Unit 1. Part -II

Basic Concepts in Robotics

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Classification of Industrial robots

- Based upon Configuration
1. Cartesian Configuration
2. Cylindrical
3. Spherical
4. Jointed arm
5. SCARA
- Based upon Drive system
1. Hydraulic
2. Pneumatic
3. Electric
- Based upon Control system
1. Limited sequence
2. Play back (Point to point and Continous Path)
3. Intelligent

2

Joint Drive Systems

- Electric
  - Uses electric motors to actuate individual joints
  - Preferred drive system in today's robots
- Hydraulic
  - Uses hydraulic pistons and rotary vane actuators
  - Noted for their high power and lift capacity
- Pneumatic
  - Typically limited to smaller robots and simple material transfer applications

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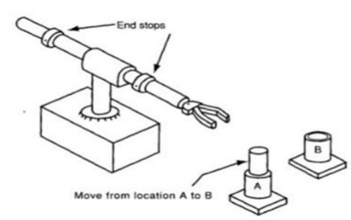
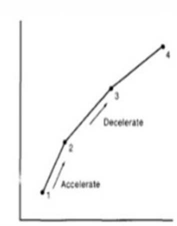
Control loop of robot system

- **Limited sequence control** Pick-and-place operations using mechanical stops to set positions (No servo motor)
- **Playback with point-to-point control**

Records work cycle as a sequence of points, then plays back the sequence during program execution but cannot stop at arbitrary points





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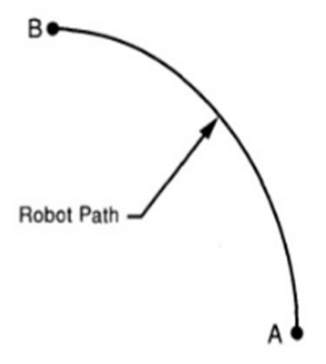
Control loop of robot system

- **Playback with continuous path control**

Greater memory capacity and/or interpolation capability to execute paths (in addition to points move in arc circle and straight line)

- **Intelligent control**

exhibits behavior that makes it seem intelligent, e.g., responds to sensor inputs, makes decisions, communicates with humans



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Robot end effectors

- The special tooling for a robot that enables it to perform a specific task
- Two types:
  - **Grippers** – to grasp and manipulate objects (e.g., parts) during work cycle

  Grippers may be design as:

  Physical constraints or Friction device

  i. Physical constraint device :

  Works like spatula that slides under an object to enable one to lift it.

  ii. Frictional devices:

  Depends upon frictional force between two materials to provide griping force.
  - **Tools** – to perform a process, e.g., spot welding, spray painting

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Classification

I. According to method of gripping mechanism:
   a. Mechanical standard grippers
   b. Vacuum grippers
   c. Magnetic grippers
   d. Adhesive grippers
   e. Miscellaneous gripper

II. According to Process tooling and devices:
   a. Drills
   b. Welding guns and torches
   c. Paint sprayers
   d. Grinder

III. According to multifunction capabilities including:
   a. Special purpose grippers
   b. Compliance devices currently in use
   c. Holding fixtures
   d. Welding Fixtures
   e. Alignment devices

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Internal and External Grippers

External gripper:

Part grasped from outside surface.

Internal gripper:

- Part grasped from inside surface.
- e.g.-Ring shaped part/Hollow part

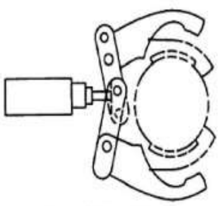

Figure 1 External gripper.

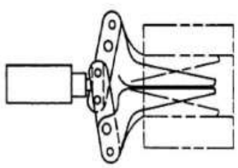

Figure 2 Internal gripper.

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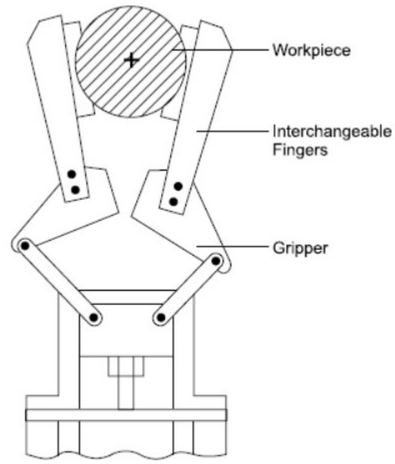
Mechanical grippers

- A mechanical gripper is an end-effector that uses mechanical fingers actuated by a mechanism to grip an object.
- The fingers are either attached to the mechanism or are an integral part of the mechanism.
- The use of replaceable fingers allows for wear and interchangeability



