ψ

Y3 = y – L3 cos Ψ

From the above equation the position of joint 3 can be determined.

3.3 ROBOT DYNAMICS:

Accurate control of the manipulator requires precise control of each joint. |The control of the joint depends on the knowledge of the forces that will be acting on the joint and the inertia's reflected at the joint (the masses of the joints and links of the manipulator) while these forces and masses are relatively easy to determine for a single joint. It becomes more difficult to determine them as the complexity of the manipulator increases. Figure 3.5 shows the different kinds of forces, torques etc., that acts on the links and joints.

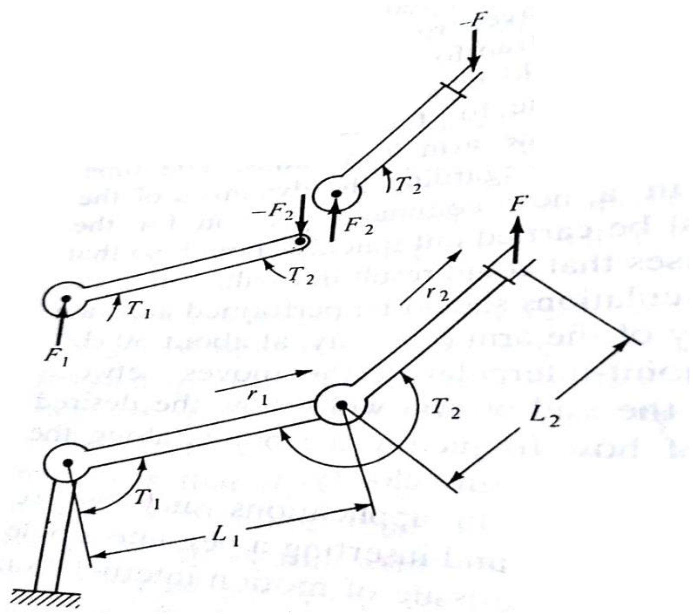


FIG 3.5 Shows the different kinds of forces, torques that acts on the links and joints

In fig (a) F1=F2; F2=F

F1=F2=F;

In fig (b) r1, r2 link vectors

T1=T2+ r1x F

T2=r2XF; where F- force, T-Torque

If the force exerted by gravity on each link is considered, Fg1 and Fg2 are the vectors acting at the centre of the link and m1 and m2 are the masses of link1 and link2. Figure 3.6 shows gravity forces and torques.

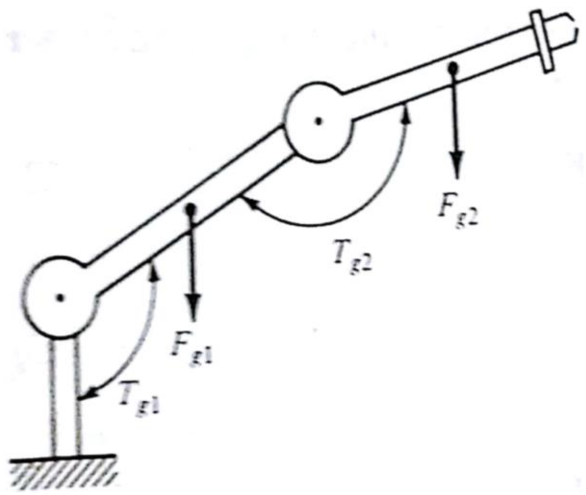


Fig 3.6 Gravity forces and torques

Balancing the forces due to gravity we get,

F2=m2g; F1=F2+m1g

The robot dynamics concerned with analysis of the forces and torques experienced by the acceleration and deceleration are present. The torques experienced by the joints due to acceleration of the links as well as forces experienced by the links due to torques by the points are also to be included in actual analysis.

Finding the acceleration of the links is difficult since.

- The acceleration is dependent on inertia of the arm, the inertia dependent on configuration position of arm and this is continually changing as joints are moved.
- Also the position and mass of the payload influences the inertia force,. This also changes as joints are moved.
- The joints react due to the torque. Hence the reactions are also to be considered in the analysis
- It becomes more and more complicated as the number of joints increases.
- The following figure 3.7 shows the dynamic forces and torques for a TRR robot.

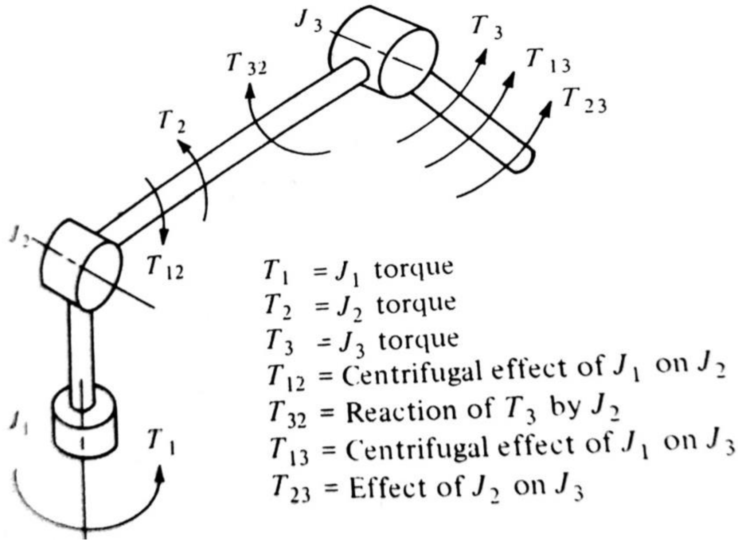


Fig 3.7 the dynamics forces and torques for a TRR robot

3.4 END EFFECTORS:

End effector is a gripper or end of arm tooling attached to the wrist of manipulator to accomplish the desired task

An end effector has four elements.

- A means of attachment of the gripper or tool to the wrist mounting plate.
- Power system for actuation
- Mechanical linkages
- Integrated sensors

End effectors can be classified into two main categories.

- Tools
- Gripper.

3.5 GRIPPERS& TOOLS:

3.5.1 GRIPPERS:

Grippers are end effectors that actually grip a part for transfer operations in the work envelope of the robot. A gripper is a component of the robot used to manipulate an object loose from the robot itself. Robot grippers are the physical interface between a robot arm and the work piece. These part handling include machine loading and unloading.

3.5.2 TOOLS:

Tools are attached directly to the robot wrist. At times, a robot is required to manipulate a tool to perform an operation on a work part. In such applications the end-effector is used as a gripper that can grasp and handle a variety of tools and the robot has multi tool handling function. However, in most robot applications in which only one tool is to be manipulated, the tool is directly mounted on the wrist; here the tool itself acts as the end effector.

- Spot welding tools
- Arc welding tools
- Spray painting nozzles
- Rotating spindles for drilling
- Rotating spindles for grinding.

3.6 GRIPPER DESIGN:

EngelBerger defines many of the factors that should be considered in assessing gripping requirements for the gripper. They are

1. The part surface to be grasped must be reachable. |It must not be enclosed within a chuck or other holding fixture.
2. The size variation of the part must be taken care of, and how this might influence the accuracy of locating the part. For example, there might be a problem in placing a rough casting or forging into a chuck for machine operations.
3. The gripper design must accomplish the change in size that occurs between part loading and unloading. For example, the part size is reduced in machining and forging operations.
4. Consideration must be given to the potential problem of scratching and distorting the part during gripping. If the part is fragile or has delicate surfaces.
5. If there is choice between two different dimensions on apart, the larger dimensions on a part, the larger dimension would be selected for grasping. Holding the part by its larger surface will provide better control and stability of the part in positioning.
6. Gripper fingers can be designed to conform to the part shape by using resilient pads or self-aligning finger makes contact with the part in more than one place. This provides better part control and physical stability. Use of replaceable fingers will follow for wear and also for interchangeability for different pat models.

Check list factors in the selection and design of grippers is given below.

Factor	Consideration
Part to be handled	Weight and size, shape, changes in shape during processing, Tolerances on the part size, surface condition, protection of detective surfaces
Actuation method	Mechanical grasping, vacuum cup, Magnet, other methods (adhesives, scoops, etc.)
Power and signal transmission	Pneumatic, Electrical, Hydraulic. Mechanical
Gripper force(mechanical gripper)	Weight of the object, Method of holding (physical constriction or friction) Coefficient of friction between fingers and object Speed and acceleration during motion cycle.
Positioning problem	Length of fingers, Inherent accuracy and repeatability of robot, Tolerances on the part size
Service conditions	Number of actuations during lifetime of gripper replace ability of wear components (fingers) maintenance and serviceability
Operating environment	Heat and temperature humidity, moisture, dirt, chemicals
Temperature protection	Heat shields, Long fingers, forced cooling (compressed air, water cooling etc.) use of heat resistant materials
Fabrication materials	Strength, rigidity, durability, fatigue strength , cost and ease of fabrication, friction properties for finger surfaces compatibility with operating environment
Other considerations	Use of interchangeable fingers, design standards, Mounting connections and interfacing with robot, Risk of robot design, Changes and their effect on the gripper design lead time for design and fabrication spare parts, maintenance, and service tryout of the gripper in production.

3.6.1 Types of Grippers:

- Mechanical Grippers
- Vacuum Grippers
- Magnetic Grippers

Types of grippers based on shape:

Singular Gripper: There is only one grasping device mounted on a robot's wrist

Double Gripper: Two gripping device is attached to the wrist to handle two separate objects. Both are actuated independently for loading and unloading

Multiple Grippers: It is applied in the case where two or more grasping mechanism is required. The double grippers are the subset of multiple grippers.

3.7 MECHANICAL GRIPPERS:

The mechanical grippers use mechanical fingers actuated by a mechanism to grasp an object. There are different types of mechanism. They are

- Pneumatic
- Electrical
- Hydraulic or mechanical

The mechanism must be able to open and close the fingers and exert sufficient force against the part when closed to hold it securely. These are designed to grasp a part either on the inside diameter or outside diameter. Figure 3.8 shows finger design of gripper.

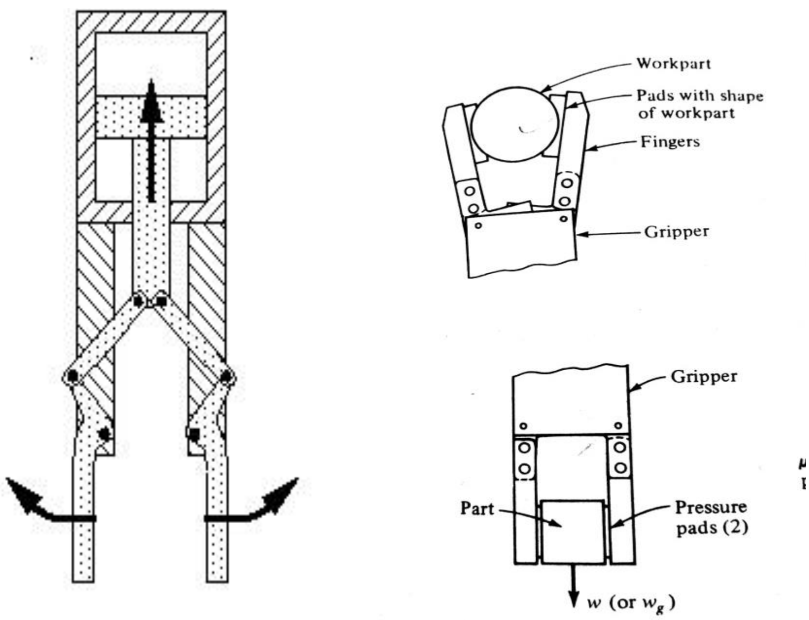


Fig 3.8 Physical construction method of finger design

The function of gripping mechanism is to translate some form of power input into the grasping action of the fingers against the part.

In some design fingers can be detachable. In most cases two fingers are enough to grasp the target in good condition. The main problem often consists of countering the gravity problem when we have to grasp something. The solution is given by applying force that we need to lift.

- Then we can consider the physical construction and the friction methods. The first one is accomplished by designing the contacting surfaces of the fingers to be in the approximate shape of the part geometry.

- In the second method the fingers applied a strong enough friction force to retain the part against gravity. This method is usually cheaper because of the design of the fingers.

To make a good contact with the surface area of the part, the gripper should have enough frictional force, which must overcome gravitational pull. Enough contact force can be achieved by providing pads, which will increase the coefficient of the friction and serves the part surface from scratching and damage.

3.7.1 Types of gripper Mechanism:

There are various ways of classifying mechanical grippers and their actuating mechanism.

One method is according to the type of finger movement used by the gripper by one of the following movement.

- Pivoting movement
- Linear or translational movement.

In the pivoting movement, the fingers rotate about fixed pivot points on the gripper to open and close. In the linear movement fingers open and close by moving in parallel to each other.

Other mechanisms used by the mechanical grippers to actuate finger movement are listed below.

- Linkage actuation
- Gear and rack actuation
- Cam actuation
- Screw Actuation
- Rope and pulley actuation

Linkage Actuation design determines how the input force F_a to the gripper is converted into the gripping force F_g applied by the fingers.

The linkage configuration also determines other operational features such as how wide the gripper fingers will open and how quickly the gripper will actuate. Figure 3.9 shows some possible linkages of gripper.

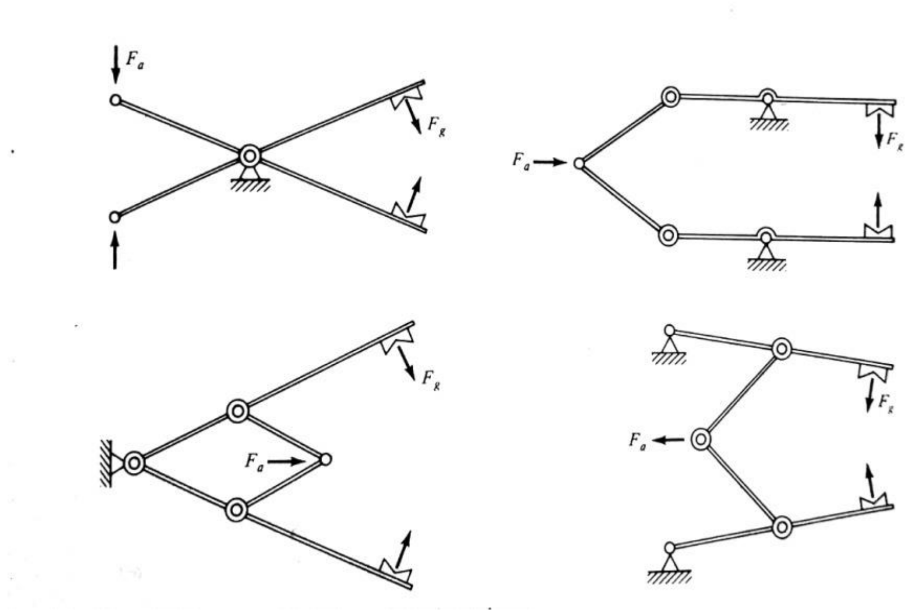


Fig 3.9 Some possible linkages for robot grippers

Another method of actuating the gripper fingers using a gear – and- rack configuration is shown in figure 3.10. The rack gear would be attached to a piston or some other mechanism that would provide a linear motion. The movement of the rack would drive two partial pinion gears, and these would in turn open and close the fingers.

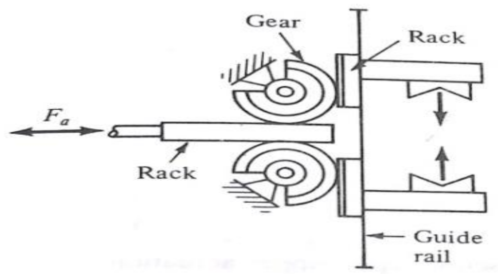


Fig 3.10 Gear –Cam – Rack method of actuating the grippers

A cam and follower arrangement, often using spring loaded follower, can provide the opening and closing of the gripper. Movement of cam in one direction would force the gripper to open, while movement of the cam in other direction would cause the spring to force the gripper to close. The advantage of this arrangement is that the spring action would accommodate different sized parts. Figure 3.11 shows cam actuated gripper.

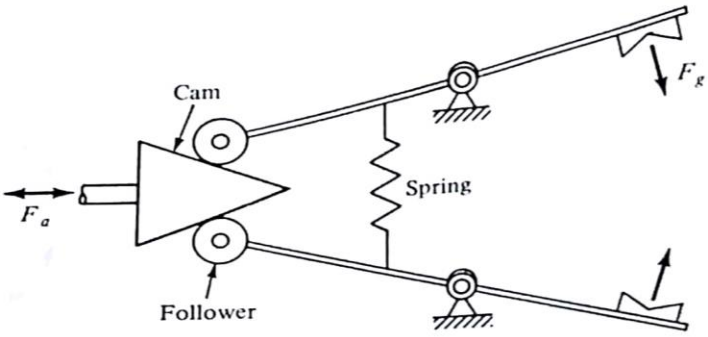


Fig 3.11 cam actuated gripper

Screw- type actuation method as shown in figure 3.12 is turned by a motor, usually accompanied by a speed reduction mechanism. When the screw is rotated in one direction, this causes the threaded block to be translated in one direction, when the screw rotated in the opposite direction, the threaded block moves in opposite direction. The threaded block is, in turn, connected to the gripper fingers to cause the corresponding opening and closing action.

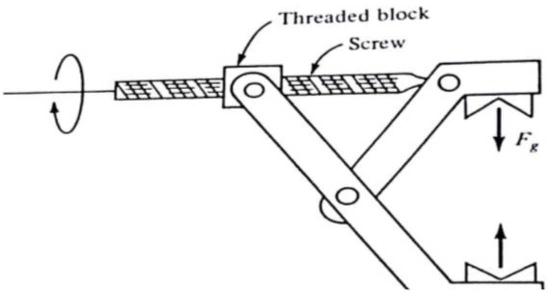


Fig 3.12 screw type actuation

Advantages:

- Less complicated and less expensive in the design
- Readily adapted to the greater variety of work pieces.

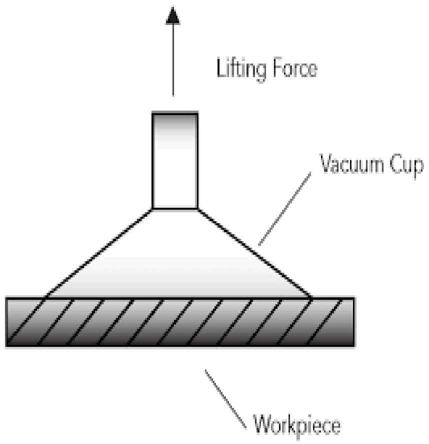
Disadvantages:

Slippage is possible.

3.8 VACUUM GRIPPERS:

It is often difficult to grasp flat large objects. However it can be done by the use of vacuum gripper. Vacuum grippers are mainly suction grippers. Vacuum gripper uses a vacuum instead of fingers to lift a part. The vacuum gripper has two components: the cups and the vacuum system. The suction cups are made of rubber like materials (silicone, neoprene). Figure 3.13 shows vacuum gripper.

Based on the design and the material suction cups are suitable for work at temperatures up to 200°C. They are really important because the efficiency depends on the source of air pressure. Number of grippers (cups) determines the size and weight of object to be grasped. Figure 3.14 shows Dual and single vacuum gripper.



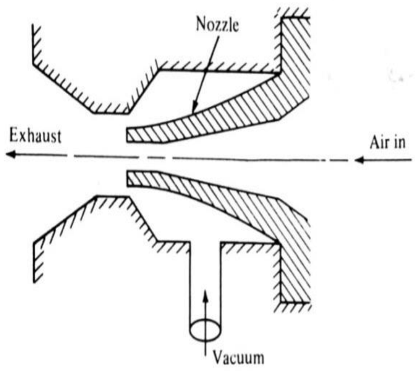


Fig 3.13 (i) Vacuum cup gripper   Fig 3.13 (ii) venture device used to operate suction cup

WORKING PRINCIPLE:

The cup creates negative pressure, which in turn creates the vacuum and the necessary lifting power. The vacuum is created between the cup and the part. This bond cause's friction .This friction allows the cup to lift the part. The holding force of the vacuum cup depends on the pressure between the outside area of the cup and inside area of the cup multiplied by the effective area of the cup.

The lift capacity of the suction cup depends on the effective area of the cup and negative air pressure between the cup on the part.

$$F = P X A$$

F-Force of lift capacity

P- Negative pressure

A-Total effective suction area

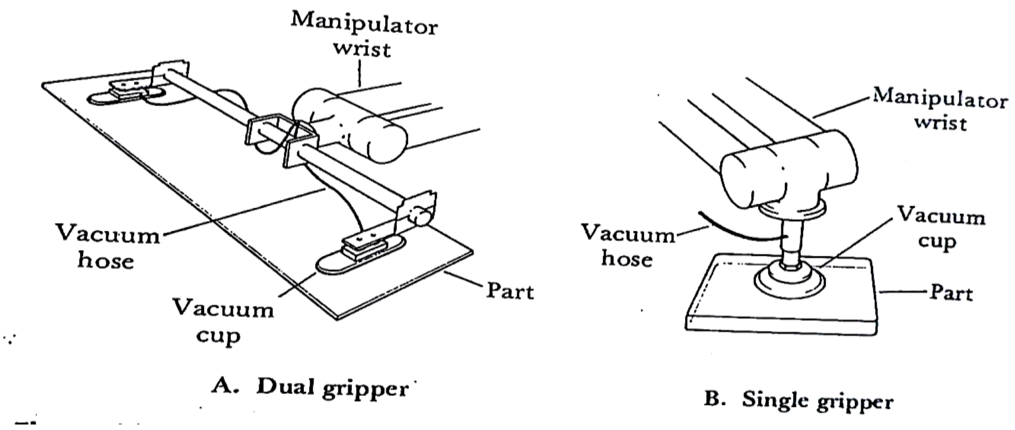


Fig 3.14 Dual and single Vacuum gripper

Advantages:

- Require only one surface of a part to grasp
- A uniform pressure can be distributed over some area, instead of concentrated at a point.
- The gripper is less weight
- Many different materials can be used.

3.9 MAGNETIC GRIPPERS:

The magnetic gripper employs the effect of a magnetic field to grasp a ferrous material. Magnetic grippers can be divided into two categories, those using electromagnets and those using permanent magnet.

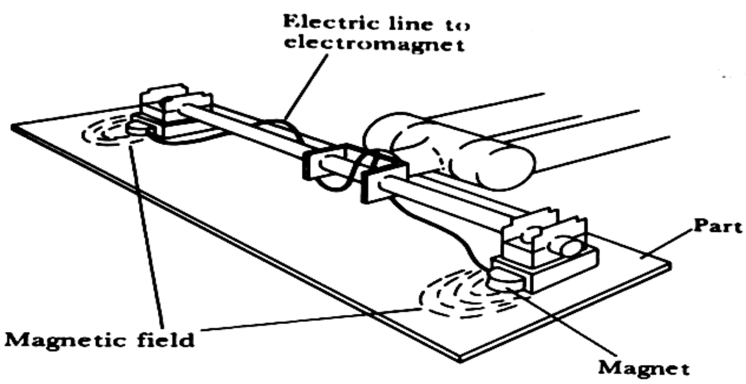


Fig 3.15 Magnetic gripper

Electromagnetic grippers are easier to control, but require a source of DC power and an appropriate controller unit. As with any other robotic gripping device, the part must be released at the end of the handling cycle. This is easier to accomplish with an electromagnet. When the part is to be released, the controller unit reverses the polarity at a reduced power level before switching of electromagnet. This procedure acts to cancel the residual magnetism in the work piece and ensures a positive release of the part.

Permanent magnets have the advantage of not requiring an external power source to operate the magnet. However there is loss of control accompanies this method. When the part is to be released at the end of the handling cycle, some means of separating the part from the magnet must be provided. A device called stripper is used to release the part at the end of handling. Figure 3.16 shows Magnetic gripper with stripper.

Permanent magnet are often considered for handling tasks in hazardous environments, the fact that no electrical circuit is needed to operate the magnet reduces the danger of spark which might cause ignition in such environments.

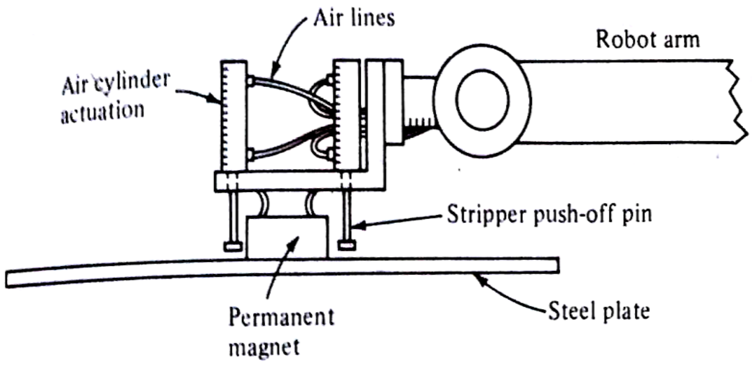


Fig 3.16 Magnetic gripper with stripper

Advantages of Magnetic gripper in robotic handling application:

- Pick up time is very fast.
- Variation in part size can be tolerated.
- The gripper does not have to be designed for one particular part.
- They have the ability to handle metal parts with holes.
- They require only one surface for gripping.

