UNIT 2

COMPONENTS OF THE INDUSTRIAL ROBOTICS

SIA GROUP

PART-A
SHORT QUESTIONS WITH SOLUTIONS

Q1. What are the design considerations of a robot?

Answer :

Design Considerations of a Robot

A robot can be designed by considering the factors such as, system stiffness, natural frequency, system compatibility, etc along with the assumption of static and rigid body. The following are different design considerations of a robot.

System specification	Range, work envelope, load capacity and reach.
System configuration	Number of degrees of freedom, joint configuration, joint travel range and drive configuration.
System performance	Velocity and acceleration, repeatability, resolution, accuracy, and service life.
Design of major components	Robot structure, joints, actuators, transmission, wiring and routing of cables.

Q2. What is the work envelope of a robot?

Answer : Model Paper-IV, Q1(d)

Work envelope of a robot is a term that represents the space, in which the robot manipulator can position itself. It is also called as work space or work volume. It determines the space that can be swept by the manipulator. Robot manipulator while performing any task has to reach to a number of work pieces, fixtures, etc., without making any collision with them. Work envelope is determined by physical characteristics of the robot such as, its physical configuration, sizes of its components and limitations on its joint movements. Therefore, work envelope can be represented in terms of radial arm extension, vertical motion, degrees of rotation etc., and should be compatible with different paths and positions required in the application.

Q3. Define the term end effector.

Answer :

An end effector is an object fastened to the wrist or robot flange, in order to complete the required work. It is also called as Gripper or end-of-arm tooling. Examples: Grippers, Sensors, Tools, etc.

In some cases, it also acts as a tool holder and the robot should have the ability to adjust the tool to place it as per the position of workpiece or job. Some of the applications of end effectors are arc welding torch, spray painting gun, etc. They are also known as multi purpose devices and their design is based on shape or size of the part to be gripped, self weight and moment of inertia.

Q4. Write about the characteristics of end effectors.

Answer : Model Paper-II, Q1(d)

Characteristics of End Effectors

1. End effectors should have the ability to hold or release the components required, during the operation.
2. They should sense the existence of component in the gripper, with the aid of sensors.
3. They must be light in weight.
4. They should verify the presence of component in the holder during maximum acceleration, during the presence of tool plate and when the gripper or holder power is lost.

Q5. What function does end-of-arm tooling serve?

Answer :

End-of-arm tooling of a robot is also known as end effector or gripper. Variety of end effectors depending on the application are attached to the wrist of the manipulator. These range from pneumatic grippers to special tools for arc welding, spray painting, handling of silicon wafers in harmful environment. Some applications make use of customized end-effectors including additional components like force measuring devices, mechanical linkages, etc. The choice of end-of-arm tooling depends on the type of application. Following are the types of end-of-arm tooling and their intended purposes in the industry.

End-of-arm Tooling	Applications
Grippers	Material handling, machine loading and unloading, palletizing, etc.
Cutting tool	Machining
Welding torch	Welding
Spray gun	Painting
Screw driver	Assembly tasks

Q6. Classify different types of grippers.

Model Paper-I, Q1(f)

Answer :

Different types of grippers are given below,

1. Mechanical type grippers,
   - (a) Flat type
   - (b) V-block type
   - (c) Circular arc type.
2. Non-mechanical type grippers,
   - (a) Vacuum cup type grippers
   - (b) Magnetic grippers
   - (c) Adhesive grippers
   - (d) Expandable bladder type grippers.

Q7. State the important factors that have to be considered in determining the required grasping force.

Answer :

Factors to be considered in determining the required grasping force are,

1. Weight of the object to be grasped and ability to withstand development of moments.
2. Speed and acceleration of the robot arm.
3. Relation between the direction of movement and the gripper position.
4. Use of friction or any type of physical construction required to hold the object.
5. Coefficient of friction existing between the object and the gripper.

Q8. List the basic types of end-of-arm tooling and state the advantages of multi-gripper system.

Answer :

Basic Types of End-of-arm Tooling

1. Attachment devices.
2. Supporting and holding devices.
3. Pneumatic pick-up devices.
4. Magnetic pick-up devices.
5. Mechanical grasping devices.

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Advantages of Multi-gripper System

1. Minimum operation time.
2. Efficient usage of robot arms and controls.
3. Improved work cell capacity.

Q9. What are the advantages and disadvantages of vacuum cups.

Answer :

Vacuum Cups

Advantages

1. In vacuum cup gripper, pressure is distributed uniformly on the surface of the part.
2. It requires only one surface of the object for grasping.
3. It is relatively light in weight.
4. It is applicable to a wide range of materials.

Disadvantages

1. It takes more time to create vacuum in the cup.
2. It is not applicable for curved surface components.
3. The maximum force to be applied depends on size of suction cups.
4. The positioning of workpiece or component may not be accurate.

Q10. Differentiate between pneumatic and hydraulic drive systems.

[Nov-11, Set-3, Q2(b) Model Paper-II, Q1(g)]

Answer :

The differences between pneumatic and hydraulic drive systems are as follows,

	Pneumatic Drive System		Hydraulic Drive System
1.	The accuracy and repeatability of pneumatic drive system are relatively less	1.	The accuracy and repeatability of hydraulic drive system are moderate.
2.	This drive system requires less floor space.	2.	This drive system requires more floor space.
3.	It is ideally suited for both rotation and linear motions.	3.	It is ideally suited for translation or rotational motions.
4.	It is generally employed in smaller robots, limited to "pick-and-place" operations.	4.	It is usually employed in larger robots.

PART-B

ESSAY QUESTIONS WITH SOLUTIONS

2.1 FUNCTION, LINE DIAGRAM REPRESENTATION OF ROBOT ARMS, COMMON TYPES OF ARMS, COMPONENTS, ARCHITECTURE, NUMBER OF DEGREES OF FREEDOM

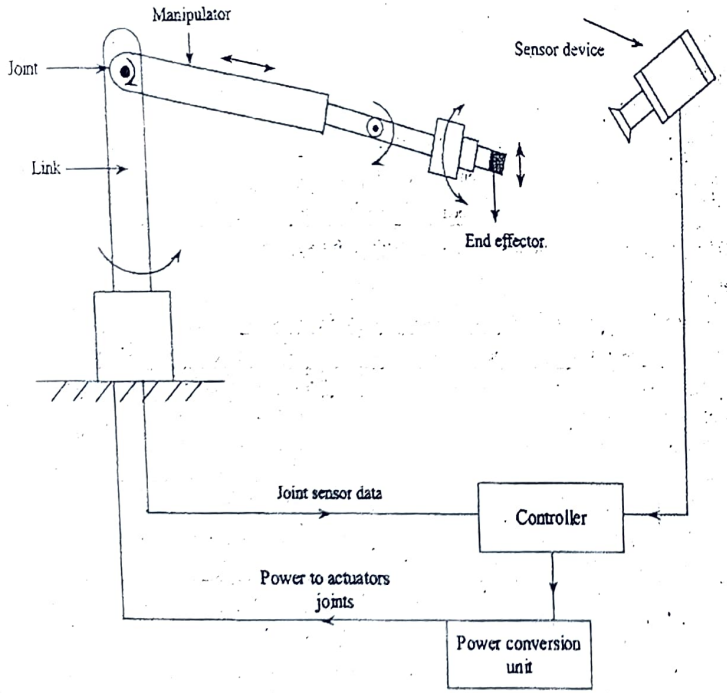
Q11. With the help of line diagram, show the basic components of a robot connected to a system.