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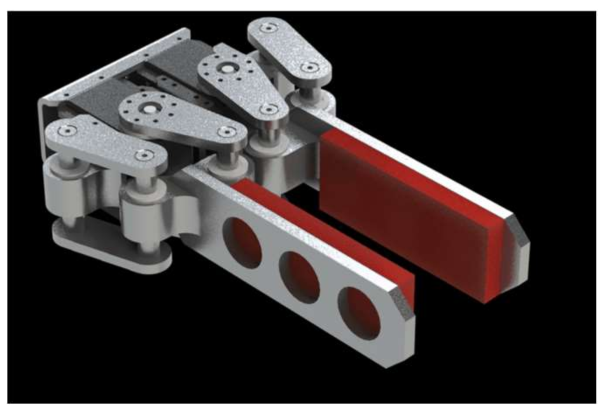
Mechanical gripper Mechanism

- Pivoting Or swinging gripper mechanism

1. Linkage actuation
2. Gear and rack actuation
3. Cam actuation
4. Screw actuation

- Translation gripper Mechanism

1. Cylinder piston actuation
2. Rotary actuation



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Mechanical gripper Mechanism

- Linkage actuation
- Gear and rack actuation

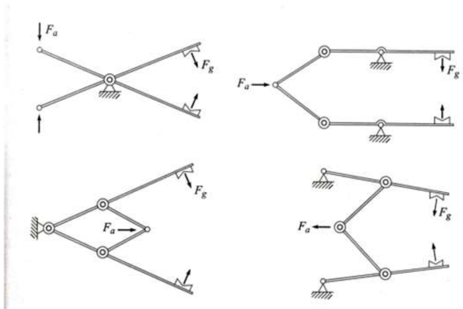

Fig. 5.6 Some possible linkages for robot grippers.

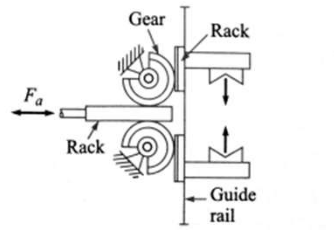

Fig. 5.7 Gear-and-rack method of actuating the gripper.

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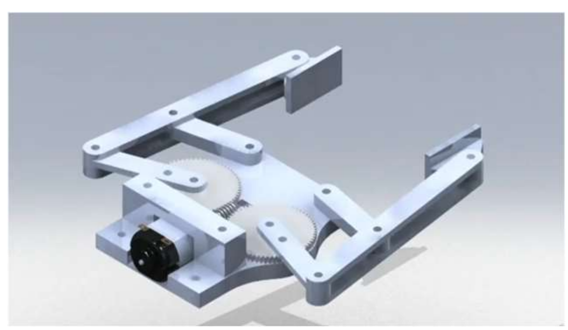
Linkage actuation & Gear and rack actuation



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Mechanical gripper Mechanism

Cam Actuated

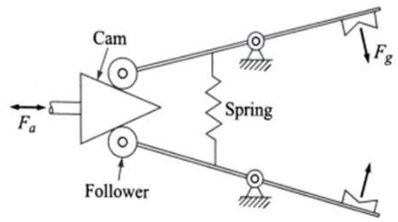

Fig. 5.8 *Cam-actuated gripper.*

Screw actuation

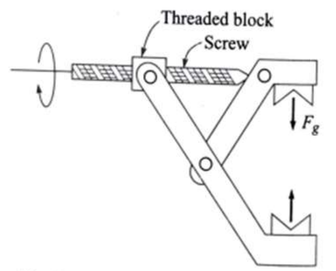

Fig. 5.9 *Screw-type gripper actuation.*

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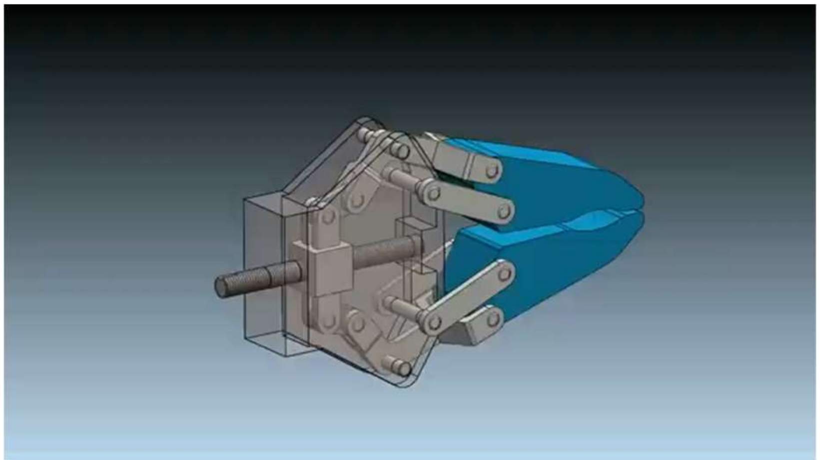
Screw actuation



