UNIT-4

Computer numerical control Machines: Numerical control, computer numerical control, axis, co-ordinate system, types of slide control and control system.

Welding, Soldering and brazing: Oxyacetylene welding, arc welding, electrodes, soldering and brazing.

Bearings: Classifications; Journal bearing, bushed, pedestal, thrust bearings, foot-step, collar. Antifriction bearings, ball and roller.

Additive Manufacturing: Introduction, classification of rapid prototyping process, types of rapid prototyping process (SLA, FDM, and LOM), advantages, and application

Computer numerical control Machines

Definition

Computer Numerical Control (CNC) is one in which the functions and motions of a machine tool are controlled by means of a prepared program containing coded alphanumeric data. CNC can control the motions of the work piece or tool, the input parameters such as feed, depth of cut, speed, and the functions such as turning spindle on/off, turning coolant on/off.

Applications

The applications of CNC include both for machine tool as well as non-machine tool areas. In the machine tool category, CNC is widely used for lathe, drill press, milling machine, grinding unit, laser, sheet-metal press working machine, tube bending machine etc. Highly automated machine tools such as turning center and machining center which change the cutting tools automatically under CNC control have been developed. In the non-machine tool category, CNC applications include welding machines (arc and resistance), coordinate measuring machine, electronic assembly, tape laying and filament winding machines for composites etc.

Advantages and Limitations

The benefits of CNC are (1) high accuracy in manufacturing, (2) short production time, (3) greater manufacturing flexibility, (4) simpler fixturing, (5) contour machining (2 to 5 –axis machining), (6) reduced human error. The drawbacks include high cost, maintenance, and the requirement of skilled part programmer.

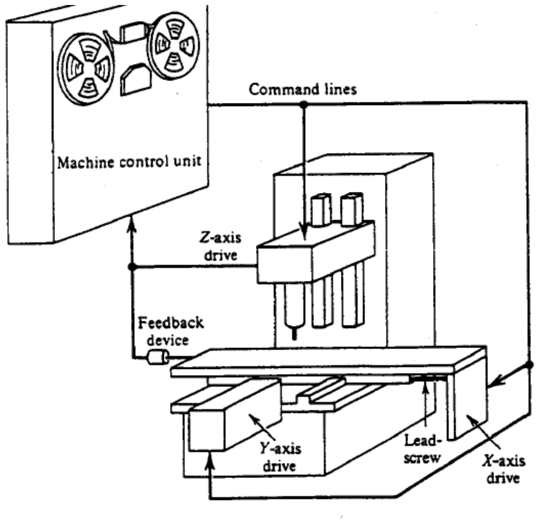
ELEMENTS OF A CNC

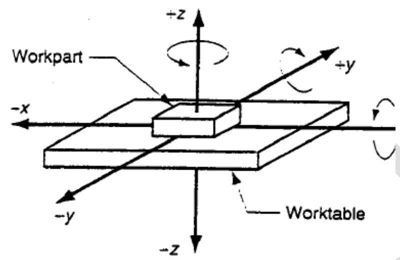
A CNC system consists of three basic components

1 . Part program
2 . Machine Control Unit (MCU)
3 . Machine tool (lathe, drill press, milling machine etc)

1. Part Program

The part program is a detailed set of commands to be followed by the machine tool. Each command specifies a position in the Cartesian coordinate system (x,y,z) or motion (workpiece travel or cutting tool travel), machining parameters and on/off function. Part programmers should be well versed with machine tools, machining processes, effects of process variables, and limitations of CNC controls. The part program is written manually or by using computer assisted language such as APT (Automated Programming Tool).





2. **Machine Control Unit (MCU)**

The machine control unit (MCU) is a microcomputer that stores the program and executes the commands into actions by the machine tool. The MCU consists of two main units: the data processing unit (DPU) and the control loops unit (CLU). The DPU software includes control system software, calculation algorithms, translation software that converts the part program into a usable format for the MCU, interpolation algorithm to achieve smooth motion of the cutter, editing of part program (in case of errors and changes). The DPU processes the data from the part program and provides it to the CLU which operates the drives attached to the machine leadscrews and receives feedback signals on the actual position and velocity of each one of the axes. A driver (dc motor) and a feedback device are attached to the leadscrew. The CLU consists of the circuits for position and velocity control loops, deceleration and backlash take up, function controls such as spindle on/off.

