① Robot Anatomy

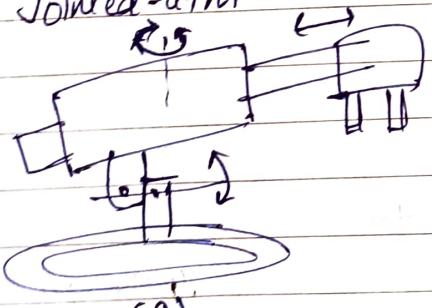
Concerned with the physical construction of the Body, Arm and Wrist of a machine.

Generally, Robots are mounted on a Base which is attached to the floor, The body is attached to the Base and the Arm assembly is attached to the Body.

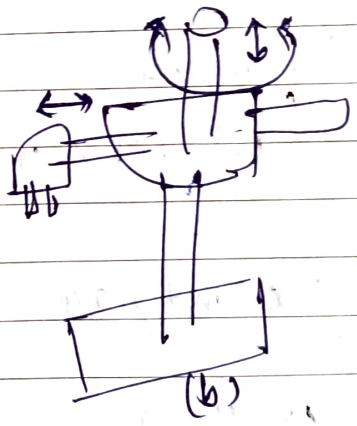
Relative movements are carried by the joints in a Robo
And the attachments which do point to point work in a Robot is called as End Effector.
(End Effector is not considered as a part of Robot-Anato

② There are 4 Common Robot Configurations

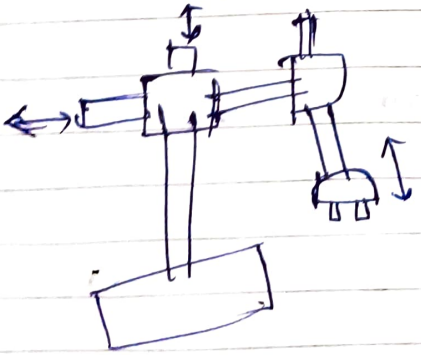
1) Polar
2) Cylindrical
3) Cartesian coordinate
4) Jointed-arms



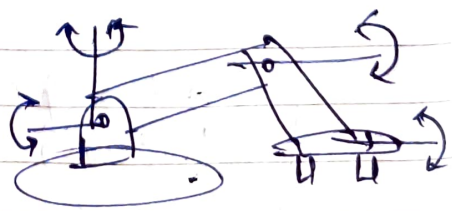
(a)



(b)



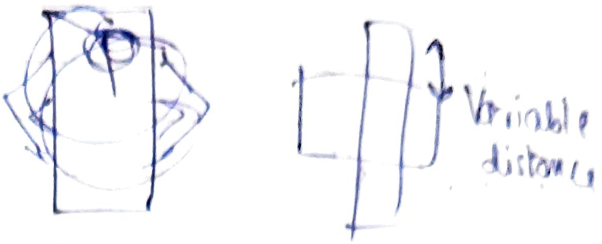
(c)



(d).