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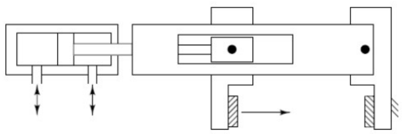
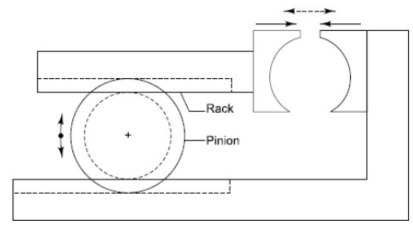
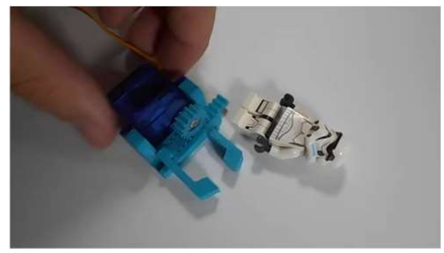
Mechanical gripper Mechanism



Translational gripper using cylinder piston



Translational gripper using rotary actuators



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Mechanical gripper

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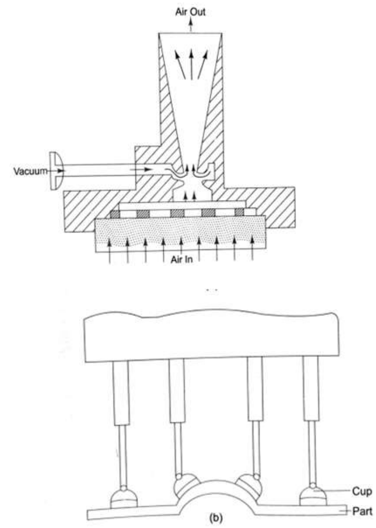
Vacuum or suction cups

- The vacuum gripper consists of a flat surface with tiny holes that forms one side of a vacuum chamber.
- Each hole in the vacuum surface provides a small lifting force so that the flexible cloth, paper, or plastic would be held into place against the vacuum surface from many points.
- Vacuum grippers are usually venturi devices, applying Bernoulli's principle to create suction by using compressed air.



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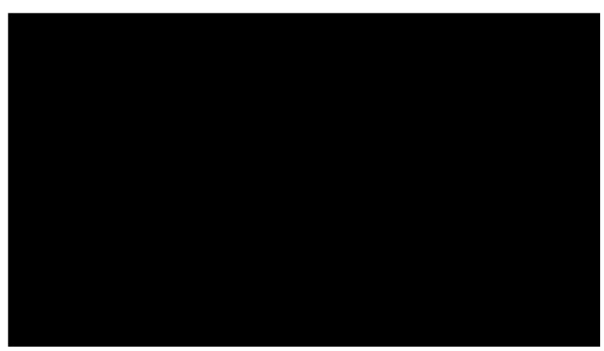
Vacuum Gripper or Suction cups



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Magnetic grippers,

Permanent Magnet: Require stripping device to release part from tool at end of cycle.

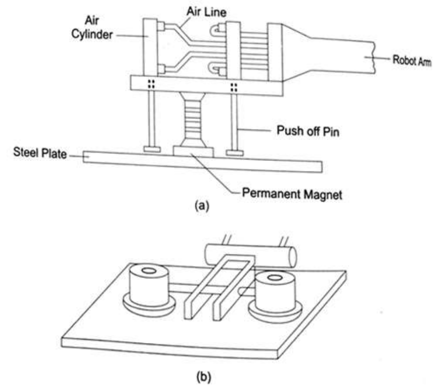
Electromagnet: Easy to control but require DC power and Controller unit.

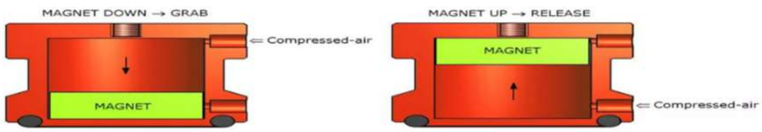
Advantages

- Variation in part size is tolerated
- Pickup time are very fast
- The have ability to handle parts with holes
- Only one surface can be used for gripping

Limitations

- Residual magnetism remain in work piece
- Multiple pickup due to magnetic penetration





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Magnetic grippers,

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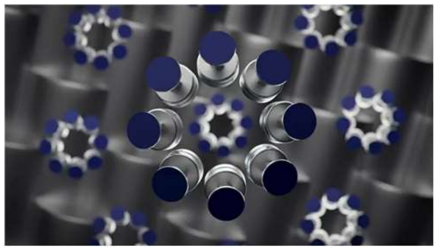
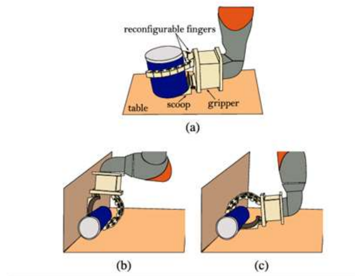
Miscellaneous devices

