



CIS009-2, MECHATRONICS ROBOTIC ARMS & HANDS

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Outline

Mechatronics

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Robot Arms

Axes of motion

Degrees of freedom

Types

Design

Industrial
Applications

End effectors

Mechanical types

Suction type

Magnetic grippers

1 Robot Arms

Axes of motion

Degrees of freedom

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Mechatronics

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ROBOT ARMS



Robot Arms

Considering design specifications

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Robot Arms

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- Robots are designed for specific purposes. For this reason there are many configurations of robotic systems available.
- Key points for robot arm design
 - Manoeuvrability
 - Intricate movements
 - Ability to carry heavy loads
 - Speed



Axes of Motion & Degrees of Freedom

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Axes of motion

Degrees of freedom

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- Terms used when discussing robot geometry and specifications of robots.
- Both terms mean differently and should not be confused with each other.



Axes of motion

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Axes of motion

Degrees of freedom

Types

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End effectors

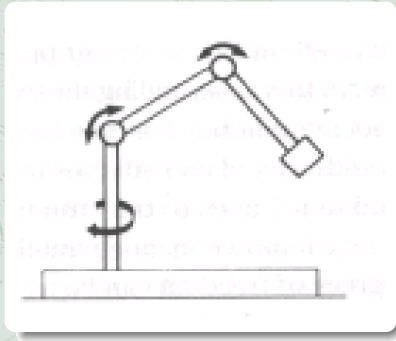
Mechanical types

Suction type

Magnetic grippers

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- Defines manoeuvrability.
- Defines complexity of robot program.
- Includes rotations and straight line movements.





Degrees of freedom

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Axes of motion

Degrees of freedom

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Types

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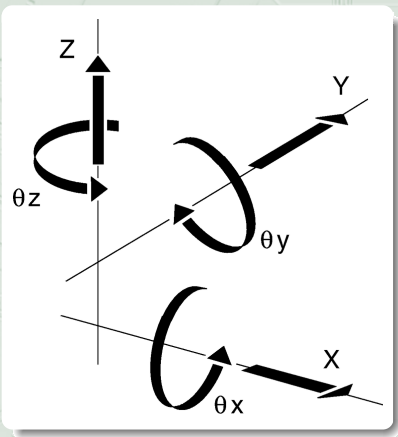
End effectors

Mechanical types

Suction type

Magnetic grippers

- The number of independent movements in which the end effector (tool or gripper) of the robot can move





Degrees of freedom

Example

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Axes of motion

Degrees of freedom

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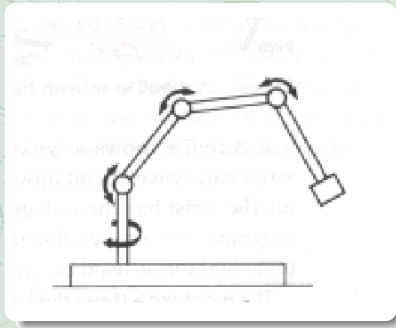
End effectors

Mechanical types

Suction type

Magnetic grippers

- A robot with four axes of motion but three degrees of freedom.
- Note that 3 degrees of freedom can allow a robot to place its end effector in any position but not at an angle.





Degrees of freedom

Adding more degrees of freedom

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Axes of motion

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Mechanical types

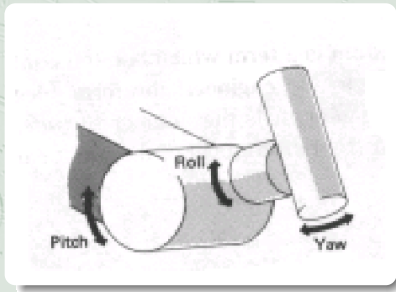
Suction type

Magnetic grippers

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- To increase the number of degrees of freedom in a robot we fit an end-effector on to the robotic arm. The end-effector is a mechanical wrist that allows for extra degrees of freedom.