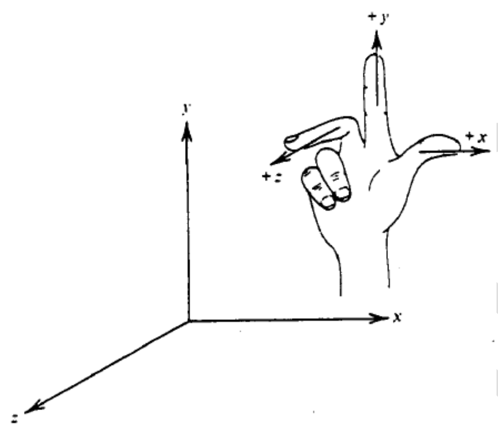
3. **Machine Tool**

The machine tool could be one of the following: lathe, milling machine, laser, plasma, coordinate measuring machine etc. Figure shows that a right-hand coordinate system is used to describe the motions of a machine tool . There are three linear axes (x,y,z), three rotational axes (i,j,k), and other axes such as tilt (9) are possible. For example, a 5-axis machine implies any combination of x,y,z, i,j,k,and 6.

AXIS SYSTEM

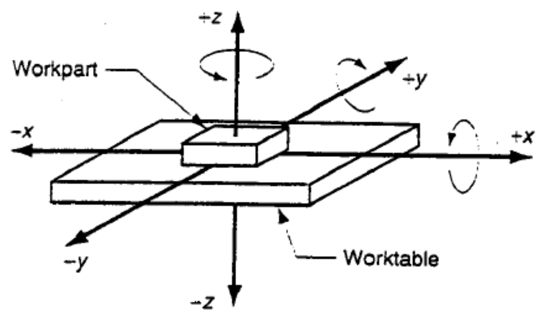
1. ***2* & 3 axes CNC machines**

   CNC lathes will be coming under 2 axes machines. There will be two axes along which motion takes place. The saddle will be moving longitudinally on the bed (Z-axis) and the cross slide moves transversely on the saddle (along X-axis). In 3-axes machines, there will be one more axis, perpendicular to the above two axes. By the simultaneous control of all the 3 axes, complex surfaces can be machined.



2. **4 & 5 axes CNC machines**

   4 and 5 axes CNC machines provide multi-axis machining capabilities beyond the standard 3-axis CNC tool path movements. A 5-axis milling centre includes the three X, Y, Z axes, the A axis which is rotary tilting of the spindle and the B-axis, which can be a rotary index table.



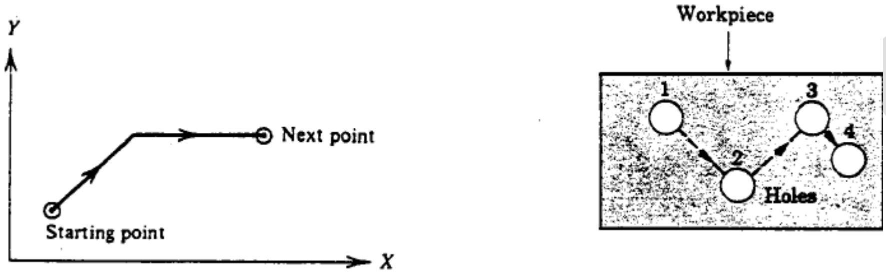
SLIDE CONTROL SYSTEM

There are two slide control system

1. Point-to-Point Systems
2. Continuous Path Systems (Straight cut and Contouring systems)

1. Point-to-Point Systems

Point-to-point systems are those that move the tool or the workpiece from one point to another and then the tool performs the required task. Upon completion, the tool (or workpiece) moves to the next position and the cycle is repeated (Figure 4). The simplest example for this type of system is a drilling machine where the workpiece move.



Cutter path between holes in a point-to-point system

2. Continuous Path Systems (Straight cut and Contouring systems)

These systems provide continuous path such that the tool can perform while the axes are moving, enabling the system to generate angular surfaces, two-dimensional curves, or three dimensional contours. Example is a milling machine where such tasks are accomplished (Figure). Each axis might move continuously at a different velocity. Velocity error is significant in affecting the positions of the cutter (Figure).

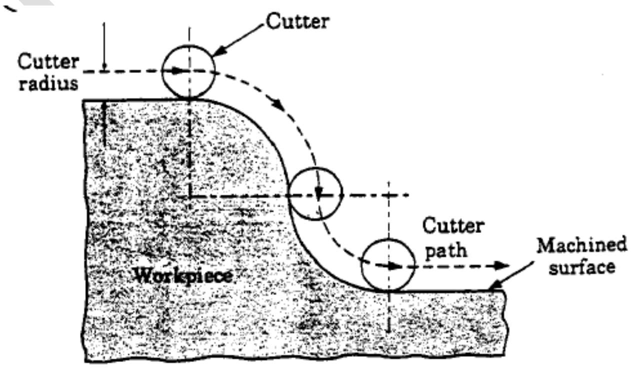
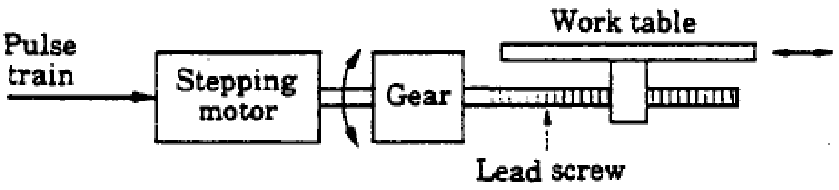