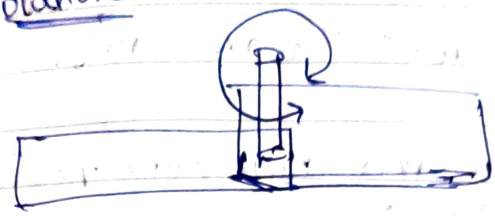
Types of Joints

(a) Linear



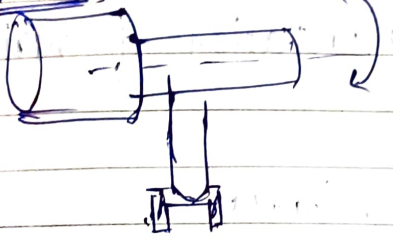
Prismatic joint or P joint

(b) Rotational



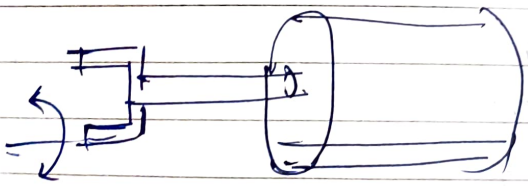
Rotating

(c) Revolving

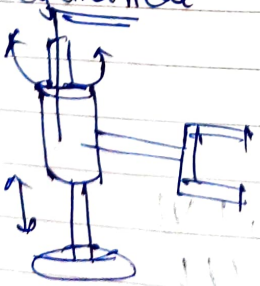


Revolving V

(d) Twisting

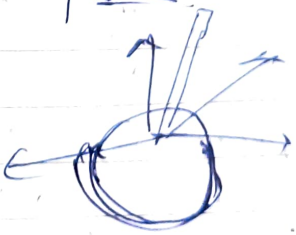


(e) Cylindrical



Cylindrical

(f) Spherical



④ Wrist Movement

1) Wrist Roll

2) Wrist pitch

3) Wrist yaw

1 → (Wrist swivel) rotation of the wrist mechanism about the arm axis.

2 → Upward and downward rotation of wrist (Wrist Bend)

3 → Left Right rotation of Wrist

⑤ Joint Notation Scheme

There are 4 types of joints (L, R, T and V)

L → Linear
R → rotational
T → Twisting
V → Revolving

for Configurations :-

Polar → TRL
Cylindrical → TLL, LTL, LVL
Cartesian Coordinate → LLL
Jointed Arm → TRR, VVR

⑥ Work - Volume

Work Volume is the term refers to the space within the robot can manipulate its wrist end.

→ Robot's physical configuration
Size of Body, Arm and Wrist
Limitations of Robot's joint movements

⑦ Robot Drive Systems

Robot's capacity to move its body, arm, and wrist is provided by the drive system used to power the Robot.

There are 3 types of Drive systems
1.) Hydraulic
2.) Electric
3.) Pneumatic

- Hydraulic & Electric used for sophisticated Robots.
- Pneumatic used for load carrying capacity Robots.

Hydraulic
↳ Large Robots
↳ Greater speed and strength
↳ Disadvantage → more floor space

↳ Accuracy and Reapeatability
↳ Small and less floor space
↳ Actuated by DC motors

- Pneumatic Drive
  - ↳ Limited DOF
  - ↳ pick and place kind jobs
  - ↳ Piston Drives

⑧ Control Systems

- Means of controlling the Drive system is called Control System

① → Limited sequence Robots
② → Playback with P to P
③ → Playback with continuous path control
④ → Intelligent Robots

① → Do not use servo-control to indicate relative positions of the joints.
→ Setting limit switches
→ Can only be moved to extreme limits of travel
→ Every Drive system can be used in this But (specifically pneumatics)

Playback

- Some motions are taught to the Robot
- Recorded into memory (Playback)
- Closed loop feedback system

2) PtoP

- Desired point locations and related actions
- Moved from P to P in sequence in recorded Playback
- Path is programmed
- Loading, unloading, spot welding.

3) Continuous Path

- Motion cycles which is path oriented
- Programmer specifies the initial and final points, the control unit calculates the sequence of individual points.
- Control unit has large storage for relocations of end effectors and arms.
- Spray coating or arc welding

1) Spatial Resolution
2) Accuracy
3) Repeatability.

① End Effectors:

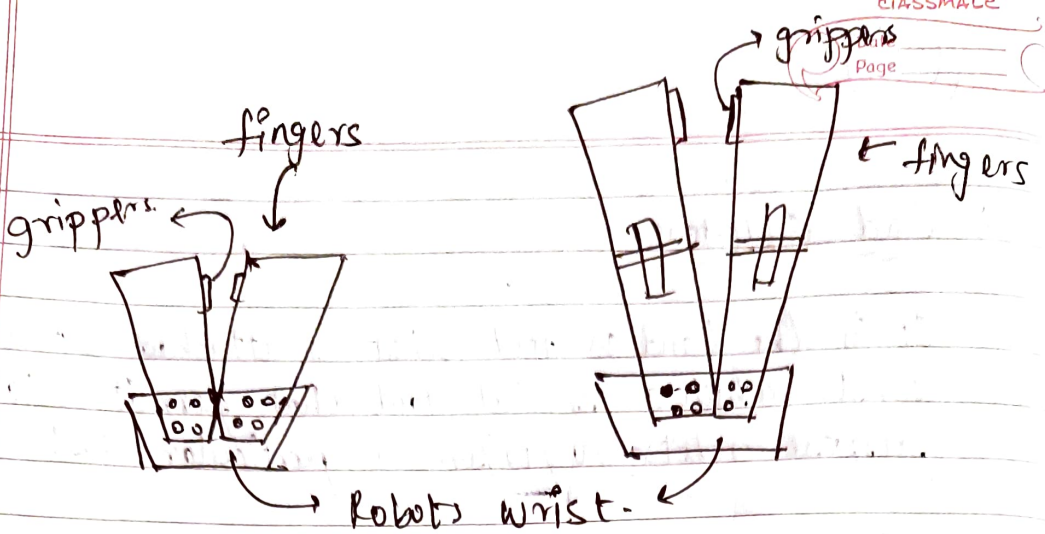
It is the hand or tool that is attached to the wrist which a special tool that permits the general purpose robot to perform a particular task.

- End effectors are divided into two categories - Grippers and Tools.
- Grippers would be utilized to grasp an object during the work cycle of a Robot.
  Can hold by 2 fingers or use additional methods or instruments like suction cups, magnets, hooks or scoops.
- A tool is used when the Robot is supposed to perform some operation on the Work part.
  Applications include arc welding, spray painting and drilling.

② Mechanical Grippers

It is an End effector that uses mechanical ~~gripper~~ fingers actuated by mechanisms to grasp an object. (Jaws)

- These mechanical fingers are attachable and detachable depending on the size of dimensions of the object to be grasped.
- They translate some form of power input into the grasping action of the fingers against the parts.

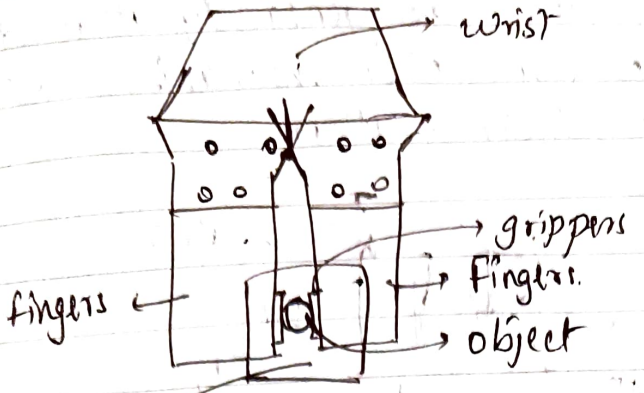


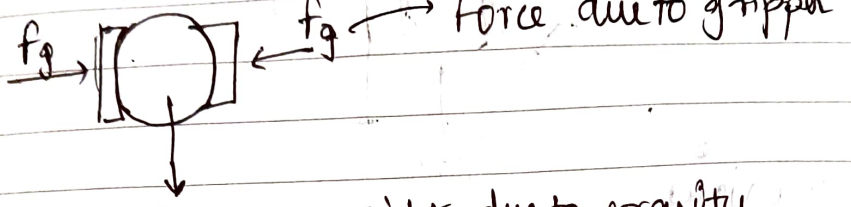
so these mechanical fingers can be detachable and attachable depending on needs.