- Adhesive grippers
- Hooks
- Scoops





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Tools

Fraunhofer
IFAM

- Machine tools
- Measuring instrument
- Camera
- Welding (spot/torch/rod /laser)
- Spray painting gun
- Assembly tools

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Gripper force analysis

Gripper force analysis

a) Friction method

b) Moment of force method

a) Following force equation can be used to determine the required magnitude of gripper force as a function of given factors:

1. If weight alone is tending to cause the part to slip out of the gripper when the force of gravity is parallel to the line contacting surface `
2. If the force tending to pull the part out of the finger is greater than the weight of the object because the acceleration or deceleration of the part could exert a force that is twice the weight of the part then

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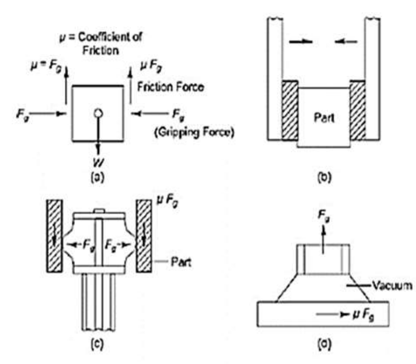
Gripper force analysis

1. If weight alone is tending to cause the part to slip out of the gripper when the force of gravity is parallel to the line contacting surface

For body to be in equilibrium

$$n\mu F_g = Mg \sin\theta$$

$$F_g = \frac{Mg \sin\theta}{\mu n}$$



a) Free body diagram b)Friction in mechanical gripper
c) Friction in plug type gripper d) Friction suction type gripper

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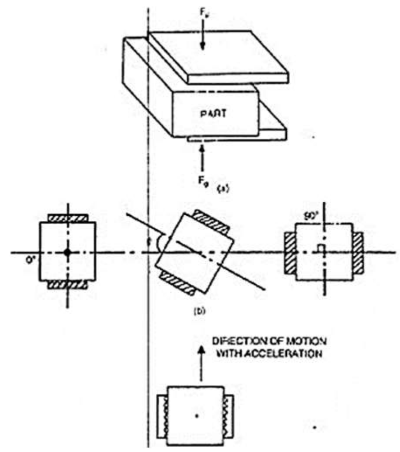
Gripper force analysis

$$Fg = \frac{Mg \sin \theta}{\mu n}$$

Where,

- Fg = the gripper force
- M = the Mass of the part (Kg)
- μ = Coefficient of friction of the finger contact surface against the part surface
- n = Number of contacting fingers
- θ = angle subtended with the horizontal
- g= Acceleration due to gravity (9.8m/s2).



a) Force acting b) Different cube orientation during gripping c) Gripping when object is moving vertically

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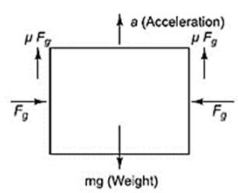
Gripper design considerations

2. If the force tending to pull the part out of the finger is greater than the weight of the object because the acceleration or deceleration of the part could exert a force that is twice the weight of the part then

nμ Fg-mg = ma (considering two fingers)

n μ Fg + ma = mg Sin θ

$$Fg = \frac{m(a + g \sin \theta)}{\mu n}$$



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Gripper Numerical

1.A cardboard carton weighing 5 kg using friction against two opposing fingers the coefficient of friction is 0.25. The weight of carton is directed parallel to the finger surface at an acceleration of 20m/sec^2

Determine:

a) required gripper force for the condition given

b) If the safety factor = 1.5, what would be the value of gripper force

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Gripper Numerical solution

Solution:

From Free Body Diagram,

a) $F_g = \frac{m(a+g\sin\theta)}{\mu n}$

$= \frac{5(20+9.81\times\sin 90)}{2\times0.25}$

$= 298\ N$

The gripper must cause a force of 298 N to be exerted by the fingers against the carton surface, assuming fingers grasp the carton at its center of mass and there are no moments that would tend to rotate the carton in the gripper.

b) <u>If factor of safety = 1.5</u>

Then,

$F_g = 1.5 \times 298$

$F_g = 447N$

The safety of factor would help to compensate for the potential problem of the carton being grasped at a position other than the canter of the mass.