Disadvantages:

- Disadvantage with magnetic grippers include the residual magnetism remaining in the work piece which may cause a problem in subsequent handling, and the possible side slippage and other errors which limit the precision.

- Another disadvantage of a magnetic gripper is the problem of picking up only one sheet from a stack. The magnetic attraction tends to penetrate beyond the top sheet in the stack, resulting in the possibility that more than a single sheet will be lifted by the magnet.

3.10 SENSOR :

Sensor is a transducer that is used to make a measurement of physical variable. The sensor is a device that is sensitive to motion, heat, light, pressure, electrical, magnetic and other types of energy.

Eg:-Photoelectric sensor, Temperature sensor, Proximity sensors.

The robot employs the sensor as a measuring device that is it computes the sensor information and acts upon that information.

Some sensors found on factory floors today basically limit switches, these switches either closed or open, which means that the decision capability of the robot controller is very limited. Other sensors allow the robot to perform various assembly tasks and give the robot more decision capabilities. These sensors include force sensor, vision sensor and tactile sensor.

3.11 TRANSDUCERS :

A transducer is a device which converts energy from one form to another form. This energy may be electrical, mechanical, chemical, optical or thermal.

Transducer is a device which is used to convert non electrical quantities in to electrical quantities. The transducer that gives electrical energy as output is known as electrical transducer.

The output of electrical signal may be voltage, current or frequency. The production of these signals is based upon resistive, capacitive, inductive effects etc. the conversion is that the converted signal is more convenient to use and evaluate.

Eg: Piezoelectric, Ultrasonic, Capacitive transducers.

Transducers can be classified into

1. Analog transducers
2. Digital transducers.

Analog transducers provide a continuous analog signal such as electrical voltage or current. This signal can the n be interpreted as the value of the physical variable that is being measured.

Digital transducers produce a digital output signal, either in the form of parallel status bits or a series of pulses that can be counted.

Difference between sensors and transducers:

Sensors are devices that detect physical, chemical, and biological signals and provide a way for those signals to be measured and recorded. Physical properties that can be sensed include temperature, pressure, vibration, sound level, light intensity, load or weight, flow rate of gases and liquids, amplitude of magnetic and electronic fields, and concentrations of many substances in gaseous, liquid, or solid form.

In order to use electrical methods and techniques for measurement, the non-electrical quantity is converted into a proportional electrical signal by a device called transducer. Therefore, transducer is a device, which converts the measured into a usable signal of some form, usually of the electrical type.

Desirable features of sensors:

- **Accuracy**: The accuracy of the measurement should be as high as possible.
- **Precision**: The precision of the measurement should be as high as possible.
- **Operating Range**: The sensor should possess a wide operating range and should be accurate and precise over the entire range.
- **Speed of response**: The transducer should be capable of responding to changes in the sensed variable in minimum time.
- **Calibration**: The sensor should be easy to calibrate. The time and trouble required to accomplish the calibration procedure should be minimum.
- **Reliability**: The sensor should possess a high reliability.
- **Cost and ease of operation**: The cost of purchase, install and operate the sensor should be as low as possible.

3.12 TACTILE SENSOR:

Tactile sensors are devices which indicate contact between themselves and some other solid object. Tactile sensing device can be divided into two classes: touch sensors and force sensors. Fig 3.19 shows tactile sensor.

Touch sensors provide a binary output signal which indicates whether or not contact has been made with the object.

Force sensors indicate not only that contact has been made with the object but also the magnitude of the contact force between the two objects

Tactile sensors are generally micro switches placed in the fingers of the grippers. These sensors tell the controller, a part has been picked up by the gripper.

Tactile sensors could allow the robot to feel various parts in a bin and select the correct path. When the robot grasp a part, the sensor feeds the data to the computer, the data are compared with data in memory for identification of the correct part.

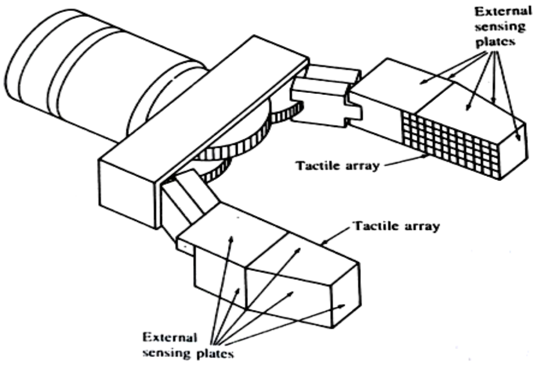


Fig 3.17 Tactile sensor

3.12.1 TOUCH SENSORS:

Touch sensor senses the present (or) absence of the object by having physical contact between the objects. When the button is pressed, electrical circuit is closed inside the sensor. When the button is released, the circuit becomes open. The receiver section senses the flow of supply. It sends a signal when physical contact is made figure 3.18 shows limit switch on conveyor line.

.The micro switch is the simplest touch sensor which either turns on (or) off as contact is made .Touch sensor used in Robotics to obtain information associated with the contact between a manipulator hand and objects in the work space.

These sensors are used in object location and recognition as well as to control the force exerted by the manipulator on a given object.

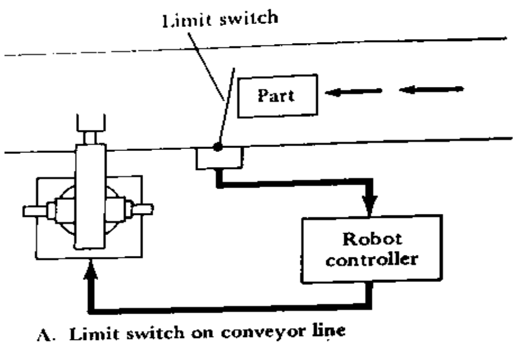


Fig 3.18 Limit switch on conveyor line

TOUCH SENSOR AS INSPECTION PROBE:

Another use for a touch sensing device would be as part of an inspection probe. An application of the touch sensor is shown in figure 3.19. In this application, the robot is inspecting different parts. The limit switch is connected to a rolling wheel. As the wheel rotates over the part, the wheel detects any faults on the linear path of the part. If the part has not been machined properly, dents or bumps are detected by the wheel. The limit switch then closes, sending a message to the controller. The controller then directed to an error subroutine of the program this subroutine commands the robot to pick up the part and deposit it in the defect basket.

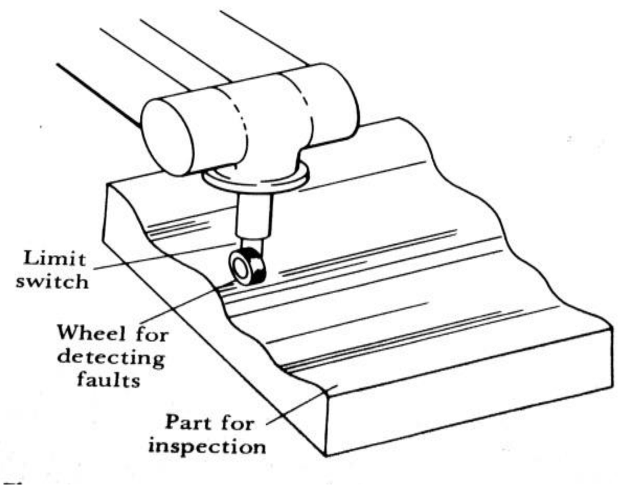


Fig 3.19 Touch sensor

3.12.2 FORCE SENSOR:

Force sensors can be used to measure the amount of downward force the robot arm is applying to a part.

The capacity to measure forces permits the robot to perform a number of tasks. These include the capability to grasp parts of different sizes in material handling, machine loading and assembly work, applying the exact level of force for the given part.

Force sensor for a robotic system is generally two types the strain wire gauge or the semiconductor strain gauge.

STRAIN WIRE GAUGE FORCE SENSOR

The strain wire gauge measures the strain that is placed on an object. The gauge converts a mechanical strain to an electrical signal. The force applied to the gauge causes the gauge to bend. This bending action also distorts the physical size of the gauge. This distortion develops a change in the resistance of the metals of the gauge. This resistance change is fed to a resistance bridge circuit that detects small changes in the gauge resistance.

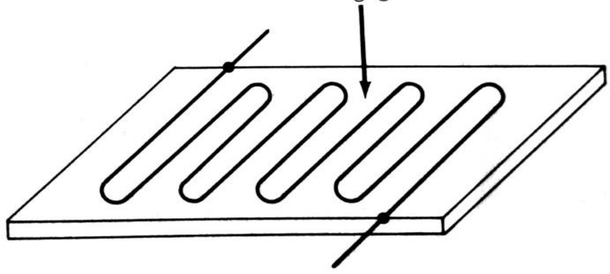


Fig 3.20 Strain wire gauge

In application, the strain wire gauge can be connected to the end of the robots hand. As the robot applies pressure to a metal, the strain gauge monitors the amount of force developed by the robots hand.

If the force applied exceeds the limit, the controller will branch to subroutine to stop the Robot's motion. Figure 3.20 shows strain wire gauge.

SEMI-CONDUCTOR STRAIN GAUGE FORCE SENSOR

Semi-conductor stain gauge is made from semiconductor material, a piezoelectric crystal. As a force is applied to the crystal, the shape of the crystal changes. This change of shape develops a voltage at the output, (piezoelectric effect).

The voltage output obtained from these materials due to piezoelectric effect is proportional to the applied stress or force. The output voltage can be calibrated against the applied stress or the force so that the measured value of the output voltage directly gives the value of the applied stress or force which is then fed to the robot controller.

The semiconductor strain gauge is used when rapid changes are taking place on the measuring device and when high sensitivity is needed. Figure 3.21 shows semiconductor strain gauge force sensor construction and working principle.

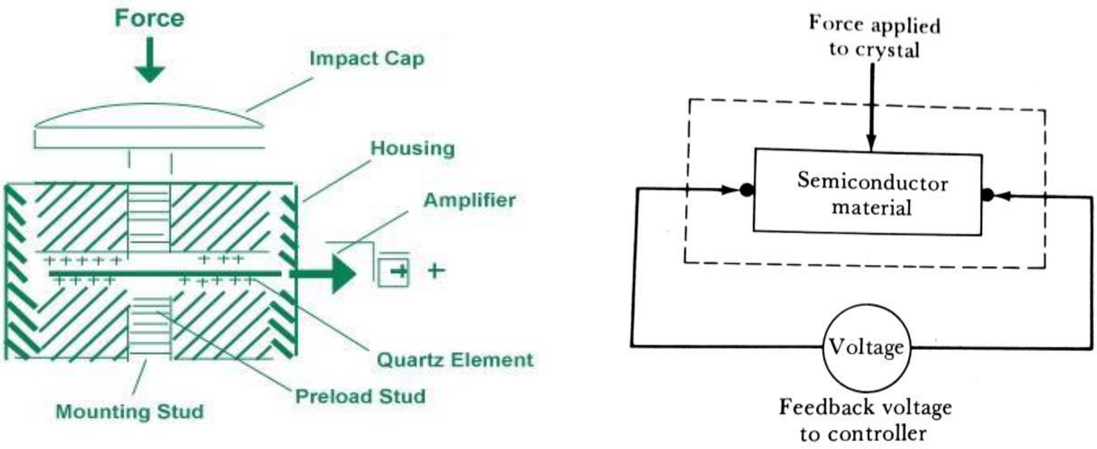


Fig 3.21 Semi-conductor strain gauge construction and working.

3.13 PROXIMITY SENSOR:

Proximity sensors are devices that indicate when one object is close to another object. How close the object must be in order to activate the sensor is dependent on the particular device. The distance can be anywhere from several millimetres and several feet.

Some of the sensor can also be used to measure the distance between the object and the sensor, and these devices are called range sensors.

Proximity range sensors would typically be located on the wrist or end effector since these are the moving parts of the robot.

One practical use of proximity sensor is to detect the presence or absence of a work part or other object. Another important application is for sensing human beings in the robot work cell.

3.13.1 PROXIMITY INDUCTIVE SENSORS:

Sensors based on a change of inductance due to the presence of a metallic object are among the most widely used industrial proximity sensors. An inductive sensor basically consists of a wound coil located in front of permanent magnet in a simple rugged housing. Figure 3.22 shows Inductive proximity sensor

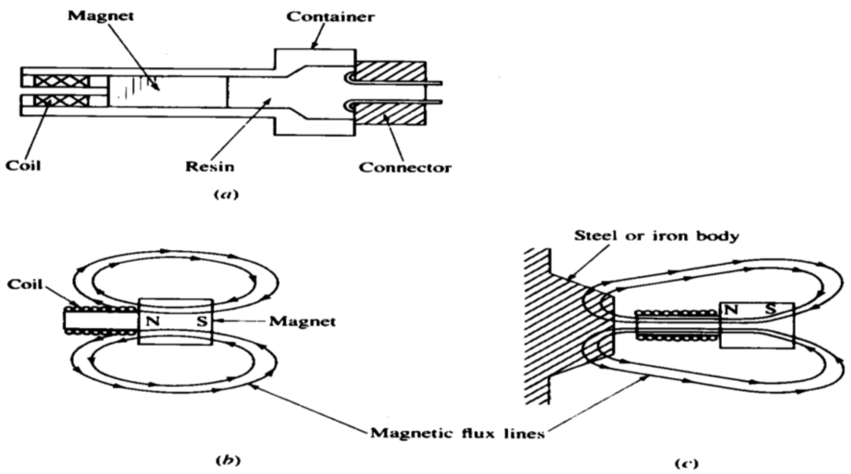


Fig 3.22 Proximity inductive sensor

The effect of bringing the sensor in close proximity to a ferromagnetic material causes a change in position of the flux lines of the permanent magnet. Under static conditions there is no movement of the flux lines and, therefore, no current is induced in the coil.

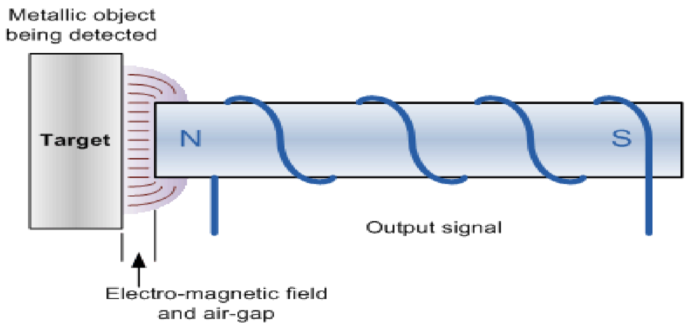


Fig 3.23 operation of proximity inductive sensor.

When a ferromagnetic object enters or leaves the field of the magnet, the resulting change in flux lines induces current pulses whose amplitude and shape are proportional to the rate of change of flux

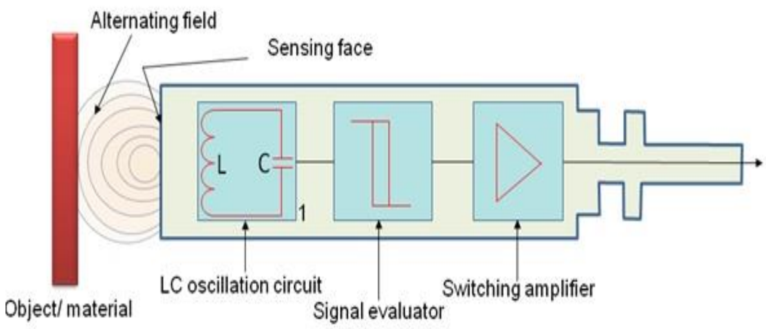


Fig 3.24 shows schematic proximity inductive switch.

Figure 3.24 shows the construction of inductive proximity switch. An inductive proximity sensor has four components; the coil, oscillator, detection circuit and output circuit. An alternating current is supplied to the coil which generates a magnetic field. When, a metal object comes closer to the end of the coil, inductance of the coil changes. This is continuously monitored by a circuit which triggers a switch when a preset value of inductance change is occurred.

Applications of inductive proximity switches

- Industrial automation: counting of products during production or transfer
- Security: detection of metal objects, arms, land mines

3.13.2 ULTRASONIC PROXIMITY SENSOR:

Acoustical devices can be used as proximity sensors. Ultrasonic frequencies (above 20,000 Hz) are often used in these devices because the sound is beyond the range of human hearing. One type of acoustical proximity sensor uses cylindrical open ended chamber, with an acoustic emitter at the closed end of the chamber.

The emitter sets up a pattern of standing waves in the cavity which is altered by the presence of an object at the open end. A microphone is located in the wall of the chamber is used to sense the change in the sound pattern. This kind of device can also be used as a range sensor. The Acoustic waves emitted by the sensors reach the object and get reflected and receiver receives the waves to generate the information about the presence of object. This type of information about the operation is called echo mode.

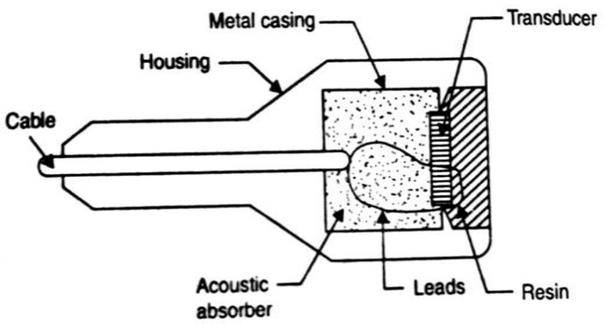


Fig 3.24(a) Ultrasonic Proximity Sensor

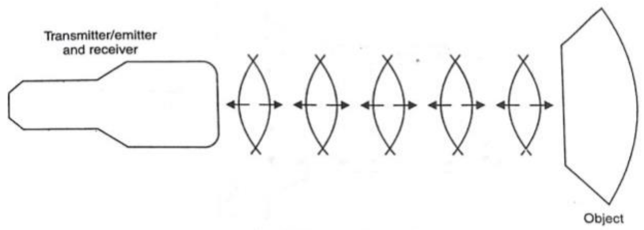


Fig 3.24(b) Standing wave pattern

3.13.3. Optical proximity sensor

The figure shows the constructional details of the optical sensor. The light emitted by a diode is focussed by the transmitter lens, on the object surface. The reflected light wave travel back and received by the photo diode. When the object is within the range of the sensor it is possible to detect the presence of the object. Figure 3.25 shows optical sensor.

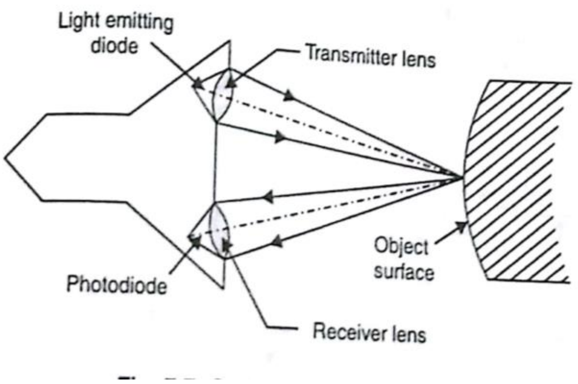


Fig 3.25 Optical sensor

The range is defined by the position and orientation of the object and the focal length of the sensor lenses.

3.14 RANGE SENSORS:

Range sensors are used to determine the location of an object (work part) in relation to the robot.

The actual distance between the object and the robot hand is measured using the range sensors within its range of operation**.**

They are used for robot navigation, and avoidance of the obstacles in the path. The main goal of any ranging system is to repeatedly obtain accurate range information of surroundings

Ranging systems are usually used in automated guided vehicles or where the robot has a large workspace. The exact location can be determined using range sensor.

The two common methods of distance measurement are,

1. Time of flight method.
2. Triangulation method

1. **Time of flight method**:
    - This method estimate the range by measuring the time elapsed between the transmission and return of a pulse. Large range finders and sonar are best known sensors of this type.
    - Time of flight ranging method consist of sending a signal from the transmitter that bounces back from the object and is received by a receiver.
    - The distance between the object and the sensor can be calculated by measuring the time of flight of the signal and by knowing its speed of travel
2. **Triangulation method**:
    - This is the simplest technique used to find distance between object and the sensor. Distance is calculated from a triangle formed between the receiver, light source and the object

3.14.1 Optical proximity Range sensors

Optical proximity sensors can be designed using either visible or invisible light sources. The infrared- reflectance sensor using incandescent light source is a common device used in range finding. By timing the interval from when the signal is sent and echo is received, a measurement of the distance between the object and the sensor is made. Infrared reflectance sensor using an incandescent light source can be used in this method.

Another optical approach of proximity sensing involves the use of a collimated light beam and a linear array of light sensors. Figure 3.26 shows optical proximity array sensor.

By reflecting the light beam off the surface of the object, the location of the object can be determined from the position of its reflected beam on the sensor array.

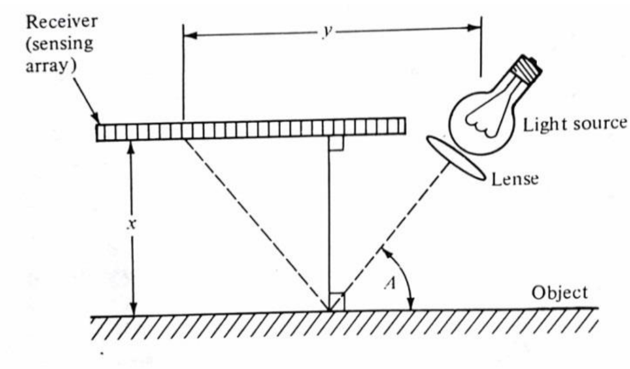


Fig 3.26 Scheme for a proximity sensor using reflected light against a sensor array

The formula for the distance between the object and the sensor is given by

X=0.5 y tan (A)

x – The distance of the object from the sensor.

Y- The lateral distance between the light source and the reflected light beam against the linear array.

A-The angle between the object and the sensor array.

Use of this device in this configuration requires surface of the object must be parallel to the sensing array.

A typical optical range sensor uses a laser scanner, is shown in figure 3.28. This operates in two methods. One based on transmitting a laser pulse and measuring the time of arrivals of the reflected pulse. And other based on transmitting an amplitude modulated laser beam and measuring the phase shift of the reflected signal. The transmitted beam and the received light are essentially coaxial.

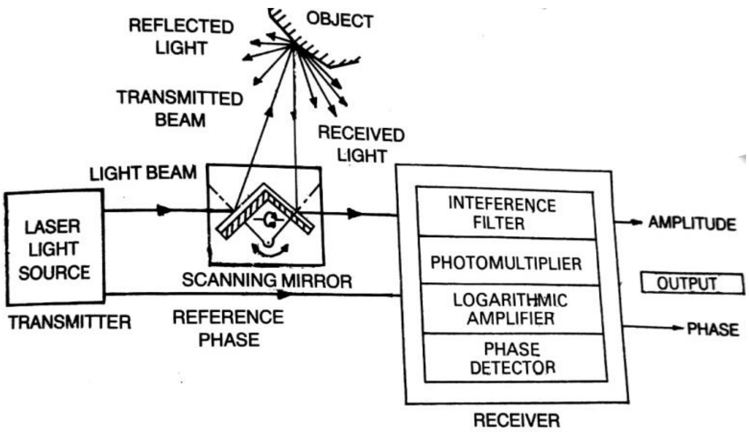


Fig 3.27 Range image Sensor

3.14.2 Ultrasonic range sensors

Ultrasonic systems are rugged, simple, inexpensive, and low powered. Most ultrasonic devices measure the distance using time of flight technic. In this technique, a transducer emits a pulse of high frequency ultrasound signals which travels certain distance and is reflected back when it encounters a separation in the medium, it is then received by a receiver. Accuracy of the measurement not only depends on the wavelength of the signal, but also to the accuracy of the time measurement and the speed of sound. Figure 3.28 shows ultrasonic range finder.