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Joint Types

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Mechanical types

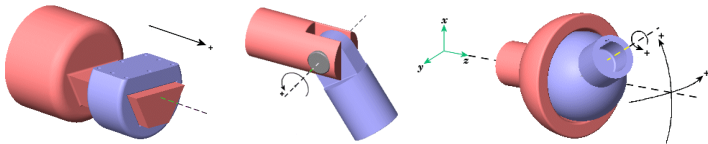
Suction type

Magnetic grippers

Prismatic joints in which the link is supported on a linear slider bearing, and linearly actuated by ball screws and motors or cylinders. One degree of translational freedom along a prismatic axis.

Revolute joints often driven by electric motors and chain/belt/gear transmissions, or by hydraulic cylinders and levers. One degree of rotational freedom about a revolute axis.

Spherical joints these are the third most utilized joint and just slide causing a revolving movement. Three degrees of rotational freedom about a pivot point.





Robot Arms

The different types of robot arms

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














Cartesian pick and place work, assembly operations, handling machine tools, arc welding.

Cylindrical assembly operations, handling machine tools, spot welding, diecasting.

Polar handling machine tools, spot welding, diecasting, fettling machines, gas welding, arc welding.

SCARA pick and place work, assembly operations, handling machine tools.

Articulated assembly operations, diecasting, fettling machines, gas welding, arc welding, spray painting.

Principle	Kinematic Structure	Workspace
 Cartesian Robot		
 Cylindrical Robot		
 Spherical Robot		
 SCARA Robot		
 Articulated Robot		

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Cartesian Robot Arm

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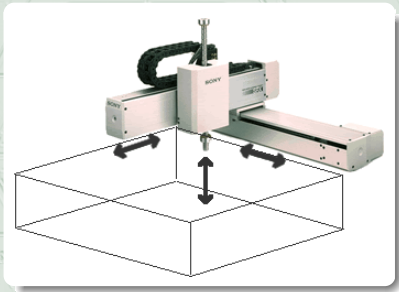
Mechanical types

Suction type

Magnetic grippers

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- “Cartesian” because the arm’s axes can be described by using the X, Y, and Z coordinate system. It is claimed that the cartesian design will produce the most accurate movements.
- Because of the highly rigidity, the Cartesian Robots are very accurate and repeatable but they lacks flexibility as they cannot reach around objects.
- Due to their mechanical structure, these robots are very easy to program and visualise





Cylindrical Robot Arm

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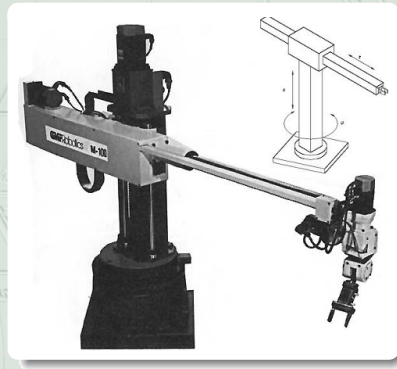
Mechanical types

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- A cylindrical arm also has three degrees of freedom, but it moves linearly only along the Y and Z axes. Its third degree of freedom is the rotation at its base around the two axes. The work envelope is in the shape of a cylinder.





Polar Robot Arm

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- The spherical arm, also known as polar coordinate robot arm, has one sliding motion and two rotational, around the vertical post and around a shoulder joint. The spherical arm's work envelope is a partial sphere which has various length radii.



- Polar robot is able to rotate in two different directions along his main axes and the third joint moves in translation forming a hemisphere or polar coordinate system.

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SCARA Robot Arm

Selection Compliance Assembly Robot Arm

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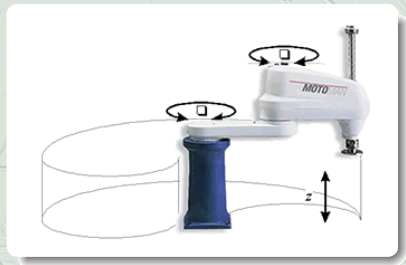
Mechanical types

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- Rotates about two axes, and some have sliding motion along another.
- By virtue of the SCARA's parallel-axis joint layout, the arm is slightly compliant in the X-Y direction but rigid in the 'Z' direction, hence the term: Selective Compliant.
- Due to their "elbow" motions, SCARA robots are also used for applications requiring constant acceleration through circular motions.



