Module 4

Joining Processes & Robotics

Lecture 20:

Objective: Introduction to joining process and different types. Discussion about soldering.

Introduction

Joining process is where two or more pieces of parts are joined together to produce a single product of required shape and size. The parts required for joining are produced by any other manufacturing technique. There are different methods used to join the parts. The joining process can be classified as :

a) Permanent joining process
b) Semi – permanent or temporary joining process

Fusing the metal together is a permanent joining process. In this process the metal is heated to its melting state and then it is fused to become one. Some of the examples for permanent joining process are welding, soldering and brazing.

Temporary joining process is where the metal is not heated. The joining process is carried out at room temperature. Temporary joining process can be done using nuts, bolts, screws and adhesives.

Soldering

It is defined as “a joining process wherein coalescence is produced by heating to a suitable temperature and by using a filler metal having a melting point not exceeding 427^{o}C and below the solidification temperature of the base metals”. The filler metal fills in the gap of the joint by capillary action. Soldering uses fusible alloys to join metals known as solder. Ordinary gas flames or electric soldering iron is used to supply the heat to melt the solder. Fluxes are used with solder in soldering process.

Fluxes are defined as any solid, liquid or gaseous materials, which, when heated accelerate the wetting of metal with the solder. Due to wetting molten solder flow into the joint and fills the space between the two pieces to be soldered. At elevated temperature flux is highly reducing in nature preventing the formation of metal oxides. Fluxes that are generally used in soldering are Rosin, Zinc Chloride and Aluminum Chloride.

The kind of solder used depends on the metals to be joined. There are two different types of solders -

Hard solders are called spelter and hard soldering process is called silver solder brazing. The hard solder has lead and silver as it constituents. The melting point of the hard solder is in the range of 350^{o}C and above. This process gives greater strength and withstand more heat than soft solder.

Soft solder is used for joining most common metals with an alloy that melts at a temperature below that of the base metal, and always below 427^{0}C. The melting range of soft solder is 150 to 200^{0}C. The solder contains tin and lead as it constituents.

Advantages:

1. The process is done at low temperatures hence, no metallurgical damage to the base metal.
2. Simple heating of the solder can dismantle the soldering joint.
3. It is cost effective

Disadvantages:

1. The strength of the joint is not good compared to welding.
2. Flux material has to be cleaned after soldering, as most of the fluxes are corrosive in nature.

Application of soldering

- Assembling electronic components to printed circuit boards.
- Making connection between copper pipes in plumbing system
- Used in joining sheet metal objects like food cans and metal containers
- Used as a semi-permanent patch for a leak in container

Examples of solder	**Application**
Tin-lead	general purpose
Tin-zinc	joining aluminum
Lead-silver	Strength at temp. Higher than room temp.
Zinc-aluminum	corrosion resistance
Tin-silver, tin-bismuth	electronic applications

Lecture 21:

Objective: Discussion about welding and its types.

Welding

At one time, the simple definition of welding was "joining metals through heating them to a molten state and fusing them together." As technology in welding processes advanced, the definition has had to change.

Welding is defined as **"**a localized coalescence of metals, wherein coalescence is obtained by heating to suitable temperature, with or without the application of pressure and with or without the use of filler material. This filler material has the melting point same as the base material**."** It is also know as a *metallurgical joining process* of two metal pieces, to produce a single piece of product. .

For today's definition of welding to be all encompassing, it would have to read, **"***the joining of metals and plastics without the use of fasteners***."**

Welding Terminologies

Base Metal – Work pieces that are needed to be joined

Weld Bead **-** A weld bead is a weld deposit produced by a single pass of the welding processes. It is also known as bead.

Puddle – The molten base metal at the joint during the welding operation.

Weld pass – Movement of weld torch from one end of the joint to the other end.

Tack Weld – it is the temporary joint done before welding to keep the work pieces to be welded in place during welding. The joints are done at the ends of the work piece.

Classification of Welding Process

The welding process can be classified based on the source of energy to heat the metal and the state of metal at the joint.

1. Pressure Welding
2. Fusion Welding

Pressure Welding

The surfaces of the joint to be welded is heated to a plastic state and forced together with external pressure to finish the joint.

Pressure welding depends on the application of pressures and temperatures, resulting in a plastic state with local deformation of the pieces to be joined in the weld area so that a bond between both pieces is made.