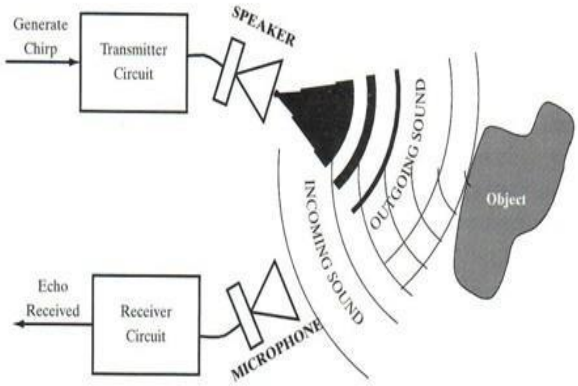


Fig 3.28 Ultrasonic range finders

3.15 FORCE / MOMENT SENSORS

The wrist force sensor is used to measure the force and torque induced on the wrist of the robotic manipulator. They can also be used to measure the joint forces.

Force sensing is accomplished in several ways .A commonly used technique is a Force sensing wrist. This consists of a special load cell mounted between the gripper and the wrist. This is another technique is to measure the torque exerted by each joint. This is usually accomplished by sensing motor current for each of the joint motor .Finally a third technique is to form an array of force sensing elements so that the shape and other information about the contact surface can be determined.

Typical force/torque sensor work on the strain gauge principle. The change in the resistance of the electrical strain gauges effected by the strain due to change in force induced is a measure of force and torque. Figure 3.29(a) shows strain gauge type wrist Force/Moment sensor.

The construction of the sensor has got a disc housing support and a deflection bar. The strain gauges are mounted on the six faces of the deflection bar. **The force and moments exerted on the wrist is transformed into measurable deflections or displacement at the wrist.**

A balanced Wheatstone bridge is used to arrange the four resistances. The galvanometer connected between X and Y with equal potential shows zero deflection when there is no force exerted .The force on the wrist changes the resistance in any one arm, which results in current flow and leads to the movement of the galvanometer needle. The change in resistance is given by, $R1/R4=R2/R3$

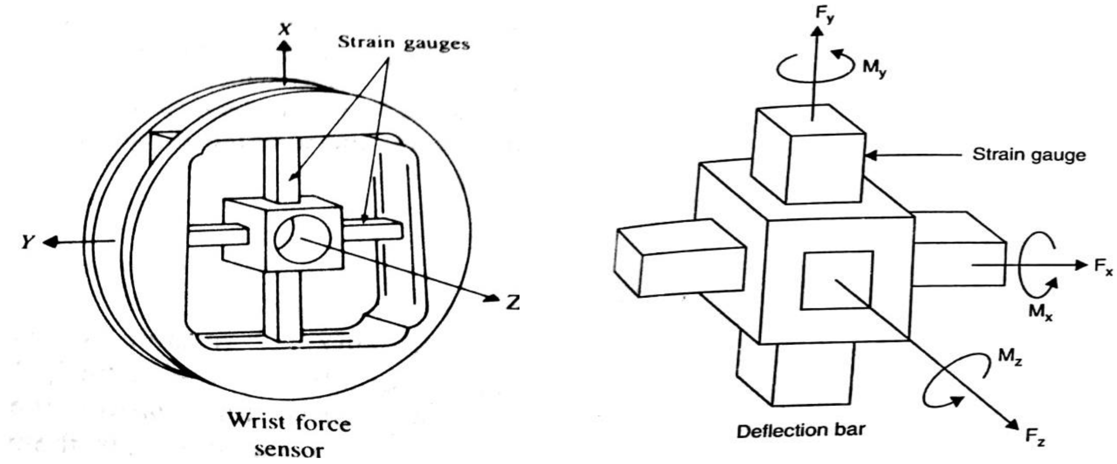


Fig 3.29 (a) Strain Gauge Type wrist Force & Moment Sensor

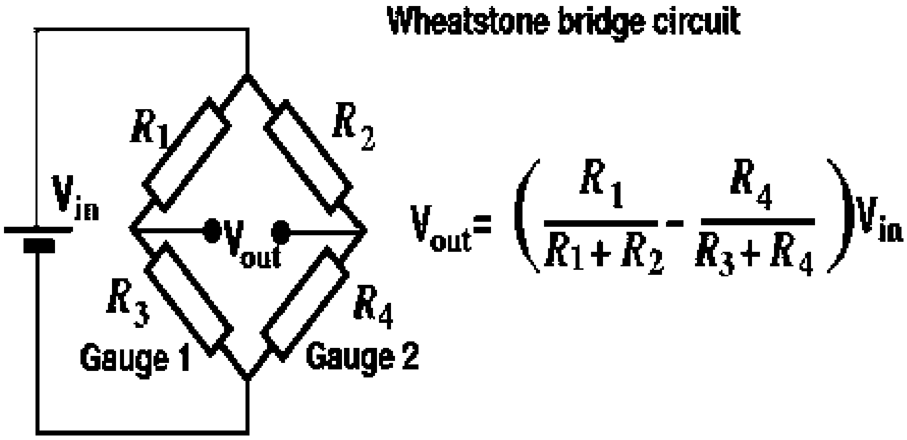


Fig 3.29 (b) Wheat stone bridge using strain gauge.

Since strain gauges are oriented normal to the X,Y,Z axes of the force coordinate frame, the three components of force and three components of moment F_x, F_y, F_z, M_x, M_y, M_z can be determined by properly adding and subtracting the output voltages, respectively. can be done by sensor calibration matrix.

3.15.1 Applications

- Force sensor permits the robot to perform a number of tasks. These include the capacity to grasp parts of different sizes in material handling, machine handling and assembly work, applying the appropriate level of force for the given part.
- In assembly application, force sensing could be used to determine if screws have become cross threaded or if parts are jammed.

3.15.2 Problems encountered while designing force sensor

Force sensing Wrists are usually very rigid devices so that they will not deflect undesirably while under load. When designing a force- sensing wrist there are several problems that may be encountered. The end-of the arm is often in a relatively hostile environment and the device must be sufficiently rugged to withstand the environment.

It must be capable of tolerating an occasional crash of the robot arm. At the same time the device must be sensitive enough to detect small forces. This design problem is usually solved by using over travel limits. An over travel limit is a physical stop designed to prevent the force sensor from deflecting so far that it would be damaged.

The calculations required to utilize a force- sensing wrist are complex and require considerable computation time.

Also, for an arm travelling at moderate -to- high speeds, the level of control over the arm just as it makes contact with an object is limited by the performance of the arm.

The momentum of the arm makes it difficult to stop its forward motion quickly enough to prevent crash.

3.16 PHOTO ELECTRIC SENSOR:

A photoelectric proximity sensor senses the presence of an object without making physical contact. It consists of a solid state LED which acts as a transmitter of infrared light and a solid state photodiode which acts as a receiver. Both are mounted in a small package.

The sensing space is approximately the intersection of two cones in front of the sensor. If the reflectance and incident angle are fixed, the distance may be measured with suitable calibration. When the received light exceeds it corresponds to a predetermined distance. Figure 3.30 shows photoelectric sensor.

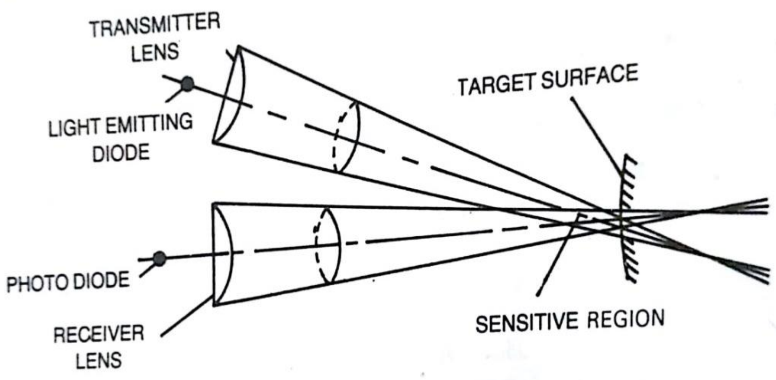


Fig 3.30 Photo electric sensor.

3.17 ROBOT VISION SYSTEM:

Machine vision is concerned with the sensing of vision data and its interpretation by a computer. The typical vision system consists of the camera and digitizing hardware, a digital computer, and hardware and software necessary to interface them. This interface hardware and software is often referred to as a pre-processor. Figure 3.31 shows schematic diagram of vision system.

The operation of the vision system consists of three functions

1. Sensing and digitizing image data

2. Image processing and analysis.

3. Application

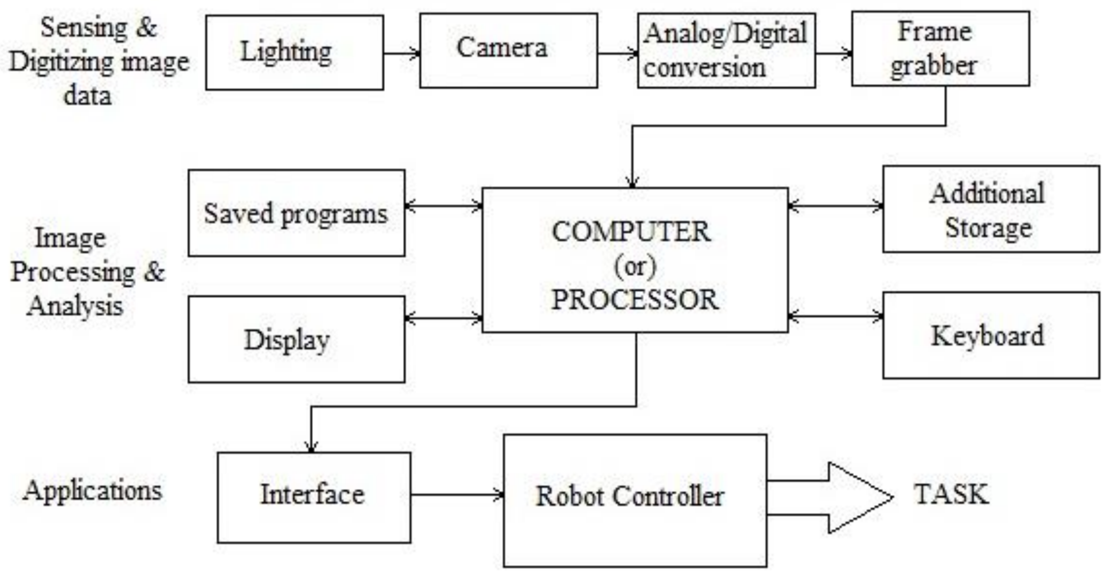


Fig 3.31 Schematic diagram of vision system

.The sensing and digitising functions involve the input of vision data by means of camera focused on the scene of interest. Special lighting techniques are frequently used to obtain an image of sufficient contrast for later processing. The image viewed by the camera is typically digitised and stored in computer memory. The digital image is called a frame of vision data, and is frequently captured by a hardware device called a frame grabber. These devices are capable of digitizing images at the rate of 30 frames per second.

The frames consist of a matrix of data representing projections of the scene sensed by the camera. The elements of the matrix are called picture elements, or pixels. The number of pixels is determined by the sampling process performed on each image frame.

A single pixel is the projection of a small portion of the scene which reduces that portion to a single value. The value is measure of the light intensity for that element of the scene. Each pixel intensity is converted in to a digital value.

The digitised image matrix for each frame is stored and then subjected to image processing and analysis functions for data reduction and interpretation of the image. These steps are required in order to permit the real time application of vision analysis required in robotic applications.

Typically an image frame will be threshold to produce a binary image , and then various feature measurements will further reduce the data representation of the image .This data reduction can change the representation of a frame from several hundred thousand bytes of raw image data to several hundred bytes of feature value data. The resultant feature data can be analysed in the available time for action by the robot system.

Sensing and digitizing function in machine vision

Image sensing requires some type of image formation device such as a camera and a digitizer which stores a video frame in the computer memory.

Sensing and digitizing functions into several steps.

- The initial step involves capturing the image of the scene of the scene with vision camera.
- The second step, digitizing, is achieved by an analog –to – digital (A/D) converter. The A/D converter is either part of a digital video camera or the front end of a frame grabber.
- The storage image is then subsequently processed and analysed by the combination of the frame grabber and the vision controller.

IMAGING DEVICES

Camera technologies available include the other black and white Videocon camera, solid state camera include charged –coupled devices, charge injection devices and silicon bipolar sensor cameras.

ANALOG - TO - DIGITAL SIGNAL CONVERSION

The analog – to – digital (A/D) conversion process involves taking an analog input voltage signal and producing an output that represents the voltage signal in the digital memory of a computer.

A/D CONVERSION PROCESS INVOLVES

The A/D conversion process involves taking an analog input voltage signal and producing an output that represents the voltage signal in the digital memory of computer.

- Sampling
- Quantization
- Encoding

Sampling: A given analog signal is sampled periodically to obtain a series of discrete- time analog signals. Figure 3.32 illustrates sampling and digitizing an analog waveform.

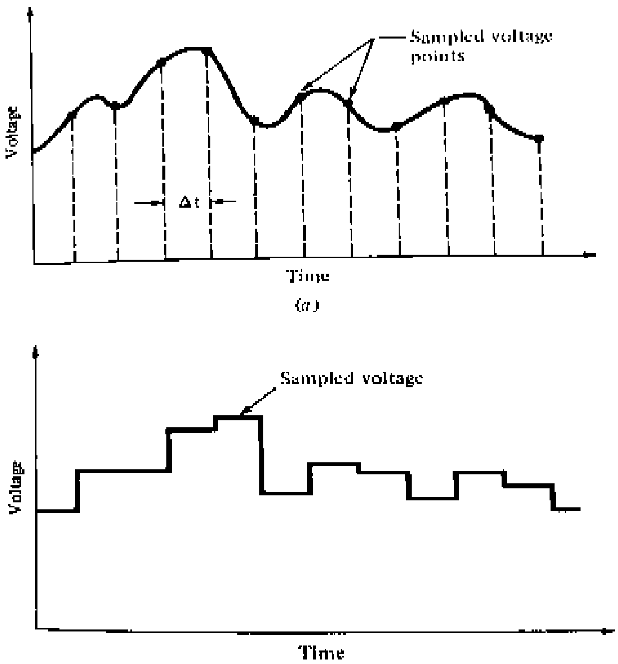


Fig 3.32 Sampling and digitizing an analog waveform

Quantization: Each sampled discrete - time voltage level is assigned to a finite number of defined amplitude levels. These amplitude levels corresponds to the grey scale used in the system

Encoding: The amplitude levels that are quantised must be changed in to digital code. The process Encoding involves representing the amplitude level by a binary digit sequence.

Image storage: Following A/D conversion, the image is stored in computer memory, typically called a frame buffer. This buffer may be part of the frame grabber or in the computer itself.

3.18 IMAGE PROCESSING AND ANALYSIS:

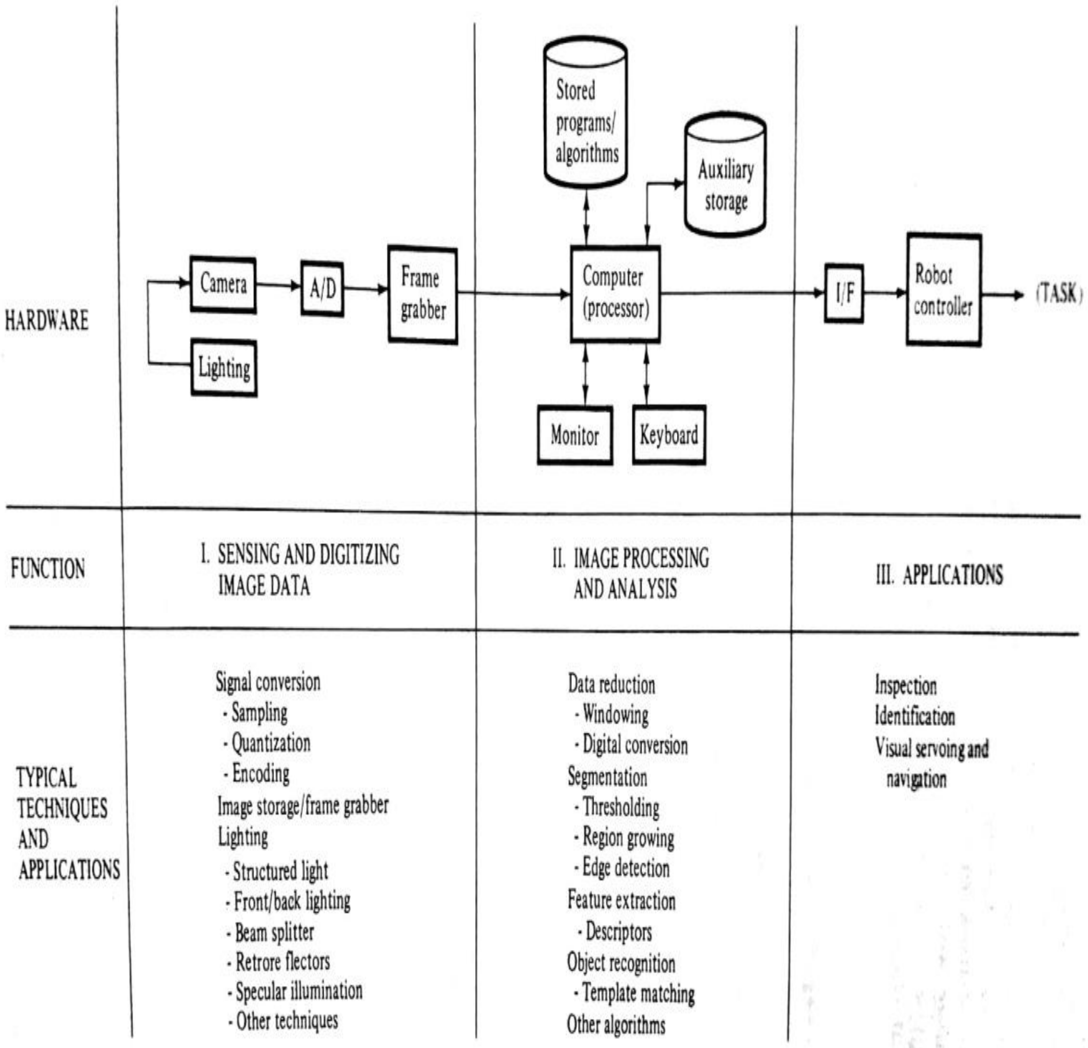


Fig 3.33 Functions of a machine vision system

The image processing and analysis technique include:

- Image data reduction
- Segmentation
- Feature extraction
- Object recognition

1. **IMAGE DATA REDUCTION**:

In image data reduction, the objective is to reduce the volume of data. As a preliminary step in the data analysis, the following two schemes have found common usage for data reduction.

a. Digital conversion
b. Windowing

The functions of the both schemes is to eliminate the bottle neck that can occur from the large volume of data in image processing

DIGITAL CONVERSION:

Digital conversion reduces the number of gray levels used by the machine vision system. Depending on the requirements of the application, digital conversion can be used to reduce the number of grey levels by using fewer bits to represent the pixel intensity.

WINDOWING:

Windowing process involves using only a portion of the total image stored in the frame buffer for image processing and analysis**.** This portion is called the window.

2. SEGMENTATION:

Segmentation is a general term which applies to various methods of data reduction. In Segmentation, the objective is to group areas of an image having similar characteristics or features. Fig 3.34 shows image segmentation.

For example, boundaries (edges) or regions (areas) represent two natural segments of an image. There are many ways to segment an image.

- Thresholding
- Region growing
- Edge detection

Thresholding:

The thresholding is a binary conversion technique is which each pixel is converted into a binary value either is Black or white. This is accomplished by utilizing a frequency histogram of the image and establishing what intensity (gray level) is to be the border between black and white. To improve the ability to differentiate, special lighting techniques must often be applied to generate a high contrast.

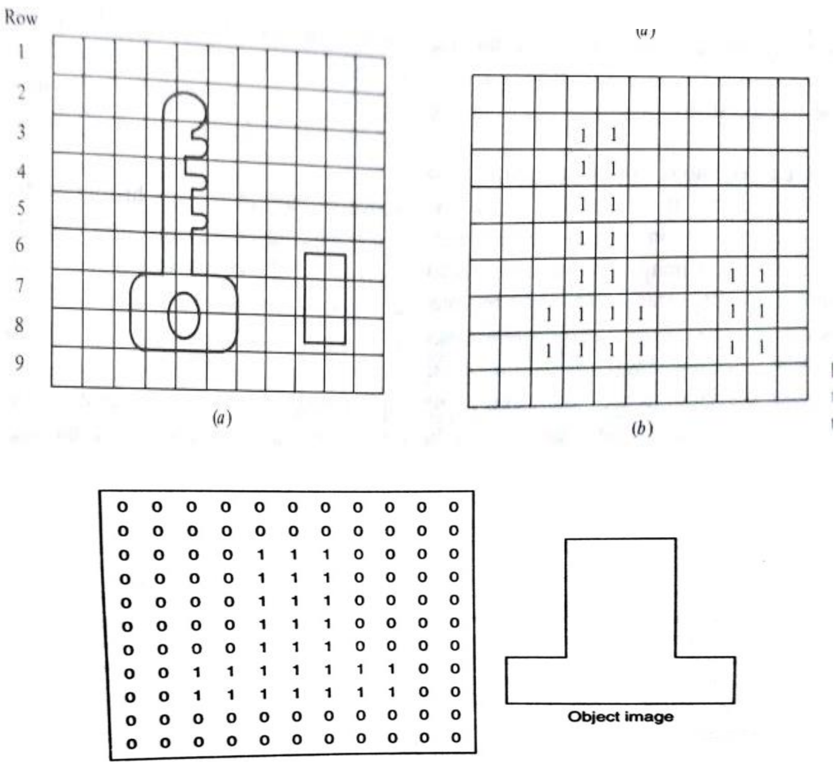


Fig 3.34 image segmentation (a) image pattern with grid (b) segmented image after runs test

Region growing:

It is a collection of segmentation techniques in which pixels are grouped in regions called grid elements based on attribute similarities. Defined regions can then or can be merged to other regions by means of an analysis of the difference in their average properties and spatial connectiveness.

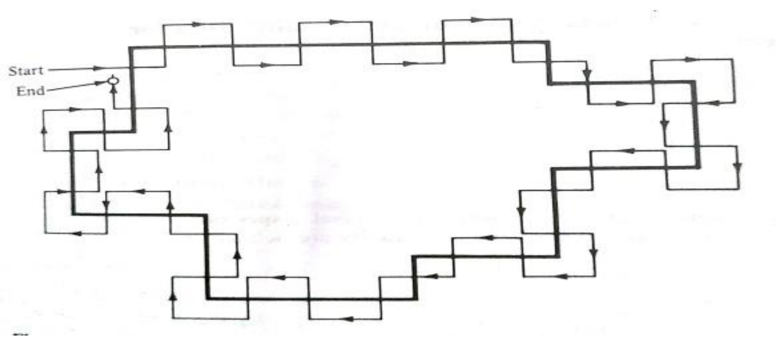


Fig 3.35 Edge following procedure to detect the edge of a binary image

Edge detection:

It considers the intensity change that occurs in the pixels at the boundary or edges of a part. Given that a region of similar attributes has been found but the boundary shape is unknown, the boundary can be found by edge following procedure as shown in Figure 3.35.

For binary image, the procedure is to scan the image until a pixel within the region is encountered. For a pixel within the region turn left and step otherwise turn right and step. The procedure is stopped when the boundary is traversed and the path has returned to the starting pixel.

3. Feature Extraction:

In machine vision applications, it is often necessary to distinguish one object from another. This is usually accomplished by means of features that uniquely characterize the object. Some features of objects that can be used in machine vision include area, diameter and perimeter.

4. Object recognition:

The next step in image data processing is to identify the e object the image represents. The recognition algorithm must be powerful enough to uniquely identify the object.

Object recognition techniques used in industry today may be classified as

1. Template –matching techniques

2. Structural techniques.

1. **Template Matching Technique**:

There is a subset of more general statistical pattern recognition techniques that serve to classify objects is an image into predetermined categories

The basic problem in template matching is to match the object with stored pattern feature set defined as a model template.

The model template is obtained during the training procedure in which the vision system is programmed for known prototype objects.

2. Structural Techniques:

They consider relationship between features or edges of an object.

For example, if the image of an object can be subdivided in to four straight lines connected at their end points, and the connected lines are at right angles, then the object is rectangle.

3.19 APPLICATIONS OF MACHINE VISION SYSTEM IN ROBOTICS:

A machine vision system is employed in a robot for recognizing the objects. It is commonly used to perform the *inspection* functions in which the industrial robots are not involved. It is usually mounted in a high speed production line for accepting or rejecting the work parts. The rejected work parts will be removed by other mechanical apparatuses that are in contact with the machine vision system.

A machine vision system can be incorporated with an industrial robot for performing the following three important tasks such as:

- Inspection
- Identification
- Visual serving and navigation

INSPECTION:

The industrial robots are only used to *support* the machine vision system when it performs the inspection tasks. During this process, it checks for accurate surface finish, exact dimension, errors in labelling, presence of holes in the work parts, and other factors.