→ There are 2 ways for constraining the part in a grippers

1) the gripper enclose the part upto some extent thereby constraining the motion of the part.
   ↳ This is done by making the grippers dimensions as the same as the objects dimensions so that the part perfectly fits into the gripper

2) Holding the parts using friction.
   ↳ fingers apply a force that is sufficient for friction to retain the part against gravity, acceleration or any other force.
   ↳ The grippers are made of a material whose coefficient of restitution is high.





W_g → weight due to gripper

$W_g = \mu n_f f_g$

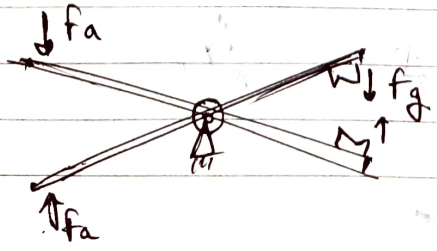
n_f → number of fingers

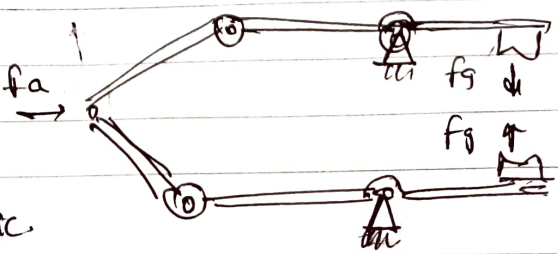
μ → coefficient of restitution

③ Types of Gripper

1. Linkage actuation
2. Gear and rack
3. Cam
4. Screw
5. Rope and Pulley
6. Miscellaneous

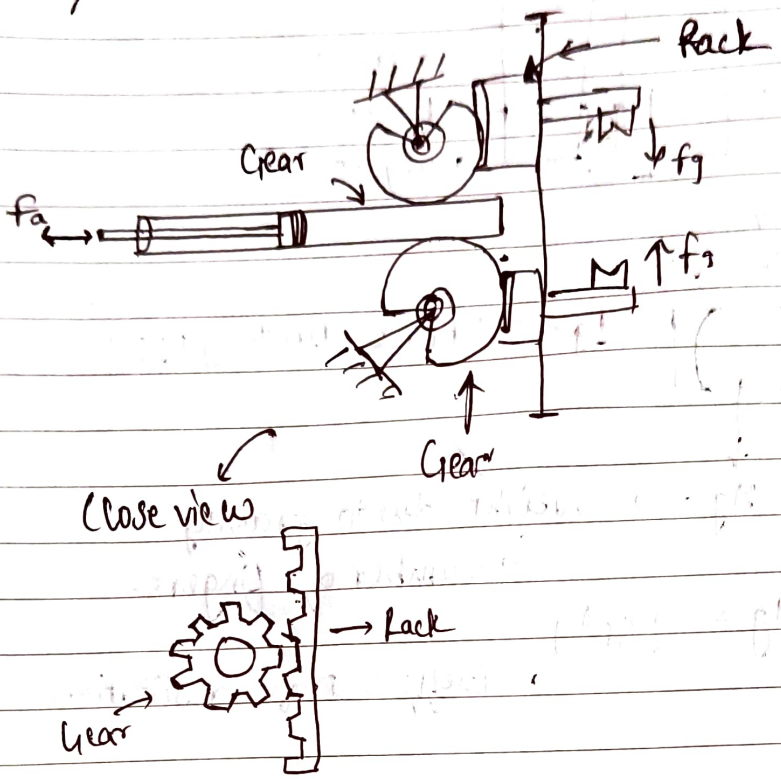
1.) Linkage covers a wide range of design possibilities to actuate the opening and closing of the gripper.





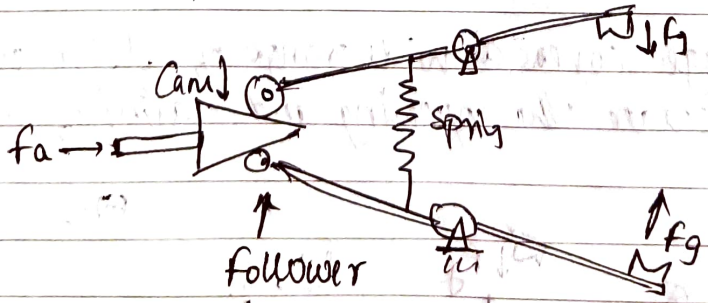
Etc.