ISO – 857 defines Pressure welding process as "Welding in which sufficient outer force is applied to cause more or less plastic deformation of both the facing surfaces, generally without the addition of filler metal. Usually, but not necessarily, the facing surfaces are heated in order to permit or to facilitate bonding"

Some of the common welding processes that can be grouped under this category are:

1. Resistance welding
2. Friction Welding
3. High Frequency welding
4. Ultrasonic Welding
5. Explosion Welding
6. Magnetic Pulse welding
7. Cold pressure welding
8. Diffusion Welding etc.,

Fusion Welding

The pieces to be joined are heated to molten state and allowed to solidify to form joint with or without the addition of filler material. The process is carried out without the application of pressure.

ISO – 857 defines fusion welding "Welding without application of outer force in which the facing surface(s) must be melted. Usually, but not necessarily, molten filler metal is added".

Some of the fusion welding processes is:

1. Gas welding
2. Electric arc welding
3. Thermit Fusion Welding

The welding Process can also be classified as based type of filler material added

1. Autogeneous
2. Homogeneous
3. Heterogeneous

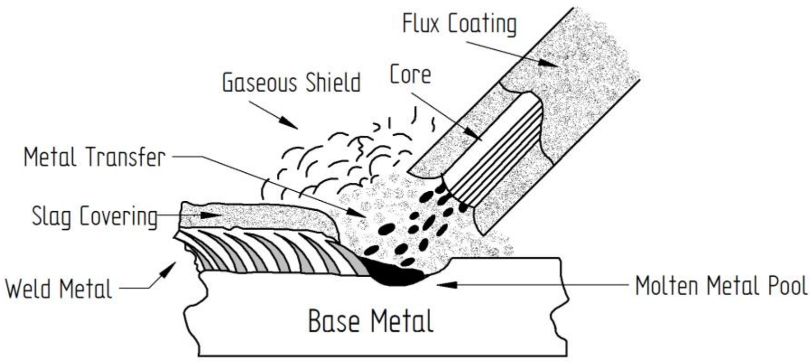
In autogeneous, there is no filler material added to join the work pieces. Some of the pressure welding processes like electric resistance welding, hot and cold pressure welding filler material are not added to the base material.

In Homogeneous, the filler material is added to compensate for the gap between the two work pieces. The filler material that is added is of the same type as that of the base material. Example – Welding of 70 – 30 brass with a 70 – 30 brass-welding rod.

In Heterogeneous, the filler material added is of different composition to that of the base material.

Arc Welding

Arc welding is one of several fusion welding processes for joining metals. By applying intense heat through an electric arc, metal at the joint is melted and caused to intermix – directly, or with intermediate molten filler metal. Upon cooling and solidification, a metallurgical bond is created. Since the joining is an intermixture of metals, the final weldment potentially has the same strength properties as the metal of the parts.



Principle of Arc welding

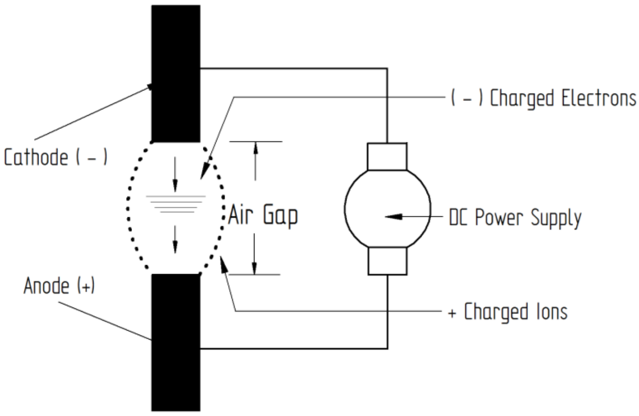
Welding arc can be defined as a "Sustained electrical discharge through an ionized gas".

There are two theories through which the arc formation can be explained:

(i) Ion exchange theory
(ii) Electron theory of arc column theory

According to ion exchange theory of arc, the electrons are emitted from the cathode and ions form the anode. The electrons at cathode get accelerated and gain energy due to passage of high current and low voltage. As these electrons enter the arc column, they lose their energy by colliding with gas molecules in the air gap between the cathode (electrode) and the anode (work piece). Due to the collision, electrons give out their kinetic energy and break the gas atoms into electrons and positive ions. The electrons and ions move towards cathode and anode respectively, concentrate at anode and cathode regions, get condensed and absorbed. This produces good amount of heat energy, which is employed for joining various metals and alloys by fusion.