[May/June-14, Set-2, Q2(b) | Model Paper-I, Q6(a)]

Answer :

The basic components of a robot connected to a system are,

1. Manipulator
2. Sensor devices
3. Controller
4. Power conversion unit.



1. **Manipulator**

It mainly consists of major links, minor links and end effector. The manipulator arm has the major and minor links, of which free end is provided with an end effector. This arm is positioned on the fixed base or movable base. The major links are referred as robot body and they help the end effector to move at required location. While, the minor links are referred as wrist or robot flange, which enables location of manipulator end points.

2. **Sensor Devices**

They are used to govern further actions of both manipulator arm and end effector, by providing a feedback signal. They are classified as,

(a) **Tactile Sensors**

These are also called contact sensors, which are held in physical contact with the body to receive signals; in order to determine the required parameters.

Examples: Force sensors, torque sensors, position sensors, etc.

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(b) **Non-tactile Sensors**

These are also called contactless sensors, which are used to obtain signals, by means of remote controller, within limited distances from the object.

Examples: Electro-optical sensors, proximity sensors, ange sensors, etc.

3. **Controller**

It is a device, which controls the manipulator system. The signals obtained from sensors are fed to controller, which decodes these signals and direct the actuator to perform the task accordingly. Control system comprises of,

(a) Memory storage
(b) Computational unit
(c) Hardware, that receives signals from sensors and feed them to actuator.
(d) User interface, which enables an operator to control the operation of robot.

4. **Power Conversion Unit**

It is an assembly of components, which is used to convert the digital signal to machine level program, by which actuators can be operated.

Q12. Define robot anatomy. Explain common types of robot arms.

Model Paper-III, Q3(a)

Answer :

Robot Anatomy

Robot anatomy deals with the study of physical construction of a robot's structural parts such as body, arm and wrist. The body linked with arm assembly is connected to the base and wrist is provided at the end of arm. Series of joints are used to have relative motion (either rotating or sliding motion) between different components of body, arm and wrist. Also, assembly of body, arm and wrist may be referred as manipulator.

Types of Arms

1. **Cartesian Robot**

Cartesian robot has simplest configuration with prismatic joints. The work envelope of Cartesian robot is cuboidal. It has large work volume, but low density. It consists of three linear axes, as shown below.

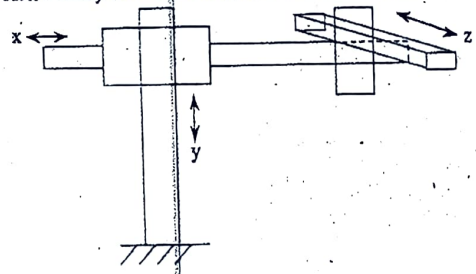


Figure: Cartesian Robot

2. **Cylindrical Robot**

Cylindrical robot makes use of two perpendicular prismatic joints and one revolute joint. The work envelope of a cylindrical robot approximates to a cylinder. It consists of two linear and one rotary axes.

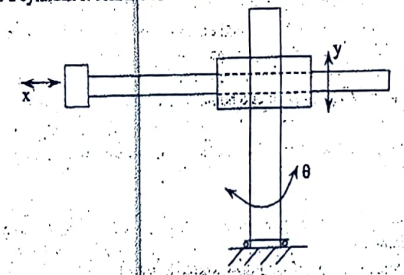


Figure: Cylindrical Robot

3. **Polar Robot**

Polar robot consists of a rotating base and a telescopic link which can be raised or lowered about a horizontal revolute joint. It has a work envelope of a partial spherical shell. It consists of one linear and two rotary axes.

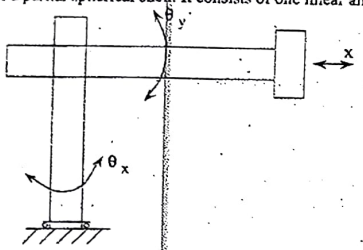


Figure: Polar Robot

4. **Anthropomorphic Robot**

Anthropomorphic robot is also known as articulated robot, jointed-arm robot or revolute robot. It functions similar to the human arm. It consists of two straight links, similar to human forearm and upper arm. These two links are mounted on a rotary table and possess a work envelope of spherical shape. It is the most efficient type of arm, since all the joints are revolute joints i.e., it consists of three rotary axes.

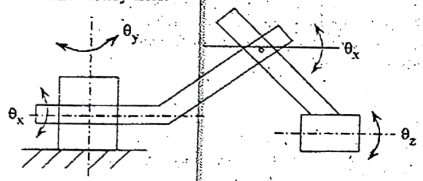


Figure: Jointed-arm Robot

Q13. What are the different types of joints used in robots? Give the degrees of freedom associated with each joint.

[Nov.-10, Set-1, Q2(b) | Model Paper-IV, Q3(b)]

Answer :

The different types of joints used in robots are,

1. Prismatic joint (linear motion)
2. Revolute joint (rotational motion)
3. Screw joint (linear and rotational motion)
4. Spherical joint
5. Planar joint
6. Cylindrical joint
7. Twisting joint.

1. **Prismatic Joint (Linear Motion)**

Prismatic joints are also called sliders, constituting purely linear motion along the joint axis. The joint slides in either directions along a singular axis. This type of motion is common in hydraulic or pneumatic cylinders. Since, there is no rotation. The degree of freedom is one (i.e., translation).

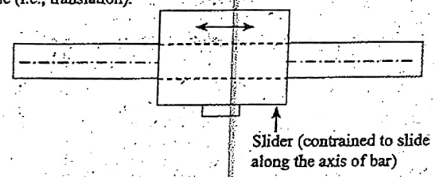


Figure: Prismatic Joint

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2. **Revolute Joint (Rotational Motion)**

Revolute joints constitute purely rotational motion along the joint axis. These joints are most commonly found in industrial robots. The degree of freedom is one and there is no translation motion.

