TUTORIAL CONTENT

Metal Joining processes:

Welding is a permanent joining process in which two metal pieces are joined together to form a single piece.

Welding is a process, in which two metal pieces,

- similar or dissimilar,
- may be joined by the application of heat,
- with or without application of pressure, and
- with or without the aid of filler material.

Classification of Welding Processes:

A. **Arc Welding**

1. Carbon arc welding
2. Metallic arc welding
3. Automatic flux shield arc welding
   (a) Submerged arc welding, (b) Electro-slag welding, (c) Electro-gas welding
4. Gas shield arc welding
   (a) Tungsten Inert Gas Welding (b) Metal Inert Gas Welding (c) Flux Cored arc welding
5. Atomic Hydrogen arc welding
6. Plasma arc welding

B. Pressure Welding

1. Electrical Resistance welding
   a) Spot Welding
   b) Projection welding
   c) Seam welding
   d) Flash welding
   e) Percussion welding
   f) Butt welding
2. Friction welding
3. Explosive welding
4. Ultrasonic welding
5. Diffusion bonding

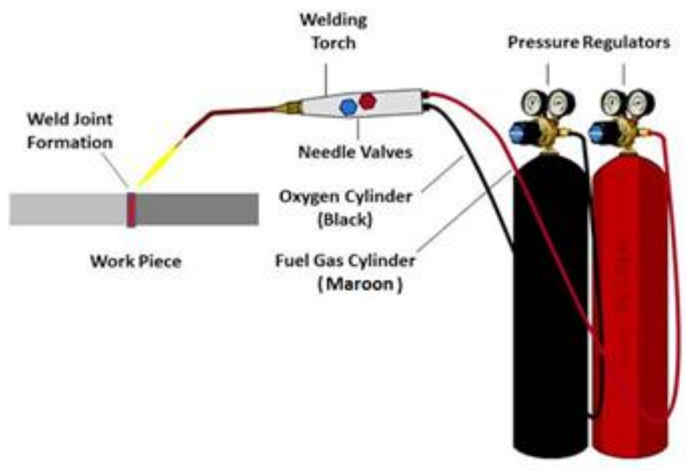
C. Fusion Welding

1. Gas welding 2. Thermit welding 3. Electron beam welding 4. Laser welding

D. Soldering, Brazing, and Adhesive bonding

Gas Welding

- Widely used Fusion welding process.
- Heat required to produce fusion of metal is obtained by burning gases (oxygen + Fuel gas), in the nozzle of a torch.
- High temperature flame is obtained at the nozzle.
- Widely used fuel gas → Acetylene (C_2H_2)
- Other fuel gases → H_2 , Propane, Butane (produce low temp)
- Oxygen + Acetylene → Burns to produce high flame temperature (3200 – 3500 ^{0}C)



<u>Major components</u>:

Welding Torch, Oxygen & Fuel Gas Cylinder, Pressure regulator, Hose & hose fittings, Goggles and Gloves.

1. **Welding Torch:**

   Consists of – Tip, a blow pipe, a mixing chamber, 2 gas lines & 2 valves for gas control.

   - Fuel gas and oxygen at suitable pressure, fed through hoses to the welding torch.
   - There are valves for each gas, which control the flow of gases inside the torch.
   - Both gases mixed there and form a flammable mixture.
   - These gases ignite to burn at the nozzle.
   - The fire flame flow through nozzle and strikes at welding plates.
   - Nozzle thickness depends on the size of the welding plates and material to be welded.

2. **Oxygen cylinder:**

   - For proper burning of fuel, appropriate amount of oxygen required.
   - Oxygen is supplied by a oxygen cylinder.
   - Oxygen in the gaseous form is compressed & stored in steel cylinders.
   - A black line is used to indicate oxygen cylinder.

3. **Fuel gas cylinder:**

   - Filled with flammable gas → acetylene gas (widely used)
   - Fuel gas selection depends on the welding material.
   - Mostly oxy-acetylene gas is used for all general purpose of welding.

- Normally these cylinders have Maroon line to indicate it.

4. **Pressure regulator:**
   - Both oxygen & fuel gases are filled in cylinder at high pressures.
   - These gases cannot be used at this high pressure for welding work.
   - So a pressure regulator is used to reduce the cylinder pressure to the working pressure.
   - It supplies oxygen at pressure about 70– 130 KN/m^2 & fuel gas at 7 – 103 KN/m^2 to the welding torch.

5. **Hose & hose fittings:**
   - Hoses are required to supply the gases from the cylinders to the torch.
   - Hoses must be strong, durable & light for easy handling.
   - Made of reinenforced rubber.
   - Colour: Black for Oxygen, Maroon for Acetylene.

6. **Goggles & Gloves:**
   - These are used for safety purpose of welder.
   - It protects eyes & hand from radiation, and flame of fire.

<u>Welding procedure:</u>

- Place the base metals to be joined, on a weld table.
- Clamp them firmly, using clamping devices.
- Check & set the gas pressures of both the gases.
- Ignite the flame, with a spark lighter, at the torch tip.
- Flame is controlled through valves situated in torch.
- Torch is to be held at about 45^0 to the work-piece, and
- Filler rod at 30 – 40^0 to the horizontal, but in opposite direction.
- Welding torch moved along the line where joint to be created.
- This will melt the interface part and join them permanently.

Advantages:

- It is easy to operate.
- Does not require high skill operator.
- Temperature control is easier.
- Low Equipment cost & maintenance, compared to arc welding .
- Equipment's are portable.
- It can be used at site.
- It can also be used as gas cutting.