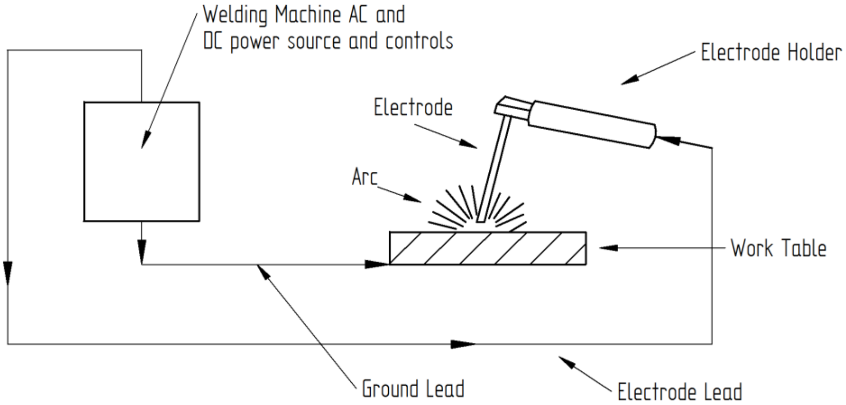
In electron theory, when an electric arc is struck between the anode and the cathode, flow of electrons takes place from cathode to anode. The electrons mass is very less and they attain high velocities. High velocity electrons strike the anode giving out their kinetic energy into heat energy. The positive charge ions move from the anode to cathode encircling the stream of electrons at the center. The maximum heat energy released from an electric arc column is at the anode when DC arc welding is done.



Electron theory of arc column

Arc Welding Equipment

For Arc welding DC and AC welding supply, electrode holder, and welding cables are used



Arc welding

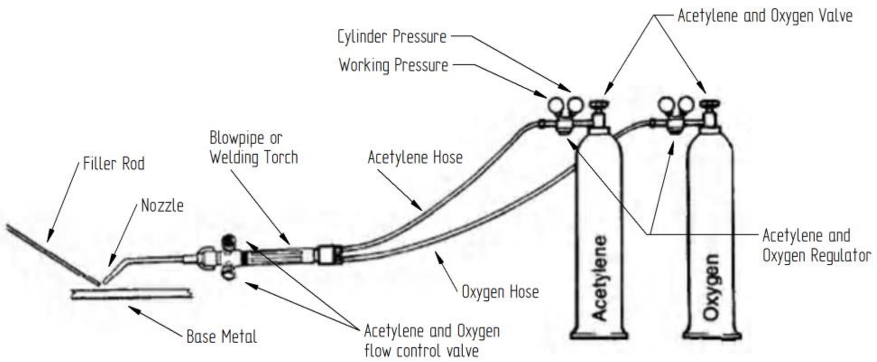
Lecture 22:

Objective: Discussion about gas welding and types of flames.

Gas Welding

Gas welding is one of the oldest methods of fusion welding process and, for many years, was the most widely used method of metal melting. The equipment is relatively simple and cheap. Heat is generated by the combustion of combustible gas with oxygen. Required gas ratio is mixed in the hand held torch. Combustion takes place at the nozzle or the outlet of the torch. This process of welding is generally known as Oxygen – Fuel Gas welding (OFT). Some of the commercial gas that is used for welding is acetylene, hydrogen, propane, butane and commercial LPG.

Oxy – Acetylene Gas welding



Oxy-acetylene welding

This is a common gas welding process. Acetylene is the fuel gas used. Acetylene produces high heat content in the range of 3200^0 C than other fuel gases. Acetylene gas has more available carbon (92.3 %) and hydrogen (7.7 %) by weight. The heat is released when the carbon breaks away from hydrogen to combine with O2 and burn.

$$C_2H_2+O_2 = 2CO+H_2+Heat$$

Gas welding equipment

(a) Two large cylinders:

One cylinder contains oxygen at high pressure and the other contains acetylene gas.

(b) Pressure regulators

The pressure regulators control the pressure of the gas as per requirements.