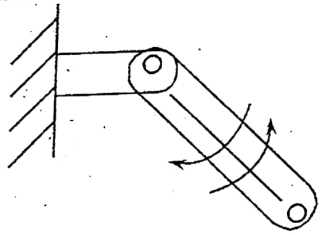


Figure: Revolute Joint

Examples

Elbow joint, waist joint.

However, most revolute joints cannot rotate completely i.e., a full 360°, as they are mechanically constrained.

3. **Screw Joint (Linear and Rotational Motion)**

Screw joints are a combination of two types of joints i.e., they constitute a simultaneous rotation and linear motion along a joint axis. These joints are more often used in tools for a robot end effector, rather than a joint of motion for a robot. This joint follows the thread of a screw, to move along axis.

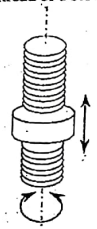


Figure: Screw Joint

4. **Spherical Joint**

Spherical joints are most utilized joints and they possess a revolving movement about a point, as shown in below.

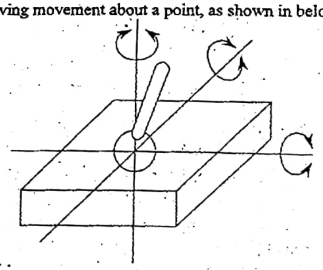


Figure: Spherical Joint

5. **Planar Joint**

It consists of three degrees of freedom, as shown in the figure i.e., one rotary and two sliding motions.

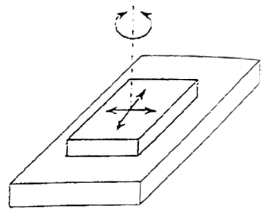


Figure: Planar Joint

6. **Cylindrical Joint**

It consists of two degrees of freedom, as shown in the figure i.e., one rotary and one sliding motion.

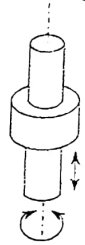


Figure: Cylindrical Joint

7. **Twisting Joint**

It consists of single degree of freedom, as shown in the figure.

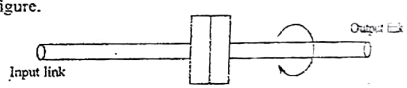


Figure: Twisting Joint

Q14. Explain resolution, payload, repeatability and accuracy of a manipulator.

Answer :

Precision of movement is a measure of dynamic performance of the robot which is concerned with the response speed and stability of the robot. Therefore, precision of movement of a robot is a function of features like spatial resolution, accuracy and repeatability.

Spatial Resolution

It is the smallest increment in the movement of robot joints. The work volume of the robot is often divided into these increments. Spatial resolution is dependent on two factors i.e., control resolution of the robot's position control system and mechanical inaccuracies of the robot. Control resolution is determined by the position control system and its feedback measurement system, while mechanical inaccuracies in joints and links of the robot are caused by elastic deflection of structural members, leakage of hydraulic fluids, gear backlash etc.

Accuracy

The ability of a robot to position its wrist end at a required point within its work volume refers to the accuracy of the robot. Accuracy can also be defined in terms of spatial resolution because, the ability to reach a desired point depends on the control increments of the joints movement. Factors such as work volume, mechanical errors and the load to be carried by the robot effects the accuracy of manipulator.

Repeatability

The ability of a robot to position its wrist end at the same point in a space continuously refers to the repeatability of a robot. It differs from accuracy, as it is the ability to return to a programmed point. When desired robot does not return to the same point on subsequent repetitions, a cluster of points on both sides of the specified point is formed, giving rise to repeatability errors.

Payload

The weight that a robot can carry, while remaining within its other specifications is known as payload. Payload of a robot is different from the weight of the robot and is usually very small, compared to the robot's weight. Maximum weight carried by the robot is usually specified at low or normal speeds. Higher payload capacity of a robot can be obtained by compensating the other specifications such as, maximum speed, accuracy and acceleration. Payloads for very large robots ranges about several hundred kilograms.

Q15. Define "degrees of freedom". Give line diagram of a cylindrical robot indicating the relative motions of its joints. Determine its total degrees of freedom.

Answer : [Nov.-10, Set-2, Q2(b) | Model Paper-II, Q2(a)]

Degrees of Freedom

Degrees of freedom are the number of independent motions that a body can undergo in a three dimensional space. A rigid body free to move in space has six degrees of freedom i.e., three translations and three revolutions. A manipulator with six degrees of freedom is known as a spatial manipulator. Among these six degrees of freedom, three are utilized for positioning the end-effector and the remaining three for proper orientation of end effector.

However, there are many manipulators that do not have full six degrees of freedom. Since, not all the tasks require six degrees of freedom, a large percentage of existing industrial robots possess 5 *DOF*. Also, symmetrical parts reduce the required number of degrees of freedom of the manipulator.

Example

Cylindrical parts can be picked up and placed, independent of gripper orientation with respect to the cylinder axis. Spatial manipulators having more than 6 DOF with surplus joints are known as redundant manipulators. These extra degrees of freedom enhance the robot's capability in reaching the sub-spaces obstructed by objects around them. Depending on the application, the types and arrangement of the robot manipulator varies considerably.

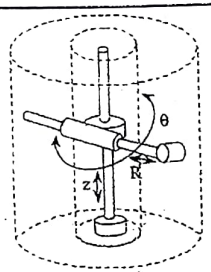


Figure: Cylindrical Robot

As shown in the figure, cylindrical robots are made up of two prismatic joints and a revolute joint, which enables, three degrees of freedom i.e., two linear motions and one rotational motion. The work volume of a cylindrical robot is a cylinder, as shown by dotted lines. The following are the three relative motions of the joints,

1. Radial in or out translation (R) of the horizontal arm.
2. Angular motion (θ) about the vertical axis.
3. Upward or downward motion of the carriage in the z-direction.

Q16. Give line diagram of a polar coordinate robot and show the associated degrees of freedom and work volume.

Answer : [Nov.-10, Set-4, Q2(a) | Model Paper-I, Q7(b)]

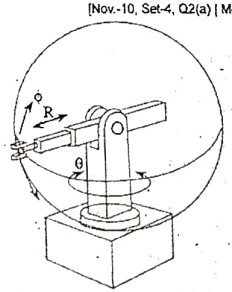


Figure: Polar Coordinate Robot

As shown in the figure, polar coordinate robot is made up of rotary or rectangular base, an elevated pivot and a telescopic arm which moves in and out i.e., it consists of two revolute joints and one prismatic joint. This robot has one linear and two angular motions. Hence, it is associated with the following three degrees of freedom,

1. Radial in or out translation (R)
2. Angular rotation (θ) about the vertical axis
3. Angular rotation (ϕ) about the axis perpendicular to vertical axis.

