STUDY MATERIAL

ON

TH-1

MANUFACTURING PROCESSES

3RD SEMESTER

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CHAPTER 1

COOLANTS AND LUBRICANTS

The metal working fluid (coolants and lubricants) usually performs the following functions:

1. Increases the tool life and produces better finish by carrying away the heat generated during metal working. It cools the tool and workpiece.

2. Provide adequate lubrication between the tool and workpiece and the tool and the chips. Minimizes the friction between mating surfaces and, thus, prevents rise in temperature.

3. Prevents the adhesion of chips to the tool or workpiece or both. It protects the finished surface from corrosion.

4. Provides a cushioning effect between the job surface and the tool to prevent adhesion of the two, such as in stamping, extrusion etc.

5. Drives away the chips, scale and dirt from cutting zone.

CHARACTERISTICS OF A GOOD CUTTING FLUID:

a) It should provide sufficient lubrication between the tool and work and the tool and chips so as to minimize tool wear and reduce power consumption.
b) It must carry away the heat generated during the process and, thus, cool the tool and workpiece both in order to minimize the tool wear and prevent distortion of the workpiece.
c) Its flash point should be amply high.
d) It should be able to impart anti welding properties to the tool and the workpiece, otherwise very poor finish may result.
e) It should not discolour the finished work surface.
f) It should be non-poisonous and should not cause skin irritation.
g) It should carry such constituents which will prevent the finished work surface and the tool from being rusted or corroded.
h) It should not produce fog and smoke during use

Types of cutting fluids:

The cutting fluids are classified as follows:

1. Cutting oils:
    a. Active cutting oils.

b. Inactive cutting oils. These are straight mineral oils or straight mineral oils mixed with fatty oils, acids or sulphurised fatty oils.

By activeness or inactiveness of the cutting oils we mean as to whether a particular cutting oil contains such constituents or not that can react chemically with work surface to help the machining operation.

2. Water soluble oils or compounds.

CUTTING FLUIDS USED IN DIFFERENT OPERATIONS:

Operations	**Suggested fluids**
1. Turning	Emulsions or straight oils.
2. Tapping and threading	Active type mineral fatty oil.
3. Drilling and boring	Soluble oils.
4. Reaming	Soluble oils.
5. Planing and shaping	Usually no cutting oil is used.
6. Milling	Sulphurised mineral fatty oils or emulsions
7. Broaching	Heavy, active type cutting oils
8. Thread rolling	Straight mineral oil or emulsions.

Types of lubricants :

The various types of metal working lubricants are:

1. Mineral oils: These lubricants do not find much favour in boundary lubrication, as in deep draw and extrusion processes. If at all they are to be used in such processes they are used in compounded form.

2. Fatty oils and acids: These are extensively used for boundary lubrication. Fatty oils are used in heat-treatment process as a quenching medium for obtaining g high degree of hardness. Fatty acid is used as a flux in tinning work.

3. Waxes: Waxes (derived from petroleum) are used in various processes like rolling, drawing, extrusion, tinning and wet coating on mould surfaces.

4. Graphite suspensions: These lubricants are widely used in foundry and forging work.

5. Compounded emulsions: The compounded emulsions are best suited for use in heavy duty operations. The water usually varies from 5 to 15 parts.

6. Conventional emulsions: These emulsions are prepared by mixing the neat soluble oils in water. The main constituents of these emulsions are soap, fat, fatty acids and water. Most of the cutting and grinding work done in the workshops involves the use of such emulsions.

7. Aqueous solutions: These solutions are principally used as coolants. However, some of them show reasonably good lubricating properties. Soda or borax in water is the cheapest and best solution mainly for cooling.

8. Compounded mineral oils: For drawing, cutting and forming operations the mineral oils are compounded with sulphurised fatty oils. The sulphurised minerals oils are commonly used under conditions of high pressures and excessive fraction. The sulphurised mineral-fatty oils are sometimes added with suitable amount of chlorine to give chlorinated compounds, which are widely used in different metal working operations.

9. Minerals: Various types of minerals (different types of salts, metals and refractory materials) are used as metal working lubricants or coolants

Cutting fluids are applied in different ways depending on the machining process, tool, workpiece material, and production conditions.

The main methods of application of cutting fluids are:

1. Flooding (Flood Cooling)

- This method involves continuously directing cutting fluid onto the cutting tool and workpiece, effectively dissipating heat, lubricating, and flushing away chips.
- A large quantity of cutting fluid is directed at the cutting zone through a nozzle.
- Ensures good cooling and lubrication.
- Simple and inexpensive method.
- Common in turning, milling, drilling, and grinding.