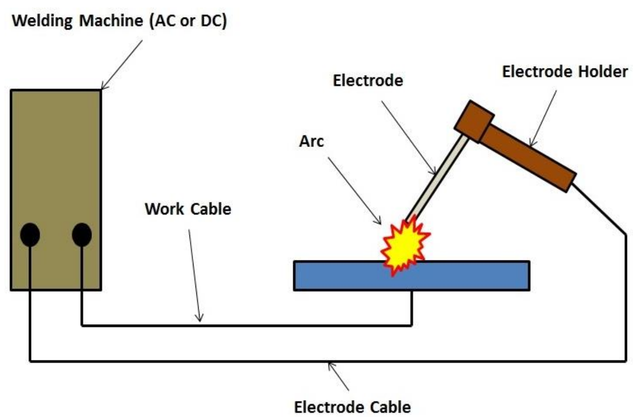
Disadvantages:

- Difficult to join heavy sections (suitable for soft & thin sections).
- Low flame temperature compared to arc welding.
- Provides low surface finish, hence needs a finishing operation after welding.
- Large heat affected zone, which can cause change in mechanical properties of parent material.
- Fluxes may produce harmful fumes.

- Higher safety issue due to flame of high temperature.
- Safety problems are associated with the storage and handling of explosive gases.
- Slow metal joining rate. (rate of heating and cooling is relatively slow)
- No shielding area which causes more welding defects.
- Refractory metals like Tungsten, Molybdenum cannot be gas welded.

Arc Welding

Production of arc :



- An electric arc is formed,
  - → whenever current is passed between two metallic electrodes,
  - → separated by a short distance.
- Whenever electrode first touches the plate,
  - → a large short circuit flows and as it withdrawn later,
  - → Current continues to flow in the form of spark, across the air gap.
- Due to this spark,
  - → air gets ionized and air becomes conducting and so,
  - → current is able to flow across the gap.

Transfer of heat to weld metal:

- Partly by direct radiation, and
- Partly by the gas or ions in the arc stream.

<u>Major components</u>:

Arc welding power source, Welding cables, Electrode holder, Welding Electrodes, Chipping hammer, Wire brush . Hand Screen and Protective clothing.

1. Arc welding power source:

- Both DC and AC are used for electric arc welding process, each having its particular applications.

- DC welding supply is usually obtained from generators driven by electric motor.
- For AC welding supply, transformers are used.

2. Welding cables:

- Cables are required for conduction of current from the power source through the electrode holder, the arc, the work-piece and back to the welding power source.
- These are insulated copper or aluminum cables.

3. Electrode holder:

- Electrode holder is used for holding the electrode manually and conducting current to it.
- These are usually matched to the size of the lead, which in turn matched to the amperage output of the arc welder.
- Electrode holders are available in sizes that range from 150 to 500 Amps.

4. Electrodes:

- An electrode is a tool used in arc welding to produce electric arc.
- Based on their characteristics, electrodes can be broadly classified into two types. They are:

Consumable Electrode:

- If the melting point of an arc welding electrode is less, it melts and fills the gap in the work-piece.

Non-consumable electrode:

- If the melting point of the arc welding electrode is high, it does not melt to fill the gap in the work-piece.

5. Chipping hammer: Chipping Hammer is used to remove the slag by striking.

6. Wire brush: Wire brush is used to clean the surface to be weld.

7. **Hand Screen**: It is used for protection of eyes and supervision of weld bead.

8. Protective clothing: The operator wears the protective clothing such as apron to protect the body from the exposure of direct heat to the body.

Advantages:

- Easy to control the temperature of the molten pool by varying the arc length.
- Equipment can be portable and the cost is fairly low.
- This process finds wide applications, because of the availability of a wide variety of electrodes.
- A wide range of metals and their alloys can be welded.
- Welding can be carried out in any position with highest weld quality.

Disadvantages:

- Thin materials cannot be welded.
- Difficult to automate the welding process.
- Difficult to join longer joints using small size electrodes.
- Metal transfer from the electrode to the joint may not be smoother because of slag melting.

- Welding process may become slower while restarting with fresh electrode.
- Skilled operator is required.

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

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.

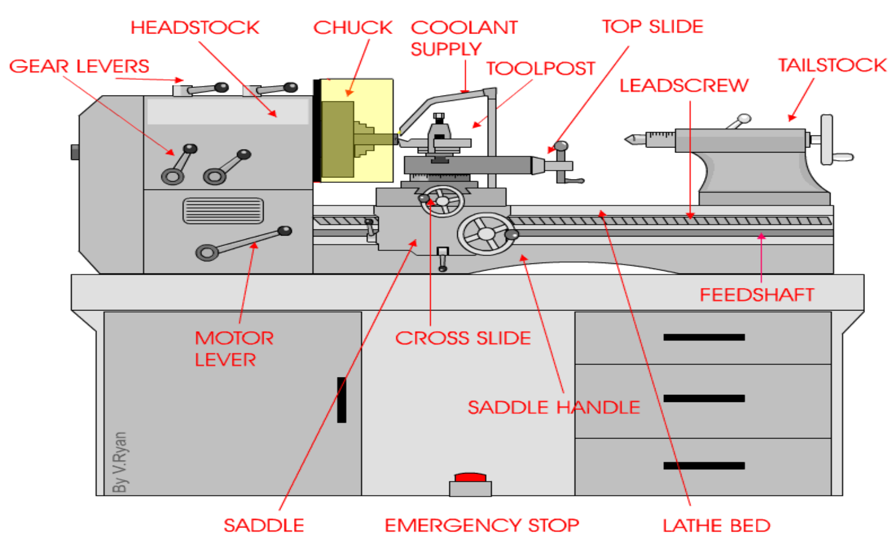
The filler metal is called as Spelters.
1. The flux used is borax or boric acid.
2. The brazing is used in copper alloys applications.
3. The temperature range is 450 to 900 degree.