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Gripper design considerations

Moment method

Here moment force is taken along the a
assume sum equal to zero

$$F_g L_g - F_a L_a = 0$$

$$F_g L_g = F_a L_a$$

$$F_a = \frac{F_g L_g}{L_a}$$

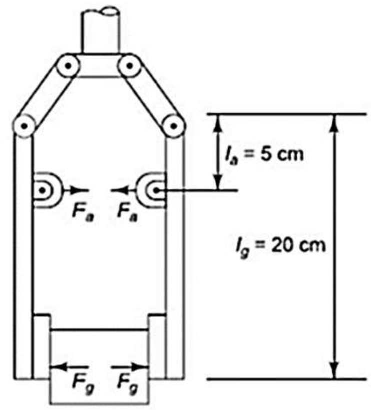
Where

F_g:- Gripping force

F_a:- Actuating force

L_a:- Distance of the actuating force from pivot

L_g:- Distance of the gripping force from pivot



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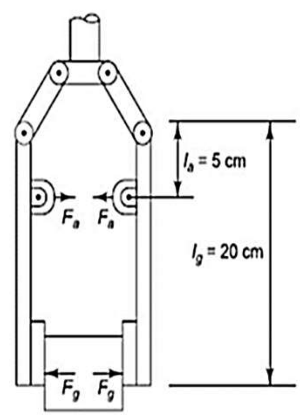
Gripper Numerical

2.A simple pivot type gripper is used to hold a box as illustrated in Fig

Find actuating force required to hold it gripper force id 20 kgf



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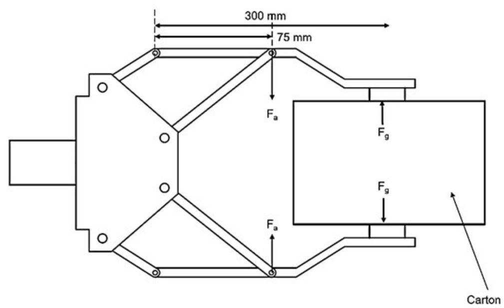
Gripper Numerical

3.An angular motion is used for holding the carton as shown in figure . The gripper force required to hold is 200N. The gripper is activated by a piston device to apply actuating force. Determine the piston force to close the gripper



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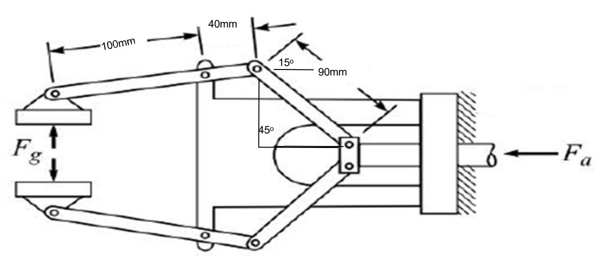
Gripper Numerical

4. The gripper shown in figure is required to hold the work piece for machining operation. The gripper force is determined to be 110 N. Determine the actuating force Fa applied to the plunger



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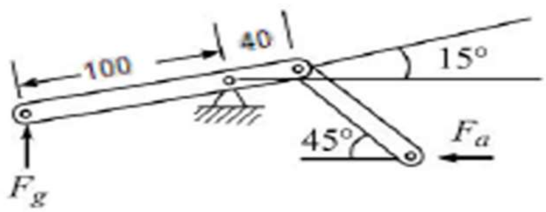
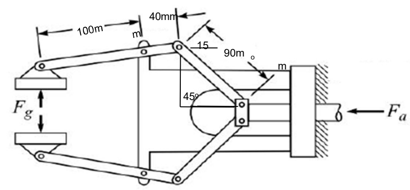
Solution

- Figure shows the symmetry of the gripper can be used to advantage so that one half of the mechanism need to be considered





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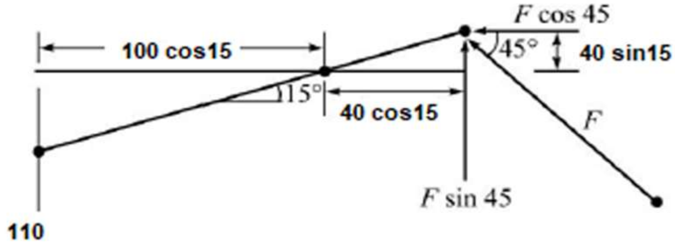
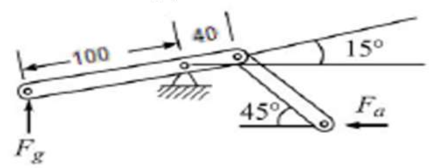
Solution

- The figure below shows the movement summed about the pivot point for the finger link against which 110N gripper force is applied





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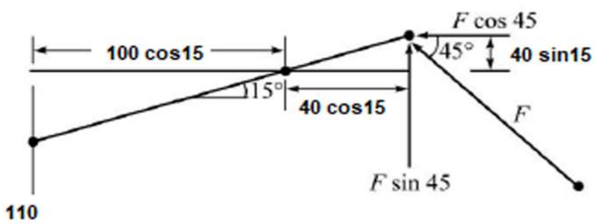
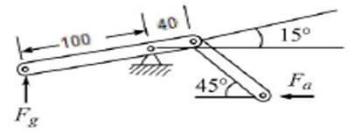
Solution