Fig. Continuous Path Systems (Straight cut and Contouring systems)

CONTROL SYSTEMS

1. Open Loop Control Systems

The open-loop control means that there is no feedback and uses stepping motors for driving the leadscrew . A stepping motor is a device whose output shaft rotates through a fixed angle in response to an input pulse (Figure 9) . The accuracy of the system depends on the motor's ability to step through the exact number. The frequency of the stepping motor depends on the load torque. The higher the load torque, lower would be the frequency . Excessive load torque may occur in motors due to the cutting forces in machine tools. Hence this system is more suitable for cases where the tool force does not exist (Example: laser cutting).



2. Closed-loop Control Systems

Closed -loop NC systems are appropriate when there is a force resisting the movement of the tool/workpiece. Milling and turning are typical examples. In these systems (Figure) the DC servomotors and feedback devices are used to ensure that the desired position is achieved. The feedback sensor used is an optical encoder shown in Figure. The encoder consists of a light source, a photodetector, and a disk containing a series of slots. The encoder is connected to the leadscrew.

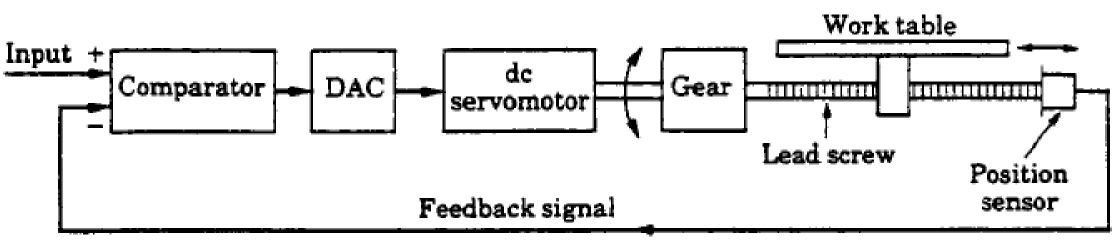


Fig. Closed-loop Control Systems

SOLDERING, BRAZING AND WELDING:

SOLDERING:

Soldering is a method of joining two thin metal pieces using a dissimilar metal or an alloy by the application of heat.

- Temperature is range of 150 to 350 degree.
- Application of flux is externally, usually rosin or borax.
- Soldering application will be electronics circuits.

PRINCIPLE OF SOLDERING

Soldering is very much similar to brazing and its principle is same as that of brazing. The major difference lies with the filler metal, the filler metal used in case of soldering should have the melting temperature lower than 450oC. The surfaces to be soldered must be pre-cleaned so that these are faces of oxides, oils, etc. An appropriate flux must be applied to the faying surfaces and then surfaces are heated. Filler metal called solder is added to the joint, which distributes between the closely fitted surfaces. Strength of soldered joint is much lesser than welded joint and les than a brazed joint.

Advantages of soldering

1) Solder joints are easy to repair
2) Solder joints are corrosion resistance.
3) Low cost and easy to use.
4) Skilled operator is required.

BRAZING:

Brazing is a method of joining two similar or dissimilar metals using a special fusible alloy. The filler metal melts and diffuses over the joint placed.

- The filler metal is called as **Spelters.**
- The flux used is borax or boric acid.
- The brazing is used in copper alloys applications.
- The temperature range is 450 to 900 degree.

PRINCIPLE OF BRAZING

In case of brazing joining of metal pieces is done with the help of filler metal. Filler metal is melted and distributed by capillary action between the faying surfaces of the metallic parts being joined. In this case only filler metal melts. There is no melting of workpiece metal. The filler metal (brazing metal) should have the melting point more than 450^{o} C. Its melting point should be lesser than the melting point of workpiece metal. The metallurgical bonding between work and filler metal and geometric constrictions imposed on the joint by the workpiece metal make the joint stronger than the filler metal out of which the joint has been formed.