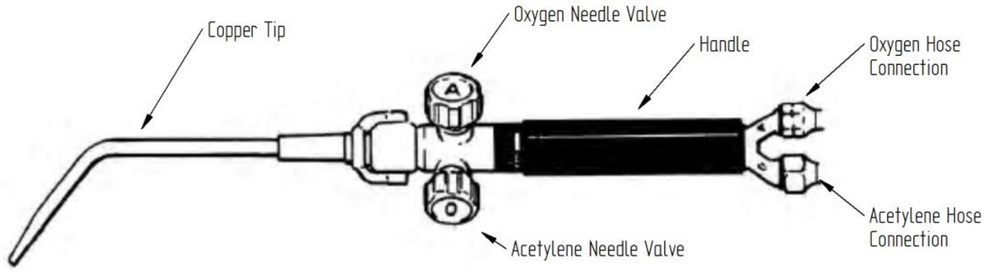
(c) Welding torch

It is a device used to mix both oxygen and acetylene gases in proper proportions and to burn the mixture at the tip.

Operation:

By adjusting the process regulators, suitable proportions of oxygen and acetylene gases enter into the welding torch. Equal volumes of oxygen and acetylene get mixed in the torch and are issued from the torch to burn in the atmosphere.

The temperature of the flame at the tip of the torch is in the range of 3200^0C and this heat is sufficient enough to melt the workpiece metal. Since a slight gap usually exists between the workpiece, a filler metal can be used to supply additional material so as to fill the gap. The deposited metal fills the joint and bonds the joint to form a single piece of metal.



Blow torch

Types of Flames

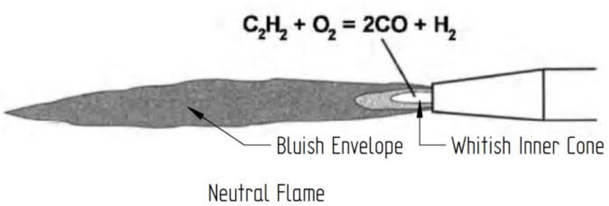
One volume of Acetylene gas requires 2.5 times the volume of oxygen for its complete combustion. Depending upon the ratio of oxygen supplied for combustion we can classify flames into 3 types. This ratio is known as gas ratio. These flame types have a great effect on the melt pool chemically. There are 3 types of flames and they are-

(i) Neutral Flame,
(ii) Carburizing flame, and
(iii) Oxidizing Flame.

(i) Neutral Flame

Neutral flame is the one that is used the most. This flame is obtained by supplying equal volumes of oxygen and acetylene. Its zones of combustion can distinguish the flame. The innermost zone, the cone, is white in color and extends a short distance from the tip of the torch. Acetylene burns in this zone to form carbon monoxide and hydrogen. The approximate temperature of the inner cone is 32000 C.

The outer cone or envelope is faintly luminous and bluish is color. Carbon monoxide and hydrogen burn with oxygen in air forming carbon dioxide and water vapour hence preventing the atmospheric oxygen coming in contact with the molten metal pool.

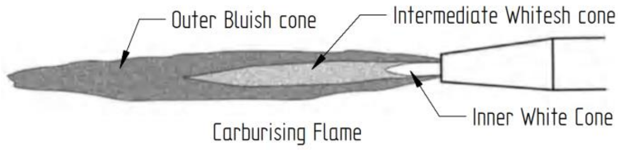


Neutral Flame

(ii) Carburizing Flame

In this flame acetylene proportion is increased in the gas ratio of 0.95 to 1.0. The flame has three zones a) inner white zone b) intermediate whitish cone and c) bluish outer envelope. The inner zone is sharply defined and white in color. In this zone there is insufficient oxygen to burn surplus acetylene. Cone temperature is approximately about 3100^0 C.

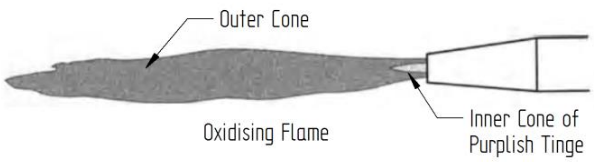
The remaining acetylene continues to the second zone known as the intermediate cone of whitish color. This intermediate zone extends in length depending up on the amount of acetylene present in the gas.



Carburizing Flame

(iii) Oxidizing Flame

In this flame there is excess of oxygen. The flame has a small inner cone and outer envelope. The inner cone is not sharply defined as in neutral flame and carburizing flame. The inner cone is purplish is color. The temperature of the inner cone is approximate of $3350 – 3400^0$ C.