The work volume of a polar coordinate robot is a sphere. Hence, it is also known as spherical robot.

Q17. Give line diagram of a Cartesian robot indicating various joints and their relative motions. Determine the total degrees of freedom of the robot. Show its work volume.

Answer : Nov.-10, Set-3, Q2(a)

Cartesian Robot

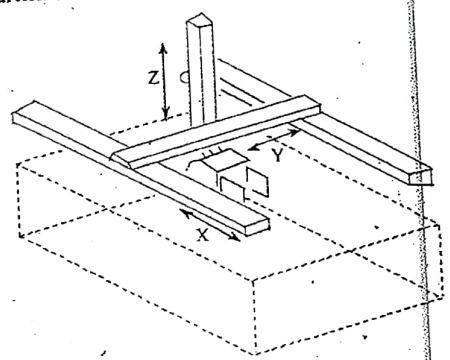


Figure: Cartesian Robot

As shown in the figure, cartesian robots are made up of three prismatic joints and hence, gives only linear motions along the three principal axes (X, Y, Z). Therefore, it has three degrees of freedom (x, y, z) in translation only.

The volume of space swept by the robot is known as work volume and it is a cuboid for cartesian robot, as shown by dotted lines.

The commonly used configurations for Cartesian robots are,

1. Gantry-type robot
2. Robot with slideway mounted arm.

Q18. Describe a 6 degree of freedom robot with a neat sketch.

Answer :

6-Degree of Freedom Robot

A robot with six degrees of freedom is used for various industrial purposes. It is based on a computer controlled manipulator, which comprises of various rigid links connected in series by either prismatic or revolute joints. PUMA and Cincinnati milacron are the examples of 6-D.O.F. robots.

PUMA Robot with 6-D.O.F

The six degrees of freedom or the motions of a PUMA robot are,

(i) Vertical motion
(ii) Radial motion
(iii) Rotational motion
(iv) Rolling motion
(v) Yaw motion
(vi) Pitch motion.

(i) Vertical Motion

The arm of the robot can be raised or lowered vertically by either turning around the horizontal axis or by sliding along the vertical axis.

(ii) Radial Motion

The radial motion of the robot arm is provided at the elbow, i.e., stretching out and pulling back actions. It is referred as elbow extension.

(iii) Rotational Motion

The rotational motion is obtained at the arm, by rotating it in either clockwise or counter clockwise direction. It is also called as arm sweep.

(iv) Rolling Motion

The rolling of the arm imparts this motion. It is also known as wrist swivel.

(v) Yaw Motion

The movement of arm in left or right direction provides the yaw motion. It is also called as wrist yaw.

(vi) Pitch Motion

The movement of wrist in upward and downward directions provides the pitch motion. It is also called as wrist bend.

All these motions are utilized to perform the tasks. A typical PUMA robot is shown in figure below.

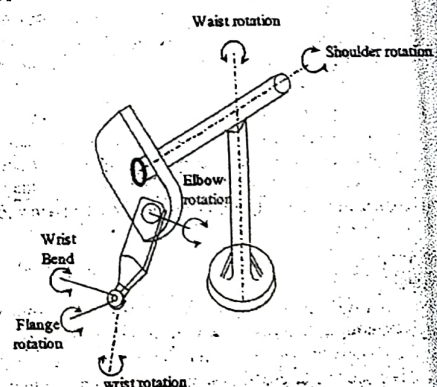


Figure: PUMA Robot with Six D.O.F.

2.2 REQUIREMENTS AND CHALLENGES OF END EFFECTORS, DETERMINATION OF THE END EFFECTORS, COMPARISON OF ELECTRIC, HYDRAULIC AND PNEUMATIC TYPES OF LOCOMOTION DEVICES

Q19. What is an end effector? Explain different types of grippers.

Answer : Nov.-11, Set-3, Q2(a)

End Effector

An end effector is a component, which is attached to the robot's wrist, to enable completion of tasks like gripping, cutting, painting, etc. It is also called as gripper or end-of-arm tooling.

Types of End-effectors

End-effectors are categorized into three types,

(i) Grippers
(ii) Tools
(iii) Universal fingers.

(i) Grippers

Grippers are used to hold either work parts or tools. These are further classified as,

(a) Mechanical grippers
(b) Suctions or vacuum cups
(c) Magnetized grippers
(d) Hooks
(e) Scoops or ladles
(f) Adhesive or electrostatic gripper.

Depending on application, grippers are selected, such as hooks for lifting purpose, scoops for fluids, magnetic grippers for ferrous materials, etc.

(ii) Tools

"Tools" are fastened directly to the robot wrist and they act as end-effectors.

(a) Machine Tools

Robot with tools as end effector can also be used as machine tools, to perform various operations. Examples are,

- Drills
- Grinding wheels
- Cutters
- Sanders.

(b) Measuring Instruments

These end effectors allow the robot to precisely measure parts by moving the arm over the part. Example: Measuring probe.

(c) Welding Torche

It is an end-effector that allow robot to weld parts together.

(d) Laser and Water Jet Cutters

These are the end-effectors, that use high intensity laser beams or high pressure abrasive water jets, to cut metal sheet or fiber glass to shape.

(iii) Universal Fingers

These grippers have been initiated to imitate a human hand, which has many degrees of freedom. This requires miniature actuators, that can produce enough power to drive the gripper joint. It consists of cable and pulley mechanism, that enables a motor to be placed at an appropriate position away from the joint.

Q20. What is a gripper used in robots? What are the considerations to be made in the selection and design of grippers?

Nov.-10, Set-1, Q2(a)

Answer :

Grippers

Gripper is a device, which is used to hold either work parts or tools.

Considerations in Gripper Selection and Design

The considerations of to be made in the design and selection of grippers are as follows,

1. The object to be grasped by the gripper should be reachable i.e., it should not be enclosed in any kind of holding fixtures.
2. Variation in sizes of the objects should be considered and its influence on the function of locating the object must be analysed.

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3. Similarly, change in size of the object occurring between loading and unloading, as seen in machining and forging operations must be taken into consideration.
4. Scratching, distorting or causing any damage to the object during gripping may cause severe problems in handling of fragile and delicate objects.
5. Better control and stability in positioning an object is achieved, if there is a larger surface contact with the object. Therefore, if there exists a choice among different dimensions on a part, larger dimension should be given preference.
6. Self-aligning fingers must be used, wherever possible, as these enable more grip. Also, to compensate wear and allow interchangeability, replaceable fingers should be preferred.