The machine vision system carries out this inspection processes automatically with less time and errors.

In addition, the human workers can also perform these operations manually, but there is a high possibility of error occurrence and increased operation time.

IDENTIFICATION:

In this process, the machine vision system performs recognizing and categorizing of work parts instead of inspecting it.

It also helps in determining the work part's position and orientation. Some of the operations accomplished by a machine vision system in the identification process are work part palletizing and de palletizing, object sorting, and gripping the parts oriented from a conveyor.

A robot is used in these tasks to take successive action and decision. Figure 3.36 shows application of machine vision system.

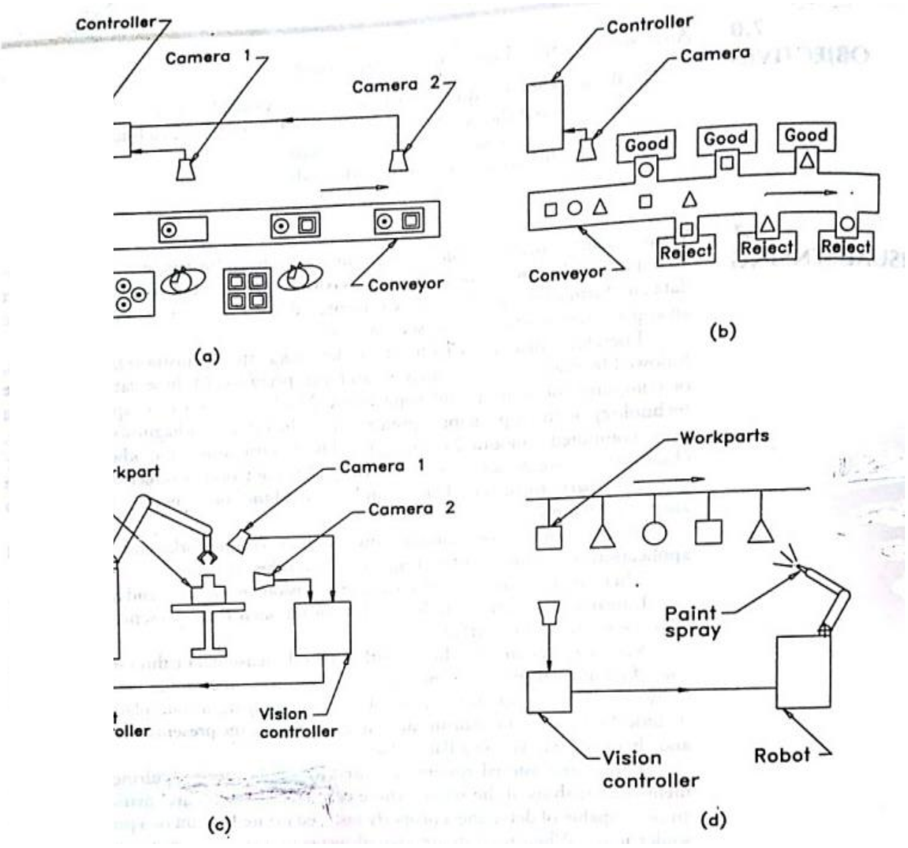


Fig 3.36 Application of Machine Vision System.

VISUAL SERVING AND NAVIGATION:

In this application, a machine vision system controls the actions of a robot according to the visual input. For example: In robot visual serving process, a machine vision system directs the path of robot's end effector to a work part in the work cell. Some applications of this category consist of positioning of work parts, seam tracking, bin picking, and retrieving and re-orienting the work parts that are moving along a conveyor. With the help of visual data, the navigational control can be used in collision protection and automatic path planning of a robot.

3.20 ROBOT OPERATING AIDS:

The robot controller has several external components that are necessary for the operation of the system during programming and for the daily operation of the robotic cell. These components are the teach pendant, the operators panel, the manual data input panel and the computer control.

3.21 TEACH PENDANT:

The teach pendant allows the programmer to enter positional data and to jog the axes to programmed positions.Figure 3.37 shows front panel of teach pendant.

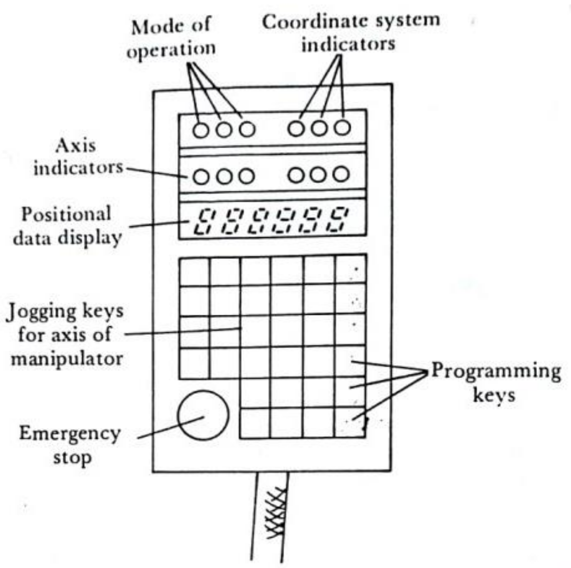


Fig 3.37 Teach pendant

The teach pendant allows the programmer to enter positional information into the user's memory of the controller.It is also used to jog the robot's axis into position.

The teach pendant has several indicators

1.Modes of operation

2.Axis coordinate indicators

3. Positional data

4 Axis jogging keys

5. Programming keys.

6.Dead man switch

7.Emergency stop button

8. Numeric keys

9. Function keys

10. Seven segment display

Teach pendant is a portable component that can be carried into the work envelope.All of the information required by the programmer can be viewed with the teach pendant. Teach pendant has several indicators.

The teach pendant has the following primary functions.

- Save as the primary point of control for initiating and monitoring operations.
- Guide the robot on motion device. While teaching locations
- Support application programs

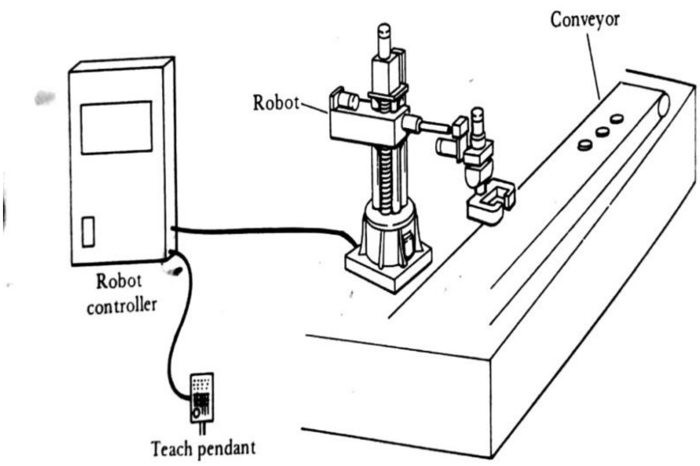


Fig 3.38 Teach pendant brought in to the work envelope

MODES OF OPERATION:

TEACH MODE:

Teaching of the program, inputting the positional data,the robot is placed in The teach mode.This allows the operator to jog the axisof the manipulator to the various positions on the programming sheet. In teach mode the programmer has full control over each axis movement from the teach pendant.Figure 3.38 Shows teach pendant at work envelope.

The programmer can jog an axis up or down or rotate an axis a full 300° The programmer can also control the speed of axis movement.

When programming the robot, the programmer will set the speed of the axis to the lowest possible range for safety of the robot.

TEST MODE:

The programmer can repeat taught path of the robot.The test mode allows the programmer to replay these positional points without turning on any of the output signal.

In the test mode, the programmer can generally go through the program in a single step process which allow programmer to see the exact point that were programmed.Figure 3.39 shows teach pendant at work envelope(In test mode).

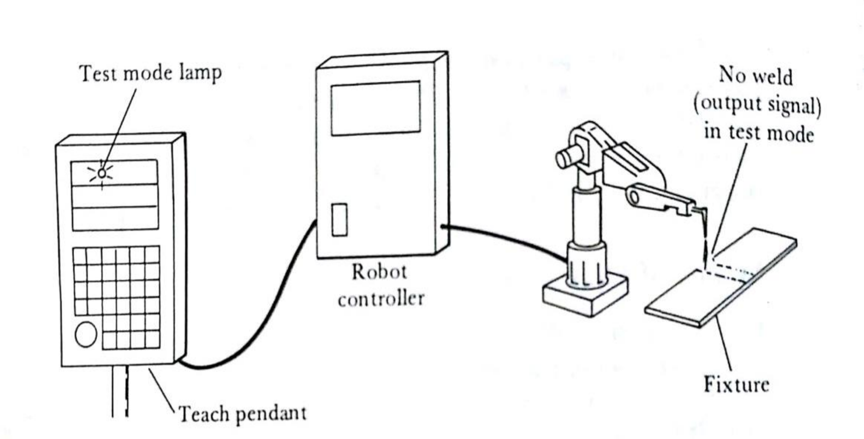


Fig 3.39 Test mode with a teach pendant

REPEAT MODE:

Once the programmer satisfied with the taught point from the test mode,the robot can be placed into the repeat mode. These paths will contnue to run until the program encounters a stop signal or an alarm condition.

JOGGING THE AXES:

The teach pendant keys allow the programmer to specify the movements of the axes and these keys are called the joggingor positional keys.

- X axis keys
- Y axis keys
- Up and down keys.

When the programmer uses these keys, the robot can be moved from minimum to the maximum of the axis limits

In cartesian coordinate system , on the teach pendant, the programmer uses the X,Y,Z axes keys for jogging the robot's axis.These keys are arranged so that movement of the axes can be in a positive or a negative direction in the cartesian coordinate system.

COORDINATE SYSTEM AND AXIS INDICATORS:

If the robot is to be jogged in articulate coordinates, the programmerselects the this mode by pressing the articulate coordinate selection key on the teach pendant placing the robot is the articulrte coordinatemode causes all of the axes of the manipulator to move to the desired location.

In teach pendant X,Y,Z axis keys used for jogging (+, -). The theta keys and beta keys also availablefor the wrist rotation.

The coordinate system indicator lamps stay illuminated as long as the programmer remains in that coordinate syatem. Changing to another coordinate system changes the indicator display.

The axis indicator turns on when the programmer selects the the axis to be jogged.

Numeric keys: The teach pendant also has numeric keys to enter numeric values

Gripper keys : To open and close the gripper ,special functional keys are available.

Seven segment keys: the teach pendant also has seven segment display that shows the various steps of the program.

Soft Keys:

Positional information can be programmed by using program soft keys.

Emergency Stop Button:

It is used for the manipulator to stop the axis movement. So the supply to drive motors is also stopped.

Delete, Input and Program Keys:

Delete Keys : To delete a any address of information from the program.The programmer can remove the data.

Input Keys: The input keys is used to input the information in to the program.

Program Keys: Programming keys are used for programming commands into the robot's address block.

Feed Rate Keys: These keys are used to input the rate at which an axis will travel to a desired position.

Display up and down keys : The programmer uses these keys to call up different addresses in the program.

Safety buttons:

Hold keys: Hold key is used to stop all axis motion of the manipulator

Dead man switch: Dead man switch is used to ensure that the robot will stop , if the teach pendant is dropped by the operator.

Emergency stop button : Completely stops the robot's movement.

The teach pendant is used with a robot or motion device primarily to teach robot locations for use in application programs.

The teach pendent is also used with custom applications that employ teach routines that pause execution at specified points and also an operator to teach or re-teach the robot locations used by the program.

3.22 MANUAL DATA INPUT PANEL (MDI):

The manual data input (MDI) panel is used to input data to the program, to input data to program control registers or to edit program information.

The major difference between the MDI panel and the teach pendant is that the axes cannot be jogged from the MDI panel.

The manual data input panel generally includes

- Alphanumeric Keyboard
- CRT
- Power off buttons

The CRT is used mainly for display of program information, programs that have been entered from the teach pendant can also be displayed on the CRT of the MDI panel.

Ex.PARAM (Parameter button)

The programmer or the operator through of the system can call up, from memory locations, the various operating parameter of the controller and view them in CRT.

The programmer through the editing process can change the parameter of the system to meet the changing needs of the program.

Programs that have been entered from teach pendant can also be displayed on the CRT of the MDI panel. Figure 3.40 shows front panel of MDI panel.

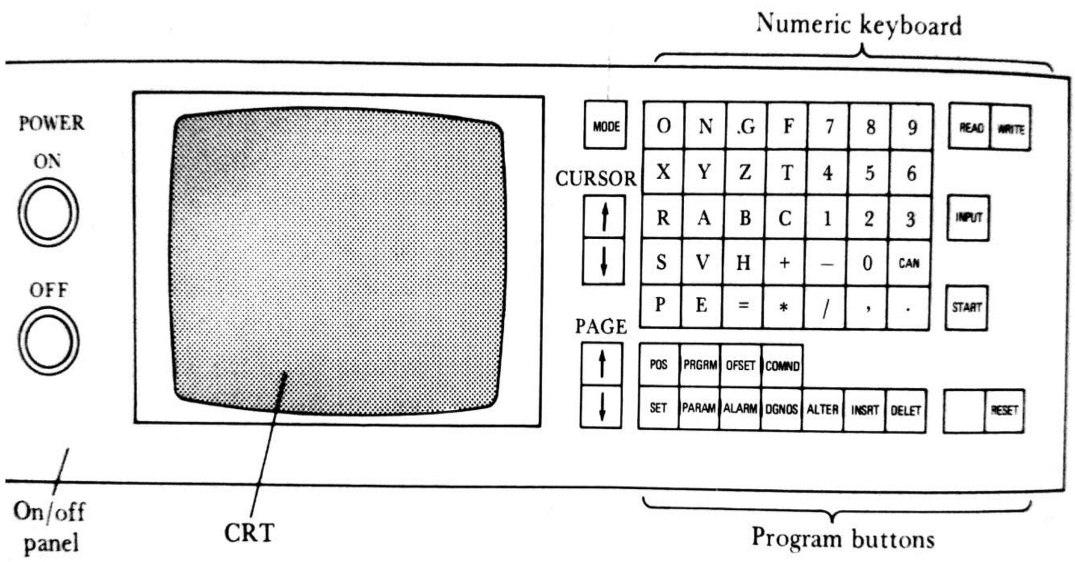


Fig 3.40 MDI display

CRT – display

The entire program can be displayed. CRT display also displays the following.

i. Positional data
ii. Program address
iii. Geometric more codes
iv. Feed rate codes
v. Service request codes

Mode Key:

The mode key on the MDI panel allows the programmer to change the modes of the controller from the MDI panel.

Page Up and Down Keys:

These keys are used to display an entire new page of data.

For instance, if the programmer wants to view the program at address 12, then by pressing page up, down key, the programmer can reach the location

Alpha Numeric Keys:

Alpha numeric keys are used to input numeric data and letters.

Read/Write Keys:

Read/write keys which allow the programmer to read and write data's to an external memory devices.

The major difference between the MDI panel and the teach pendant is that the axes cannot be jogged from the MDI panel.

Input Keys:

Input key is also used to insert data into the different operational registers of the program. Input key allows the programmer to insert data, if data must be added to certain locations in the program.

Start Key:

Start key is used to start the operation of the program.

PRGRM Key:

If the programmer wants to call up the program screen, then the PRGRM key is used.

DELETE, ALTER and INSERT key.

MDI panel may also be a remote operating device allowing it to be used with several robot controllers. Programmer can carry the MDI panel to different robot locations.

3.23 COMPUTER CONTROL (Totally Automated process) :

Many new industrial plants around the world are developing a total automated process. In this process, the operation of the plant is controlled from one central computer. **The computer is networked throughout the plant to the different machining operations, some of which may be robotic cells.** The programmer can control and program of all the robots from one central computer location.

All of the control paths of all the various registers and all of the various codes for service, geometric moves and feed rates can be taught, programmed and changed from the main computer terminal.

The total operation involving computer control of an industrial plant is called a flexible manufacturing system (FMS)..

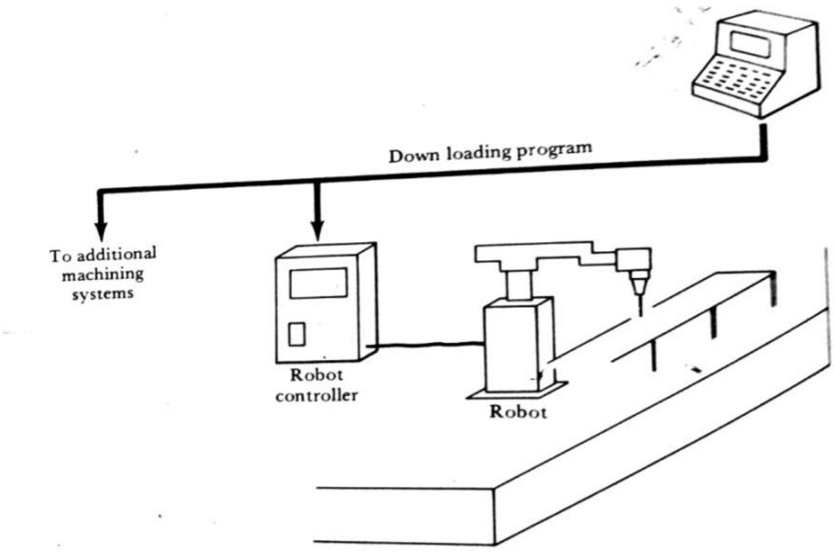


Fig 3.41 Figure illustrate important feature of the FMS:

Figure 3.41 illustrates FMS. The communication link between the main computer and the work cells on the plant.

The major control in this operation is the programme consists at the CAD terminal. From this terminal, the programmer can cause the robot to move to the various positions on the conveyor line. Each of the different robots in the FMS will have a special task that it must perform. This task is programmed and downloaded to each robot controller. As the parts pass down the assembly line, each manipulator will perform some task on the assembly of the part.

ADVANTAGE OF COMPUTER TERMINAL:

- The programmer can serve many different robotic cells at one time from the CAD terminal.
- FMS allows the programmer to upload programs from the robot to the main computer and download programs from the computer to the robotic work cell.
- With the FMS, the main computer keeps track of the different applications that the work cell has performed.
- FMS also provides communication link notification to the operator, if troubles develop in the program

Model Questions

2 MARKS

1. What is proximity sensor?

2. What is transducer?

3. What is robot kinematics?

4. What is image processing?

5. State the use of transducer.

6. What is an end effector?

7. State the purpose of range sensor.

8. Write two advantages of vacuum gripper

9. State the use of proximity sensors.

10. What is touch sensor?

11. What is tactile sensor?

12. State the use of force sensor.

13. What is gripper?

14. State the disadvantages of magnetic gripper.

15. State the advantages of mechanical gripper.

16. State the advantages of vacuum gripper.

17. What is range sensor?

18. State the use of operational Aids.

3 MARKS

1. Define robot kinematics

2. State the purpose of vision system.

3. What are the functions of machine vision system?

4. What is proximity sensor?

5. What is meant by gripper? State different types of grippers.

6. Write short notes on magnetic gripper.

7. Write short notes on vacuum gripper.

8. List out types of operational Aids?

9. What is teach pendants?

10. Write short notes on Computer control?

11. Write short notes on tactile sensors.

12. Write short notes on range sensor.

13. What is force sensor?

14. Write short notes on photo electric sensor.

15. Draw teach pendant.

16. Draw MDI control.

17. What is photoelectric sensor.

10 MARKS

1. Explain mechanical gripper with neat diagram. State its advantage and disadvantage

2. Explain vacuum gripper with neat diagram. State its advantages

3. Explain image processing and analysis with neat diagram.

4. Explain working of magnetic gripper state the disadvantages.

5. (I) Explain force sensors in robotics.

   (II)Explain the applications of vision system.

6. Explain the operation of any two proximity sensors in detail.

7. What is tactile sensor .Explain?

8. Explain the factors to be considered in designing gripper

9. Explain teach pendent with neat diagram.

10. What is MDI control? .Explain in detail.

UNIT-IV

ROBOT PROGRAMMING

Robot programming-Lead-through methods and textual robot languages- motion specifications- motion interpolation- Basic robot languages-Generation of robot programming languages –on line and offline programming- robot language structure- Basic commands- Artificial intelligence and robotics.

4.1 ROBOT PROGRAMMING:

For the robot operator or user to get the task done from the robot manipulator, there is the need for an efficient and effective communication method. This communication can be done using robot programming. **Robot programming works as an interface between the user and robot.** Robot programming is concerned with teaching the robot, its work cycle.

Programming is the set of commands or instructions that tell the robot what tasks to perform. A large portion of the program involves the motion path that the robot must execute in the work cycle. A robot is programmed by entering the programming commands into a controller memory. Robot programming is usually final step involved in building a robot.

Robot programming is accomplished in several ways. Robot programming methods are.

1. Lead-through methods
2. Textual robot languages.
3. Manual setup programming method.

Lead-through methods (Teach by showing methods):

In lead-through method, it requires the programmer to move the manipulator through the desired motion path and that path is stored or recorded into the memory by the robot controller.

Lead- through methods are the first real robot programming methods used in industry.

Textual robot languages:

Robot programming with textual languages is like computer programming. The programmer types the program on a CRT (Cathode ray tube) monitor in a high level language. The textual languages started to be developed in the 1970s.

Manual Setup programming procedure:

Manual setup programming language is used for simple, low technology robot. Low technology robots are limited sequence robots controlled by Mechanical stops and limit switches. This kind of programming is referred as manual setup procedure method.

4.2LEAD-THROUGH PROGRAMMING METHODS:

In lead-through programming, the robot is moved through the desired motion path in order to record the path into the controller memory.

Steps involved in lead-through teaching method

- Leading the manipulator in slow motion controlled throughout the entire task operation
- Storing the joint angles at needed path locations
- Editing and play-back of the taught motion
- Replay of the motion by the robot at a speed as specified by the user.

Types of lead-through Method

Manual lead-through

Powered lead-through

4.2.1 Manual Lead-through method (Walk through Method)

- In the manual lead-through method, programmer physically grasps the robot arm and manually moves it through the desired motion cycle.
- If the robot is large and awkward to physically move, **a special programming apparatus is often substituted for the actual robot.** This apparatus has basically the same geometry as the robot
- Teach button is located near the wrist of the robot for making manipulator to move easily.
- In manual lead- through method ,the motion cycle is divided into hundreds or even thousands of individually closely spaced points along the path and these points are recorded into the controller memory
- Manual lead-through method is used for **continuous path programming**, where motion cycle involves smooth curvilinear movements of the robot arm
- Most common example for this kind of application is spray painting, in which robot wrist is attached with spray-painting gun to execute smooth, regular motion pattern in order to apply the paint evenly over the entire surface to be coated

- Continues arc welding is another example in which continuous – path programming is required and this is sometimes accomplished with the manual lead through method.

4.2.2 Powered lead-through method:

- The powered lead-through method makes use of a teach Pendant to control the various joint motors and to power drive the robot arm and wrist through a series of points in space.
- Each point is recorded into memory for subsequent play back during the work cycle.
- **The Teach pendant is usually small hand-held device (control box) with combinations of toggle switches, dials and buttons to regulate the robot's physical movements and programming capabilities.** Figure 4.1 shows teach pendant front panel.
- Powered lead-through method is limited to point to point motions rather than continuous movement, because of the difficulty in using teach pendant to regulate complex geometric motions in space.
- Point to point movements of the manipulator is used in industrial robot applications such as part transfer tasks, Machine loading and unloading and spot welding.

Teach pendant diagram

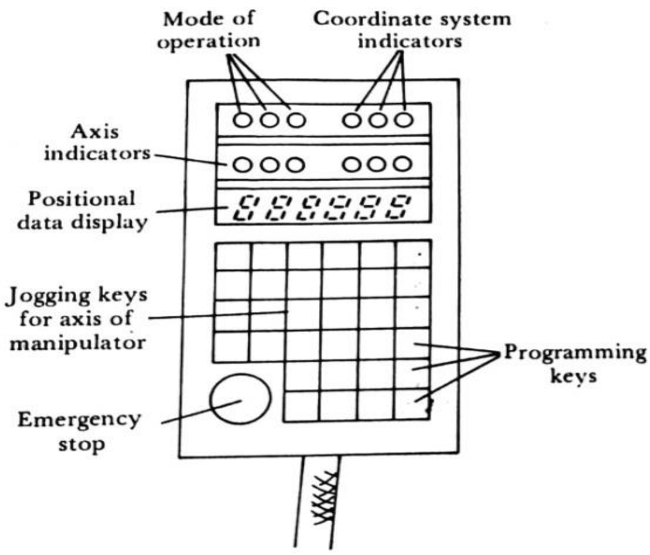


Fig 4.1 Teach pendant front panel

The control system for both the lead-through procedures operate in either of two modes: teach mode, run mode

Teach mode – Teach mode is used to program the robot

Run mode – Run mode is used to execute the program

Fig 4.2 illustrates Robot programming using teach pendant in test mode.