Differences between soldering, brazing and Welding

S.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 upto some extent.
2	Temperature required is up to 3800^{o}C of welding zone.	Temperature requirement is up to 450^{o}C.	It may go to 600^{o}C in brazing.
3	Workpiece to be joined need to be heated till their melting point.	No need to heat the workpieces.	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	No heat treatment is required.	No heat treatment is required

	generally required to eliminate undesirable effects of welding.		after brazing.
7	No preheating of workpiece is required before welding as it is carried out at high temperature.	Preheating of workpieces 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.

Metal Machining Processes



Lathe:

- Oldest & most important machine tool.
- Job to be machined is rotated & the cutting tool is moved relative to the job.
- Basically developed to produce circular objects.
- But many other operations can also be performed on lathes.
- E.g.-facing, parting, necking, knurling, taper turning, forming, drilling, reaming, milling & drilling operation etc.
- Lathe is called the mother of the entire machine tool family.
- Lathe can be defined as a machine tool which holds the work between two rigid & strong centres, or in a chuck or face plate while the latter revolves.
- Cutting tool is rigidly held & supported in a tool post & feed against the revolving work.

Classification of Lathes:

Engine lathe or Centre Lathe, Speed Lathe, Turret Lathe, Capstun Lathe, Automatic Lathe& CNC Lathe.

Major components of Lathe:

Lathe Bed:

- It is the base or foundation of the lathe.
- It is a heavy & rigid casting made in one piece to resist deflection and vibrations.
- It holds or supports all other parts, that is, head stock, tailstock & carriage etc.
- Top of the bed is planed to form guides or ways.

Head stock:

- It is permanently fastened to the left hand end of the lathe.
- It serves to support the first operative unit of the lathe, i.e. spindle.
- It’s also called as **live centre** because it turns with the work.
- It serves as housing for the driving pulleys, back gears & spindle.

It consists of the following parts:

- Cone pulley, Back gears & lever, Main spindle, Live centre, & Feed reverse lever.

Tail stock:

- It’s on the other end of the bed from the headstock.
- Its chief function is to hold the dead centre so that long work pieces can be supported between centres.

Carriage:

- In between the headstock & tailstock is the carriage.
- It’s movable on the bed ways.

- Its purpose is to hold the cutting tool & to impart to it either longitudinal or cross feed.

<u>It has five major parts</u>:

Saddle, Cross slide, Compound rest, Tool post, Apron.

(a) Saddle:

- It is the base of the carriage. (H-shaped casting)
- It slides along the outer guideways of the lathe bed.
- Supports the cross-slide, compound rest & tool post.

(b) Cross slide:

- It is mounted on top of saddle.
- It provides cutting tool motion which is perpendicular to the centre line of the lathe .
- Cross feed movement may be controlled by manual or by power feed.

(c) Compound rest:

- Mounted on top of the cross-slide.
- It has a graduated circular base & can be swiveled around a vertical axis.
- It can be clamped to remain at any angular setting.

(d) Tool post:

- Mounted on the compound rest.
- It slides in a T-slot.
- Cutting tool/ tool holder is firmly held in it.

(e) Apron:

- It is the hanging part in front of the carriage.
- It is secured underneath the saddle & hangs over the front of the bed.
- It contains the gear, clutches, & levers for operating the carriage by hand and power feeds.

Lathe operations:

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<u>Facing</u>:
• Machining the end of job
→ To produce Flat surface
→ or to Reduce Length of Job
• Feed: in direction perpendicular to work-piece axis
→ Length of Tool Travel = radius of work-piece.
• Depth of Cut: in direction parallel to work-piece axis.
• Cutting tool is moved at right angles to the work using the cross slide.
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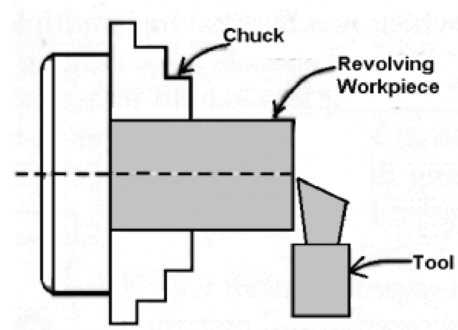

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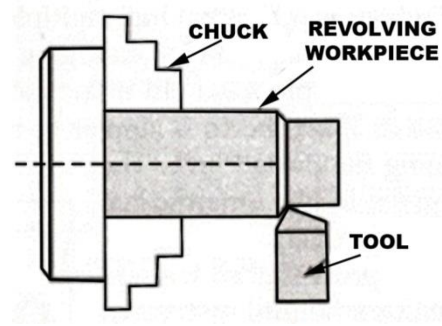
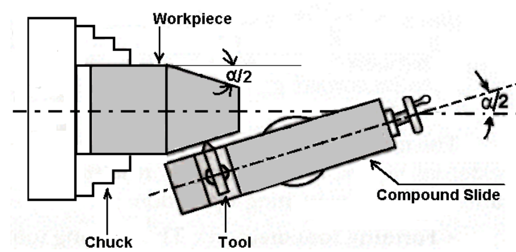
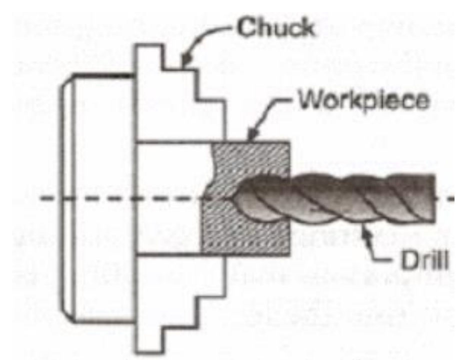
Turning: • **Machine** length of job to reduce diameter of Job. • **Feed:** in direction parallel to work piece axis. • **Depth of Cut:** in direction perpendicular to work- piece axis. Turning may be performed at various speeds, depth of cuts and feeds, depending on: • Work piece and tool materials. • Surface finish and dimensional accuracy required. • Characteristics of the machine tool.	