Oxidizing Flame

Sl No.	Welding	Soldering	Brazing
1.	It is a high temperature process where the base metals are heated above their melting temperature.	It is a low temperature process where the base metals are not melted.	The base metals are not melted but broadly heated to a suitable temperature.
2.	The filler material used is made of same material as that of the base metal.	Filler material used is not the same as that of the base metal.	Filler material used is not the same as that of the base metal
3.	Joint is formed by the solidification of the molten filler metal with the molten base metal	Joint is obtained by means of diffusion of the filler metal into the base metal.	Joint is obtained by means of diffusion of the filler metal into the base metal associated with surface alloying.
4.	Strength of the joint obtained in welding is much stronger than the parent metal	Strength of the joint obtained in soldering is very low when compared to that of brazed and welded joints.	Strength of the joint lies in between that of welded and soldered joints.
5.	Since welding is carried out at high temperatures**,** the metal adjacent to the weld portion called the heat affected zone is affected to a large extent.	Heat affected zone is almost negligible since the process is carried out at lower temperatures.	Although base metals are heated, the heat affected zone is not too much when compared to welding.
6.	Requires certain finishing operations like grinding, filling etc.	Joints can be used as it is without any finishing operations.	Surface finish is good. In some cases, finishing operations are required.
7.	Welding produces stronger joints. Hence this process is used for fabrication and structural applications.	Since the joint obtained is not much strong, this process is mostly used for joining thin sheet metals, pipes, wires etc.	Finds applications in arts, jewelry works and also in industries.

Lecture 23:

Objective: Introduction to robotics and its classification.

Introduction

Robots are devices that are programmed to move parts, or to do work with a tool. Robotics is a multidisciplinary engineering field dedicated to the development of autonomous devices, including manipulators and mobile vehicles.

What is a robot?

In 1980, the Robot Institute of America (RIA) came up with the following

Definition:

A robot is a reprogrammable multifunctional manipulator designed to move material, parts, tools, or specialized devices through variable programmed motions for the performance of a variety of tasks.

Nowadays, this definition would be considered too restrictive, as it reflects the concentration of the RIA on robot manipulators on an assembly line. Robotics has broadened over the years in many ways: to include mobility platforms, to address the service sector as well as the manufacturing sector, and to incorporate man-machine interactions, not just autonomy, in tele-robotic and virtual reality systems. For this reason more convenient is a broad definition:

A robot is device that operates with some degree of autonomy, usually under computer control.

A basic distinction is between mobility and manipulation. A mobile robot can be any form of vehicle, such as a motorized cart, a car, a plane, or a submersible, and in the case of land navigation it can have wheels, tracks, or legs. The main goal of a mobile robot is transport, under guidance of on-board sensors and an intelligent controller.

A manipulator is a mechanical linkage, which may or may not be arm-like, with a gripper or tool to perform some action on the environment.

CLASSIFICATION OF A ROBOT

Robots have been classified under the following categories:

1. **Based on their physical configuration**

    a) Polar co-ordinate configuration

    b) Cylindrical co-ordinate configuration

    c) Cartesian co-ordinate configuration

    d) Jointed arm configuration

2. **Based on the type of drive system**

    a) Hydraulic drive system

b) Pneumatic drive system

c) Electric drive system

3. Based on the control system and dynamic performance

a) Limited sequence robots

b) Play back robots with point-to-point controls

c) Play back robots with continuous path controls

d) Intelligent robots

4. Based on the position of robots

a) Mobile robots

b) Stationary robots

5. Based on the area of application

a) Domestic robots

b) Industrial robots

c) Defense robots

d) Research robots

6. Based on the type of controllers

a) ON-OFF controllers

b) Proportional controllers

c) Integral controllers

d) Proportional-plus-integral controller (P-I controller)

e) Proportional-plus-derivative controller (P-D controller)

f) Proportional-plus-Integral-plus-Derivative controller (P-I-D controller)

7. Based on the type of end effectors

a) Grippers

b) Tools

8. Based on the type of programming methods

a) Manual programming

b) Walk through programming

c) Lead through programming

d) Off-line programming

Lecture 24:

Objective: Discussion about Robot physical configuration.