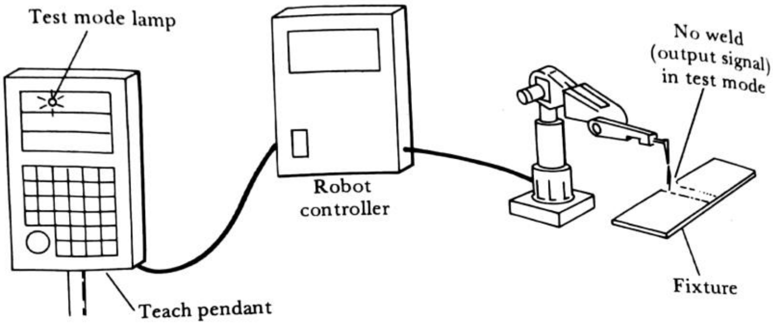


Fig 4.2 Robot programming using teach pendant.

Advantages of Lead -Through method:

- Simple procedure
- This method can be used for repetitive operations, in factory environments.
- The Skill requirement of the programmer are relatively modest
- These procedures can be readily applied in the plant

LEAD-THROUGH PROGRAMMING

Manual lead through method	Powered lead through method
• An operator grasps physically and moves the wrist end in the path of operation, which is recorded in the memory. • Operator uses a teach button while in teach mode. • During run mode wrist end repeats the taught motion. • When robot structure is complicated a geometrically similar model is used to ease the robot handling. • More useful in continuous operations Applications: • Spray painting • Continuous movements	• Control box with buttons known as teach pendant is used to control joints. It is a device used to record movements into robot's memory • The points of motion is recorded in the memory, and converted to motion programs. • The program is utilised to play- back the motion during cycle of operation. • More useful in point to point motion Applications: • Point-point movement. • Spot welding • Part transfer • Loading and unloading

4.3.TEXTUAL ROBOT LANGUAGE:

Robot programming with textual languages is like computer programming. The programmer types the program on a CRT monitor in a high level English –like language.

Examples of textual robot languages are

WAVE, AL, AML, RAIL, VAL, VALII

4.4 MOTION SPECIFICATION:

Irrespective of robot configuration, several methods are used by the programmer during teach mode to actuate the robot arm and wrist.

Types of methods for defining positions in space:

1. Joint movements
2. X,Y,Z co-ordinate motions (World co- ordinate)
3. Tool co- ordinate motions**.**

1. Joint Movement:

Joint movement method is the most basic mode and it involves the movement of each joint by teach pendant. The teach pendant has a set of toggle switches to operate each joint in either of its two directions until the end effector has been positioned to the desired position. This method of teaching points is referred as joint mode.

Limitations:

1. Successive positioning of the robot arm in a sequence of point is very difficult.
2. Time consuming way of programming the robot.

2. X, Y, Z co-ordinate motion (World co – ordinate)

The world coordinate mode refers to the fixed x, y, z directions of the robot.

This method is called as world co-ordinate motion which allows the wrist location to be defined using the conventional Cartesian coordinate system with origin at some location in the body of the robot. Many robots can be controlled during the teach mode to move in X, Y, Z co-ordinate motion.

In this method wrist is being moved in motions that are parallel to the X, Y, Z axes. Two or three additional joints which constitute the wrist assembly are almost rotational and while programming is being done in the x, y,z system to move arm, body joints, and the wrist is usually maintained by the controller in a constant orientation. Figure 4.3 shows x, y, z method of defining points in space.

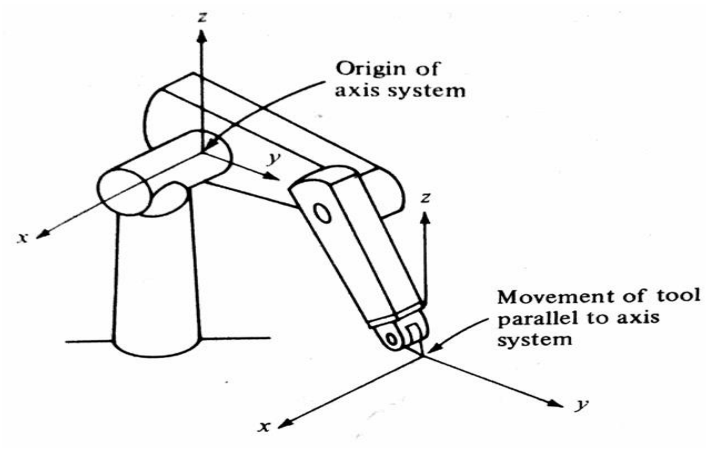


Fig4.3 x, y,z Method of defining points in space

3. Tool co-ordinate motion:

This is a Cartesian coordinate system in which the origin is located at some point on the wrist and the XY plane is oriented parallel to the face plate of the wrist and the Z axis perpendicular to the face plate and pointing in the same direction of the tool or other end effector attached to the faceplate. Figure 4.4 illustrates tool mode for defining points in space.

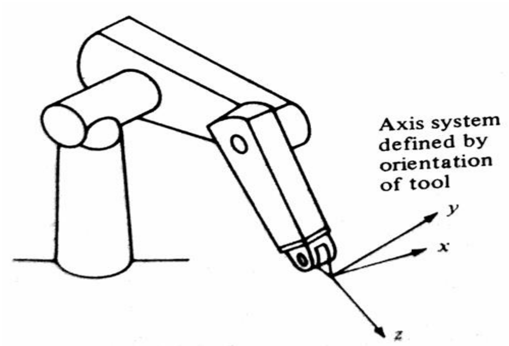


Fig 4.4 Tool mode for defining points in space

This method of moving the robot could be used to provide a driving motion of tool.

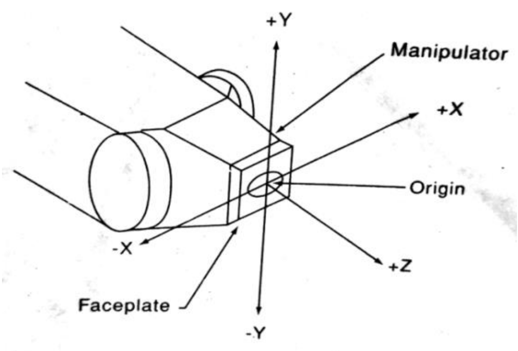


Fig 4.5 origin of the co-ordinate system at the center of tool – mounting plate

Limitation:

Significant amount of computational effort must be accomplished by the controller in order to permit the programmer to use tool motion for defining motions and points.

Reason for Defining a Point:

The two main reasons for defining points in a program are

1. To define a working position for the end effector
2. To avoid obstacles

(1) To define a working position for the end effector :

This is the case where, the robot is programmed to pick up a part at a given location or to perform a spot welding operation at a specified location. Each location is defined as a point in the program.

This defining includes safe position that is required in the work cycle. It is necessary to define a safe, remote point in the workspace from which the robot would start the working in the work cycle.

(2)To avoid obstacles:

If one or more points are in space are defined for the robot, which ensures it will not collide with other objects located in a work cell. Machines, conveyors and other pieces of equipment in a work volume are examples of these obstacles.

By defining a path of points around these obstacles collusions can be prevented.

4.5 MOTION INTERPOLATION:

Interpolation is a process used to estimate intermediate points between two points.

For example, we are programming two axis servo controlled Cartesian robot with 8 addressable points for each axis. The total of 64 addressable points (work cell) that the robot to perform the task within the work cell. Figure 4.6 illustrates two axis servo controlled Cartesian robot work space.(8x8 addressable points).

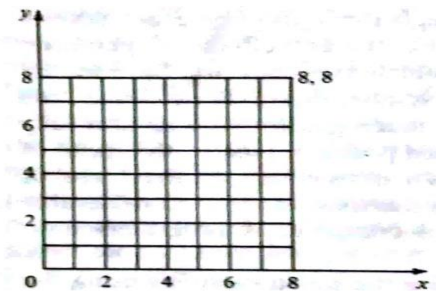


Fig 4.6 8x8 addressable points (Robot work space)

Example: To Program the robot to work or perform in the 8x8 addressable work space (figure 4.6) is shown in TABLE 4.1

Step	Move
1	1,1
2	8,1
3	8,8
4	1,8
5	1,1,

TABLE 4.1 steps involved in robot work cycle.

In the above robot program, if step3 in the program is removed, Robot would execute step4 by tracing a path along the diagonal line from point (8, 1) to (1, 8). This process is referred as interpolation.

There are different interpolation schemes that can be specified by the programmer for the robot to get from one point to another.

1. Joint interpolation
2. Straight-line interpolation
3. Circular interpolation
4. Irregular smooth motions (manual teach- pendant programming)

1. Joint interpolation:

It is the default procedure that is used by the controllers. That is the controller will follow a joint interpolated motion between two points unless the programmer specifies straight-line or some other type of interpolation**.**

In joint interpolation, the controller determines how far each joint must move to get from the first point defined in the program to next. It then selects the joint that requires the longest time. This determines the time it will take to complete the move. Based on the known move time, and the amount of the movement required for the other axes, the controller subdivides the move into smaller increments so that all joints start and stop their motion at the same time. For example, the move from point 1, 1 to point 7, 4 in the grid of Fig 4.6.

Linear joint 1 must move six increments and joint 2 must move three increments as in TABLE-2. The intermediate points along the path between 1, 1 and 7, 4 are generated by the controller. The resulting path between 2 points is a straight line approximation.

Step	Move	Comments
1	1,1	user specified starting points
2	2,2	Internally generated interpolation point
3	3,2	Internally generated interpolation point
4	4,3	Internally generated interpolation point
5	5,3	Internally generated interpolation point
6	6,4	Internally generated interpolation point
7	7,4	Internally generated interpolation point

TABLE-2. - Program to illustrate joint interpolation

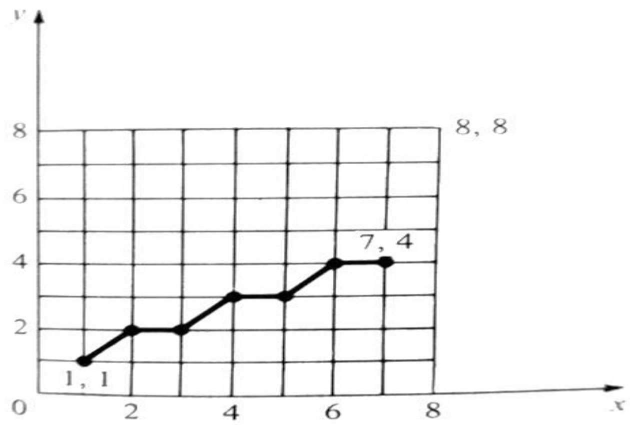


Fig 4.7 Interpolated path taken by the Robot for the TABLE-2

2. Straight Line Interpolation:

In straight line interpolation, the robot controller computes the straight line path between two points and develops the sequence of addressable points along the path for the robot to pass through. Straight line interpolation is very useful in applications such as Arc welding, laying material along a straight path.

3. Circular Interpolation:

Circular interpolation requires the programmer to define a circle in the robot's workspace. This is most conveniently done by specifying three or four points that lie along the circle. The controller then constructs an approximation of the circle by selecting series of points that lie closest to the defined circle. The movement that are made by the robot actually consist of short straight line segments.

Circular interpolation therefore produces a linear approximation of the circle. If the grid work of addressable points is dense enough, the linear approximation looks very much like real circle. The circular interpolation can be done using a textual programming than with the lead-through technique (teach pendant techniques).

Figure 4.8 shows grid for a robot with one rotational and one linear axis, with each axis divided into eight addressable locations.

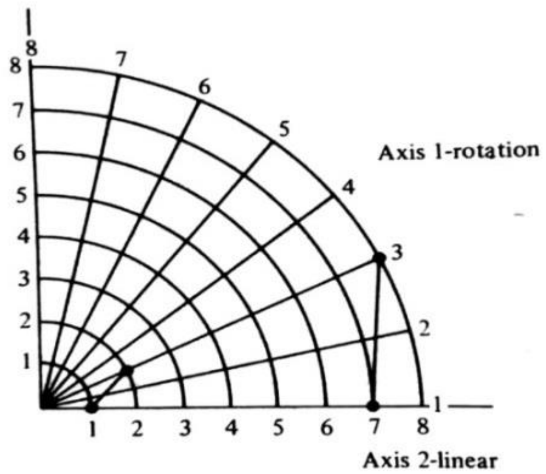


Fig 4.8 Circular Interpolation

4. Irregular smooth motion:

In manual lead-through programming, when the programmer moves the manipulator wrist to teach spray painting or Arc Welding, the movements typically consist of combinations of smooth motion segments. These segments are sometimes approximately straight, curved, back and forth motions. These movements are irregular smooth motions, and an interpolation process is involved in order to achieve them.

To approximate the irregular smooth pattern being taught by the programmer, the motion path divided into a sequence of closed spaced points that are recorded into the controller memory. These positions constitute the nearest addressable points to the path followed during programming. The interpolated path may consist of thousands of individual points that the robot must play back during subsequent program execution.

4.6 BASIC PROGRAMMING LANGUAGE:

Currently, a large number of robot languages are available. The basic robot programming languages are,

- WAVE
- AL
- AML
- RAIL
- VAL
- VAL II

WAVE:

The first robot language was WAVE, developed in 1973 as an experimental language for research at the Stanford Artificial intelligence laboratory.

Research involving a robot interfaced to a machine vision system was accomplished using the WAVE language. The research demonstrated the feasibility of robot hand-eye coordination.

Trajectory calculations through coordination of joint movements, end-effector positions and touch sensing were some of the few features of wave. But algorithm was too complex and not user friendly. It is a first generation language

AL :

AL was developed in the year 1974 at Stanford. It could be used to control multiple arms in tasks requiring arm coordination.

The syntax of the language can implement various subroutines, involving activities between the robot and its surroundings.

Different sensors can be incorporated and programming can take care of some condition monitoring statements. It is a first generation language

AML :

AML – Initial development of this language was taking place at T.J Watson research lab of IBM corporations starting around 1976. A manufacturing language (AML) has been commercially available since 1982 with IBM's robotic products.

AML is a high level interactive programming language designed for robotic programming. It is a subroutine oriented programming.

It provides variety of data types and operators, System subroutines, Control structures debugging facilities, to improve program readability.

AML language is directed at assembly and related tasks. It is a second generation language

RAIL :

RAIL was developed in 1981 by Automatix, and used for its robotic assembly and arc welding, as well as machine vision language for the control of both vision and manipulation RAIL is Automatic's language for computer- aided manufacturing. It supports many commands and control of vision system.

RAIL is designed to control the company's Robovision, Cybervision and Autovision systems. Robot vision is a system for robotic Arc welding. There are special commands for interfacing robot and the Welding equipment.

RAIL also contains commands for interfacing with machine vision system (Autovision) which are designed for inspection and identification in a manufacturing operation. Cybervision is the system for assembly.

RAIL contains commands for controlling the robot in an assembly operation and for interfacing with external devices as parts feeders, conveyors, sensors and material handling equipment. It is a second generation language.

VAL :

VAL (Victor's Assembly Language) was introduced in 1979 by unimations, Inc., for its PUMA robot series. VAL is very user friendly.

VAL is a robot programming language and control system originally designed for use with unimation robots It is developed to provide ability to define robot task easily.

VAL provides arm movement in joint, world and tool coordinates gripping and speed control. VAL can be used by the manufacturing engineers responsible for implementing desired applications. It is a first generation language.

VALII :

VAL II is an enhanced version of VAL robot programming language released by unimation in 1979 for its puma series industrial robot. VALII system has more interlocking facility.

It is a computer based control system and a language designed for the Unimation Industrial robot .It provides capability to easily define the task a robot is to perform , Since the task are defined by user –Written programs.

Benefits of the language include ability to respond to information from sensor systems such as machine vision and Working in unpredictable situations. . It is a second generation language

HELP - HELP was developed by general Electric Company. It acts more or less like RAIL. It has the capability to control two robot arms at the same time.

4.7 GENERATION OF ROBOT PROGRAMMING LANGUAGE:

The textual robot languages possess a variety of structures and capabilities. These languages are still evolving. In this section we identify two generations of textual languages and speculate about what a future generation would be like.

FIRST GENERATION OF LANGUAGE:

- It makes use of combinations of command statement and teach pendant procedure for developing robot programs.
- They are developed largely to implement motion control with textual programming language and so they are called as motion level language.
- AL &VAL languages are an example for first generation language.

Features :

- Ability to define manipulator motion (using the statements to define the sequence of the motion and the teach pendant to define the point locations.)
- Ability to define straight line interpolation
- Branching and Elementary sensor commands involving binary (on-off) signals.
- They can be used to define the motion sequence of the manipulator (MOVE Instruction)
- They have Input/output capabilities (WAIT,SIGNAL)
- They can be used to write subroutines. (BRANCH).

Limitations :

- Inability to compute arithmetic and complex calculations
- Inability to use complex sensors
- Limited capacity to communicate with other computers.
- These languages cannot be readily extended for future enhancements.

Advantage:

- For writing programme of Low to medium complexity, as shop person can use teach pendant methods of programming (Easier to use)
- Person with computer programming experience would probably find first generation language easier.

SECOND GENERATION OF LANGUAGE :

- Second generation language is called “structure programming” language because they possess structured control constructs used in computer programming languages.
- Second generation languages include AML,RAIL,MCL and VALII
- Second generation languages are similar to computer programming language.
- They make use of teach pendant to define locations in the work space.

Features and capabilities :

1. **Motion control**–This feature is basically the same as for the first generation languages.
2. **Advanced sensor capabilities -The** enhancements in the second generation languages typically include the capacity to deal with more than simple binary (on- off) signal, and the capability to control devices by means of the sensory data.
3. **Limited intelligence -**This is the ability to utilize information received about the work environment to modify system behaviour in a programmed manner.
4. Communications and data processing - Second generation languages generally have provisions for interacting with computers and computer data bases for the purpose of keeping records, generating reports, and controlling activities in the work cell.

Disadvantages:

- Computer programmer’s Skills are required to accomplish the programming.(skilled programmers)
- The second generation languages commonly make use of a teach pendant to define in the work space which will interrupt regular production work.

FUTURE GENERATION LANGUAGE (“World modelling”) :

- Future generation robot languages will involve a concept called World modelling robot or task object programming.
- Other terms sometimes used instead of world modelling include model-based languages and task-object languages.
- In a programming scheme based on world modelling ,the robot possess knowledge of the 3D world and is capable of developing its own step by step procedure to perform a task based on a stated objective of what is to be accomplished.
- The robot system has in its control memory a 3D dimension model of its working environment, including manipulator, work cell, tools, part and other objects. The model might be generated by either inputting 3D geometric data into the control memory or providing the robot with the capacity to see the work environment and properly interpret what it sees.

- The robot develops its own 3D model of the workspace.
- Capacity for Automatic self-programming
- The human programmer gives the system an objective, and the system should develop its own program of actions required to accomplish the objective.

In principle, it should be possible with future generation languages to accomplish robot programming completely off-line without using a teach pendant

Limitations:

There are problems to be solved before future generation languages using off-line programming become reality.

Accuracy – The model is not the same as the real world. There will always be some positional error between the actual physical objects in the work environment and the computer model used by the robot.

High level object oriented command-Offline programming concerned with Artificial intelligence would permit the robot to accept a high level objective oriented command and translate the instruction into series of actions required to accomplish it.

4.8 ON LINE PROGRAMMING:

Programming of robot by means of a computer at the robot console is called ON LINE programming**.**

- On line programming takes place at the site of production itself and involves the work cell. The robot is programmed with a teach box as shown in fig 4.9(a).

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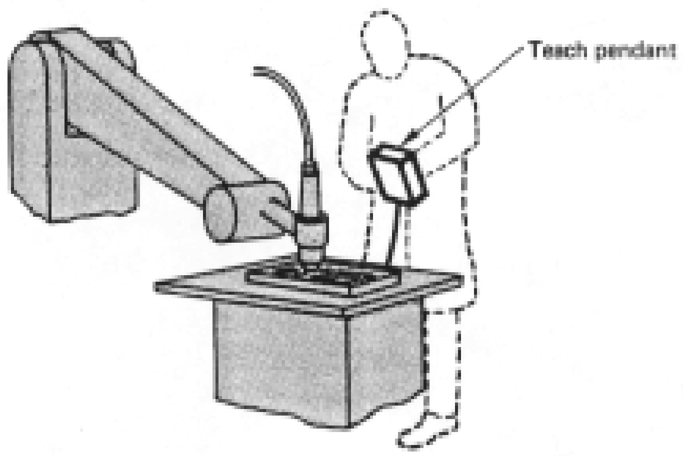


Fig 4.9 (a) ON-LINE programming

- Online programming use robot to generate the programme. Teaching /guiding the robot through sequence of motion that can be executed repeatedly. It is a “Record playback approach “where the robot plays back a sequence of move.

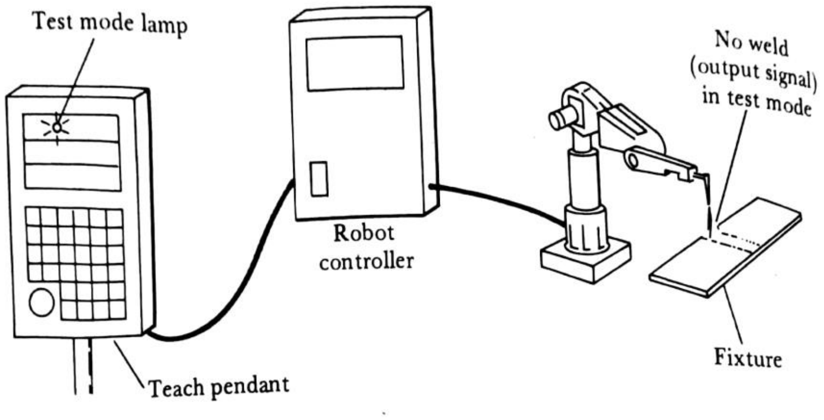


Fig.4.9. (b) On-Line programming using Teach –pendant

Figure 4.9(b) illustrates On-Line programming using teach pendant in test mode.

- It is used for basic robot task such as paint spraying, simple pick and place operations where robot moves with commands used by the teach pendant.
- In this type of programming, programmes exist only in the memory of robot control system. It is often difficult to transfer, document, maintain and modify.

Advantages:

- Easily accessible
- Robot is programmed in concordance with the actual position of equipment.

Disadvantages:

- Slow movement of the robot is required while programming
- Program logic and calculations are hard to program
- Suspension of production while programming
- Cost equivalent to production value.
- It occupies valuable production equipment
- Poorly documented

4.8.1 OFF- LINE PROGRAMMING:

Off-line programming is a technique done by means of a computer where any changes made to the program have no effect on the actual operation of hard wire circuits. It is used in industry to improve efficiency

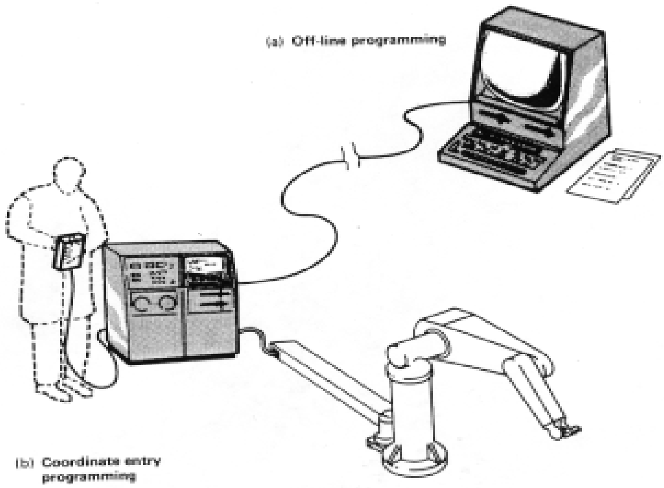


Fig. 4.10 OFFLINE programming

- It does not interfere with production as the program for the robot is created outside production process on an external computer
- Offline programming is most often used in robots research to ensure that **advanced control algorithms** are operating correctly before moving them on to a real robot.
- Offline programming takes place on a computer and models of the work cell with robot pieces and surroundings. It is represented through a graphical 3D model.
- It permits robot programming at remote computer terminal and robot controller programming can be downloaded for execution.
- It is a quick way to test an idea before moving it to robot.
- Robot programming is verified in simulation and errors are rectified.
- The robot programming can be created by the reuse of existing CAD data so that programming will be quick and effective.