2.) Gear and Rack are generally attached to a piston or some other mechanism which provides a linear motion.



3.) Cam and follower arrangement uses a spring loaded follower which provides opening and closing action to a gripper

↳ gripper might need to handle both raw and finished parts, which can differ in size. The spring insures a secure grip regardless the sizes. With the help of cam and spring



4.) screw mechanism provides precise control over the grippers opening and closing through the screw's rotation.

5.) Rope and Pulley mechanism in which rope runs through a series of pulleys
Tension Device (spring) used to oppose the motion of a rope.
Gripper open and closes according to the movement of the rope.

(4) Vaccum (1) Cups, Magnetic (2) grippers, Adhesive (3) grippers
Hooks (4).

→ 1.) Vaccum cups use suction mechanism to hold onto a ~~grip~~ object.
↳ Create a vaccum type environment which keeps on creating pressure to hold onto the object.

2.) Magnetic gripper use magnets as tools to hold onto magnetic materials and seperating the non-magnetic once from them.

3.) Adhesive grippers uses some sticky type material to hold onto some light objects.

4.) Hooks can latch onto objects, scoops can lift objects by sliding underneath them.

1.) Spot Welding
- This tool creates small welds spots to join metal pieces together.
- for precise welding tasks

2.) Arc-Welding
- Uses an electric Arc to weld metals.
- High precision

3.) Spray painting
- spray paints evenly on surfaces, ensuring smooth finish

4.) Rotating spindles
- Drilling, wire brushing, Grinding etc

5.) Heating Tourches
- flamethrowers in a smaller version

6.) Water Jet Cutting
- high-pressure water jet used for cutting through materials.

⑥ Key Design Considerations for Grippers

1.) Reachability
2.) Size Variations
3.) Size Changes
4.) Fragility
5.) Grasping Dimensions
6.) Resilient Pads

③

Sensors

Transducer & Sensor

① • A transducer is a device that converts one type of physical force into another form.

~~• Sensor & transducer requires calibration~~

• A sensor is a transducer that is used to make a measurement of a physical variable of interest. Ex:- Speedometers etc.

There are 2 types of sensors :-

1.) Analog transducers
2.) Digital transducers

1.) → provides a continuous analog signal such as electricity voltage or current.

2.) → Digital once produce a digital output signal.
- either in parallel status bits (or) series of pulses that can be counted.

② Features of Sensors

1.) Accuracy
- Accuracy should be high as possible
- No positive or negative errors should be seen.

2.) Precision
- Precision should be high as possible.
- No ~~xx~~ random variability in measured variable.

3.) Operating Range
- Should possess a wide operating range

4.) Speed of Response
- Response should be instantaneous
- Minimum time delay.

5.) Calibration
- Should be easy to calibrate
- time and trouble required to calibrate should be minimum.

6.) Reliability
- No frequent failures should be seen

7.) Cost — less, no highlyskilled operator to be required.

(3) Types of Sensors

1.) Tactile sensors
2.) Proximity and range sensors
3.) Miscellaneous sensors and sensor-based systems
4.) Machine Vision

1.) → Indicate contact between themselves and some other solid object
  - a) Touch Sensors
  - b) Force Sensors

a) Touch
  - Provide a binary output based on if contact is made with the object.
    Ex:- Microswitches
  - Can indicate the presence or absense of parts in multifunctional operations
    Ex:- Conveyor Belt

b) Force
  - Contact as well as magnitude of force b/w the two objects.
  - Can indicate if screws have become cross-threaded or jammed.
  - Can be accomplished by
    (i) Force sensing Wrist.