Taper turning:

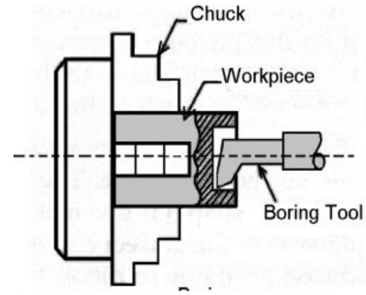
- It is an operation on a lathe, to produce conical surface on the cylindrical work-pieces.

By Swiveling the Compound rest: • Suitable for the work-pieces which require steep taper for short lengths. • Compound tool rest is swiveled to the required taper angle, and then locked. • Carriage is also locked at that position. **For taper turning,** • Compound tool rest is moved linearly at an angle. • This method is limited to short tapered lengths, due to the limited movement of the compound tool rest.	

Drilling: • A cylindrical hole is produced in a work piece, by the drill. • The drill bit is fitted into the barrel of the tailstock. • First the drill is brought in contact with the work piece. • In this position the tailstock is locked on to the bed with the help of lever, to avoid the backward movement of the tailstock. • Feed is given to the drill with the help of hand wheel of the tailstock. • Before drilling operation, centre is marked on the either face of the work piece, to avoid the eccentricity. • During the operation, the drill moves in longitudinal direction, parallel to the centre line of the lathe machine. • During this operation the work piece is rotated at lower speed.	

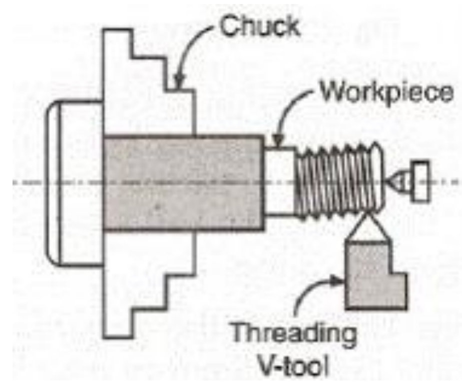
Boring:

- Boring cannot originate a hole like drilling.
- In this, the hole is enlarged, which has been produced previously by drilling, casting or forging.
- Boring is used to correct error in concentricity and alignment in the previously drilled hole.



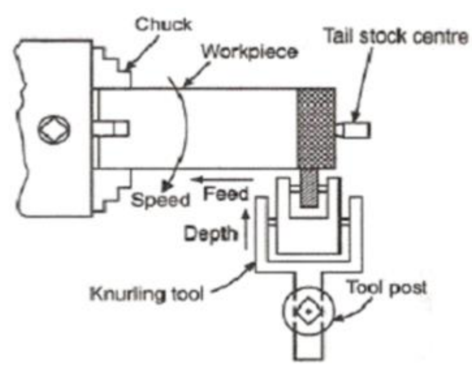
Threading:

- Helical grooves are produced over the cylindrical surface of the work piece.
- Work-piece is made to rotate with uniform speed (low).
- Definite relationship between the rotation of the work piece in the Spindle and longitudinal travel of the Carriage is required.
- Cutting tool is to be moved longitudinally, with uniform linear motion over the rotating work-piece.
- Lead screw provides proper movement to the tool.
- Feed rate is provided with the help of Cross Slide.



Knurling:

- In this, diamond shaped pattern is embossed over the surface of the work piece.
- Knurling is useful to grip the work piece firmly.
- Knurling tool is used for this operation, which consists of set of hardened steel rollers.
- Tool moves specific lengthwise, which is parallel to the centre line of the lathe with the help of Carriage.
- Feed rate is provided with the help of Cross Slide.
- During this operation, the work piece is rotated at lower speed.

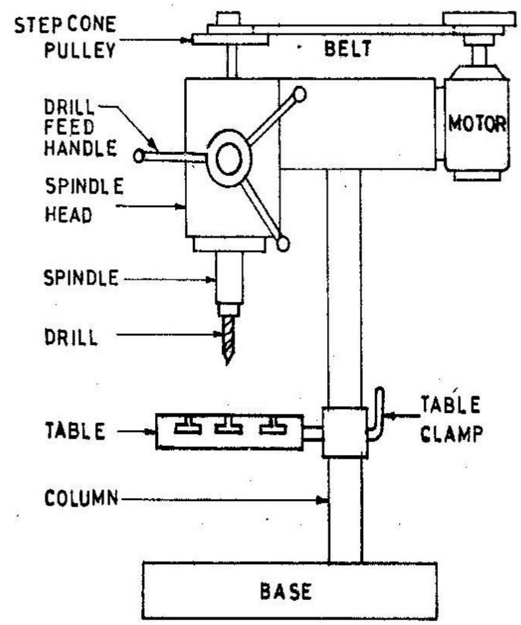


Drilling Machines

- Most common machine tool, next to an engine lathe.
- Used to drill holes of different sizes.
- Drilling is the operation of making a hole in a work-piece, using a drill bit or twist drill.
- Rotating tool held in the spindle, is fed vertically against the stationary work-piece.

Bench or Sensitive Drilling Machine:

- Light duty drilling machine.
- Widely used in small workshops.
- Usually placed on benches, hence the name.
- Holes of sizes up to 15 mm are drilled.
- Operator senses or feels the cutting action of the metals and apply the required pressure on the work-piece, during drilling.