- One disadvantage is that it can be more expensive because the controlling software requires inverse kinematics for linear interpolated moves. The work envelope of the SCARA robot tends to be difficult to control, and restricted in volume coverage.

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Articulated Robot Arm

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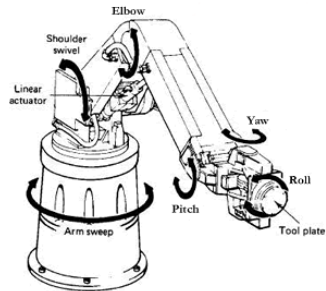
Suction type

Magnetic grippers

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- The arm has a trunk, shoulder, upper arm, forearm, and wrist. All joints in the arm can rotate, creating six degrees of freedom. Three are the X, Y, and Z axes, and pitch, yaw, and roll. Pitch is when you move your wrist up and down. Yaw is when you move your hand left and right. Roll is rotating your entire forearm.

- Very flexible with the ability to reach over obstructions. Achieve any position and orientation within the envelope.
- Disadvantage: Difficult to control.



- Motion from one point to another can be difficult to visualise as the robot will move each joint through the minimum angle required.



Accuracy & Repeatability

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Axes of motion

Degrees of freedom

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Accuracy How close does the robot get to the desired point? When the robot's program instructs the robot to move to a specified point, it does not actually perform as per specified. The accuracy measure such variance. That is, the distance between the specified position that a robot is trying to achieve (programming point), and the actual X, Y and Z resultant position of the robot end effector.

Repeatability The ability of a robot to return repeatedly to a given position. It is the ability of a robotic system or mechanism to repeat the same motion or achieve the same position. Repeatability is a measure of the error or variability when repeatedly reaching for a single position. Repeatability is often smaller than accuracy.



Degree of Freedom (DOF)

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Axes of motion

Degrees of freedom

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- Each joint or axis on the robot introduces a degree of freedom. Each DOF can be a slider, rotary, or other type of actuator. The number of DOF that a manipulator possesses thus is the number of independent ways in which a robot arm can move. An industrial robot typically have 5 or 6 degrees of freedom. 3 of the degrees of freedom allow positioning in 3D space (X, Y, Z), while the other 2 or 3 are used for orientation of the end effector (yaw, pitch and roll). 6 degrees of freedom are enough to allow the robot to reach all positions and orientations in 3D space. 5 DOF requires a restriction to 2D space, or else it limits orientations. 5 DOF robots are commonly used for handling tools such as arc welders.

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Resolution

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- The smallest increment of motion or distance that can be detected or controlled by the robotic control system. It is a function of encoder pulses per revolution and drive (e.g. reduction gear) ratio. And it is dependent on the distance between the tool center point and the joint axis.

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Reach & Envelope

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Robot Arms

Axes of motion

Degrees of freedom

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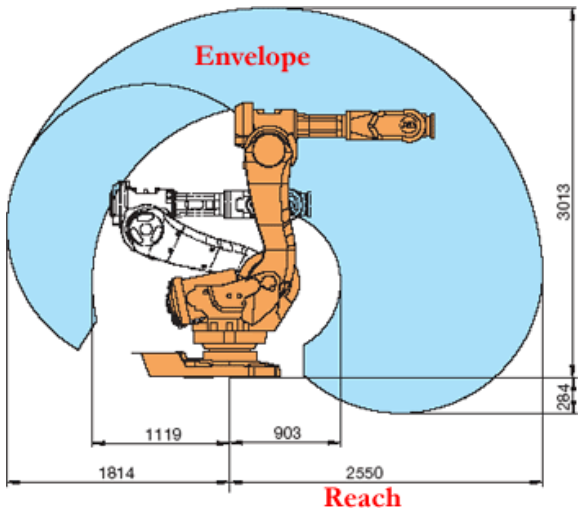
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Envelope

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Robot Arms

Axes of motion

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- A three-dimensional shape that defines the boundaries that the robot manipulator can reach; also known as reach envelope.

Maximum envelope the envelope that encompasses the maximum designed movements of all robot parts, including the end effector, workpiece and attachments.

Restricted envelope is that portion of the maximum envelope which a robot is restricted by limiting devices.

Operating envelope the restricted envelope that is used by the robot while performing its programmed motions.