Q21. Explain the basic definition and operation of mechanical grippers.

Answer :

Mechanical gripper is a type of end-effector that consists of mechanical fingers to grasp an object. These mechanical fingers or jaws are the extensions of the gripper, which makes contact with the object to be lifted. The gripper uses suitable mechanism along with detachable or integral fingers to serve the desired purpose. Grippers can be designed to accommodate any number of fingers. However, two fingers are generally sufficient to hold the object.

Gripper mechanism is operated by the power input from the robot i.e., pneumatic, electrical, hydraulic, mechanical, etc. It must be able to exert sufficient force required to hold the part and must open and close fingers whenever required.

To hold the part with fingers, there are two general ways, they are physical constriction of the part between the fingers and holding with the help of friction. In the first approach, the part is enclosed in the gripping fingers, by designing the finger surface to be of approximate shape of the part geometry. In the second approach, friction between the fingers and the part is utilized for holding or gripping. The force applied by the fingers must be sufficient for friction to hold the part against gravity, acceleration etc.

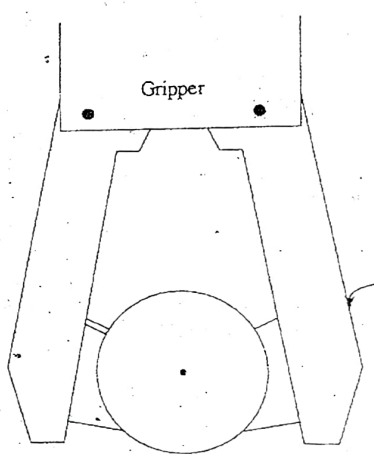


Figure (1): Physical Constriction Method

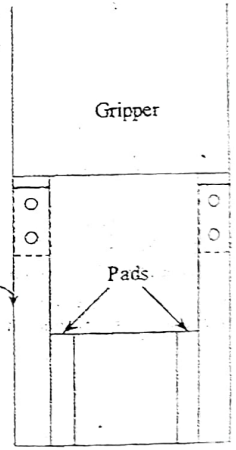


Figure (2): Friction Method

Q22. Explain the classification of mechanical grippers according to the type of actuators for finger movement.

Answer : [Nov.-11, Set-4, Q2(a) | Model Paper-II, Q2(a)]

Mechanical Grippers

It is an end-effector used to grasp an object, by means of mechanical fingers.

The mechanical grippers are classified according to the type of finger movement as,

1. Pivoting or swinging movement
2. Linear or translational movement.

1. Pivoting or Swinging Movement

In pivoting or swinging movement, the fingers are rotated about a fixed pivot axis. The various swinging grippers are rotary actuator gripper, screw type actuated gripper, etc.

(a) **Rotary Actuator**

In this, the actuator is placed at the cross point of two fingers as shown in figure.

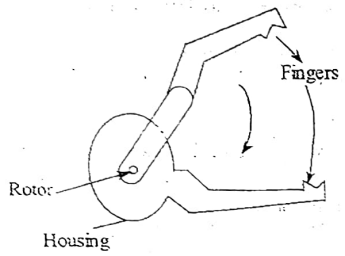


Figure: Rotary Actuator

The two fingers are connected to rotor and housing of an actuator respectively. Thus, the finger movement directly enables grasping and releasing operation.

(b) **Screw Type Actuated Gripper**

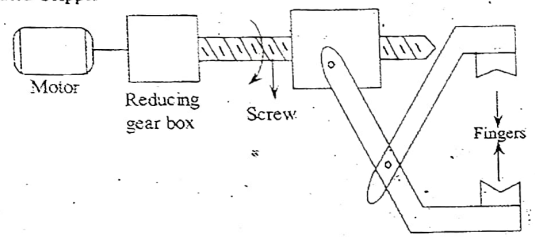
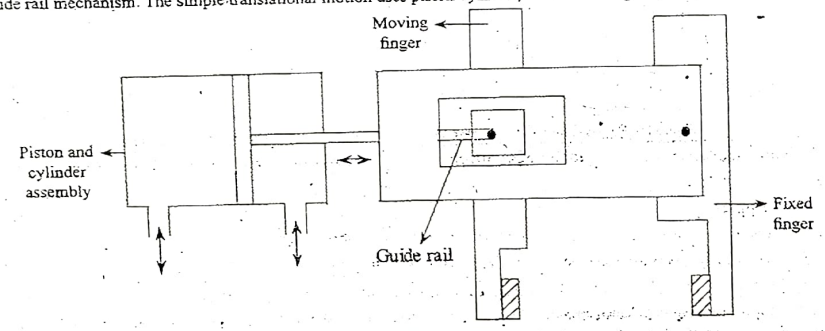


Figure: Screw Type Actuator

In screw type actuation, the screw is turned by a motor through speed reduction mechanism. Due to this rotation, the threaded block moves, causing fingers to perform grasping and releasing action.

2. **Linear or Translational Movement**

In linear movement, the grasping and releasing action takes place by moving left finger parallel to a fixed finger, through a guide rail mechanism. The simple translational motion uses piston-cylinder, as shown in figure below.



Figure

When the piston rod moves towards right, the finger slides along a guide rail and produces the grasping action, whereas, the release action occurs when the piston moves towards left.

Q23. Sketch and explain general linkage mechanisms with an example.

May/June-14, Set-4, Q2(a)

Answer :

Linkage Mechanisms for Mechanical Grippers

Some of the commonly used linkage mechanisms for mechanical grippers are as follows,

(i) Linkage actuation mechanism
(ii) Cam actuation mechanism
(iii) Screw actuation mechanism
(iv) Rack and pinion actuation mechanism.

(i) **Linkage Actuation Mechanism**

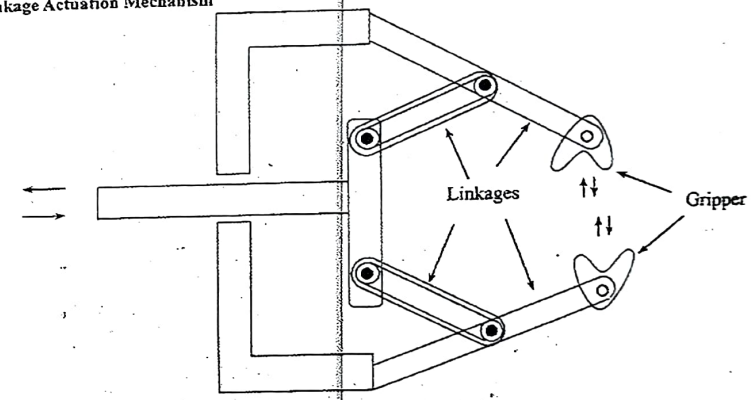


Figure (1): Linkage Actuation Mechanism

Linkage actuation mechanisms are designed based on gripping force, maximum capability of a finger to open and time required for actuation of gripper. At lower actuating force, higher gripping force can be obtained by various linkages. Opening width of gripper and gripping speed usually depends on the linkage configuration. In this, the forward and backward movement of linkages causes opening and closing of gripper respectively. A typical linkage mechanism is shown in figure (1).