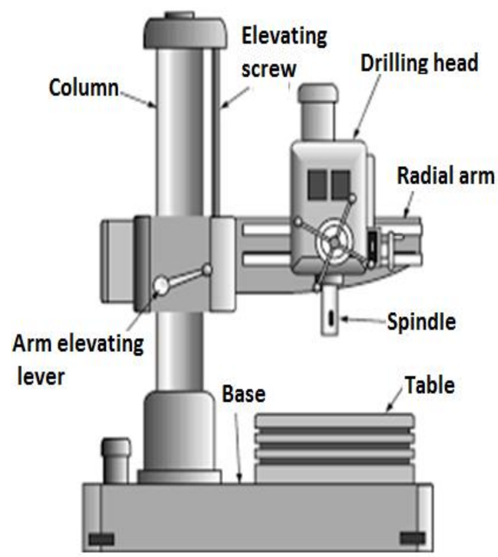
Major components:

- **Base:** Rigid, Strong, Mounted on bench, Supports all other components.
- **Vertical column:** Mounted over the base, Supports the Drill head, Electric motor & work table.
- **Drill head:** A speed gear box & Spindle feed mechanisms are housed.
- **Work table:** Can be raised or lowered on the vertical column, & locked in the required position.
- **Electric motor:** Mounted on top of end the column, on its rear side.

- Power is transmitted to the main spindle through the stepped cone pulley and gearing systems.
- A drill chuck is fitted in the spindle at its lower end, for small size drills.
- For bigger sizes, the drill itself will be fitted directly in the spindle.
- Work-piece is clamped firmly on the table, using clamping devices.
- Before drilling, the centre of the work piece is to be marked with a punch.
- Then, tip of the drill is aligned with the centre of the work piece.
- Drilling is carried out by rotating the feed wheel.

Radial Drilling Machine:

- Used to perform drilling operations on the work-pieces, which are large & heavy and difficult to mount on the table.



Major components:

Base: Heavy, strong and rigid.

Vertical column: Circular section, mounted with a long horizontal arm (Radial arm).

Radial arm: Can be raised, lowered & swung in the horizontal plane, to any desired location.

Drill head:

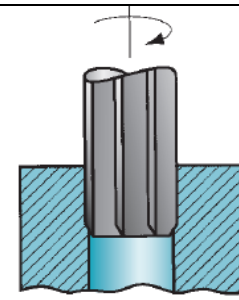
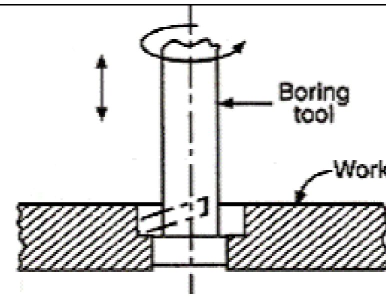
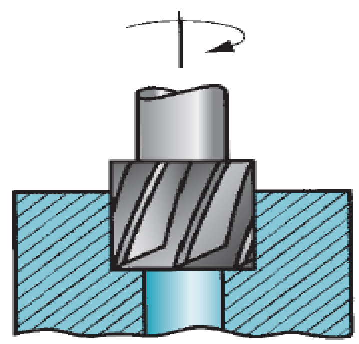
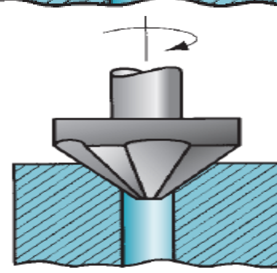
- Mounted on the radial arm.
- Can be moved to & fro, and locked at the desired position, Can be swiveled, to drill the holes at an angle

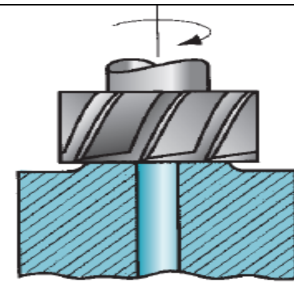
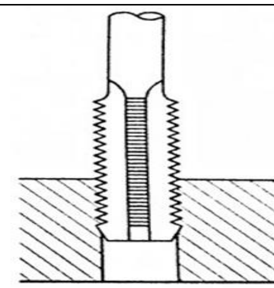
- Movements of the Radial arm & Drill head, are controlled by individual electric motors, makes it easier & faster location of the drill centre on the work-piece.

Work table: Strong, heavy and rigid.

- Drilling is carried out on heavy work-piece, in any position, without moving it.

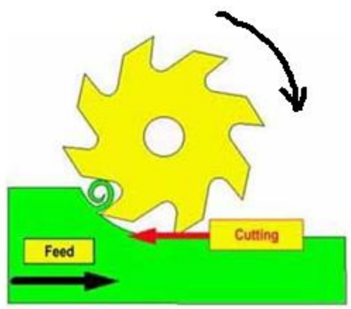
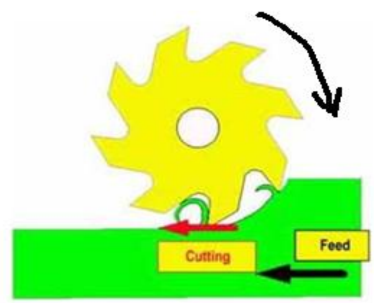
Drilling Machine operations:

Reaming: • It is a sizing & finishing operation performed in a previously drilled hole by Reamer. • Reamer is similar to twist drill, but has straight flutes. • Reaming speed is almost half that of drilling speed. • Removes only a small amount of material to produce smooth surface.	
Boring: • Boring is done to increase the size of an already drilled hole. • When a suitable sized drill is not available, → Initially a hole is drilled, to the nearest size, and → then, boring is done to get the required size. • Boring is also done to machine rough surfaces of cast holes.	
Counterboring: • Produces large sized hole, at only one end of the job, through a small depth. • Pilot guides the tool. • Pilot size will be equal to the initially drilled hole. • Interchangeable pilots of different sizes are used. • Recess formed in the job accommodates, round head bolts, grooved nuts etc. **Countersinking:** • It is an operation of making the end of a previously drilled hole, in to a conical shape. • Tool used → Counter sink • Counter-sunk holes are useful to accommodate, flat head countersink bolts & rivets.	 