BRAZING PROCESSES

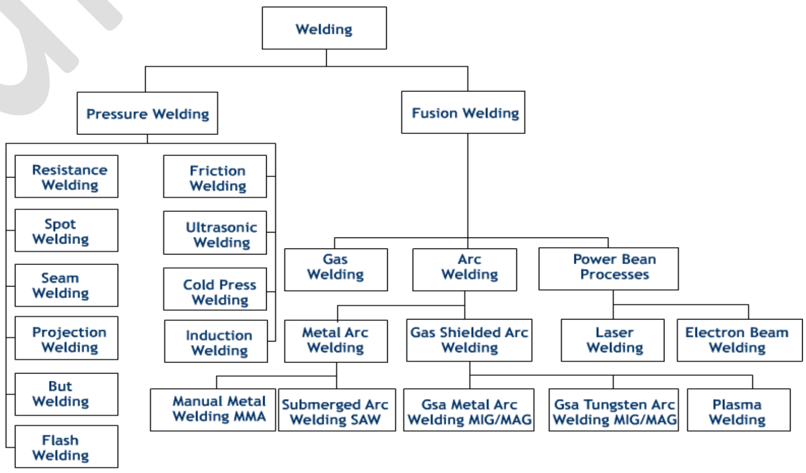
All the processes covered here can also be applied to soldering processes. These common processes are.

1. Torch Brazing
2. Furnace Brazing
3. Induction Brazing
4. Resistance Brazing
5. Dip Brazing
6. Infrared Brazing

WELDING

WELDING: Welding is a process of metallurgically joining two pieces of metals by the application of heat with or without the application of pressure and addition of filler metal. The joint formed is a permanent joint. Modern methods of welding may be classified under two broad headings.

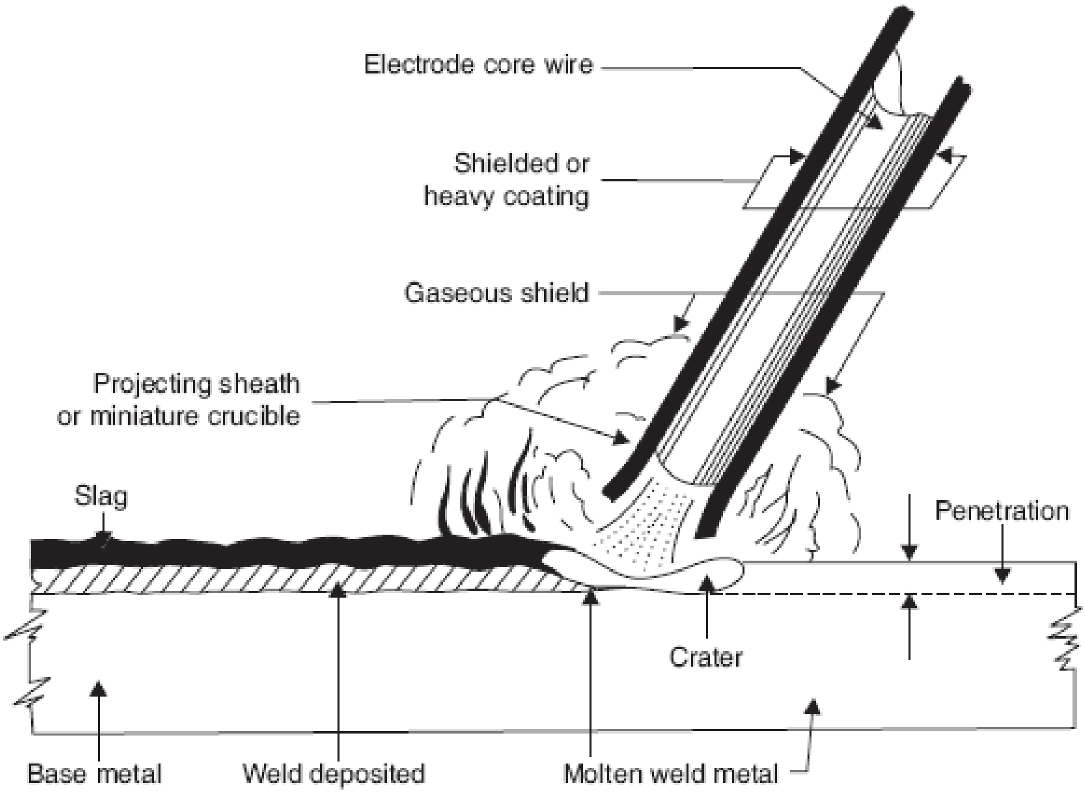
Classification of welding



Types of Welding

1) **Fusion Welding:** joining two metal pieces is heated up to molten state and allowed to solidify, also called as no-pressure welding.
   Ex- Arc welding and Gas welding
2) **Pressure welding:** joining parts to be heated up to plastic state and applying external pressure.
   Ex- Resistance welding and Forge welding.