Reach The maximum horizontal distance from the center of the robot base to the end of its wrist.



Speed & Payload

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Robot Arms

Axes of motion

Degrees of freedom

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Magnetic grippers

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Maximum Speed A robot moving at full extension with all joints moving simultaneously in complimentary directions at full speed. The maximum speed is the theoretical values which does not consider under loading condition..

Payload The maximum payload is the amount of weight carried by the robot manipulator at reduced speed while maintaining rated precision. Nominal payload is measured at maximum speed while maintaining rated precision. These ratings are highly dependent on the size and shape of the payload due to variation in inertia.



Medical Robots

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Robot Arms

Axes of motion

Degrees of freedom

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- Robots are used in medicine because they are high precision machines. By tooling with surgical instruments, they have been used in the field of robotic surgery to perform closed-chest, beating-heart surgery.
- The first generation of surgical robots aren't true autonomous robots that can perform surgical tasks on their own, but they are lending a mechanical helping hand to surgeons.



- These machines still require a human surgeon to operate them and input instructions. Remote control and voice activation are the methods by which these surgical robots are controlled.



Military Robots

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Robot Arms

Axes of motion

Degrees of freedom

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- Military robots are capable of replacing humans to perform many, if not most combat functions on the battlefield. Suggested by the U.S. Joint Forces Command, the presence of autonomous robots, networked and integrated, on the battlefield will take human out of the loop as early as 2025. Military robots may look like vehicles, airplanes, insects or animals or other objects in an attempt to camouflage or to deceive the adversary.



- On the ground, robots have been deployed as mine sweepers and for bomb disposal. Defence contractors in the USA are developing autonomous “robot soldiers”, though currently it looks more like tanks than humans.

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Space Robots

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Robot Arms

Axes of motion

Degrees of freedom

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Magnetic grippers

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- Space robotics is generally divided into two main areas:
 - robotic manipulators - such devices are deployed in space or on planetary surfaces to emulate human manipulation capabilities.
 - Robotic Rovers - they are deployed on planetary surfaces to emulate human mobility capabilities.





Robots in Automobile Industries

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Robot Arms

Axes of motion

Degrees of freedom

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Magnetic grippers

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- In the automobile industry, robotic arms are used in diverse manufacturing processes including assembly, spot welding, arc welding, machine tending, part transfer, laser processing, cutting, grinding, polishing, deburring, testing, painting and dispensing. Robots have proved to help automakers to be more agile, flexible and to reduce production lead times.





Electronics/Semi-Conductor

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Robot Arms

Axes of motion

Degrees of freedom

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- Application of clean room Robots in semiconductor manufacturing results in the reduction in scrap from broken wafers and chips, which translate into major cost savings in wafer handling. The avoidance of contamination and the savings in scrap from dropped wafers in machine loading and unloading can exceed millions of dollars. Typically, clean Room robots are used predominantly in machine loading, unloading, and parts transfer in the semiconductor industry, though, assembly, packaging, and testing processes are other application areas for clean room robots.



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Food & Beverage

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Robot Arms

Axes of motion

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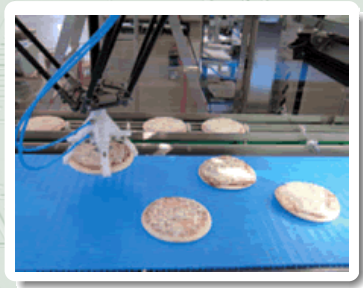
Mechanical types

Suction type

Magnetic grippers

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- While food and beverage applications represent a small fraction of industrial robotics installation, it is widely recognize as one of the fastest growing segments. The vast majority of robots in the Food & Beverage industry are found in the packaging area, with secondary functions such as case packing and palletizing dominating. High-speed Material Handling robotic arms and vision-guided systems are beginning to work alongside and-in many cases-instead of humans in food factories.



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Ship Buiding

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Robot Arms

Axes of motion

Degrees of freedom

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- Unlike the automobile industry where the use of robots is widespread, shipbuilding is more of a 'one-of-a-type' production. This makes efficient and cost-effective robotic implementation extremely difficult to achieve.