Spot facing: • It is a finishing operation, to produce a flat surface, usually around the drilled hole. • It gives a good bearing surface, for a screw or bolt head. **Tool** → Spot facing tool, or Counterboring tool • Can also be used to smoothen the surfaces of the castings.	
Tapping: • Operation of producing internal threads in a previously drilled hole. • Tool → Tap • Tap is a fluted, threaded tool. • Before tapping, a hole slightly smaller than the tap is drilled. • Spindle is made to rotate at low speeds, during tapping.	

Milling Machines

<u>Principle of Milling</u>:

Up Milling or Conventional Milling	**Down Milling or Climb Milling**
	

1. Up Milling or Conventional Milling:

To remove the metal,

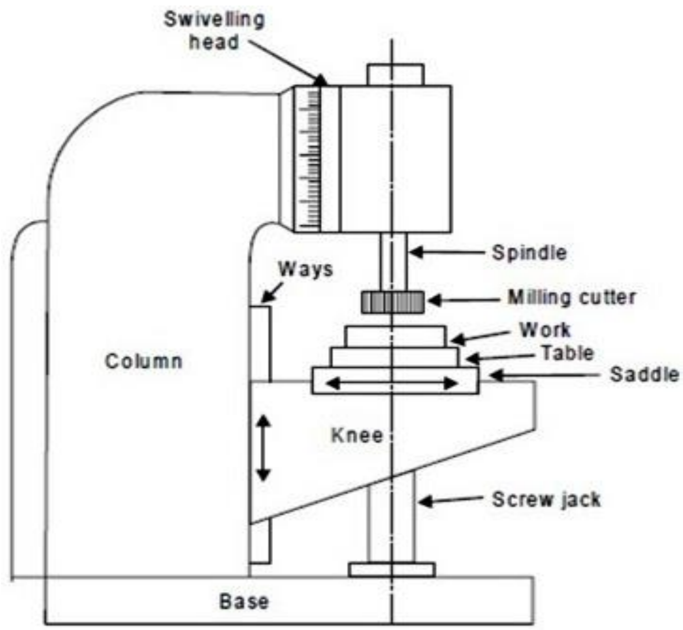
→ Cutter rotates in the opposite direction, against the direction of travel of the work-piece.

- Chip thickness → Nil at entrance & maximum at the tooth exit.
- Cutting forces are directed upwards, and the work piece tends to be lifted up from the table.
- Clearance between table & saddle increases.
- While taking heavy cuts, vibrations may be caused, resulting in poor surface finish.
- Disadvantage: Chips are deposited in front of the cutter.

2. Down Milling or Climb Milling:

- Cutter direction is in the same direction of work-piece travel.
- Chip thickness → Maximum near tooth entrance & minimum at the exit.
- Higher speeds & feeds can be employed.
- Cutting forces act downward.
- Work-piece is pressed against the table.
- Saddle does not produce vibrations.
- Produces high quality surfaces.
- Chips are deposited, behind the cutter & out of the way.

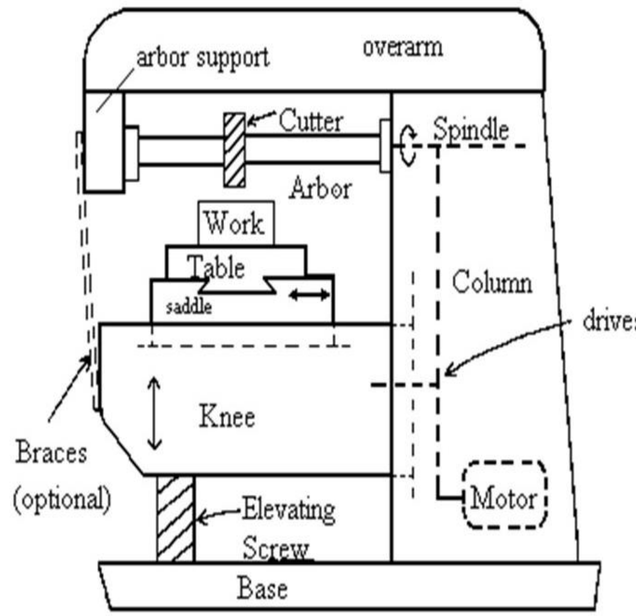
Vertical Milling Machine:



- Spindle is mounted with its axis vertical & perpendicular to the work table.
- Column & base are formed in to an integral casting.
- Spindle head is fitted vertically, in the guideways provided in the projecting end of the column.
- Spindle can be moved up & down on the guideways.
- Saddle is mounted on the guideways, provided on the top of the base.
- Saddle can be moved in the transverse direction.
- Work table mounted on the saddle, can be moved longitudinally.
- Work –piece is made to move only in the horizontal plane, during machining, but not vertically.
- Rotating cutter can be either raised or lowered, to give the required depth of cut.
- Axis of the cutter is vertical.
- Suitable for cutting long grooves & slots, and also to produce flat faces.

Horizontal Milling Machine:

<u>Major components:</u>



Column:

- Forms a single casting with the base.
- Houses the spindle.
- Transmission system from motor to spindle.
- Supports table & its lifting mechanism.
- Front vertical face carries guide-ways on which knee moves up & down.
- Supports an overarm at the top.
- Overarm supports the arbor.

Arbor:

- A horizontal shaft provided with a straight body & tapered shank.
- On straight portion, cutters are mounted.
- Tapered end fits in to the tapered hole of the spindle.
- Other end of the arbor is mounted in a bearing, housed in the projected overarm. (yoke)

Knee:

- A casting mounted on the front vertical slide of the column.
- Can be moved up & down by an elevating screw.
- Upper face of the knee is provided with guideways to mount the saddle.