- Taking moment along pivot point .





$$110(100 \cos 15^o) = F \sin45^o (40 \cos15^o) + F\cos45^o (40 \sin 15^o)$$

$$10625.18 = 27.32 F + 7.3205 F$$

$$F = 306.73$$

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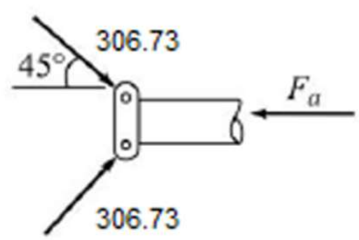
Solution

The force applied to the plunger to deliver the force of 306.73N to each finger is shown in figure below

$$F_a = 2 \times 306.73 \cos 45^o$$

$$F_a = 433.399N$$

Hence the power input require actuating force of 433.399N



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Gripper design considerations

Factor to be considered in assessing gripper requirements.

1. The part surface to be grasped must be reachable.
2. The size variation of the part must be accounted for because this might influence the accuracy of the locating the part.
3. The gripper design must accommodate the change in size that occurs between part loading and unloading.
4. Consideration must be given to the potential problem of scratching and distorting the part during gripping.
5. If there is choice between two different dimensions on the part the larger dimension should be selected for grasping
6. Gripper finger can be designed to conform to the part shape by using resilient pads or self aligning fingers.
7. The important factors that determine the grasping force are:
   a) The weight of the object
   b) The speed and acceleration with which the relationship
   c) Physical constriction or friction that is used to hold the part
   d) The coefficient of friction between the object gripper fingers

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Vacuum Gripper

Lift capacity (F_g) depends upon

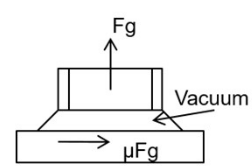
Effective area (A) of suction cups used to create Vacuum (mm^2)

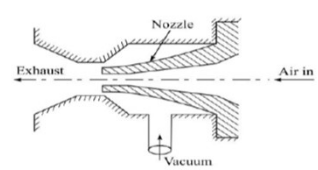
Negative air pressure (P)(N/mm^2)

$F_g = P \times A$ or $P = F_g / A$

Where $F_g = F$ = Force or Lift capacity

Negative air pressure(p) = Atmospheric pressure – Residual pressure in vacuum cup





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Numerical on vacuum gripper

5.A Vacuum gripper is used to lift flat plates of EN 31 steel. Each piece of steel is 6mm thick and measures 600 × 900 mm. The gripper will utilize two suction cups separated by 150 mm for stability. Each suction cup is round and has a diameter of 125mm. Two cups are considered a requirement to overcome the problem that the plates may be off centre with respect to the gripper. A safety factor of 1.5 is to be used to allow for acceleration of the plate and for possible contact of the suction cup against the plate which would reduce the reflective area of the cup.

Determine the negative pressure required (Compared to atmospheric pressure of 0.1N/mm ^{2}) to lift the plates if the density of steel is 7.85×10^{-5} N/mm^3

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Solution

Given :-

Plate dimension = 600mm x 900mm x 6 mm

Suction cup diameter = 125

Factor of safety

Atmospheric pressure = 0.1 N/mm^2

Density of steel = 7.85 x 10-5 N/mm3

weight of steel = ?

Area of Suction Cup =?

Area of two Cup = ?

Negative pressure = ?

Negative pressure applying factor of safety = ?

40

Solution

Weight of steel = 600 x 900 x 6 x 7.85 x 10-5

= 254.34

Area of Suction Cup = $\pi/4$ x $(125)^2$ = 12271.84

Area of two Cup = 2 x12271.84 = 24543.69

Negative pressure = 254.34/2453.69 = 0.01 N/mm^2

Negative pressure applying factor of safety = 1.5 X0.01

= 0.015 N/mm^2

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Robot Movement and Precision

- Speed :-Speed defines how quickly the robot arm moves from one point to another.
- Stability:- Stability refers to robot motion with the least amount of oscillation. A good robot is one that is fast enough but at the same time has good stability

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Robot Precision of movement

Control Resolution

- It is define as the smallest incremental change that the controller can distinguish
- The control resolution is determined by the robot's position control system and its feedback measurement system
- The controller divides the total range of movements for any particular joint into individual increments that can be addressed in the controller. The bit storage capacity of the control memory defines this ability to divide the total range into increments
- For a particular axis, the number of separate increments is given by
  Number of increments = 2^n

where **n** is the number of bits in the control memory

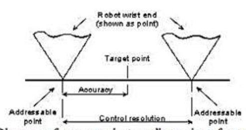

Figure 1.1: Diagram of accuracy in two dimensions frame, without mechanical inaccuracy consideration [Gro86].