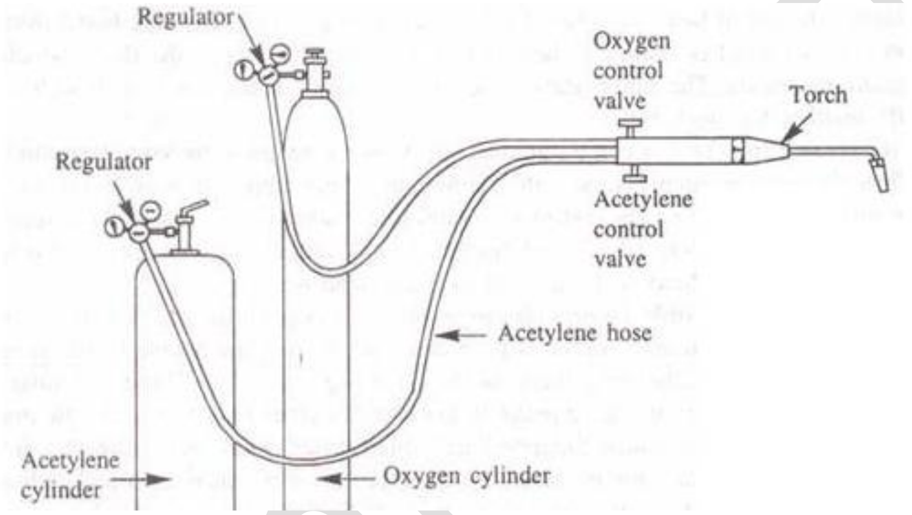
Electric Arc Welding



A typical arc welding setup is shown in Figure. Arc welding is a method of joining metals with heat produced by an electrical arc. In this process the heat necessary to melt the edges of the metal to be joined is obtained from an electric are struck between the electrode (filler rod) and the work, producing a temperature of 3000-4000^{O} C, in the welding zone. The heat of the arc melts the base metal or edges of the parts fusing them together. Filler metal, usually added melts and mixes with molten base metal to form the weld metal. The weld metal cools and solidifies to form the weld. In most cases, the composition of the filler material, known as welding rod, needed to provide extra metal to the weld, is same as that of the material being welded.

Oxy-Acetylene Welding

Gas welding is a fusion welding process, in which a flame produced by the combustion of gases is employed to melt the metal. The molten metal is allowed to flow together thus forming a solid continuous joint upon cooling. By burning pure oxygen in combination with other gases, in special torches, a flame upto $5000^{O}C$ can be attained. The gas is purchased in cylinder and connected through resulting valves and pressure gauges into flexible hoses attached to the nozzle. A typical arrangement is shown in Figure



Types of flames:

1. **Neutral Flame**
2. **Carbonizing Flame**
3. **Oxidizing Flame**

1. Neutral Flame

The correct adjustment of the flame is very important for reliable works. When oxygen and acetylene are supplied to the torch in nearly equal volumes, a neutral flame is produced having a maximum temperature of 3200C. This neutral flame is desired for most welding operations. Neutral flame has little effect on the base metal and sound welds are produced when compared to other flames. Figure shows neutral flame.

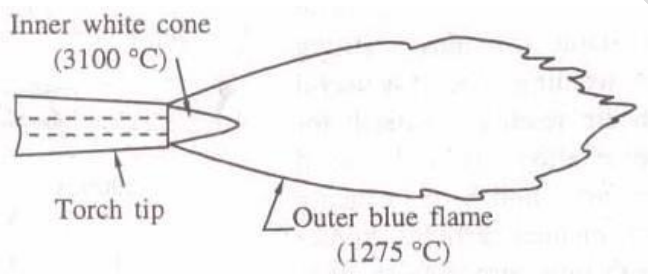


Fig : 1. **Neutral Flame**

2. Carbonizing Flame

In a carbonizing flame or reducing flame excess of acetylene is present. The temperature of this flame is low. The excess unburnt carbon is absorbed in ferrous metals, making the weld hard and brittle. In between the outer blue flame and inner white cone, an intermediate flame feather exists, which is reddish in colour. The length of the flame feather is an indication of the excess acetylene present. Figure shows a carbonizing flame. Carbonizing flame is used for welding high carbon steels and cast iron, alloy steel and for hard facing.

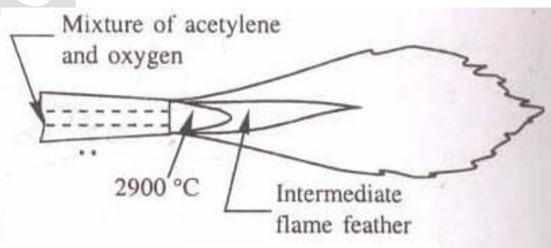


Figure : Carbonizing Flame

3. Oxidizing Flame

In an oxidizing flame excess of oxygen is present. The flame is similar to the neutral flame with the exception that the inner white cone is some what small, giving rise to higher tip temperatures. Excess of oxygen in the oxidizing flame causes the metal to burn or oxidize quickly. Oxidizing flame is useful for welding some nonferrous alloys such as copper and zinc base alloys. The Figure 7 shows the oxidizing flame.