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Construction

Mechatronics

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Robot Arms

Axes of motion

Degrees of freedom

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Magnetic grippers

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- Construction robots aim to improve the efficiency of work at construction sites. With proper planning and development, robots are used in the applications like inner pipe crawling, excavation, load transport, mining and submersion, bricklaying, earth work, foundation/ steel-framework, prefabrication of reinforcement, pavement work and many others. Generally, where there are dangerous conditions or accessibility and/or space limitations that persist, robots will be used.



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Mechatronics

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Robot Arms

Axes of motion

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END EFFECTORS

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End effectors

Mechatronics

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- End effectors are devices fitted to the end of robot arms and used to perform various tasks. They are divided into two groups:

Grippers These are used for holding and grasping objects. They include mechanical hands, hooks magnetic and suction devices for holding and grasping objects.

Tools Devices that are used by robots to perform operations on objects. Typical examples are: drills, paint sprays, grinders welding torches etc.



End effectors

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Robot Arms

Axes of motion

Degrees of freedom

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Magnetic grippers

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- There are four general categories of robot grippers, these are:
 - Impactive** jaws or claws which physically grasp by direct impact upon the object.
 - Ingressive** pins, needles or hackles which physically penetrate the surface of the object (used in textile, carbon and glass fibre handling).
 - Astrictive** suction forces applied to the objects surface (whether by vacuum, magneto- or electroadhesion).
 - Contigutive** requiring direct contact for adhesion to take place (such as glue, surface tension or freezing).

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Mechanical grippers

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Robot Arms

Axes of motion

Degrees of freedom

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Magnetic grippers

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Friction between gripper and the object depends on two factors:

- Surfaces in contact e.g. metal on metal, metal on rubber, smooth surfaces, rough surfaces.
- The force which is pressing the surfaces together. The required amount of friction between the gripper and the surfaces must be considered.

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Gripper pads

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Robot Arms

Axes of motion

Degrees of freedom

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Suction type

Magnetic grippers

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- Sometimes gripper pads are used to provide greater friction between gripper and objects.
- Gripper pads also provides a protection for the object from being compressed.
- Polyurethane is a well known material for use as pads.

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Two-finger gripper

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Robot Arms

Axes of motion

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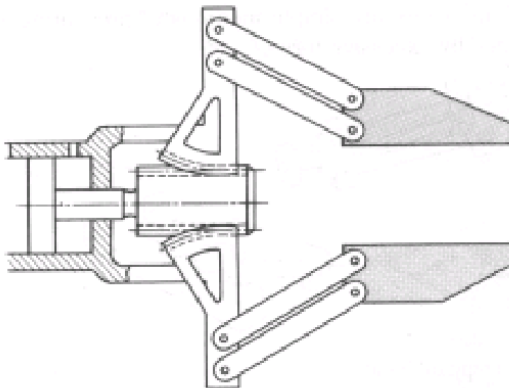
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V-shaped gripper

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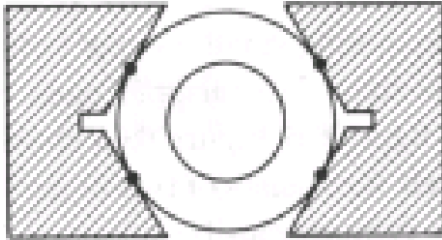
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A cylinder gripper

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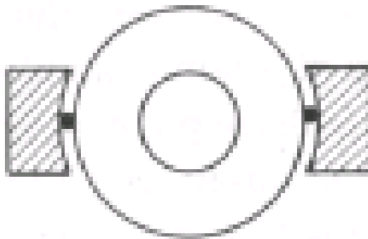
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mechanical grippers

Examples of mechanical grippers

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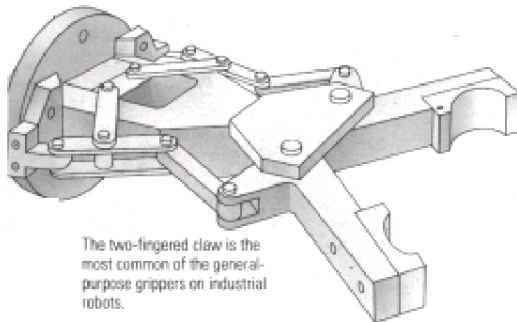
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The two-fingered claw is the most common of the general-purpose grippers on industrial robots.