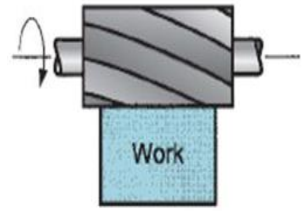
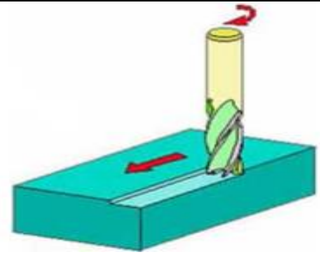
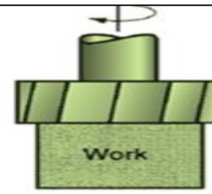
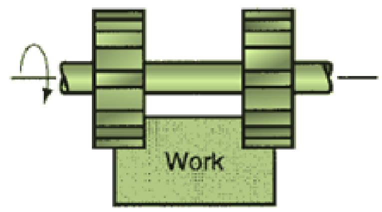
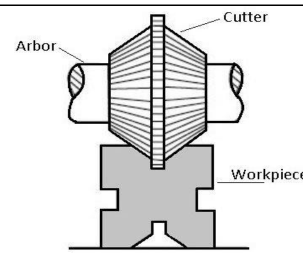
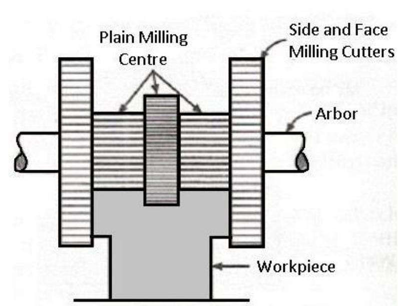
Saddle:

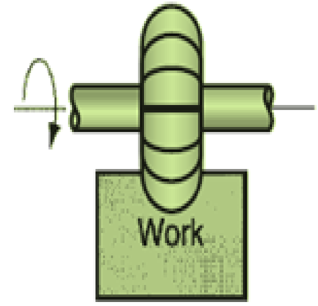
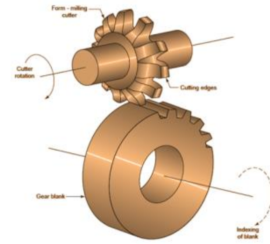
- A casting provided with two slides, one at the top & other at the bottom,
- Exactly 90^0 to each other.
- Bottom slides provide, transverse movement to the saddle,
- Top slides provide, longitudinal movement to the table.

Table:

- Mounted on top of the saddle.
- Top of the table is provided with several full length T-slots for mounting, Vice or other work holding devices.
- Axis of the cutter is horizontal.
- Feed is given by moving the table along with the work piece, against the rotating cutter.
- Suitable for machining Keyways, grooves, gear teeth, splined shafts.

Milling operations:

Plain/Slab Milling: • Produces flat horizontal surfaces parallel to the axis of rotation of the cutter.	
End Milling: • Used to provide slots, Pockets & Key ways. • Axis of cutter is perpendicular to the surface of the work piece. • Depth of cut can be achieved nearly half the diameter of the cutter.	
Face Milling: • Produces a flat surface perpendicular to the axis of rotation of the cutter. • Can be done in vertical or horizontal planes.	
Straddle Milling: • Two milling cutters, placed on arbor, → are used to produce flat vertical surface, → on either side of a work piece, in one stretch. • Ex: To produce heads of hexagonal bolts.	
Angular Milling: • Produces angular surfaces on the work pieces. • Cutters will have their teeth inclined to their axis. • Ex: V-guides, Dovetail grooves are machined.	
Gang Milling: • More than one cutter is used at a time, during drilling. • Produces a no. of flat surfaces or, a combination of flat & angular surfaces in one cutting operation. • Cutters are mounted on a single arbor. • Suitable for mass production.	
Form Milling: • Produces irregular or contoured surfaces, concave or convex,	

• Using suitable cutters. • A concave shaped cutter, → produces a convex shape on the work piece, • While, a convex shaped cutter produces a concave shape.	
Gear cutting: • Operation of Milling gear teeth on a gear blank. • Makes use of a cutter that has the profile (spur/ Helical/Bevel) of the gear teeth to be cut. • Gear blank is suitably indexed after each cut.	

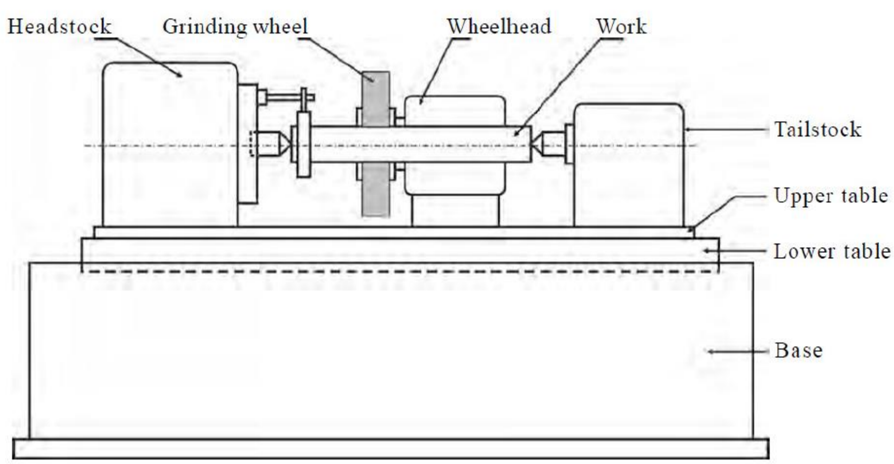
Grinding Machines

- It is a metal cutting operation which removes very less amount of material from the work.
- Cutting tool: An abrasive wheel having many no. of cutting edges.
- Grinding is done to obtain very high dimensional accuracy and better appearance.