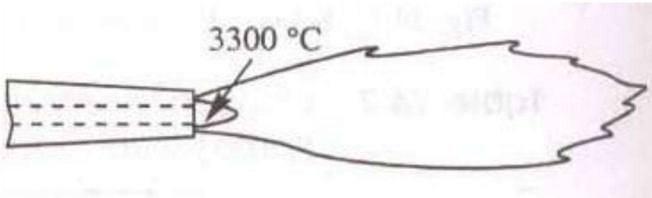


Figure : Oxidizing Flame

Differences between soldering, brazing and Welding

Sl. No.	Welding	Soldering	Brazing
1	These are the strongest joints used to bear the load. Strength of a welded joint may be more than the strength of base metal.	These are weakest joint out of three. Not meant to bear the load. Use to make electrical contacts generally.	These are stronger than soldering but weaker than welding. These can be used to bear the load up to some extent.
2	Temperature required is up to 3800°C of welding zone.	Temperature requirement is up to 450°C.	It may go to 600oC in brazing.
3	Work piece to be joined need to be heated till their melting point.	No need to heat the work pieces.	Work pieces are heated but below their melting point.
4	Mechanical properties of base metal may change at the joint due to heating and cooling.	No change in mechanical properties after joining.	May change in mechanical properties of joint but it is almost negligible.
5	Heat cost is involved and high skill level is required.	Cost involved and skill requirements are very low.	Cost involved and sill required are in between others two.
6	Heat treatment is generally required to eliminate undesirable effects of welding.	No heat treatment is required.	No heat treatment is required after brazing.
7	No preheating of work piece is required before welding as it is carried out at high temperature.	Preheating of work pieces before soldering is good for making good quality joint.	Preheating is desirable to make strong joint as brazing is carried out at relatively low temperature.

BEARINGS

Bearings are machine elements which are used to support a rotating member viz., a shaft. They transmit the load from a rotating member to a stationary member known as frame or housing. They permit relative motion of two members in one or two directions with minimum friction, and also prevent the motion in the direction of the applied load.

Classification of bearings

a) Radial Bearings:-These are also known as Journal Bearings. In these bearings the main load is perpendicular to the axis of rotation of the moving element.
b) Thrust Bearings:-In these bearings the load acts along the axis of rotation.

1. **Journal Bearing:** In this the bearing pressure is exerted at right angles to the axis of the shaft. The portion of the shaft lying within the bearing in known as journal. Shaft are generally made of mild steel.

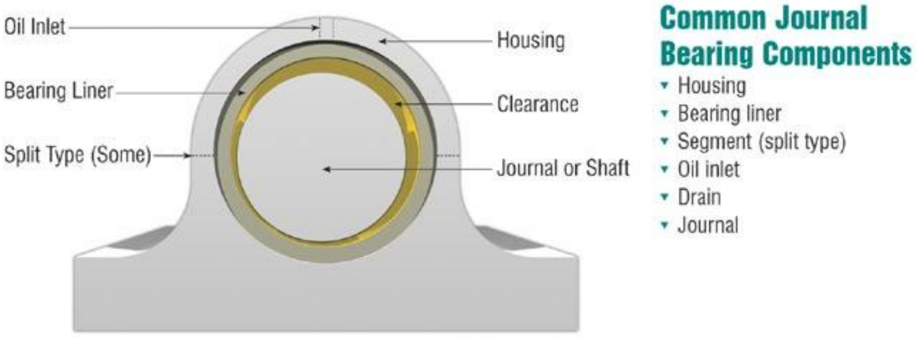
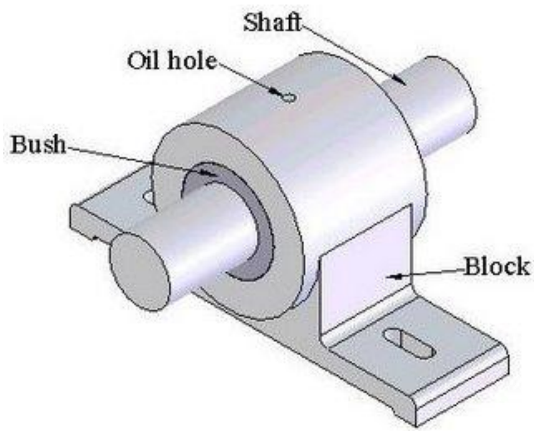