(ii) **Cam Actuated Mechanism**

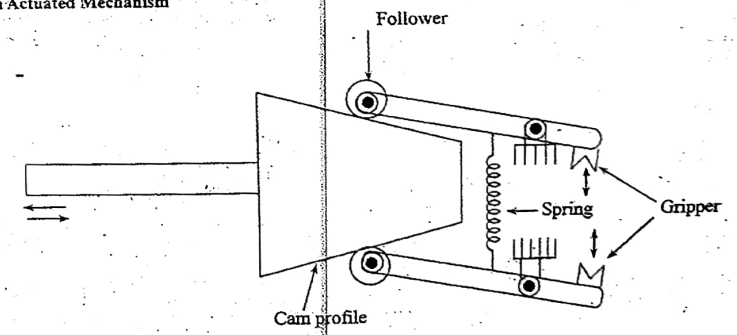


Figure (2): Cam Actuation Mechanism

In cam actuated mechanism, the opening and closing action of grippers is achieved by the spring loaded follower. Due to spring action, the gripper is forced to grasp and release the object depending upon the movement of cam, as shown in figure (2). A wide range of designs are possible for opening and closing the gripper. It is commonly used for holding various work parts of different sizes.

(iii) Screw Actuation Mechanism

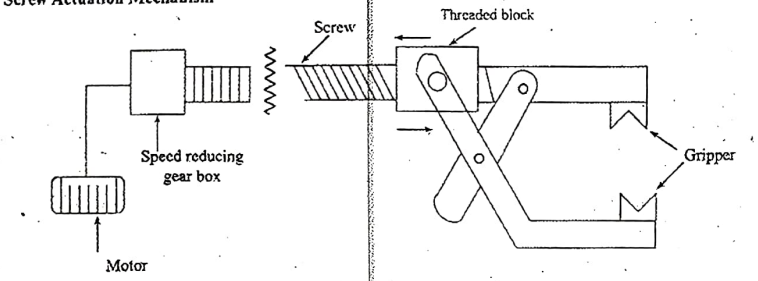


Figure (3): Screw Actuation Mechanism

A screw actuated mechanism is shown in figure (3). It consists of a threaded block, positioned on a screw, which is attached to a motor through speed reducing gear box. Threaded block is connected to the gripper with the help of levers. Due to the rotation of screw by the motor, threaded block tends to move either in forward direction or backward direction, depending upon the rotation of screw. This results in opening and closing action of gripper.

(iv) Rack and Pinion Actuation Mechanism

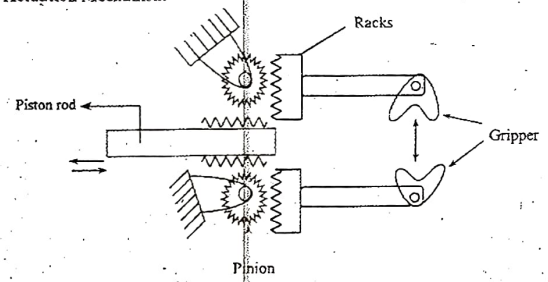


Figure (4): Rack and Pinion Mechanism

In rack and pinion mechanism, the gear and racks are connected with the help of a piston, which provides linear motion. Due to this motion , two pinion gears are driven, which in turn drives the racks. Thus, opening and closing of grippers is accomplished. In this mechanism, the pinion gears are fixed, but the piston moves, as shown in figure (4).

Q24. Explain in detail about two point and three point grippers.

Answer :

Two-point Gripper

Two point gripper is the basic model of end effectors. This type of mechanical gripper is mostly suitable for industrial robots. Two fingured grippers are generally sufficient to hold most of the objects, especially cylindrical objects. There are various gripping mechanisms to actuate the two point grippers to hold or release the object. One of the mechanisms is as follows,

Rotary Actuated Translation Gripper Mechanism

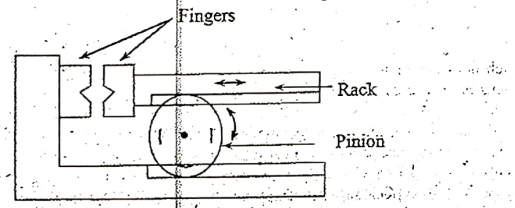


Figure (1): Rotary Actuated Translational Gripper

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Rotary actuated translation gripper consists of two racks, which develop a linear motion due to rotational movement of pinion. As the pinion starts rotating, the movable rack is actuated in forward and backward direction depending upon the direction of rotation of pinion. The pinion gear moves in both clockwise and anticlock wise direction, as shown in figure (1).

Three-point Gripper

To obtain higher gripping capability on the workpiece and to increase the degree of freedom, three finger mechanical grippers are used. The main purpose of using three finger gripper is to improve versatility of gripping and to hold spherical objects of different sizes. The centre of spherical objects can be placed at desired position by using three finger gripper, as shown in figure (2).

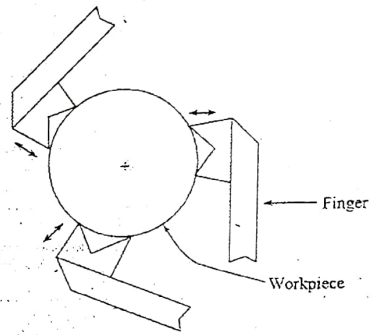


Figure (2): Three-point Gripper

Three-point gripper consists of a specially designed three point chuck for this purpose. The fingers can move either independently or together in a straight or curved path towards the centre, as required. Usually, the fingers are placed at an angle of 120° from each other. The fingers are driven by an electric motor through a screw and bevel gear mechanism. The holding or releasing action is obtained by its translational motion, depending upon rotational direction of screw.

Q25. What is a compliant gripper? Why are complaint fingers used?

Answer :

Compliant Gripper

A device which does not require any assembly and has no kinematic joints is termed as compliant gripper (or one-piece device). They are employed as end effectors in robots, to hold the work parts or tools during an operation. In this type of gripper, due to the absence of wear and backlash, the input displacement or force can be effectively converted into an output. They are used in applications like nano-scale manipulator, precise tools, etc.