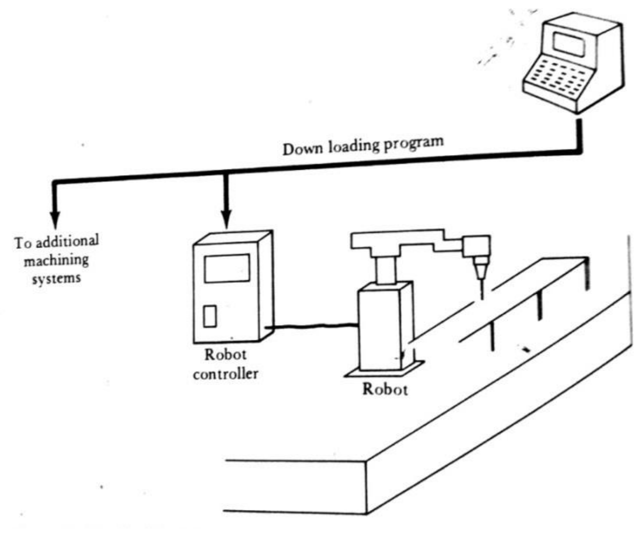


Fig. 4.11.Illustrates the communication link between the main computer and the work cells on the plant.

Advantages:

- The program can be easily modified without wasting a valuable timing of robot
- Graphical computer simulation can be done.
- Off line programming can be incorporated with the data base.
- Robot can be used for other application.
- Engineering and geometric modifications can be done.
- Verification of the program through simulation and visualization.
- Sensors can be used for external simulation which is taken into account in response.
- Procedure and subroutine can be added and need not be changed every time.
- Well documented through simulation model with appropriate programs.
- It does not occupy production equipment.

Disadvantage:

- Offline programming has had a very high burden rate and demanded the need of expert users.

4.9 ROBOT LANGUAGE STRUCTURE:

The language must be designed to operate with robot system.

- It must be able to support the programming of the robot.
- It should have ability to Control robot manipulator.
- It must be Interfaced with peripherals in the work cell.
- It should also support with data communications with other computer systems in the factory.

Robot system showing various components of the system that must be coordinated by means of the language is shown in fig 4.12.

Operating systems:

Operating system is software that supports the internal operation of the computer system. The purpose of operating system is to facilitate the operation of the computer by the user and to maximize the performance and efficiency of the system associated with peripheral devices**.**

The operating system is computer software that allows the user to carry out the following mechanisms.

- Writing a new program
- Editing the existing program

- Executing a given program
- Perform other functions like compiling and interpreting.

The robot language operating system contains three basic modes of operation.

1. Monitor mode
2. Run mode
3. Edit mode.

Monitor mode - Establishes overall supervisory control of the systems.

- In this mode ,user can define location in space using teach pendant
- Sets the speed control for the robot
- Storing of the functional programs
- Transfer program between storage devices and control memory
- Move back and forth between the other modes of operation.(co-ordinating with run mode and edit mode)

Run mode :

- Run mode is used to execute the robot program
- Performs the sequence of instructions.
- Display of the error messages during execution.
- For testing new program in the run mode, debugging procedure built into the robot language for correcting a program and developing a new program.
- Testing new program and debugging.
- Change over to edit mode for correction.
- Most modern robot language permits the user to cross back into the monitor mode or edit mode while the program is being executed

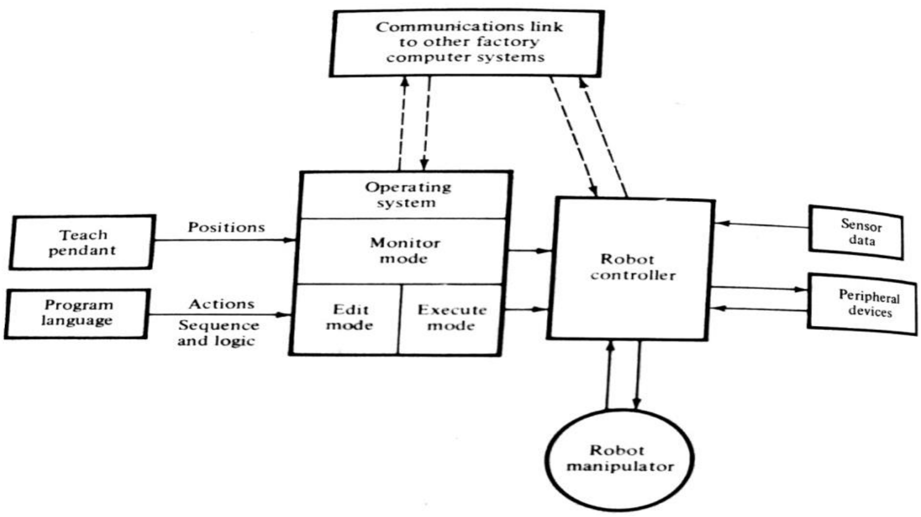


Fig 4.12 Robot Language structure

Edit mode:

- It provides an instruction set that allows the user to write a new programs or to edit existing programs.
- Operation of editing mode differ from one language to other language(Language dependent)
- Editing operation includes delete, make change to existing instructions and insert the new line in the programme,

As with a computer programming language, the robot language program is processed by the operating system using either interpreter or compiler

Compiler:

- Compiler is a program in the operating system that passes through the entire source program and translates all the instructions into machine level codes that can be read and executed by the robot controller.
- MCL language is processed by compiler programme.
- Compiled programs result in faster execution times.

Interpreter:

- An interpreter is a programme in the operating system that executes each instruction of the source program (source program is the user's robot language program) one at a time (line by line execution).
- VAL language is processed by interpreter program.
- Source program that is processed by interpreter can be edited more readily.

4.10 BASIC COMMANDS IN ROBOT:

The basic elements and functions that should be incorporated into the language are listed below.

The most important commands in Robot languages are those which control the movement of the manipulator arm

Forward – commands robot to move forward

Backward – Commands robot to move backwards

Left –commands robot to rotate left.

Right – commands robot to rotate right

BASIC COMMANDS:

MOVE AND RELATED COMMANDS

SPEED CONTROL

DEFINING A POINT IN A WORKS PLACE

PATHS AND FRAMES

END EFFECTOR OPERATION COMMANDS

SENSOR OPERATION COMMANDS

MOVE AND RELATED COMMANDS (Manipulator motion control)

These commands are used to control the movement of the manipulator arm.

Move - This moves the robot to the location specified by point A1

MOVE A1

This command makes the end of the arm to movefrom present position to the point A1

MOVES - This command performs straight line interpolation, which provides straight

Line movement.

MOVES A1

This command makes the end of arm to move from present position to the point A1 in a straight line

MOVE A1 via A2

This command moves robot arm to point A1 to pass through point A2.

MOVE A via A2

APPROACH AND DEPART COMMANDS

The related move sequence an approach to a point and departure from the point

APPRO A1, 100

DEPART 50

The APPRO command causes end effector to be moved to the vicinity of point A1.

The DEPART commands causes the Robot to move away from the point along tool z axis to a distance of 50 mm.

DMOVE COMMANDS

DMOVE commands perform incremental move, the direction and distance of the move must be defined. This command is used for specifying the particular joints to be moved.

DMOVE (1, 10)

Moves the joint 1 by an increment of 10.

SPEED CONTROL COMMAND

This command indicates speed with which the robot arm is moved.

SPEED V IPS (INCH PER SECOND)

Speed of end effector v inches per second.

SPEED 60 IPS (INCH PER SECOND)

This command indicates the speed of the end effector duringprogram execution. Speed of the end effector is 60 inches per second.

SPEED R

This command operate the arm end effector at R per cent of the normal speed.

SPEED 75

This command indicates that the robot should operate at 75% of normal speed.

DEFINING A POINT IN A WORKS PLACE

Motion control involves use of points in the workspace. The locations of these points must be defined in the program. Defining a point is done by using teach pendant.

HERE A1 (point location is named as A1)

The position and orientation of each joint are captured in control memory. The first three values indicate x, y, z coordinates in world space and the remaining values indicates wrist rotation angle.

<15.534, 23.003, 14.58, 25.090, 125.75>

An alternative way of specifying points in workspace is by typing them into the control memory without using teach pendant.

DEFINE A = A1 <15.534, 23.003, 14.58, 25.090, 125.75>

This A1 indicates point location in a space .The first three values indicate x,y,z coordinates and remaining values indicates wrist rotation.

Paths and Frames

PATH

Several points can be connected together to define a path in the workspace. The following statement might be used to specify a path

DEFINE PATH1 = PATH (A1, A2, A3, A4)

Accordingly the path, PATH1 consist of the connected series of points A1, A2,A3,A4 defined to the robot world space. The path can consist of two or more points .All points specified in the path statement must have been previously defined. The manner in which robot moves between the points in the path is determined by the motion statement.

MOVE PATH1

FRAME:

A pattern would consist of a path which contains several moves and although all paths are identical , their position and orientation in space vary around the path.In this situation, it would be convenient to program the routing path relative to a reference frame and then redefine the reference frame for location on the path

DEFINE FRAME1 = FRAME (A1, A2, A3)

Here the variable name is FRAME1, its position in space is defined using three points A1, A2, A3

A1 – ORIGIN OF THE FRAME

A2 – POINT ALONG THE X AXIS

A3 – POINT IN THE XY PLANE.

END EFFECTOR OPERATION

This command is used to open and close the gripper finger.

OPEN

CLOSE

OPEN and CLOSE cause the action to occur during execution of the next motion.

OPENI and CLOSEI

This command makes the action to occur immediately.

CLOSE 60 MM

This makes the width of the opening of 60 MM. It informs gripper to close keeping 50mm width between the fingers.

CLOSE 3.0 LB

This command is used to apply 3-LB gripping force against the part.

CENTER

Closes the gripper slowly till the establishment of contact with the object to be gripped.

SENSOR OPERATION

This command can be used for both Turning ON and Turning OFF the output signal

SIGNAL 5, ON

SIGNAL 5, OFF

This command allows the signal from output port 5 to be turned on at one point in the program and turned off at another point in the program.

REACT 15, SAFETY

The change in signal, in the input line 15, should be deviated to the sub-routine SAFETY.

4.11ARTIFICIAL INTELLIGENCE &ROBOTICS:

Artificial intelligence is the part of computer science concerned with the characteristics such as think, behave and react with intelligence as human do.

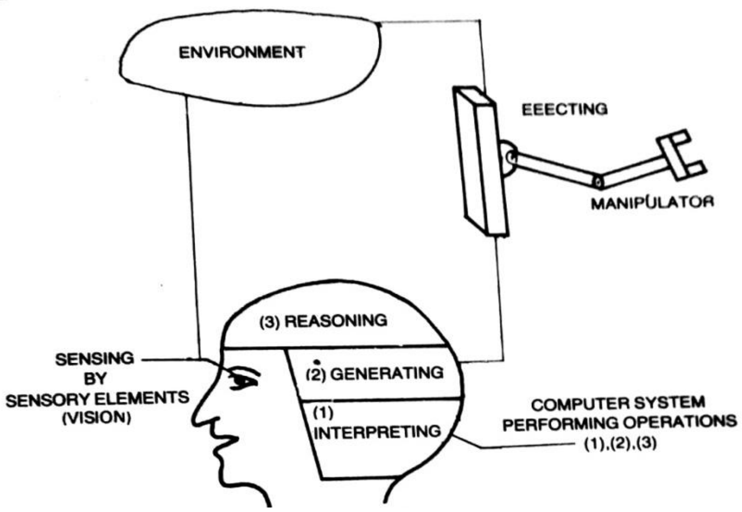


Fig 4.13 Basic model of Artificial Intelligence.

The capability of a computer to perform the functions that generally performed by a human intelligence (learning, adapting, recognizing, classifying, self-correction and/or improvements, store and retrieve information from memory , problem solving, calculate ,reasoning, learn from experience, use natural language fluently, and adapt new situation). Figure 4.13 illustrates the basic model of Artificial intelligence**.**

A manufacturing process is basically a sophisticated process. An operator uses his arm, hands, senses and brain to perform operations like grasping, holding, orienting, inserting, aligning, fitting and screwing. For precision, a robot has to interact with the environment around it in a manner similar to man.

Therefore Robot should be intelligent if it has to emulate human capabilities.

An intelligent robot has served arm and end effector has sensors and adaptive control functions with the help of a computer.

Adaptive control action is necessary to correct errors in position and orientation of the workplaces and the end effector.

An intelligent robot must determine cause and effect phenomena. So it must detect the faults and minimize their effects.

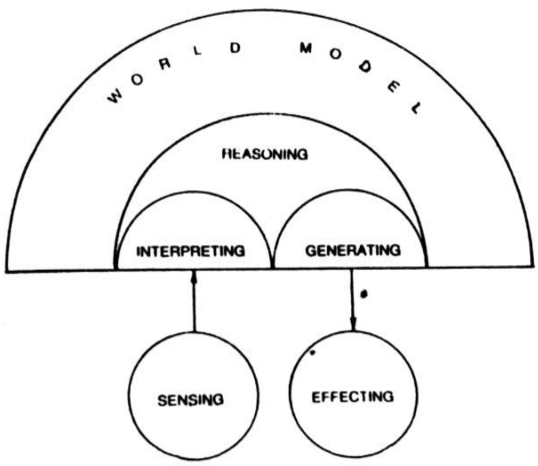


Fig 4.14 Components of Artificial Intelligence.

A smart robot needs brain and sensory system so as to be able to think and then move and manipulate. The thinking process such as brain functions are performed by a computer. Sensing and effecting are the body functions that can be performed using the basic laws.

In order to accomplish a task both the brain and the body functions are to be coordinated. Sensing includes seeing, hearing, touching, smelling and measuring. The sensors gather and produce information.

Effecting can be done by actions. The actions can be accomplished by manipulators using body, arm, wrist, hands, fingers, and legs wheeled vehicles and with various means of communication.

For example effecting can be done by communicating sounds, Displaying pictures and graphics.

The components of interpreting generating and responding are necessary to acquire knowledge about the environment. Figure 4.14 illustrates components of Artificial intelligence.

These components recognize, locate and assemble the objects and direct the changes in the environment. Interpreting, Generating and reasoning information means to understand the environment.

Goals of AI Research :

- Problem solving
- Expert systems, vision, learning
- Processing information and applying knowledge
- Wisdom and understanding
- Processing of natural language to perform instruction.

Artificial intelligence is defined as intelligence that matches or exceeds that of human intelligence. The potential application of AI are endless they stretch from military, house hold work, medical field, computer games and robotic pets.

APPLICATIONS OF AI AND ROBOTICS :

AI and Robotics has been implemented in the various domains such as −

- **Industries** − Robots are used for handling material, cutting, welding, colour coating, drilling, polishing, etc.
- **Military** − Autonomous robots can reach inaccessible and hazardous zones during war.
- **Medicine** − the robots are capable of carrying out hundreds of clinical tests simultaneously, rehabilitating permanently disabled people, and performing complex surgeries such as brain tumours.
- **Exploration** − the robot rock climbers used for space exploration, underwater drones used for ocean exploration are to name a few.
- **Entertainment** − Disney’s engineers have created hundreds of robots for movie making.

Model Questions

PART-A

1. State the need for robot programming.

2. What are the different types of robot programming?

3. What is lead through programming?

4. What is teach pendant?

5. List the methods of motion specification.

6. What is motion interpolation? List the types of motion interpolation method.

7. List robot language operating system modes.

8. What is first generation language? Give example.

9. What is second generation language? Give example.

10. What is artificial intelligence?

11. Write any three textual robot languages.

12. Mention the advantages of online programming

13. List out the advantages of offline programming.

14. List the generation of robot programming language.

15. Mention the use of speed command.

PART-B

1. Distinguish between manual and power lead through method.

2. Differentiate on-line and off line programming.

3. What is textual robot language?

4. List out the basic robot languages.

5. Write short notes on Future generation languages.

6. List few motion commands and explain.

7. List the advantages of lead through programming.

8. Write short notes on textual robot language.

9. Write short notes on joint interpolation.

10. Mention the features of second generation language.

11. What is circular motion interpolation?

12. Write any three basic commands used in robot programming.

13. List outthe gripper commands used in robot programming

14. Write short notes on Artificial intelligence.

15. What is powered lead through programming?

PART-C

1. Explain lead through programming method. State its advantages and limitations.

2. Explain online and off line programming with necessary diagrams.

3. Describe in detail about artificial intelligence and robotics.

4. Explain robot language structure with a neat diagram.

5. Explain briefly any two generation of robot programming language.

6. Explain motion interpolation in detail.

7. Explain in detail about future generation robot language.

8. Illustrate the features of second generation language.

9. Explain in detail about artificial intelligence.

10. Explain basic programming language.

UNIT V

ROBOT APPLICATION IN MANUFACTURING

Robot application in manufacturing – material handling –assembly finishing –adopting robots to work station - requisite and non – requisite robot characteristics –stages in selecting robot for individual application – precaution for robot –future of robotics.

Economics analysis for robotics – cost data required for the analysis – methods of economic analysis – pay back method – equivalent uniform annual cost method – return on investment method.

5.1 ROBOT APPLICATION IN MANUFACTURING

Current day robot applications include a wide variety of production operations, some of them are

1. **Material handling Application**:

   Material transfer and machine loading / unloading: These are applications in which the robot grasps and moves a work part from one location to another. This category includes applications in which the robot transfers parts into and out of a production machine.

   Eg. Load/Unload operations are carried out in metal machining operation; die casting, plastic moulding and forging operations.

2. **Processing Operation**:

   These are operations in which the robot uses tool as end effectors to accomplish some processing operations on a work part.

   Eg. Spot welding, arc welding, spray painting and certain machining operations.

3. **Assembly and inspection**:

   The robot is used to put components together into an assembly or the robot is used to perform some form of automated inspection operation with the help of machine vision system.

5.2MATERIAL HANDLING:

Material handling applications are those in which the robot is required to move materials or parts from one location and to another.

Material handling operations are divided into two categories.

1. Material transfer applications
2. Machine loading/ unloading applications

General considerations in robot material handling:

- **Part positioning and orientation**: In most parts handling applications, the parts must be presented to the robot in known position and orientation.
- **Gripper design**: Special end effectors must be designed for the robot to grasp and hold the work part during the handling operation.
- **Minimum distance moved:** The material handling application should be planned so as to minimize the distances that the parts must be moved.
- **Robot work volume**: The cell layout must be designed with proper consideration given to the robot's capability to reach the required extreme location in the cell.
- **Robot's weight capacity:** The load capacity of robot must not exceed the weight of the robot for material handling application
- **Accuracy and repeatability**: some application requires material to be handled with high precision.
- **Robot configuration and degrees of freedom and control**:
  Many parts transfer operation is simple enough that they accomplished by a robot with two to four joints of applications. Machine loading application often requires more degrees of freedom. Robot control requirements are unsophisticated for most material handling operations. Palletizing operation and picking parts from a moving conveyor are examples.
- **Machine utilization problems:**
  It is for the application to effectively utilize all pieces of equipment in the cell.In a machine loading/unloading operations, it is common for the robot to be idle while the machine is working, and the machine to be idle while the robot is working.

5.2.1 MATERIAL TRANSFER APPLICATIONS

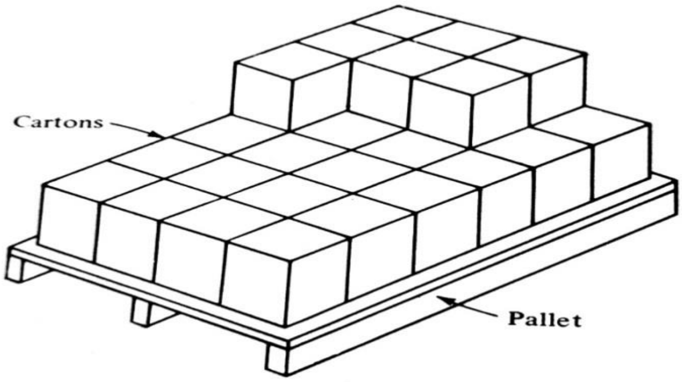
Material transfer applications are defined as operations in which the primary objective is to move apart from one location to another.

These applications are called pick and place operations because the robot simply picks the part from one location and places it in another location

Some material transfer applications have motion patterns that change from cycle to cycle. A more complex example of material transfer is palletizing.

Pallet is a storage area which consists of a number of cells to store work piece of different size.

In this type of application, the robot must place each part in a different location on the pallet, thus forcing the robot to remember or compute a separate motion cycle until pallet is fully loaded. Fig 5.1 illustrates the pallets where applications have motion pattern



.Fig 5.1 Typical pallet arrangements

The use of pallets for material handling and storage in industry is widespread. Instead of handling individual cartons or other containers, a large number of these cartons are placed on a pallet, and the pallet is then handled.

The only handling of the individual cartons arises when the product is placed onto the pallet or when it is removed from the pallet.

Robot can be programmed to perform this type of work. Because the motion pattern varies in the palletising operation, a computer controlled robot using high level programming language is convenient. This feature facilitates the mathematical computation of the different pallet locations required during the loading of a given pallet.

A less sophisticated robot limited to lead-through programming can also be used, but the programming becomes laborious, because each individual carton location on the pallet must be individually taught.

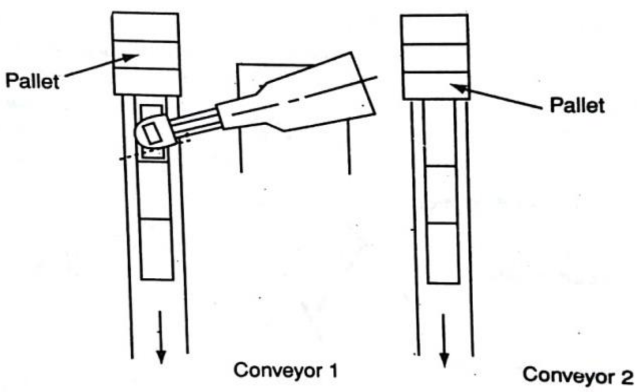


Fig 5.2 Palletising Process.

The other operations include

- De palletizing operations
- Inserting parts into carton from the conveyor
- Removing parts from carton
- Stacking and un stacking operation

Barcodes and other optical schemes are used to solve identifying the cartons and the way in which they are loaded and unloaded.

Pick and Place Operation:

Pick and place operations involve tasks in which the robot picks up the part at one location and moves it to another location.

A typical pick and place operation by suitable end-effectors can be performed by a cylindrical coordinate robot. Figure 5.3 (a) shows simple pick and place operation.

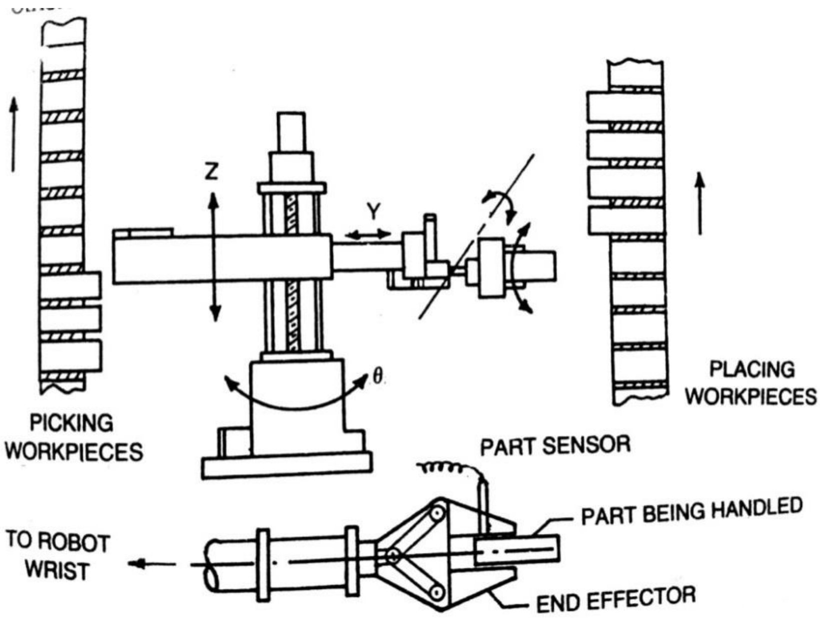


Fig 5.3 (a) Pick and place operation

In simple pick and place operation, the robot needs only 2 degrees of freedom. 1^{ST} degree of freedom is needed to lift part from the pickup point and put it down at the drop off point.

2^{nd} degree freedom is required to move the part between these two positions. For part reorientation requires additional degree of freedom.