2. Jet Application / High-Pressure Cooling

- Cutting fluid is supplied at high pressure (50–100 bar or more) directly into the cutting zone.
- Helps break chips, improves tool life, and reduces built-up edge.
- Used in CNC machining, deep-hole drilling, and difficult-to-cut alloys (e.g., titanium).

3. Mist Cooling (Aerosol / Minimum Quantity Lubrication – MQL)

- Cutting fluid is atomized into a fine mist with compressed air and directed to the cutting zone.
- Reduces fluid consumption.
- Provides lubrication more than cooling.
- Environmentally friendly and commonly used in high-speed machining, drilling, and tapping.

4. Drop-by-Drop / Trickle Feed

- Cutting fluid is supplied drop by drop or in small amounts.
- Used in small machines, light cutting operations, or where excess fluid is undesirable.
- Common in watch-making, precision machining, and tapping.

5. Through-Tool / Internal Cooling

- Cutting fluid is delivered through internal channels in the tool (e.g., drills, milling cutters, grinding wheels).
- Ensures fluid reaches the cutting edge directly.
- Very effective in deep-hole drilling, reaming, gun drilling, and modern CNC machining.

6. Splashing / Brushing / Manual Application

- Cutting fluid is applied manually using a brush, hand spray, or splash.
- Suitable only for small jobs or maintenance work.
- Not suitable for high-speed machining.

7. Submerging (Immersion)

- Entire workpiece and tool are submerged in a bath of cutting fluid.
- Ensures continuous cooling and lubrication.
- Common in grinding and certain precision machining operations.

<u>Here’s a clear classification of lubricants based on their physical state:</u>

1. Solid Lubricants

These are used where liquid lubricants fail (e.g., high temperature, vacuum, extreme pressure).

Examples:

- Graphite

- Molybdenum disulfide (MoS_2)
- Boron nitride
- PTFE (Teflon)

Applications:

- Spacecraft and vacuum systems
- High-temperature furnaces
- Extreme pressure contacts
- Dry-film coatings

2. Liquid Lubricants

The most widely used type. Provide a thin film between moving surfaces.

Types:

- **Mineral oils** (derived from petroleum)
- **Synthetic oils** (esters, silicones, polyalphaolefins, etc.)
- **Vegetable oils** (castor oil, rapeseed oil, etc., less common in industry)

Applications:

- Internal combustion engines
- Hydraulic systems
- Gearboxes and bearings

3. Gaseous Lubricants

Used in specialized high-speed or precision systems where minimal friction is required.

Examples:

- Air
- Steam
- Helium, Argon, Nitrogen (in special cases)

Applications:

- Gas bearings in turbines
- High-speed gyroscopes
- Space and aerospace applications
- Cleanroom equipment (where liquid/solid lubricants may contaminate)

✅**Summary:**

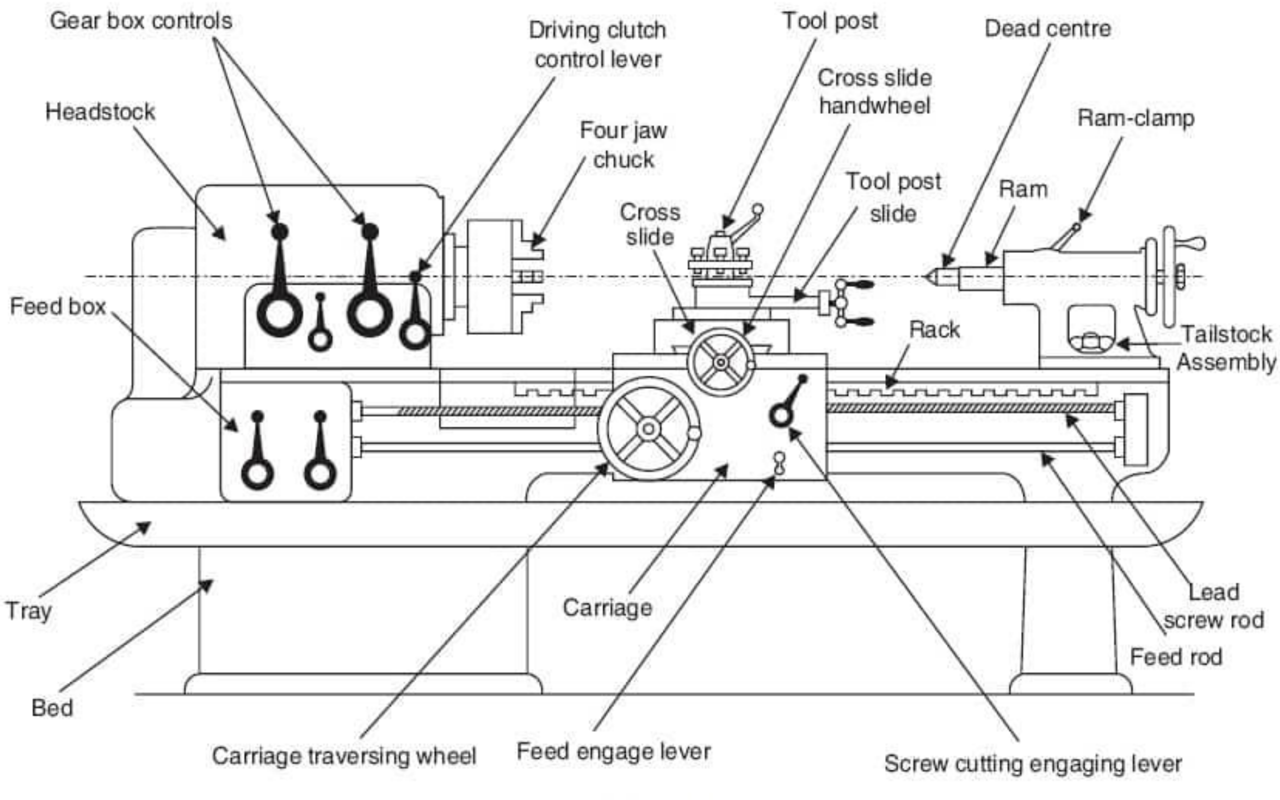
Solid lubricants → Graphite, MoS_2, PTFE (used in high temp/pressure, vacuum).