Types of grinding machines:

1. Cylindrical grinding machines
2. Internal grinding machines
3. Surface grinding machines
4. Tool and cutter grinding machines
5. Special grinding machines

<u>Cylindrical grinding machines</u>:



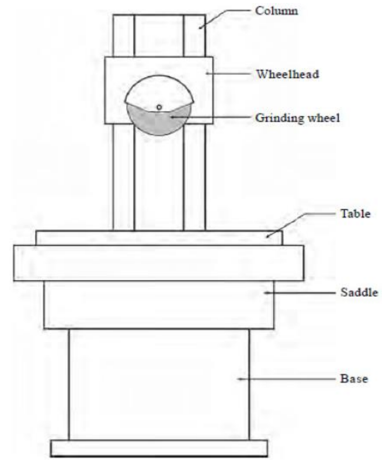
- Used to grind external surfaces like cylinders, taper cylinders, faces of the work.
- There are two types machines and they are,

1. External cylindrical grinding machines
2. Internal cylindrical grinding machines

<u>Surface grinding machines</u>:

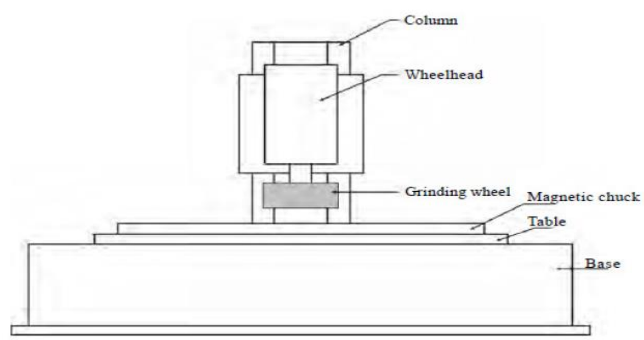
- Used to finish plain or flat surfaces horizontally, vertically or at any angle.
- There are four different types of surface grinders. They are:
  1. Horizontal spindle and reciprocating table type
  2. Horizontal spindle and rotary table type
  3. Vertical spindle and reciprocating table type
  4. Vertical spindle and rotary table type

Horizontal spindle Surface grinding machines:



- Grinding wheel is mounted on a horizontal spindle, and the table is reciprocated to perform grinding operation.
- Though the area of contact between the wheel & the work is small, the speed is uniform over the grinding surface and the surface finish is good.

Vertical spindle Surface grinding machines:

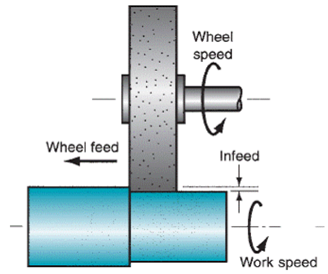
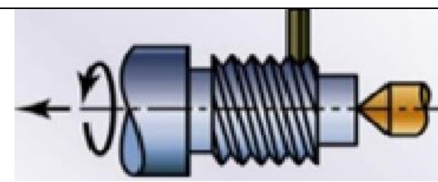


- The face or sides of the wheel are used for grinding.
- Area of contact is large and stock can be removed quickly.
- But a criss-cross pattern of grinding scratches is left on the work surface.

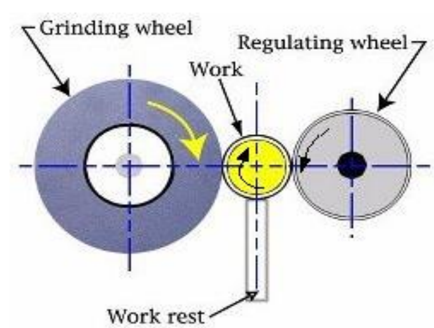
Grinding Machine Operations:

- Grinding is the operation of removing excess material from metal parts by a grinding wheel made of hard abrasives.
- The following operations are generally performed in a grinding machine.
  1. Cylindrical grinding

2. Taper grinding
3. Gear grinding
4. Thread grinding

1. Cylindrical grinding: • It is performed by mounting and rotating the work between centres in a cylindrical grinding machine. • Work is fed longitudinally against the rotating grinding wheel to perform grinding. • The upper table of the grinding machine is set at 0° during the operation.	
2. Taper grinding: • Taper grinding on long work-pieces can be done by swivelling the upper table. • If the work-piece is short, the wheel head may be swivelled to the taper angle.	
3. Gear grinding: • Teeth of gears are ground accurately on gear grinding machines for their shape. • Gear grinding is done by the generating process or by using a form grinding wheel. • The generating process makes use of two saucer shaped grinding wheels. • These wheels are used to grind two faces of successive teeth.	
4. Thread grinding: • These are used to grind threads accurately. • Grinding wheel itself is shaped to the thread profile. • These grinding wheels have one or multi threads on them.	

5. Centreless grinding:



In this, work piece is held between 2 wheels.

1. **Grinding wheel** → Rotates at high speed (fixed position)
2. **Regulating wheel** → is smaller & rotates at low speeds.
   Movable to required position,
   Made of Rubber bonded abrasives.

- Both wheels rotate in the same direction, with different speeds.
- Work-piece is placed over a work rest.
- Angle of the work blade helps to keep the work-piece in contact with and under the control of the slower rotating regulating wheel.

- Work rest along with regulating wheel move towards the grinding wheel.
- Work-piece is held by pressing it between the two wheels, and is rotated by the friction.
- Grinding wheel removes the material & force applied to the work-piece is directed downward.
- Regulating wheel does not remove material because of its lower speed.

Advantages of Centreless grinding:

- Eliminates the need for work-piece center holes, and
- Work head fixtures that are required in the other cylindrical grinding methods.
- Centreless grinding, if set up properly,
    - → will achieve excellent roundness,
    - → surface finish, and
    - → dimensional tolerances.