Spatial Resolution

- The spatial resolution of a robot is the smallest increment of movement into which the robot can divide its work volume.
- It depends on the system's control resolution and the robot's mechanical inaccuracies.

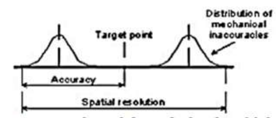

Figure 1.2: Diagram of accuracy and spatial resolution in which mechanical inaccuracies are represented by a statistical distribution [Gro86].

- Control/ Spatial resolution $= \dfrac{\text{Range of joint}}{\text{Number of increments}}$

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Numerical on Resolution

1.Using a robot with degree of freedom and having 1sliding joint with full range of 1m, if the robot control memory has a12 Bit storage capacity then find out control resolution for the axis of motion

Solution

Control resolution = Range / Number of increments

Control Resolution = $1m/2^n$

Control Resolution = $1/2^{12}$

=0.000244

= 0.244 X10^3m = 0.244mm

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Numerical on Resolution

2.A robot's control memory has 8-bit storage capacity. It has two rotational joints and one linear joint Determine the control resolution for each joint, if the linear link can vary its length from as short as 0.2 m to as long as 1.2 m.

Solution

Control memory = 8 bit
From the equation above, number of increments = 2^8 = 256
(a) Total range for rotational joints = 360
Control resolution for each rotational joint = 360/256
= 1.40625
(b) Total range for linear joint = 1.2 - 0.2 = 1.0 m
Control resolution for linear joint = 1/256 = 0.003906 m
= 3.906 mm

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Robot Precision of movement

Accuracy

- Accuracy can be defined as the ability of a robot to position its wrist end at a desired target point within its reach(work volume).
- In terms of control resolution, the accuracy can be defined as one-half of the control resolution

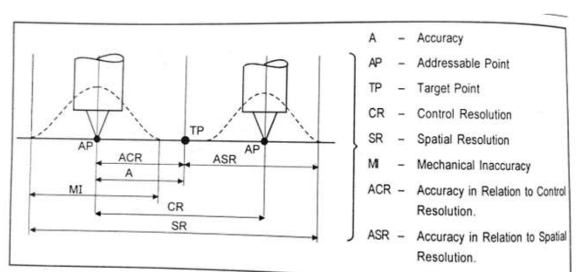

Fig. 1.22 : Accuracy and Resolutions

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Robot Precision of movement

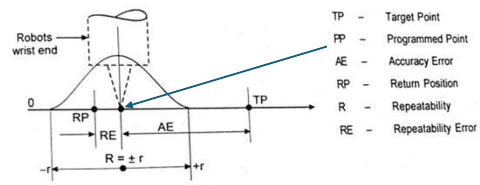
Repeatability

Repeatability refers to the robot's ability to position its end-effectors at a point that had previously been taught to the robot.

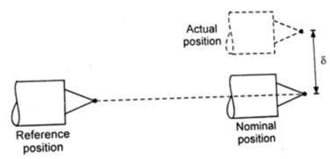
It is affected by resolution and component in accuracy

Desired point –TP, return to PP, but goes to RP

The δmax ± is the manufacturers repeatability



Errors in accuracy and repeatability



Measurement of repeatability

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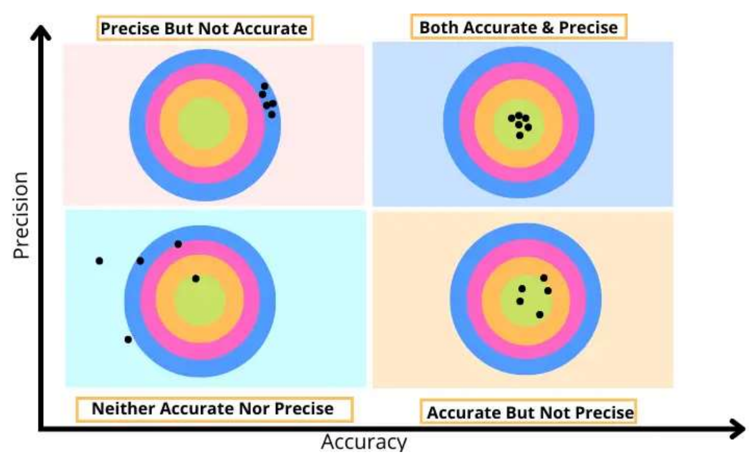
Precision and accuracy



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Robot Precision of movement

Compliance :-

- It refers to the displacement of the wrist end in response to force exerted against it.
- It gives ability to manipulator to tolerate misalignments of mating parts
- It helps in preventing jamming , wedging and galling of parts
- It affects robot precision movement under load
- High compliance:- wrist displaced a large amount by relatively small force (springy or spongy)
- Low compliance :- manipulator is relatively stiff and is not easily displaced
- It is a tensor