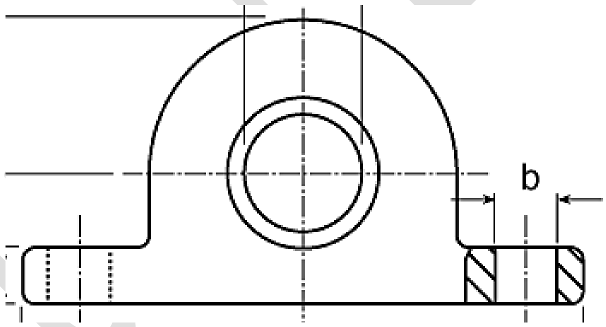
Figure 2. Plain Bearings (Journal Bearings)

2. **Bushed bearing:** It is a modification of solid bearing. A bush of brass or gunmetal is press fitted inside the bearing. Shaft sits on the bush instead directly in contact with bearing. A grub screw or a pin inserted half inside the bush and half in the block prevents sliding or rotating of bush against bearing. The basic purpose of bush is that when bush gets worn out, it can be easily replaced instead replacing the whole bearing. The boltholes in the block are made longer with semi-circular ends for adjusting the position of the bearing. A pictorial drawing of bushed bearing is shown in fig



3. Pedestal Bearing

This type of bearing consists of I) a cast iron pedestal, ii) gun metal, or brass bush split into two halves called “brasses”, and iii) a cast iron cap and two mild steel bolts. The detailed drawing of a pedestal bearing is shown in image below. The rotation of the bush inside the bearing housing is arrested by a snug at the bottom of the lower brass. The cap is tightened on the pedestal block by means of bolts and nuts. The detailed part drawings of another plummer block with slightly different dimensions are also shown in image below

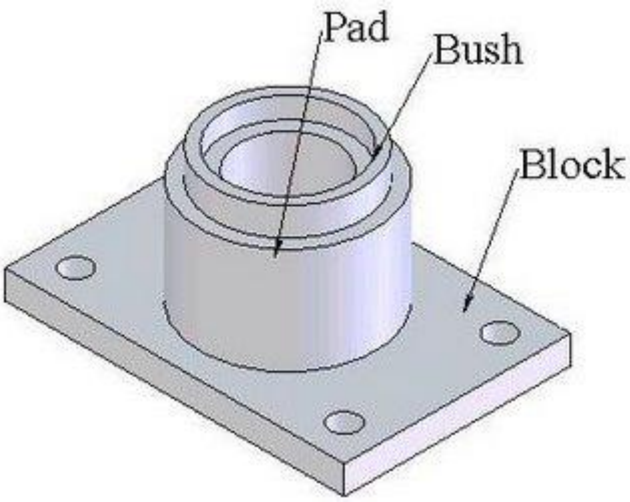


4. Thrust bearings

A thrust bearing is a particular type of rotary bearing. Like other rotary bearings they permit rotation between parts, but they are designed to support a high axial load while doing this (parallel to the shaft). Different kinds of thrust ball bearings are used to support different amounts of axial load. Thrust ball bearings are used in applications that use little axial load, where a ring supports ball bearings.

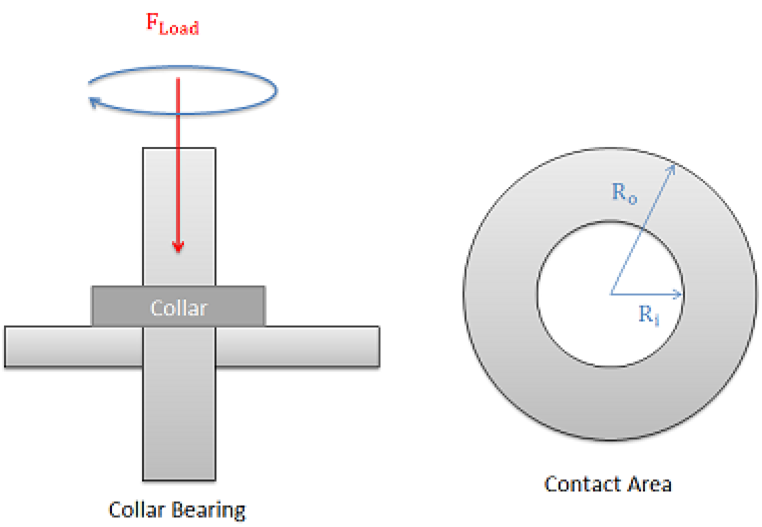
5. Foot-step bearing

Footstep bearing is used to support shaft vertically. It consists of a cast iron block into which a gunmetal bush having a collar at the top is fitted. The shaft rests on a steel pad. The pad is prevented from rotating by a pin, inserted half inside the block and half in the pad and away from the centre. The collar of the bush is made hollow to serve as an oil cup for lubrication of the bearing. A pictorial drawing of footstep bearing is shown in fig