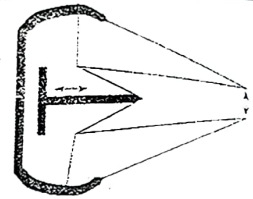


Figure: Compliant Gripper

Advantages

Compliant fingers or grippers are used due to its following advantages.

1. Position sensing is easily possible through an inductive proximity switch.
2. Easy installation at any desired position.
3. Continuous adjustable strokes can be obtained.
4. It is highly reliable and gives long service life.
5. It is simple in construction, compact in design and has less weight.

Q26. Describe about vacuum grippers and magnetic grippers.

Answer : (Nov.-10, Set-3, Q2(b) | Model Paper-IV, Q6.)

Vaccum Cups

Vacuum cups also known as suction cups can be used as grippers to handle objects of certain types like glass. These cups grasp the object by creating a vacuum between the cup and the object. Objects to be handled by vacuum cup should be smooth, flat and clean.

Vacuum cup is usually round in shape and consists of some source of removing air between the cup and part surface to create the required vacuum. Vacuum pumps and venturimeters are the two most common sources of creating vacuum. Venturimeter is a simple device and its initial cost is less than vacuum pump. The lifting capacity of the cup depends on the effective cup area and the negative air pressure existing between the cup and the object to be handled.

Lifting capacity, $F = P \times A$

Where,

F – Negative air pressure

A – Effective cup area.

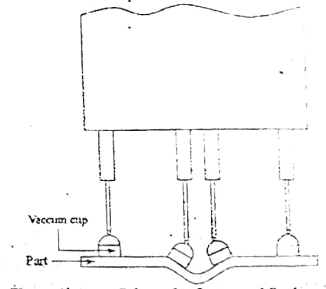


Figure: Vacuum Gripper for Contoured Surface

Magnetic Grippers

Magnetic grippers are widely used for handling all ferrous materials, except stainless steel, as it does not get attracted towards the magnet. Generally, magnetic grippers are classified into two types as given below,

1. Magnetic grippers using permanent magnets
2. Magnetic grippers using electromagnets.

From the above two, electromagnetic grippers are easy to control, but requires a source of D.C power and a suitable controller unit, whereas, permanent magnet grippers does not require any external power and hence, they can be used in hazardous and explosive environments. By using electromagnets, the chances of residual magnetism in the workpiece can be reduced with the help of controller unit, which reverses the polarity.

The following are some of the advantages of magnetic grippers,

1. Any change in the size of the parts can be readily acceptable
2. The time required for grasping the objects is relatively less
3. Generally, single surface is required for holding the objects
4. It is also possible to hold the metal parts with holes.

However, the main disadvantage of magnetic grippers is that, it is difficult to pickup single sheet from the stack.

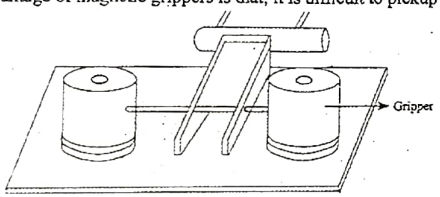


Figure: Electromagnetic Grippers

Q27. Compare pneumatic, magnetic and vacuum end effectors.

Answer : [April/May-13, Set-2, Q7 | Model Paper-III, Q4(b)]

	Pneumatic End-effectors		Magnetic End-effectors		Vacuum End -effectors
1.	It is a gripper mechanism, which converts pneumatic power input into grasping action against the object.	1.	It is employed for handling of ferrous materials.	1.	It is also known as suction cup and is used mainly for handling certain type of objects like glass.
2.	In this mechanism, the coefficient of friction increases between the object and finger surfaces due to pneumatic power.	2.	It uses the principle of electro-magnetism.	2.	It uses vacuum pump to create pressure difference.
3.	It uses mechanical clamping for scooping or ladling powders, plastics or molten metal.	3.	It transfers only shafts or chips.	3.	It transfers only flat, smooth and clean objects such as, sheets of glass, plastics or thin sheets of papers.
4.	The change in the size of an object is acceptable with additional equipment.	4.	Any change in the size of part or object can be readily acceptable.	4.	The change in size is not acceptable.
5.	The time required for grasping an object is less compared to vacuum end effector.	5.	The time required for grasping is relatively less, when compared to pneumatic and vacuum end effectors.	5.	The time required is more than other end effectors.
6.	It requires all the surfaces for holding the object.	6.	It requires only single surface for holding the object.	6.	It also requires the single surface for grasping an object.
7.	It can handle the parts with holes.	7.	It can also handle the metal parts with holes.	7.	It is not possible to handle the parts with holes.
8.	The weight of this end-effector is more compared to vacuum end-effector.	8.	The weight of magnetic end effector is more compared to pneumatic end effector.	8.	It is relatively light in weight compared to pneumatic and magnetic end effectors.

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Q28. Mention the applications of the following types of grippers,

(i) Vacuum cups

(ii) Magnetic grippers

(iii) Adhesive grippers

(iv) Scoops.

Answer : Nov.-11, Set-2, Q2(a)

Applications

(i) Vacuum Cups

1. It is used for handling perforated sheets, rough metal sheets and sheet metal parts.
2. It is used for handling special types of objects like glass.

(ii) Magnetic Grippers

1. It is used for handling ferromagnetic work pieces.
2. It is used for handling complex laser-cut workpieces and also metal sheet with holes.

(iii) Adhesive Grippers

1. It is used to lift fabrics and light weight materials.
2. It is used, where the component to be handled must be gripped on one surface or side only.

(iv) Scoops

1. Scoops are used to handle certain material in powder or liquid form like food materials, granular substance or molten metals etc.

Q29. Explain,

(i) Adhesive grippers

(ii) Robot drive system.

Answer : Nov.-10, Set-4, Q2(b)

(i) Adhesive Grippers

In this type of grippers, adhesive substances are used for grasping the object, by sticking to them. The basic requirement of the objects that are to be handled using this type of grippers are that, they must be gripped on one side only. The limitation of this type of gripper is that, the adhesive substance loses its stickiness with repeated use. This limitation can be avoided by loading the adhesive material in the form of a continuous ribbon that is attached to the robot wrist. This feeding mechanism is similar to a type writer ribbon mechanism. This type of grippers are generally used to handle fabrics and light weight materials.

(ii) Robot Drive System

Robot drive systems are the central elements employed for supplying power to the robots in order, to enable motion of various linkages and joints.