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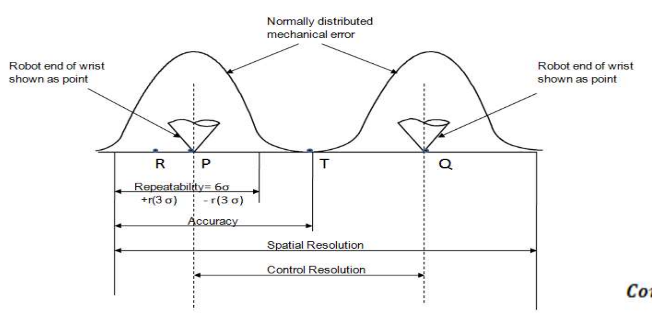
More formulas



$$Control\ Resolution = \frac{Range\ of\ Movement}{2^n}$$

- P, Q – Programmed Points (Addressable Points) capacity
- R – Return Position
- T –Target Point

Where, n is control bit memory storage

$$Spatial\ Resolution = 2 \times Accuracy$$

$$= Control\ Resolution + 6\sigma$$

$$Repeatability = \pm r = \pm 3\sigma$$

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Numerical on resolution , accuracy and repeatability

3.One of the axes of a RRL robot is a Sliding mechanism with a total of 700mm. The robot's control memory has a 10-bit capacity. In addition, it has been observed that the mechanical inaccuracies associated with moving the arm to any given programmed point form a normally distributed random variable with the mean at the taught point and the standard deviation equal to 0.10mm. Assume that the standard deviation is isotropic (it is equal in all directions). By definition, three standard deviations include "all" of the mechanical errors in the arm movement. With these definitions and assumptions, determine the following:

a) The control resolution for this axis.
b) The spatial resolution for this axis.
c) The defined accuracy of the robot for this axis
d) The repeatability of the robot

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Solution

Given :-

N= 10

Range = 700mm

ϱ = 0.1mm

Control resolution = Range / Number of increments

Control Resolution = 700mm/2^{10}

Control Resolution = 0.6836

Mechanical error = 3ϱ = 3x 0.1 = ± 0.3

Spital resolution = control resolution + mechanical error

= 0.6836 + 0.6 = 1.2836

Accuracy = ½ (Spital resolution) = ½ (1.2836) = 0.6418

Repeatability = ± 3ϱ = 3*0.1= ± 0.3 or = 0.6

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Specification of robot

- Number of axis/ DOF
- Speed
- Actuator
- Payload
- Precision, Accuracy Repeatability
- Level of machine intelligence
- Application

Some of the typical broad robot specifications are given below:

1. Cincinnati Milacron

Model	—	T3 586
Manipulator end-effector	—	6 DOF, RRR-3A
Speed	—	900 mm/s
Actuator	—	hydraulic
Payload	—	100 kg
Repeatability	—	± 1.25 mm
Applications	—	Forging, investment, casting, machine tool loading, welding, machining, inspection, etc.

2. Puma (Unimation)

Model	—	550
Manipulator end-effector	—	6 DOF, RRR-3A
Speed	—	1000 mm/s
Actuator	—	Electrical
Payload	—	3 kg
Repeatability	—	± 0.10
Applications	—	Machine tool loading, part transfer, assembly, welding, inspection, education

3. Seiko Instruments

Model	—	M 700
Robot manipulator end-effector	—	3 DOF RP-1A
Speed	—	312 mm/s
Actuator	—	Pneumatic
Payload	—	1 kg
Repeatability	—	± 0.03 mm
Applications	—	Machine tool loading/ unloading, material handling, assembly, inspection.

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MCQ

1. **Which one of the following terms refers to the up - down motion of a robot arm?**
   1. Yaw
   2. Pitch
   3. Lateral/ Elevate
   4. Roll
2. **Let us suppose that a serial manipulator is to be clean blackboard with the help of duster. What is the minimum degrees of freedom it should have?**
   1. 3
   2. 4
   3. 5
   4. 6

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Match the following and suggest the suitable

2. A robot is less accurate but has good repeatability. Another robot is accurate but poor in repeatability. Which robot will you select for-

   a) Spray painting operation - Accurate but poor in repeatability

   b) Spot welding operation - Less accurate but good in repeatability

3. For each of the following tasks, state whether a gripper or an end-of-arm tooling is appropriate:

   a) Welding - Tool HH0

   b) Scraping paint from a glass pane - Gripper

   c) Assembling two parts - Gripper

   d) Drilling a hole - Tool

   e) Tightening a nut of automobile engine - Tool

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Slide 55

HH0 EOA
Hrishikesh Kishor Jadhav, 2024-08-23T09:45:54.659