(i) Force - Sensing Wrist

↳ To provide information about the 3 components of force f_x, f_y, f_z and 3 moments M_x, M_y, M_z.

↳ Component as Controller

1 → Measures the forces at the wrist in each axis direction.
2 → Calculate the force offsets required.
3 → Calculates torque to be applied so that offsets match.
4 → Then provide torque.

Defects

↳ Must be able to tolerate the occasional crash of the Robot Arm.
↳ Momentum of arm makes it difficult to stop from crashing.

c) Joint Sensing

↳ force feedback, Precision control, Safety, Performance Monitoring

d) Tactile Array Sensors

↳ Arranged like pixels on a screen → they detect by pressure applied on them.

3.) Proximity and Range Sensors

↳ Detect how close is an object without touch

↳ Using rays or lasers to detect

Range

↳ Measure exact distance to an object

④ Uses of Sensors

1.) Safety monitoring

2.) Interlocks in workcell control

3.) Part inspection for quality control

4.) Determining position

- Concerned with sensing of vision data and its interpretation by a computer.

Process
- Sensing and digitizing image data
- Image processing and analysis.
- Application

→ (1) Imaging Devices

→ Taking pictures of photos or small frames of the object which needs to be worked on.
→ By using a camera

→ (2) Lighting

→ Good illumination of the scene is important because of its effect on the level of complexity of image-processing algorithms required

→ (3) Analog-to-Digital

→ here the analog signal is converted into digital form for each pixel.

→ (4) Image Storage

→ then stored into the computers memory.

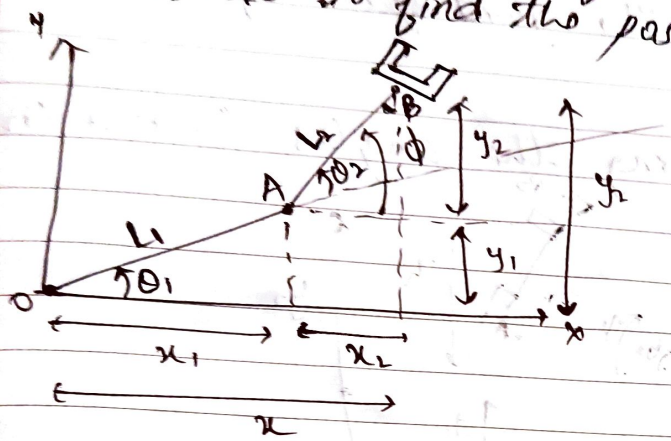
→ Distinguishing an object with another compared to previously stored results.

→ (6) Object Recognition

→ Identifies the object in the image represented

① Forward kinematics

→ refers to the use of kinematics equations of robots to find the position of end effects.



→ So basically finding out (x, y) co-ordinate.

$x_1 = L_1 \cos\theta_2$ $\quad x_2 = L_2 \cos(\theta_1 + \theta_2)$

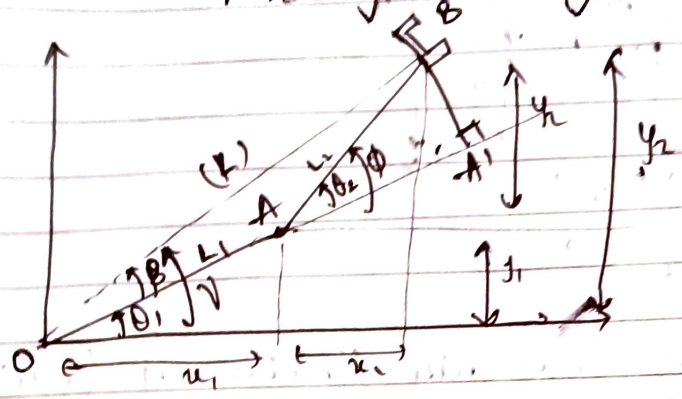
$y_1 = L_1 \sin\theta_1$ $\quad y_2 = L_2 \sin(\theta_1 + \theta_2)$

$(x, y) \Rightarrow (x_1 + x_2,\ y_1 + y_2)$

② Reverse Kinematics

→ refers to the use of kinematics equations to determine the joint space from desired position.