The following are the three types of robot drive systems which are available for industrial robots,

1. Hydraulic drive system
2. Electric drive system
3. Pneumatic drive system.

These drive systems are selected based on the power required, positional accuracy, repeatability, speed of operation, stability, reliability and other parameters.

1. Hydraulic Drive System

In this system, a hydraulic fluid is pumped through motors, cylinders or other hydraulic actuating mechanisms. The main advantage of hydraulic drive system is that, they provide higher levels of forces, power and speed with accurate control. The disadvantage of hydraulic drive system is that, they occupy larger floor space and there are chances of fluid leakage. This type of drive system is best suited in wet, dry and potentially explosive environments.

2. Electric Drive System

Electric drive system uses electric motors like A.C servo and D.C servo motors. Compared to hydraulic and pneumatic drive systems, electric drive systems provide high accuracy and faster response. This type of drive systems can be used repeatedly with low maintenance and are best suited for small robots with light pay loads. The main disadvantage of electric drive system is, it consists of electronic circuits or controls which may fail when exposed to high temperature, wet or dusty environments.

3. Pneumatic Drive System

Pneumatic drive system is driven by compressed air. This type of robot drive system requires less floor space and is cheaper than other drive systems. The payload carrying capacity and the speed of the motion is controlled by the compressibility and operating power of air. Generally, this type of drive system is used in pick-and-place robots.

Q30. What are advantages and disadvantages of the following robot drive systems?

(i) Hydraulic drive systems

(ii) Pneumatic drive systems.

Nov.-11, Set-2, Q2(b)

Answer :

(i) Hydraulic Drive Systems

The advantages and disadvantages of hydraulic drive systems are as follows,

Advantages

1. It is possible to generate very large forces directly at the required location.
2. Greater load carrying capacity than pneumatic and electric drive systems.
3. It uses accumulator to store hydraulic energy, which is used when there is a need of power.
4. Hydraulic driven robots can withstand shock loads.
5. It is possible to change velocities of displacements in a smooth manner.
6. It is especially used for painting since this drive systems are safe in intrinsic environment.

Disadvantages

1. Oil leakage is possible.
2. Mechanical supports are required for accurate displacements.
3. Variation of the fluid viscosity occurs due to temperature changes.
4. High installation and operating cost.
5. Requires more maintenance.

(ii) Pneumatic Drive Systems

The advantages and disadvantages of pneumatic drive are as follows,

Advantages

1. It is possible to generate very large forces.
2. It can be easily moved in any spatial locations.
3. Pneumatic systems are very safe, since, there is no risk of fire or explosion.
4. The initial cost of pneumatic system is very low.
5. High speed and accuracy can be obtained by these systems.

Disadvantages

1. Since air is compressible, it can be difficult to control speed and precision of a system.
2. It needs special auxiliary equipment.
3. Accuracy of pneumatic systems is poor at low velocities.
4. The output power of pneumatic systems is considerably less than that of other systems.

Q31. Discuss suitable design of robot end-effectors to grip objects like,

(a) Shafts

(b) Rings

(c) Flanges.

Answer :

The robot end-effector is a gripper or end-of-arm tooling attached to the robot arm (wrist of manipulator), to enable completion of the desired tasks.

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The general design considerations for end-effectors or grippers are as follows,

- Determine the weight , spacing and orientation of the object.
- Estimate the speed and acceleration with which robot's arm moves.
- Determine the coefficient of friction between the object and the gripper finger.
- Determine the foot print objects and spacing with the gripper jaw design.
- Determine the gripper stiffness and strength.
- The gripper must be designed to allow grasping of all objects.
- Grooved shapes are oftenly used to grip object likes, shafts, rings and flanges.

Design of V-Shaped Cavity

V-shaped grippers are used for handling cylindrical workpieces, since, they can accomodate a wide range of diameter variations in the workpiece. Figure shows a typical geometrical configuration of V-shaped gripper.

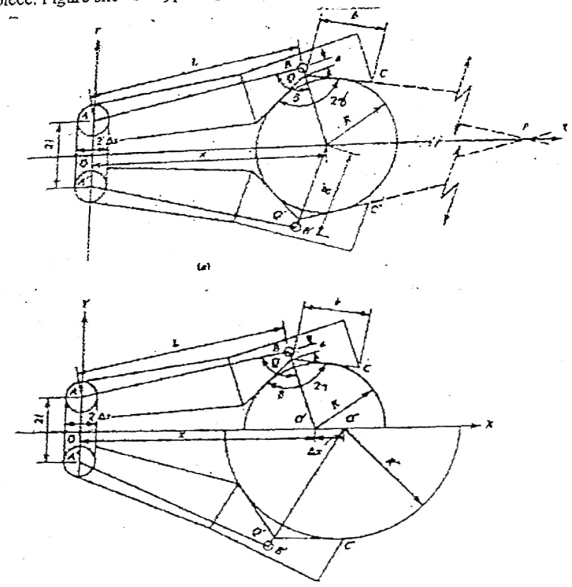


Figure: V- Shaped Gripper

During the gripping operation, each finger contacts the object at two points of the cavity. Let the parameter of grasping mechanism be r, B, R, L, l, a and b, as shown in figure.

Since, the cylindrical workpiece is grasped between the fingers of effector and the hand element cannot intersect, the following inequality exists.

i.e., $x - R < \Delta s$ ...(1)

Where,

x – Distance between the centre of object and origin 'O'

R – Radius of object

$\Delta s = \frac{1}{2}$ (width of hand element).

But, the distance 'x' is given by the equation,

$$x = \sqrt{\left[L^2 + \left(\frac{R}{\sin r} + a\right)^2 - 2L\left(\frac{R}{\sin r} + a\cos\beta\right)\right]} - l^2 \quad \text{... (2)}$$

For swinging movement of hand, the hand element is designed by keeping 'β' value constant.

If β= 90°, then,

$$x = \sqrt{L^2 + \left(\frac{R}{\sin r} + a\right)^2 - 2L\left(\frac{R}{\sin r}\right) - l^2} \quad \text{... (3)}$$

In translation hand, each block is kept parallel to other block.

i.e., $\angle B0'0 = 90°$

∴ From Figure,

$$\cos\beta = \frac{R' - l}{L} \quad \text{... (4)}$$

Where,

$$R' = \frac{R}{\sin r} + a \quad \text{... (5)}$$

Substituting equation (4) in equation (2),

$$x = \sqrt{L^2 - \left(\frac{R}{\sin r} + a - l\right)^2}$$

For the object to contact each finger at the two points the following inequality must be satisfied.

∴ $D < 2b \tan r$

Where, D – Diameter of object.