Robot physical configuration

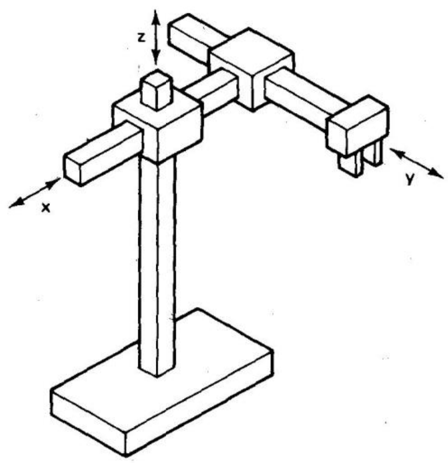
Industrial robots come in a variety of shapes and sizes. They are capable of various arm manipulations and they possess different motion systems. Robot configuration specifies the possible movements provided by different robots. The majority of present commercially available robots possess one of these four basic configurations.

Classification based on Physical configurations:

Four basic configurations are identified with most of the commercially available industrial robots

1. **Cartesian co-ordinate configuration (L-O-O configuration):**

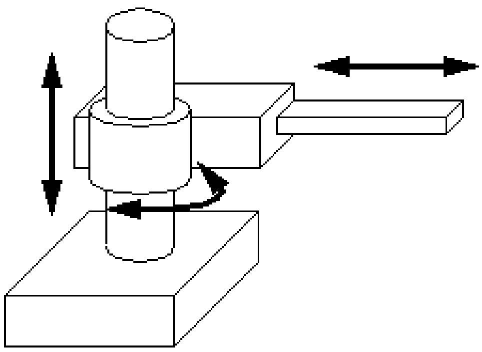
Cartesian co-ordinate robot consists of three perpendicular slides arranged in X, Y and Z directions. By moving these three slides relative to one another the robot is capable of operating within a rectangular work area. It robot is also called as XYZ robot, rectilinear robot (or) Box configuration robot. This configuration robot consists of one Linear prismatic joint (L) and two orthogonal prismatic joints (O) and also called as L-O-O configuration robot. Example- IBM RS-1.



Cartesian co-ordinate configuration

2. **Cylindrical co-ordinate configuration (T-L-O):**

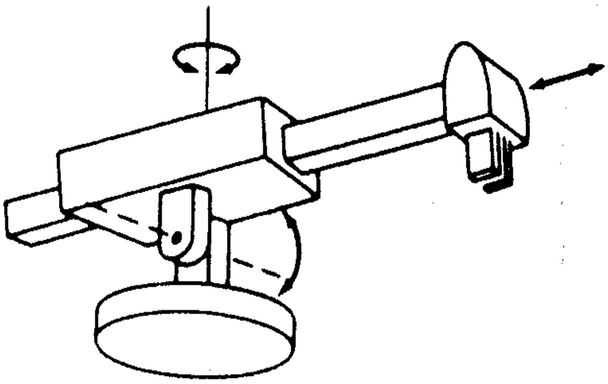
Cylindrical configuration robot consists of a vertical column and a slide which can be moved up or down along with the column. The robot arm is attached to the slide so that it can move radially with respect to the column. By rotating the column, the robot can be able to achieve the workspace similar as cylinder. It consists of one Twist joint (T), one orthogonal Prismatic joints (O) and one linear prismatic joint (L) and hence is also called as T-L-O configuration. It has a rigid structure with a very high load carrying capability. A cylindrical configuration robot has very repeatability with least error. Example: M1A-developed by GM.



Cylindrical co-ordinate configuration

3. **Polar configuration (T-R-L configuration)**:

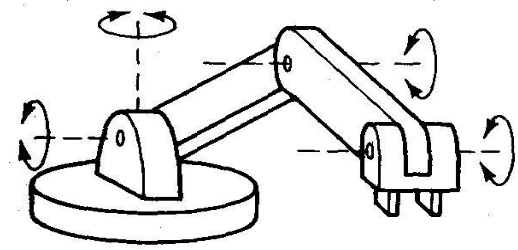
This configuration also goes by the name "spherical coordinate" because the workspace within which it can move its arm is a partial sphere as shown in figure. It uses a telescopic arm that can be raised or lowered about a horizontal joint. This robot consists of one linear prismatic joint (L), a Rotational joint (R) and a Twist joint (T), and hence is also called as T-R-L configuration. These joints provide the robot with the capacity to move its arm in a spherical space and hence this robot is sometimes called as spherical co-ordinate robot. The workspace within which the polar configuration robot moves its arm will be spherical in shape. Most of the commercially available robots possess polar configuration. Example: UNIMATE 2000 series, MAKER 110