In the simplest case, the part is presented to the robot by some mechanical feeding device or conveyor in a known location and orientation. The known location is stationery location achieved either by stopping the conveyor at the appropriate position or by using mechanical stop to hold the part at stationery location.

An input interlock (limit switch) would be designed to indicate that the part is in position and ready to pick-up. The robot would grasp the part, pick it up, move it .and position it at a desired location.

In robotic material handling, tracking arises when parts are carried along a continuously moving conveyor and robot is required to pick parts from the conveyor. In oppose case when robot must put parts on to a moving conveyor. In either case a more sophisticated sensor interlock system is required to determine the presence and locations of the parts in the robot tracking window.

In material handling the robot must be interfaced to sensor system to distinguish between different parts using subroutines

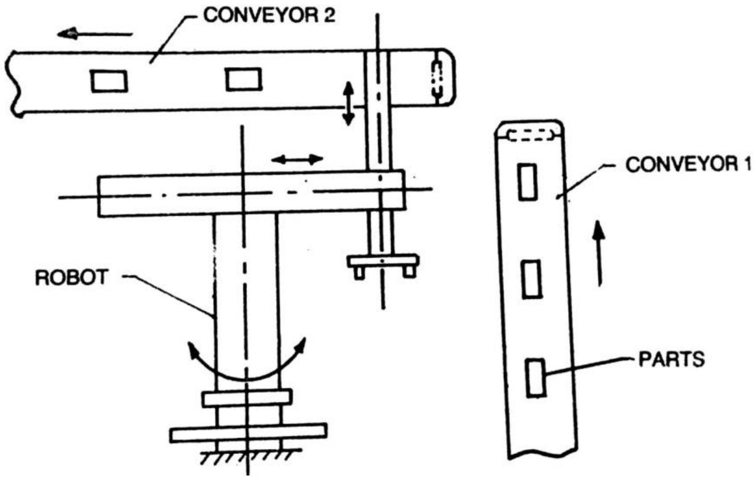


Fig. 5.3 (b) Pick and place operation on conveyors

5.2.2 MACHINE TOOL LOADING AND UNLOADING:

These applications are material-handling operations in which the robot is used to service a production machine by transferring parts to or from the machine. There are three cases that fit into this application category

Machine Loading / Unloading:

The robot loads a raw work part into the process and unloads a finished part. The fig shown in 5.4 indicates a gripper attempting to insert a cylindrical work piece into chuck.

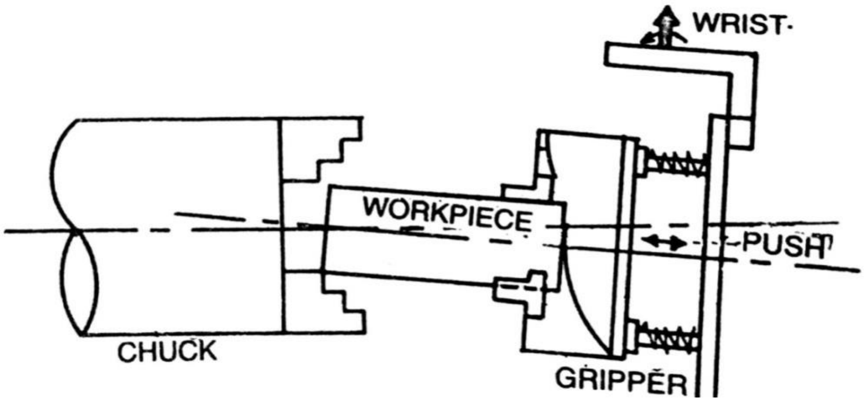
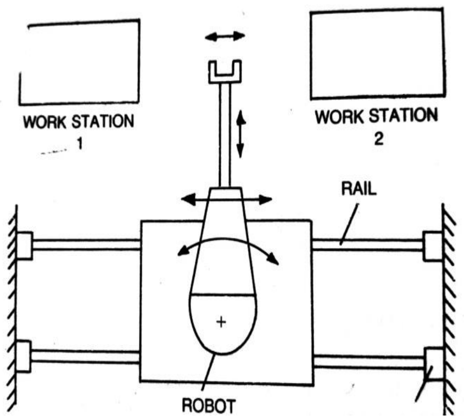


Fig 5.4 (a) indicates a gripper attempting to insert a cylindrical work piece into chuck



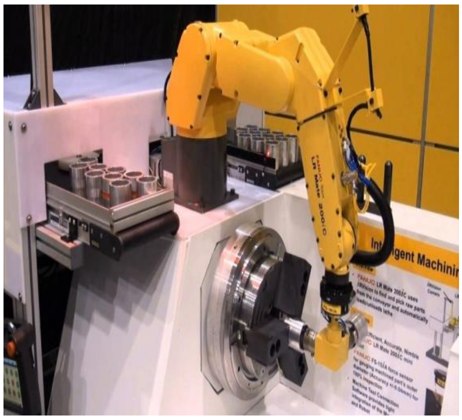


Fig 5.4(b) robot serving two stations

Fig 5.4(c) Machine Loading

Machine loading: The robot must load the raw work part or materials into the machine but the part is ejected from the machine by some other means. In a press working operation, the robot may be programmed to load sheet metal blanks into the press, but the finished parts are allowed to drop out of the press by gravity.

Machine unloading: The machine produces finished parts from raw materials that are loaded directly into the machine without robot assistance. The robot unloads the part from the machine. Examples in this category include die-casting and plastic moulding applications.

Loading and unloading parts is often combined with other robotic tasks in the manufacturing process. In this operation, the robot has complete control over the entire work cell.

The main concerns in this application are

1. Reach of the manipulator
2. The number of axes of the manipulator
3. The weight capacity of the manipulator

Typical manipulators used in machine loading and unloading are cylindrical coordinate manipulators and articulate manipulators. In the machine loading and unloading operation the timing of the robot and the lathe machine must be coordinated. The time required for the robot or machine to do its job is its cycle time. The robot's cycle time must match the machine's cycle time for efficient operation**.** Robots have been successfully applied to accomplish the loading and /or unloading function in the following production operation**.**

1. Die casting
2. Plastic mouldings
3. Forging and related operation
4. Machining operations
5. Stamping press operations.

1. DIE CASTING

Die casting is a manufacturing process in which molten metal is forced into the cavity of a mould under high pressure.

The mould is called a die (hence the name, die casting). Common metals used for die casting are alloys of zinc, tin, lead, aluminium, magnesium and copper. The basic die casting process is shown in fig 5.5

The die consists of two halves that are opened and closed by a die casting machine. During operation the die is closed and molten metal is injected into the cavity by a pump. To ensure that the cavity is filled, enough molten metal is forced into the die that it overflows the cavity and creates "flash" in the space between die halves. When the metal has solidified, the die is opened and the cast part is ejected, usually by pins which push the part away from the mould cavity.

When the part is removed from the machine, it is often quenched (to cool the Perl) in a water bath. The flash that is created during the casting process must be removed subsequently by a trimming operation which cuts around the periphery of the part.

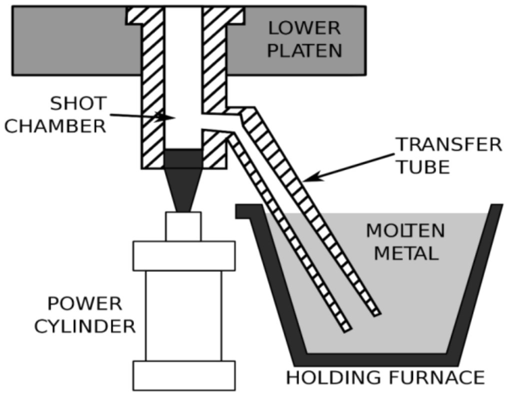


Fig 5.5 Die casting

Thus the typical die-casting production cycle consists of casting, removing the part from the machine, quenching and trimming.

The die-casting machines have traditionally been tended by human operators. The work tends to be hot, repetitive, dirty and generally unpleasant for humans. Because of these conditions, die casting was one of the very first processes to which robots were applied.

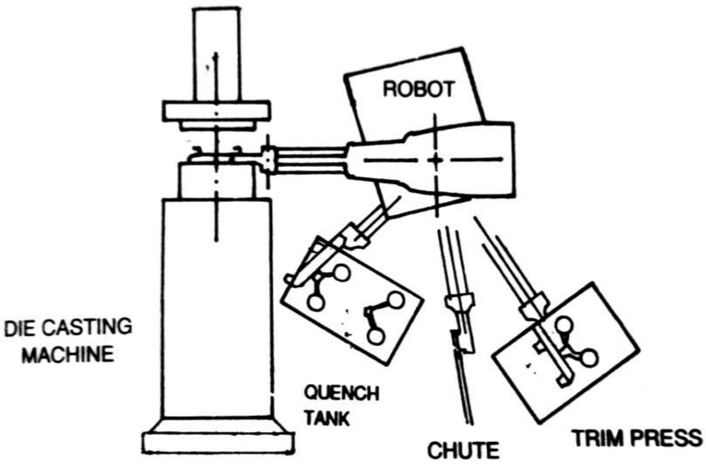


Fig 5.6 Die casting process

A typical illustration of loading and unloading a die casting machine by a robot is shown in the figure 5.6. The robot wrist can be mounted with dual gripper, one on the top and the other at the bottom. The wrist on turning through 180 ° can present either of the grippers. The robot first picks up a part from chute and approaches the die casting machine. The robot reverses its wrist and with the aid of a gripper picks up the finished part out of the die. The wrist is turned and the robot then places the gripped part in the die casting machine. The robot moves and brings the part already taken out to the quench tank.

The part is then dipped into the tanks for cooling. The robot picks up the previously quenched part and brings it to the trim press for trimming. The trimming operation removes the spur and gates from the cast product. It can retrieve the part and place it in storage or a conveyor.

2. PLASTICMOULDING:

Plastic moulding is a batch volume or high volume manufacturing process used to make plastic parts to final shape and size. The term plastic moulding covers number of processes, including compression, moulding, injection moulding, thermoforming, and extrusion.

Injection moulding is the most important commercial process forwhich robots are often used. A thermoplastic material is introduced in to the process in the form of small pellets or granules from a storage hopper. It is heated in a heating chamber to 200 to 300 ° c to transform it into semi fluid state and injected into the mould cavity under high pressure.

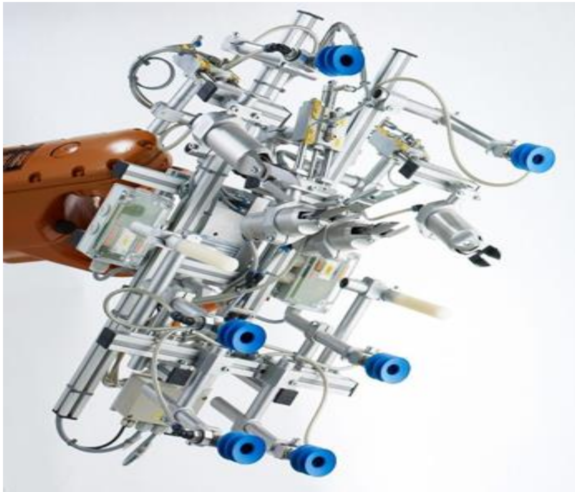
The plastic travels from the heating chamber into part cavity through a sprue - and-runner network that is designed in the mould. When the plastic material has hardened sufficiently, the mould opens and part are removed from the mould.

Injection moulding is accomplished using a highly sophisticated injection moulding machine which maintains the following parameters

1. Temperature 2. Pressure 3. Amount of material injected in to the mould cavity.

A robot can conveniently be employed specially in cases where the product should not be dropped owing to its fragile nature.

Six-axis articulated robot tends an injection molding machine producing plastic components for ear protectors. (*Courtesy of ABB Robotics*)



Robot end-of-arm tooling with slide-out nippers and part sensors for plastics injection molding. (*Courtesy of ASS End of Arm Tooling, Inc.*)

Fig 5.7 (a) & (b) shows typical injection moulding operation

3.FORGING AND RELATED OPERATION;

A Robot can also help in forging operations when heavier parts are to be loaded or unloaded from or into the furnaces. Forging is a metal working process in which metal is pressed or hammered into the desired shape.

It is most commonly performed as a hot working process in which the metal is heated to a high temperature prior to forging. These operations include die forging and upset forging.

Die forging is a process accomplished on a machine tool called a drop hammer in which the raw billet is hit one or more times between the upper and lower portions of the forging die. The die often has several cavities of different shapes which allow the billet to be gradually transformed from its elementary form in to the desired final shape. The photo shown below is a example for robotic usage in die forging

Fig 5.8 shows typical forging operation

Upset forging, also called upsetting, is a process in which the size of a portion of the work part is increased by squeezing the material into the shape of a die.

Forging, especially hot forge operation, is one of the worst industrial jobs for humans. The environment is noisy and hot, with temperature at the workplace well above 100°F, for hot forging. The operation itself is repetitive, often requiring considerable physical strength to move and manipulate the heavy parts during the operation.

Hence robots can be used for handling parts in forging. While designing a robot for forging operation, the following factors are to be considered

- Designing of gripper – The parts are hot and gripper must be protected against the temperature
- The gripper must be designed to withstand the shock from the hammer blows
- The gripper must be designed to accommodate changes in the shape

4.MACHINING OPERATIONS

Machining is a metal working process in which the shape of the part is changed by removing excess material with a cutting tool.

There are a number of different categories of machining operations, the principal types include turning, drilling, milling, shaping, planning and grinding. Commercially, machining is an important metalworking process and is widely used in many different products, ranging from those that are made in low quantities to those produced in very high numbers.

Robots have been successfully utilized to perform the loading and unloading functions in machining operations**.** The robot is typically used to load a raw part into a machine tool and to unload the finished part at the completion of the machine cycle.

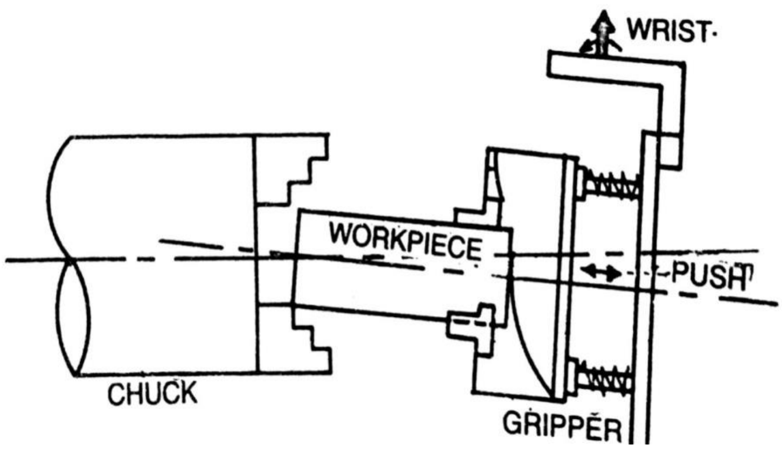


Fig 5.9(a) Loading a part into a machine

The following robot features are used for loading/unloading applications

- Dual gripper
- Up to six joint motions
- Good repeatability
- Palletizing and de palletizing capability.

- Programming features. – To handle irregular elements such as tool changes or pallet changes.

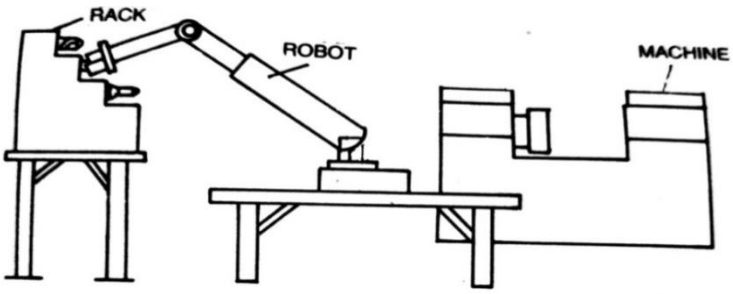


Fig 5.9 (b) shows the robot used to place the finished part in a rack after completing the Machining operation.

Fig 5.9 (c) shows the laser cutting operation using robot

5STAMPING PRESS OPERATIONS:

Stamping press operations are used to cut and form sheet metal parts. The process is performed by means of a die set held in a machine tool called a press.

Robots are being used for handling parts in press working operations, largely as a result of safety issues. The typical task performed by the robot is to load the flat blanks into press for the stamping operations.

Fig 5.10 stamping press operation.

One of the limiting factors in using industrial robots for press loading is the cycle time of the press. Generally cycle times for stamping press operation is very short. These cycle rates are too fast for currently available commercial robots. There is generally a direct relationship between the physical size of the part and the press cycle time required to make a part. Robots are typically used in press working for larger parts.

5.3 ASSEMBLY FINISHING :

The term assembly is defined to mean the fitting of two or more discrete parts to form a new sub-assembly. The process usually consists of the sequential addition of components to a base part or existing subassembly or a complete product. Assembly operations involve a considerable amount of handling and orienting of parts to mate them together properly**.**

There are variety of assembly processes used in industry today. These include mechanical fastening operations (using screws, nuts, bolts, etc.,), Welding, brazing, bonding by adhesives. Some of these processes are more adaptable to automatic assembly.

Components may be composed into a sub assembly or into a complete product in the assembly system. From the viewpoint the assembly system can be defined as the integrated structure of machines, auxiliary devices and human assemblers all employed for accomplishing the task in a process in which materials (components) energy and information are fed as input and the assembled product is obtained as the output.

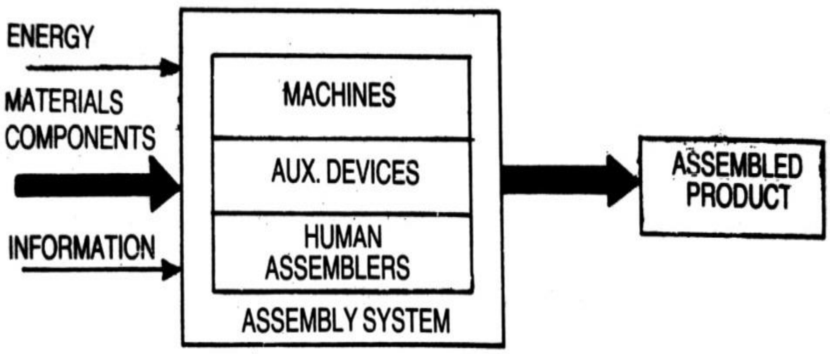


Fig 5.11 Assembly Finishing

The complexity of assembly depends on how the building blocks are composed from the individual components to sub-assemblies first and then to complete assembled machine or products and finally to the entire plants with several interconnected machines.

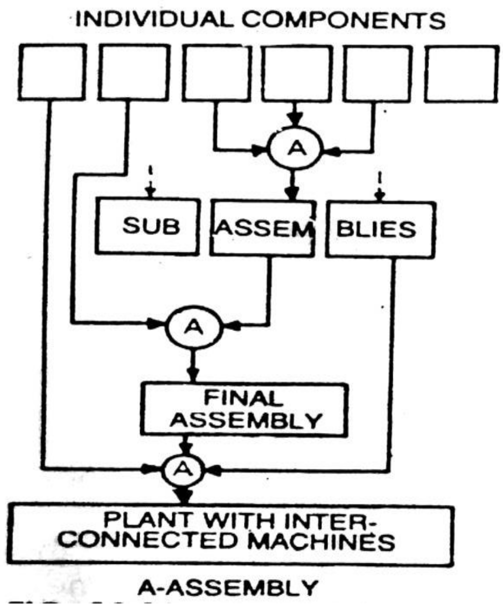


Fig 5.12 Assembly of Individual components.

BROAD CLASSIFICATION ASSEMBLY SYSTEMS:

Manual system:

Assembly is carried out by the assembler who has simple and mostly passive auxiliary equipment at his disposal, such as tables, fixtures, component boxes etc.

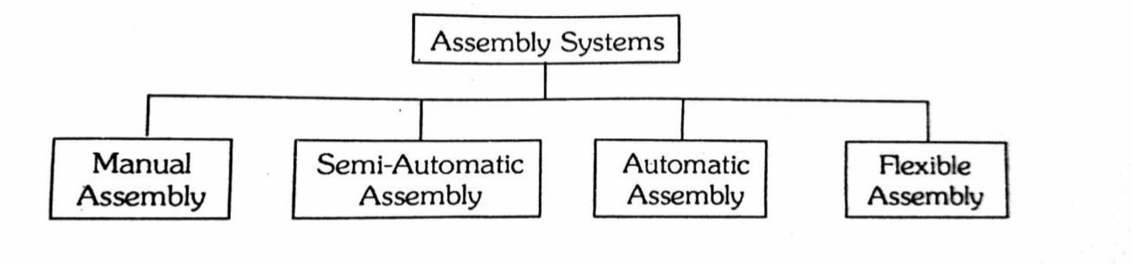


Fig 5.13 Classification of Assembly system.

Semiautomatic Assembly:

The assembly is carried out with automatic machines in which some manual operations are also adopted.

Automatic Assembly:

It is a mechanical assembly comprising machine systems which follow a program. The system accomplishes the tasks based on the pre-planned program.

Flexible Assembly:

Flexible refers to the system's ability to accept variations in different modes of the assembly tasks accommodating the design characteristics of the components and product variations without any considerable change in the tooling. it is suitable for multi station assembly task.

ASSEMBLY PROCESS:

Actual assembly process can be divided into three main constituent functions namely, handling, composing, checking and adjusting

Handling includes storage of the components in either un oriented or oriented fashion as in the case of hoppers or magazines respectively, orienting, aligning and inserting a component, moving, feeding, orienting, aligning and inserting a component, moving, feeding ,escapement of a component.

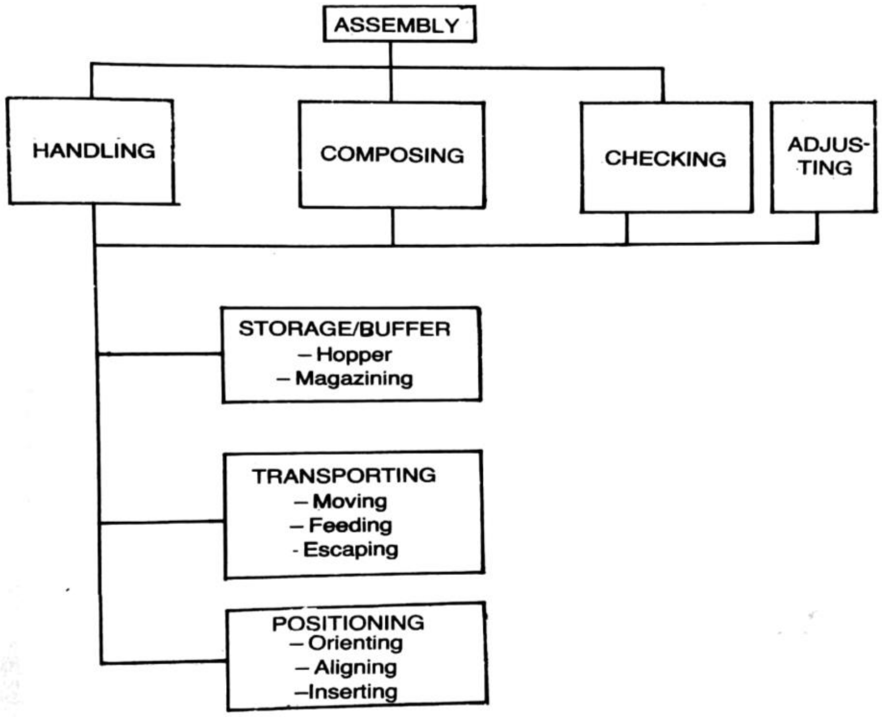


Fig 5.14 Assembly process.

Composing connects the components to create a new shape. Checking and making necessary adjustments is the process by which the recognition (of pattern), presence and absence of the components, dimension and quality measurement etc. are carried out adjusting refers to operation subsequent to checking e.g. if parts are missing it must bring the new part or align the part.

Rules and Procedures to be followed for ease of assembly using robots:

- For robotic assembly a suitable gripping device should be designed for ease of assembly.
- Robot vision system can be used for assembly of the components randomly picked up by the assembly robot from conveyors.
- The assembly robotic cell should be modular cell. If the production run increases, more modular cells can be used.
- Minimizing number of parts required in a robotic assembly is a big advantage.
- The components for the assembled product should be selected for ease of assembly.
- Parts should be designed for feeding and orienting for automated assembly for which product simplification and if necessary, redesigning the products are necessitated.

Simple example for robotic assembly is the insertion of electronic components. These components could be resistors, capacitors, diodes, transistors, heat sinks etc. Industrial robots used for this type of assembly operations are typically small, with light load capacities. Large proportions of assembly task require a robot capable of lifting weights of five pounds or less.