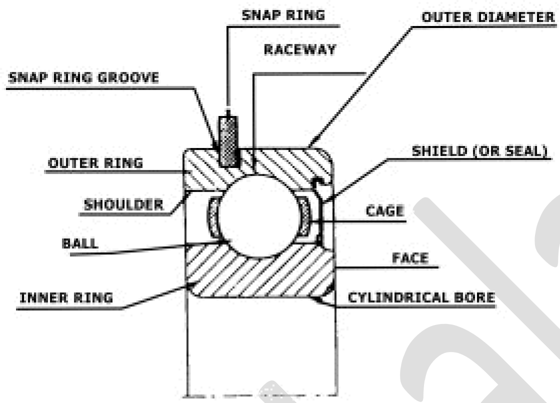
6. Collar bearing

To start our analysis of disc friction we will use the example of a collar bearing. In this type of bearing, we will have a rotating shaft traveling through a hole in a surface. The shaft is supporting some load force as shown and a collar is used to support the shaft itself. In this case we will have a hollow circular contact area between the rotating collar and the stationary surface.



7. Antifriction bearing

Antifriction bearings can be categorized to two different configurations: axial ball and roller bearings. They are more desirable than plain bearing due to their lower friction and reduced lubrication requirement. However, the life of antifriction bearing is limited by the fatigue life of the material they are made of and the type of lubricant being used. The types of antifriction bearing are group by the shape of the rolling element and they are ball bearings, cylindrical roller bearings, tapered roller bearings, and needle roller bearings.



8. **Ball and roller bearing:** A ball bearing is a type of rolling-element bearing that uses balls to maintain the separation between the bearing races.The purpose of a ball bearing is to reduce rotational friction and support radial and axial loads. It achieves this by using at least two races to contain the balls and transmit the loads through the balls. In most applications, one race is stationary and the other is attached to the rotating assembly (e.g., a hub or shaft). As one of the bearing races rotates it causes the balls to rotate as well. Because the balls are rolling they have a much lower coefficient of friction than if two flat surfaces were sliding against each other.

Ball bearings tend to have lower load capacity for their size than other kinds of rolling-element to the smaller contact area between the balls and races. However, they can tolerate some misalignment of the inner and outer races

- ## ADDITIVE MANUFACTURING (AM)

Additive Manufacturing (AM) refers to a process by which digital 3D design data is used to build up a component in layers by depositing material

Rapid prototyping

Rapid prototyping is a group of techniques used to quickly fabricate a scale model of a physical part or assembly using three-dimensional computer aided design (CAD). Construction of the part or assembly is usually done using 3D printing or "additive layer manufacturing" technology

Types of Rapid prototyping

1. Stereolithography (SLA)
2. Ballistic particle manufacturing (BPM)
3. Directed light fabrication (DLF)
4. Direct-shell production casting (DSPC)
5. Fused deposition modeling (FDM)
6. Laminated object manufacturing (LOM)
7. Shape deposition manufacturing (SDM) (and Mold SDM)
8. Solid ground curing (SGC)
9. Stereolithography (SL)
10. Selective laser sintering (SLS)

1. **Stereolithography (SLA):** Stemming from similarities with the lithography process, SLA uses a liquid photopolymer substance to print in 3-D. SLA exposes the liquid polymer to ultraviolet light which cures (hardens) the polymer. The polymer substance starts as a liquid in a vat and then is exposed to the ultraviolet light curing the substance one layer at a time. Once the photopolymer has been exposed to the light enough times, the design is removed from the liquid and covered with a protective layer.

2. **Fused deposition modeling (FDM):** Fused deposition modeling (FDM) is an additive manufacturing technology commonly used for modeling, prototyping, and production applications. It is one of the techniques used for 3D printing.FDM works on an "additive" principle by laying down material in layers; a plastic filament or metal wire is unwound from a coil and supplies material to produce a part.

3. **Laminated object manufacturing (LOM): LOM** is a rapid prototyping system developed by Helisys Inc. In it, layers of adhesive-coated paper, plastic, or metal laminates are

successively glued together and cut to shape with a knife or laser cutter. Objects printed with this technique may be additionally modified by machining or drilling after printing. Typical layer resolution for this process is defined by the material feedstock and usually ranges in thickness from one to a few sheets of copy paper.

The process is performed as follows:

- Sheet is adhered to a substrate with a heated roller.
- Laser traces desired dimensions of prototype.
- Laser cross hatches non-part area to facilitate waste removal.
- Platform with completed layer moves down out of the way.
- Fresh sheet of material is rolled into position.
- Platform downs into new position to receive next layer.
- The process is repeated.

END