Polar configuration

4. **Jointed-arm configuration (T-R-R configuration):**

This type of robot is combination of cylindrical and articulated configurations. This is similar in appearance to the human arm, as shown in fig. The arm consists of several straight members connected by joints which are analogous to the human shoulder, elbow, and wrist. The robot arm is mounted to a base which can be rotated to provide the robot with the capacity to work within a quasi-spherical space. The workspace within which this robot can move its arms is irregular. This consists of no prismatic joints, but has two rotary joints (R) and one twist joint (T) and hence is also called as T-R-R configuration. This type of configuration has higher reach from the base. They are useful in continuous path generation and in applications like spray painting and welding. Example: SCARA, Milacron T3



Jointed-arm configuration

Lecture 25:

Objective: Discussion about advantages, disadvantages and applications of robots.

Advantages of robots

- Robotics and automation can, in many situation, increase productivity, safety, efficiency, quality, and consistency of Products.
- Robots can work in hazardous environments.
- Robots need no environmental comfort.
- Robots work continuously without any humanity needs and illnesses.
- Robots have repeatable precision at all times.
- Robots can be much more accurate than humans; they may have milli or micro inch accuracy.
- Robots and their sensors can have capabilities beyond that of humans.
- Robots can process multiple stimuli or tasks simultaneously, humans can process only one at a time.
- Robots replace human workers who can create economic problems.

Disadvantages of robots

Robots lack capability to respond in emergencies, this can cause:

- Inappropriate and wrong responses
- A lack of decision-making power
- A loss of power
- Damage to the robot and other devices
- Human injuries
- Robots may have limited capabilities in different degrees of Freedom
- Dexterity
- Sensors
- Vision systems
- Real-time response

Robots are costly, due to

- Initial cost of equipment
- Installation Costs
- Need for peripherals

- Need for training
- Need for programming.

ROBOT APPLICATIONS

1. Material-handling applications

Involve the movement of material or parts from one location to another. It includes part placement, palletizing and/or de-palletizing, machine loading and unloading.

2. Processing Operations

Robot performs a processing procedure on the part. The robot is equipped with some type of process tooling as its end effectors. Manipulates the tooling relative to the working part during the cycle. Industrial robot applications in the processing operations include:

- Spot welding
- Continuous arc welding
- Spray painting
- Metal cutting and deburring operations
- Various machining operations like drilling, grinding, laser and water jet cutting, and riveting.
- Rotating and spindle operations
- Adhesives and sealant dispensing

3. Part Placement

The basic operation in this category is the relatively simple pick-and-place operation. This application needs a low-technology robot of the cylindrical coordinate type. Only two, three, or four joints are required for most of the applications. Pneumatically powered robots are often utilized.

4. Palletizing and/or De-palletizing

The applications require robot to stack parts one on top of the other, that is to palletize them, or to un-stack parts by removing from the top one by one that is de-palletize them. Example: process of taking parts from the assembly line and stacking them on a pallet or vice versa.

5. Machine loading and/or unloading

Robot transfers parts into and/or from a production machine.

There are three possible cases:

- Machine loading in which the robot loads parts into a production machine, but the parts are unloaded by some other means.

Example: a press working operation, where the robot feeds sheet blanks into the press, but the finished parts drop out of the press by gravity.

- Machine loading in which the raw materials are fed into the machine without robot assistance. The robot unloads the part from the machine assisted by vision or no vision.

Example: bin picking, die casting, and plastic moulding.

- Machine loading and unloading that involves both loading and unloading of the work parts by the robot. The robot loads a raw work part into the process ad unloads a finished part.

Example: Machine operation difficulties

6. **Stacking and insertion operation**

In the stacking process the robot places flat parts on top of each other, where the vertical location of the drop-off position is continuously changing with cycle time. In the insertion process robot inserts parts into the compartments of a divided carton.

Module – V

Refrigeration

Lecture 26:

Objective: Introduction to refrigeration and discussing its principle.

Introduction