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mechanical grippers

Examples of mechanical grippers(1)

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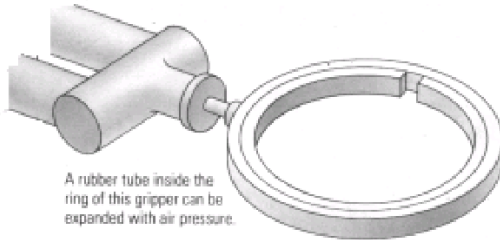
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A rubber tube inside the ring of this gripper can be expanded with air pressure.

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Suction grippers

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- Devices operated vacuum gripper. The vacuum may be produced by two methods: (1) pump operated vacuum and (2) venturi operated vacuum.
- Devices with a flexible suction cap which presses onto the work piece. To release work piece compressed air is blown into the cup.

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Suction gripper using vacuum

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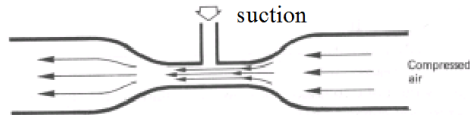
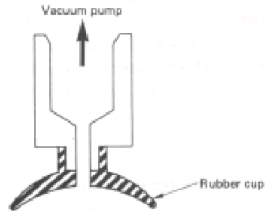
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- A venturi is a thin tube connected to a larger inlet and outlet. Compressed is blown through the inlet. Surrounding layer of air is dragged into the tube. Creating a suction in the direction of the arrow.

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Lifting capacity of suction cups

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Diameter of Suction cup (cm)	Lifting Capacity of 25% vacuum (kg)
1.0	0.2
2.0	0.5
5.0	5.0
10.0	20.0

$$\text{Lifting Capacity (kg)} = \frac{0.785(\% \text{ Vacuum})}{100} d^2$$

- where d = diameter of suction cup in cm.

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Speed considerations

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- Creation of the vacuum can take sometime (i.e. it can cause delays). This delay must be taken into account when several thousands of lifting operations are expected.
- To avoid delays use suction cup of larger diameter so that sufficient force is produced before maximum vacuum has been given time to develop.

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Grippers operated by compressed air

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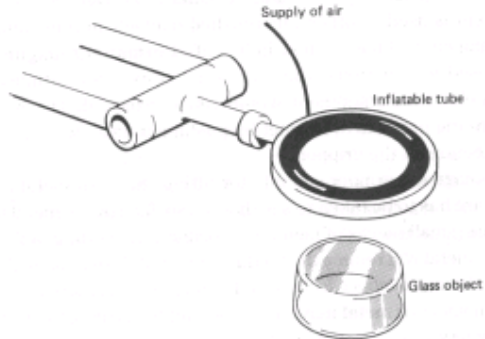
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- Compressed air is used to inflate a rubber tube that grips the object. The object is released by deflating the tube.

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Magnetic grippers

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Magnetic grippers

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- Used for lifting ferromagnetic objects made from nickel, cobalt, iron and steel (60% of iron). Magnetic grippers have to be in complete contact with surface of the object to be gripped. Flat metals are suitable for magnetic grippers.

- Advantages

- Precise positioning of gripper is not necessary.
- Used with objects with different sizes.
- Used with objects with irregular shapes.
- Act instantaneously.

- Disadvantages

- Demagnetises with temperature, especially permanent magnetic types.
- Require the magnetic grip to be applied evenly across a large object.

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Magnetic grippers

Mechatronics

David Goodwin

Robot Arms

Axes of motion

Degrees of freedom

Types

Design

Industrial
Applications

End effectors

Mechanical types

Suction type

Magnetic grippers

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Permanent magnet

- Used in situations where there is explosive atmosphere (i.e. where sparks from the electrical equipment may cause hazards).
- The object picked may be released by pushing it away with an ejector pin fitted to the centre of the gripper.

Electromagnetic

- Operated by a DC electric current that is passed through a coil wound on a magnetic material.
- Retains some amount of magnetism when current is switched off.
- To release objects a reverse current is applied to the coil.

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