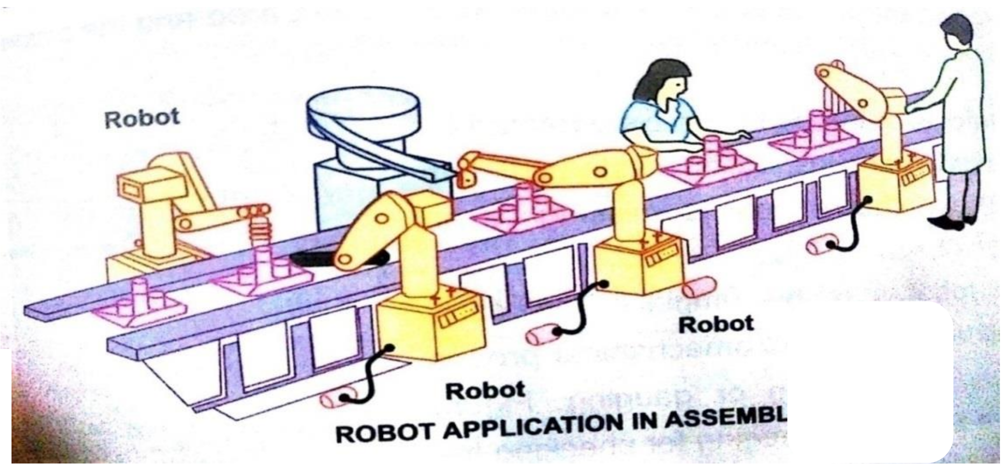


Fig 5.15Application of Robot in Assembly

The most common assembly configurations are jointed arm, SCARA, and Cartesian coordinate. Programming is often done using machine programming language, together with a powered teach pendant to teach locations in the work cell. Accuracy requirements in assembly work are often more demanding than in any other applications.

5.4 ADOPTING ROBOTS TO WORK STATION:

Industrial robots generally work with other pieces of equipment. These pieces of equipment include conveyors, production machines, fixtures and tools.

The robot and the associated equipment form a work cell. **Physical design of the work cell and the design of the control system which will coordinate the activities between robot and work cell.**

Physical design of work cell:

Robots work cell can be organised into various arrangements or layouts

1. Robot centred cell
2. Inline robot cell
3. Mobile robot cell.

1.Robot centered work cell:

In the robot cantered cell, the robot is located at the approximate center of the cell and the equipment is arranged in a partial circle around it. An application of the robot centered cell is arc welding. With these robot cantered cell arrangements, a method for delivering the work parts into and/or out of the cell must be provided. Figure 5.16 shows robot centered cell.

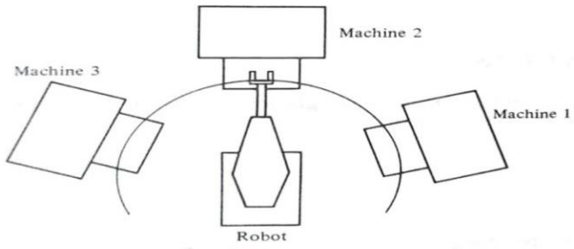


Fig 5.16 Robot Centered Cell

2.In line robot work cell:

With the in line cell arrangement, the robot is located among a moving conveyor or other handling systems and perform a task on the product as it travels past on the conveyor. Example of this arrangement car body assembly plants in the automobile industry .Figure 5.17 Inline robot work cell.

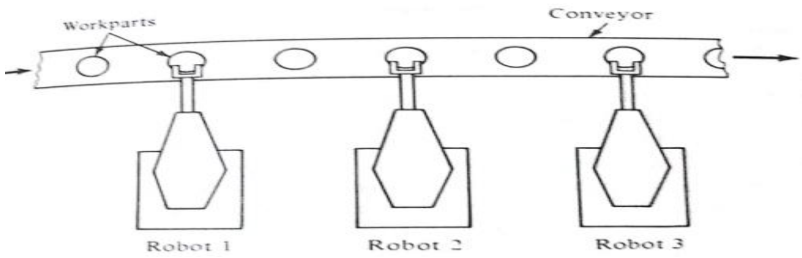


Fig 5.17In line Robot work cell

3.Mobile Robot cell:

In this category of robot cell design is one in which the robot is capable of moving to the various pieces of equipment within the cell.

This is typically accomplished by mounting the robot on a mobile base which can be transported on a rail system. The rail system used in robot cells are either tracks fastened to the floor or overhead rail system .Figure 5.18 Mobile robot cell.

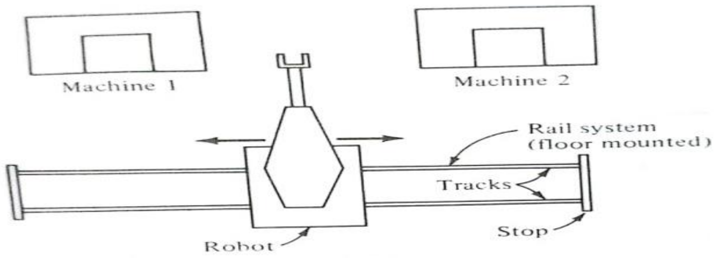


Fig 5.18 Mobile robot cell

Criteria for establishing and utilizing a robotic work cell include:

- It must be capable of performing required machining functions on a limited number of parts of sizes within predetermined limited
- One worker must be capable of operating the work cell with minimal skill requirement.
- Part programming must be done on line
- Safety sensors must be installed for protection of personnel. Equipment and work in process.
- Consistent quality must be maintained on parts.
- Productivity must be increased to make the system economical.
- Manual parts fabrication in the work cell must be feasible in case of system failure.

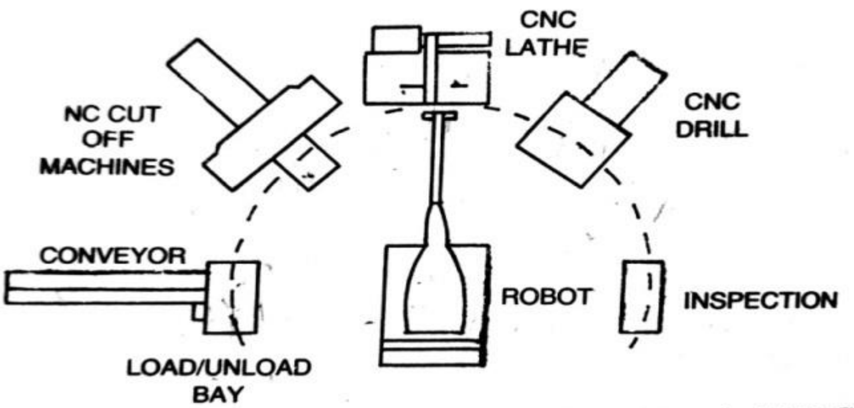


Fig 5.19 Adaptability of robots to work station.

5.5 REQUISITE AND NON-REQUISITE CHARACTERISTICS:

Requisite Characteristics:

The requisite characteristics are ones that must be satisfied by a robot in order to perform the application. If any of the robots do not satisfy the requisite characteristics then the robot is excluded from further consideration.

Example:

- No. of axis
- Type of program
- Type of motion
- Accuracy
- Repeatability
- Stability

Non-requisite Characteristics:

Non –requisite characteristics are the One that are not necessary to accomplish the application but would be highly beneficial during installation and application.

Example:

- Ease of programming
- Ability to edit program
- Work volume

When the robot is being programmed the speed of the arm should be set at low speed.

5.6 STAGES IN SELECTING A ROBOT:

In an industry, the engineers will be having several robots under their control. According to the job given, the engineers must be able to select the perfect robot. This is only possible, if the engineers are well known about the technical features of every robot.

Stage1:

The important technical factors that are to be considered before selecting a robot for an application are:

- Type of job
- Configuration
- Number of axes
- Drive system
- Programming method
- Control system
- Load carrying capacity
- Ease of programming
- Precision of motion.

Stage 2:

If a deviation from the needed specification is made, it should be made in the direction of greater robot capabilities rather than less. Choosing of Alternate robot individuals should satisfy needed specification.

Stage 3:

To make final selection of the robot, the following decision procedure is suggested.

- The procedure consists of preparing a detailed listing of the technical features for the particular application.
- Systematically comparing these features against the specifications of the alternative models under consideration.
- It is advantages to divide the list of technical features two categories: must and desirable.
- The 'desirable" features are ones that are not necessarily required to accomplish the application.
- The" must "features are ones that must be satisfied in order to perform operation.

Stage 4:

The specification of each robot candidate would be compared to each of the desirable features, and a rating score would be assigned to the robot candidature, to indicate how well robot satisfies the particular features. Based on the relative score application engineer selects the robot for a particular operation.

For more details, here are some of the applications and technical features required for selecting a robot.

Machine Loading:

- To perform machine loading, a robot should be of either cylindrical, jointed arm, or polar configuration.
- It requires only four or five axes.
- The drive system must be hydraulic for loading heavy weights. Otherwise electric type is enough.
- The programming method needed for this operation will be powered lead-through.
- As this is a simple process, it can have either point to point or limited sequence control system.

Assembly Operation:

- The configuration of the robot must be Jointed Arm or Cartesian.
- The number of axes can be from three to six.
- It requires an electric drive system for this process.
- It must be capable of programming in textual languages or powered lead-through method.
- It must have either continuous path or point to point control system.

5.7 PRECAUTION FOR ROBOTS:

One of the first fundamental reason for using robots in industrial applications is to remove human operators from hazardous work environments. Hazardous in the workplace include heat, noise, fumes, and other discomforts, physical dangers, radiation, toxic atmospheres and other health hazards.

The second aspect of the safety involves the potential hazards to humans posed by the robots itself.

There are three occasions when humans are close enough to the machine to be exposed to danger these are.

- During the programming of the robot.
- During the operation of the robot cell(especially human work in the cell)
- During the maintenance of robot.

The type of risk encountered during these times include

- Physical injury from collision between human and robot.
- Electrical shock
- Objects(parts or tool dropped from the gripper)
- Loose power cables or leaking hydraulic lines on the floor

Some of these risks can be reduced with straight forward safety measures such as

- Proper grounding of electrical cables to prevent shock.
- Raised floor plate to cover power cables and hydraulic lines.
- During the maintenance the power to the machine should be turned off.

Workplace design consideration for safely:

- Certain safely features can be designed into the robot work cell. These include physical barriers to limit intrusion into the cell, emergency stop buttons to halt the cell operation, and laying out the equipment in the cell for maximum safety.
- The most common approach is to construct a physical barrier around the periphery of the robot work cell. The barrier has the effect of preventing human intruders from entering the vicinity of the robot, while it is operating. The barrier often consists of a fence with a gate access to the work cell.
- The gate is equipped **with an interlock device** so that the work cell is interrupted when the gate is open.
- Another approach of safety is to **use two position parts manipulator can be used to** exchange parts between the robot and worker. This kind of arrangement prevents collision between the worker and the robot.
- Another approach of safety used in industry is to use steel post as a physical barrier at the limits of programmed motion cycle.

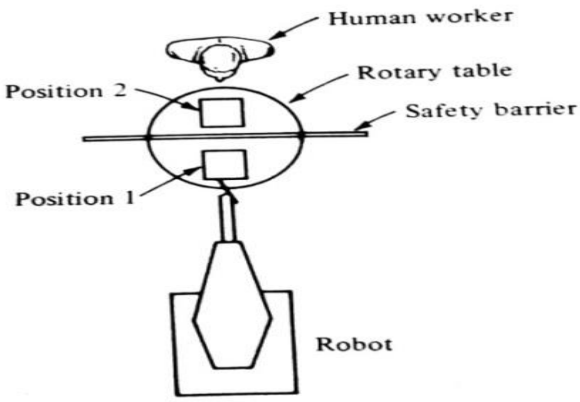


Fig 5.20   Two position parts manipulator

Safety Sensors and Safety Monitoring:

- Safety monitoring involves the use of sensors to indicate conditions or events that are unsafe or potentially unsafe.

- The sensors used in safety monitoring range from simple limit switches to make sure that certain steps in sequence control have been carried out, to sophisticated vision system that are able to scan the workplace for intruders and other deviations from normal operating conditions.

  The national bureau of standards defines three levels of safety sensor system in robotics

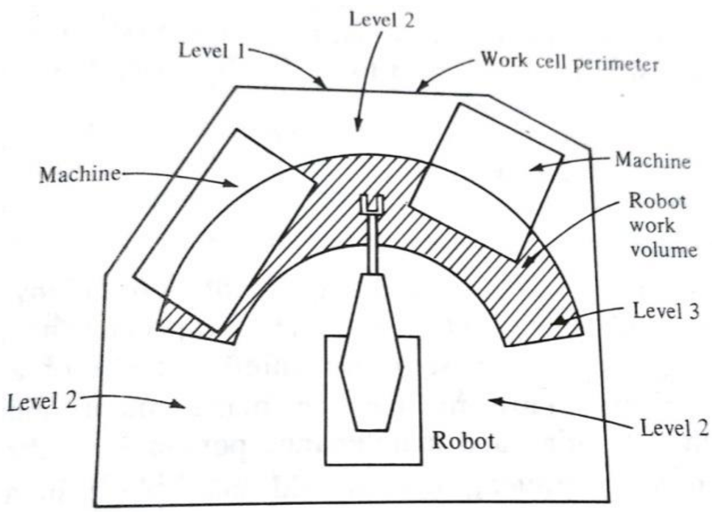


Fig. 5.21 Safety Sensors and Monitoring

- Level 1 – Perimeter penetration detection
- Level 2 –Intruder detection inside the work cell.
- Level 3 – Intruder detection in the immediate vicinity of the robot.

Pressure sensitive floor mats and light curtains can be used for either level 1 or level 2 systems. Proximity sensors can be located on the robot arm as level 3 sensors.

Sensor detection system can be take any one of the following action to prevent unsafe operation

- Complete shutdown of the robot upon detection of the intruder
- Activation of warning alarms.
- Reduction in the speed of robot to a safe level.
- Directing to work robot in other work cell.
- Directing robot to move away from intruder.

5.8 FUTURE OF ROBOTICS:

1. Intelligence:

- The future robot should be intelligent robot
- It will be capable of making decision about the task performed based on high level command.

- It is expected to give feedback data from its environment.
- It must be capable of making decision based on high level programming commands.

2. Sensor Capability:

- The future robots will have a wide array of sensor capabilities including vision, tactile sensing and others.
- These sensor capabilities would permit robot to be more aware of its environment, to communicate with human operators more readily, and to make use of the higher level of intelligence.

3. Telepresence:

- It must possess a telepresence capability.
- The ability to communicate information about its environment.(which may be unsafe for humans)
- Telepresence is concerned with channel of communication. The functions of telepresence are information acquisition using advanced sensor capabilities, feedback of this information to a remote location and display of this information in a manner that facilitates interpretation by humans.

4. Mechanical design:

- The basic design of a robot must be more efficient, more reliable with improved power and actuated system.
- Some robots will have multiple arms with advanced control systems to coordinate the actions of the arms working together.

5. Mobility and Navigation:

- Future robots will move by its own and navigation will be easier. Providing robot with capacity to move under their own power would greatly increase their potential utilization.
- Robot mobility in the factory environment can be used either to move components or perform jobs that require significantly.

6. Universal Gripper:

- Robot gripper design will be more sophisticated. It will be universal or more capable of doing variety of tasks.
- Future robotics with full potential designed more like human hand, both in their sensory and control capabilities.

7. System integration and networking:

- In future all of the production equipment will share a common database, in order for robots to participate in the factory network system,
- They must be able to communicate with the network. Robots are able to share data with host computers, In order to realize the full capabilities of the factory wide real time control system.

5.9 ECONOMIC ANALYSIS:

Before starting the development of a robot, some of the data must be collected to carry out economic analysis effectively. They are:

- Type of robot to be installed
- Cost to install a robot
- Time taken to produce a robot
- Savings and benefits in the development

In an industry, the investment put on the development of a robot can be compared and analysed by three common methods such as:

- Pay back method
- EUAC (Equivalent Uniform Annual Cost
- ROI (Return on Investment method

5.10 COST DATA REQUIRED FOR THE ANALYSIS :

The cost data required to perform the economic analysis of a robot project divide into two types.

I. Investment Cost

II. Operating Cost

I. Investment Cost –

1. Robot purchase cost
2. Engineering cost
3. Installation cost
4. Special tooling

1. Robot Purchase Cost:

The basic price of the robot from the manufacturer. (Excluding end effector) with proper options to perform the applications.

2. Engineering Cost:

The cost of and design by the user company's engineering staff to install robot.

3. Installation Cost:

This includes the labour and materials needed to prepare the installation site.

4. Special Tooling:

This includes the cost of the end effector, parts positioner, and other fixtures and tools required to operate the work cell.

5. Miscellaneous Cost:

This covers the additional investment cost not included by any of above categories.

II. Operating cost and saving –

1. Direct labour cost
2. Indirect labour cost
3. Maintenance
4. Utilities.

1. Direct Labour Cost:

The direct labour cost associated with the operation of the robot cell.

2. Indirect Labour Cost:

The indirect labour cost that can be directly allocated to the operation of the robot work cell. These costs include supervision, setup, programming, and other personnel cost.

3. Maintenance Cost:

This covers the anticipated cost of maintenance and repair for the robot cell.

4.Utilities:

This includes the cost of utilities to operate the robot cell. (Electricity, air, pressure, gas).

Training – Training might be considered to be an investment cost.

At the beginning of our project, the investment cost is being paid in to the project with no immediate return. When installation is completed and the project begins operation, the operating costs begin. However there is also compensating cash flow representing revenues to the company which should exceed the amount of operating cost.

NET CASH FLOW= REVENUE – OPERATING COST

At the beginning of the operation, there are usually start-up problems to be solved. These difficulties often prevent the net cash flow from immediately reaching the steady state.

If the robot project is a good investment, the net cash flow will allow the company to recover its investment costs in the project in a relatively short period.

Payback Period – The Period (Length of time) at which the investment is recovered is called payback period.

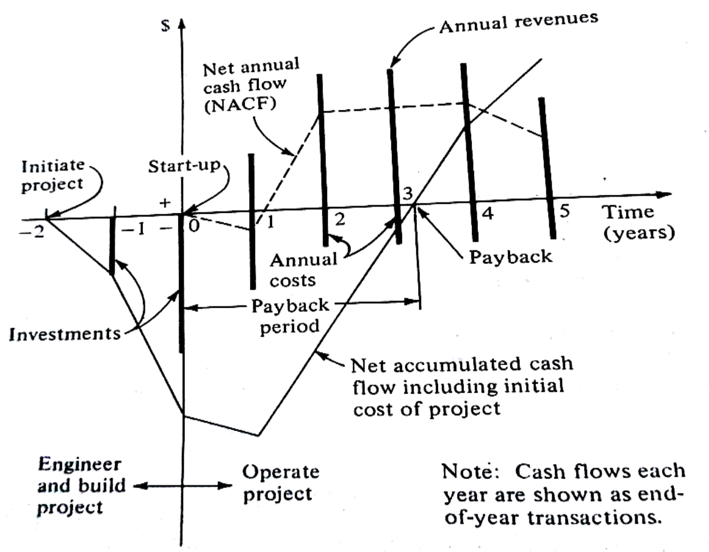


Fig 5.22 life cycle of cash flow in a capital investment project.

5.11 Methods of Economic Analysis :

1. Payback methods
2. Equivalent uniform annual cost method.
3. Return on investment method.

1. Payback Method :

The payback method uses the concept of the payback period. The payback period is the length of time required for the net accumulated cash flow to equal the initial investment in the project.

The duration taken to equal the initial investment and net accumulated cash flow in the development of a robot is called as payback period or payback method. **If the net annual cash flows are identical to every year, then it can be stated by a formula given below.**

NET CASH FLOW= REVENUE – OPERATING COST

Payback period = Investment cost/Net Annual cash flow

n=IC/NACF

n= payback period

IC=the investment cost

NACF=the net annual cash flow

When there is year to year difference in the cash flow, the formula is given below.

$$0 = -(IC)+\sum_{i=1}^{n}(NACF)$$

In this equation the value is determined so that sum of the annual cash flows is equal to the initial investment cost.

In the special case when the annual cash flows are equal

$$0 = -(IC) + n(NACF)$$

Here costs are treated as negative values and revenues or savings are treated as positive value (Logical convention).

Most companies today require paybacks of no more than two or three years**. An investment whose cash flow pays back the investment in less than one year is considered excellent.**

For Example

Annual operating cost- Rs. 20,000

Annual revenue cost

(Labour, maintenance and other expense)-Rs. 65,000

Expected service life. (Robot project) - 5years

Total investment cost (P) is-Rs 1, 00,000

Net annual cash flow (A) = Rs 65000- Rs 20000= Rs 45000

n(payback period) = IC/NACF = 100000/45000 = 2.22 years

Payback period of this project is 2.22 years. Hence the project would not be a good one to be considered.

Disadvantage: payback period method ignores the time value of money.

EUAC method:

The EUAC is the short form of Equivalent Uniform Annual Cost method. It is used to alter the total cash flows and investments into the equivalent uniform costs over the expected time of developing a robot.

It is done by employing different interest features that are connected with the calculations of engineering economy.

EUAC converts all of the present and future investment and cash flows in to their equivalent uniform cash flows over the anticipated life of the project.

To begin with, the company must select a **Minimum Attractive Rate of Return** (MARR) which is used as a criterion to decide whether potential investment project should be funded .MARR values of 20 to 50% are not unusual for robots.

Using the interest factors for the MARR to make the conversion, the EUAC then sums up EUAC vales for each of investment and cash flow associated with it.

IF EUAC is greater than zero, this is interpreted to mean that the actual rate of return associated with the investment is greater than MARR, and then the project is considered attractive. If EUAC is less than zero project is unattractive.

For Example

Annual operating cost-Rs. 20,000

Annual revenue cost-Rs. 65,000

The robot project 5 Year service life.

Total investment cost (P)is–R s 1, 00,000

Net Annual Cash Flow (A) =Rs 65000- Rs 20000= Rs 45000

In this method the initial investment cost 1, 00,000 must be converted in to its equivalent uniform annual cash value using the capital recovery factor. The sum of the annual cash flow would be

EUAC = 1, 00,000(A/p, 30%, 5) + 65000- 20000

EUAC = - 100000(.41058) + 45000 (The value .41058 is taken from 10.00 percent compound interest factor table)

EUAC = 3942

Since the resulting uniform annual cost value is positive. This robot project would be a good investment.

3. Return on Investment Method:

The return on investment is the expansion of ROI method. It is used to determine the return ratio of the current project, which is related to the anticipated expenditures and profits (estimated cost and revenues).

ROI = Total amount saving/Total investmentX100

The rate of return is then compared with the company's MARR to decide whether the investment is justified.

For Example

The company' MARR is 30%

Annual operating cost - Rs. 20,000

Annual revenue cost - Rs. 65,000

The robot project 5 Year service life.

Total investment cost (P)-Rs1, 00,000

Net annual cash flow (A)=Rs 65000- Rs 20000= Rs 45000

The rate of return rate = A/P = 45000/100000= .45

Percentage of rate of return = A/P X100 =.45X100 = 45%

Since the rate of return is greater than MARR, the project would be a good investment.

Model Questions

PART-A

1. List out robot application in Manufacturing.

2. What is material transfer?

3. What is pick and place operation?

4. List out any two machine loading and unloading operations.

5. List out material handling application.

6. What is machine loading and unloading?

7. List out requisite characteristics of robot.

8. List out non-requisite characteristics of robot?

9. What is future robotics?

10. List out various methods used in economic analysis of robot.

PART-B

1. Mention robotic application in manufacturing process industries.

2. Write short notes on Material transfer applications.

3. Write short notes on precaution for robots.

4. What are requisite characteristics?

5. What are non- requisite characteristics?

5. Write short notes on future robotics.

6. What is ROI method? Explain.

7. What is MARR in EUAC method?

8. Write short notes on pay back method.

9. Write short notes on EUAC method?

10. Write shot notes on safety in robotics.

11. List out the factors to be considered for the selection of robot.

PART-C

1. Explain material transfer in manufacturing industries with necessary diagrams.

2. Explain assembly finishing with neat diagram.

3. Explain in detail the stages for selecting robot for individual application.

4. Explain robot adaptability in work station with necessary diagrams.

5. Explain in detail the precautionary measures to be taken in industries for robot.

6. Explain any two methods of economic analysis used in robot.

7 Mention the stages to be considered in the selection of a robot.

8. Explain the procedure adopted in the selection of a robot.

9. Briefly explain the material handling application of robots.

10. Explain the requisite and non- requisite characteristics of a robot.

11. Explain future of robotics in detail.

12. Explain any two machine loading and unloading operation in detail.