→ Finding the angles θ_1 and θ_2



Take R as resultant → $R^2 = x^2 + y^2$

$R^2 = (OA')^2 + (A'B)^2$

→ $\cos\theta_2$ →

$$\theta_2 = \cos^{-1}\left[\frac{x^2+y^2-L_1^2-L_2^2}{2L_1L_2}\right]$$

For θ_1 → $\tan\beta = \frac{L_2\sin\theta_2}{L_1+L_2\cos\theta_2}$

$$\beta = \tan^{-1}\left[\frac{L_2\sin\theta_2}{L_1+L_2\cos\theta_2}\right]$$

$\tan\gamma = y/x \qquad \gamma = \tan^{-1}(y/x)$

$\theta_1 = \gamma - \beta \Rightarrow \tan^{-1}(y/x) - \tan^{-1}\left[\frac{L_2\sin\theta_2}{L_1+L_2\cos\theta_2}\right]$

(5) Material Transfer and Machine Loading / Unloading

(1) Pick and Place operations (2 degrees of freedom) L, R.

- These are tasks where a Robot picks up a part from one location and moves it to another.
  → (Manufacturing & assembly lines).

Process

(i) Presentation of the Part
  → The part is usually stopped at a position on a conveyor belt.
  → A sensor (limit switch) indicated that the part is ready to pickup.

(ii) Robot Picks Up the Part.

(iii) Movement of the Part

(iv) Placement of the part.

(2) Palletizing

- It is the process of loading and stacking products, like cartons or boxes, onto a pallet.
  → Handling large quantities of goods becomes more efficient.

(i) Manual Palletizing

↳ Man or workers doing tasks.

(ii) Automated Palletizing

↳ Robots are often used to automate the palletizing process.

Process

(a) Presentation of Carton
(b) Picking up Carton
(c) Placement of Pallet

(3) Machine Loading and Unloading

- It refers to the process of transfering parts to and from a production machine, often using robots to automate these tasks.

Process

(a) Presentation of Parts
(b) Robot Loading
(c) Processing
(d) Robot Unloading.

Applications

- Die Casting
  → Robots load raw materials into die-casting machines and unload finished parts
- Plastic Molding
  → Robots handle plastic parts in molding processes
- Forging
  → Robots load and unload parts into forging operation
- CNC operations
- Stamping Press operations.

④ Die Casting

- Manufacturing process where molten metal is injected into a mold under high pressure to create metal parts.

Process

(a) Preparing the Die
(b) Injection of Molten Metal
(c) Cooling and Solidification
(d) Opening the Die
(e) Trimming

⑤ Plastic Molding

- Manufacturing process used to create plastic parts in various shapes and sizes.

Process

(a) Material Preparation
(b) Heating
(c) Injection
(d) Molding
(e) Cooling and Solidification
(f) Ejection

⑥ Spot Welding

- Process used to join 2 pieces of sheet metal together at specific points.

Process

(a) Positioning the Metal
(b) Applying Electrodes
(c) Passing current
(d) Cooling and releasing.

- The Welding gun is attached to the Robots End Effector or the Wrist.

⑦ Continuous Arc Welding

- Process where continuous Electric Arc is used to join two pieces of metal.

Process

(a) Positioning of the Metals
(b) Generating the Arc
(c) Creating Weld

Problems faced

(i) Heat and Hazards
(ii) Precision and Control
(iii) Adaptability
(iv) Sensor Integration
(v) Complexity of Programming

⑧ Features of Welding Robot

(i) Work Volume and DOF
(ii) Motion Control System
(iii) Precision of Motion
(iv) Interface with other Systems.
(v) Programming