Liquid lubricants → Mineral, synthetic, vegetable oils (most common in engines and machines).

Gaseous lubricants → Air, steam, inert gases (used in turbines, gyros, aerospace).

LATHE

Lathe is considered as one of the oldest machine tools and is widely used in industries. It is called as mother of machine tools. It is said that the first screw cutting lathe was developed by an Englishman named Henry Maudslay in the year 1797. Modern high speed, heavy duty lathes are developed based on this machine. The primary task of a lathe is to generate cylindrical workpieces. The process of machining a workpiece to the required shape and size by moving the cutting tool either parallel or perpendicular to the axis of rotation of the workpiece is known as turning. In this process, excess unwanted metal is removed. The machine tool useful in performing plain turning, taper turning, thread cutting, chamfering and knurling by adopting the above method is known as lathe.



Engine lathe

The main function of lathe machine is to remove metal from a piece of work to give it the required shape and size. The work is held securely and rigidly on the machine and then turn against the cutting tools which remove metal from the work in the forms of chips.

Main parts of a lathe

Every individual part performs an important task in a lathe. Some important parts of a latheare listed below:

1. Bed

2. Headstock
3. Spindle
4. Tailstock
5. Carriage
    a. Saddle
    b. Apron
    c. Cross-slide
    d. Compound rest
    e. Compound slide
    f. Tool post
6. Feed mechanism
7. Lead screw
8. Feed rod

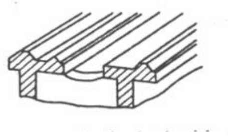


Fig 1 : Lathe bed

Bed

Bed is mounted on the legs of the lathe which are bolted to the floor. It forms the base of the machine. It is made of cast iron and its top surface is machined accurately and precisely. Headstock of the lathe is located at the extreme left of the bed and the tailstock at the right extreme. Carriage is positioned in between the headstock and tailstock and slides on the bed guide ways.

The top of the bed has flat or 'V' shaped guide ways. The tailstock and the carriage slides on these guide ways. Inverted 'V' shaped guide ways are useful in better guide and accurate alignment of saddle and tailstock. The metal burrs resulting from turning operation automatically fall through. Flat bed guide ways can be found in older machine tools. It is useful in heavy machines handling large workpieces. But then the accuracy is not high.

Headstock

Headstock is mounted permanently on the inner guide ways at the left hand side of the bed. The headstock houses a hollow spindle and the mechanism for driving the spindle at multiple speeds. The headstock will have any of the following arrangements for driving and altering the spindle speeds:

(i) Stepped cone pulley drive
(ii) Back gear drive
(iii)All gear drive

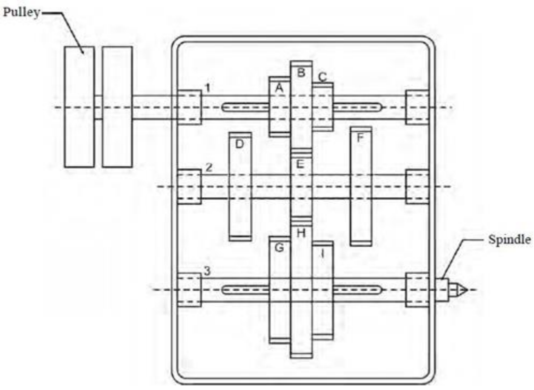


Fig 3: All gear drive

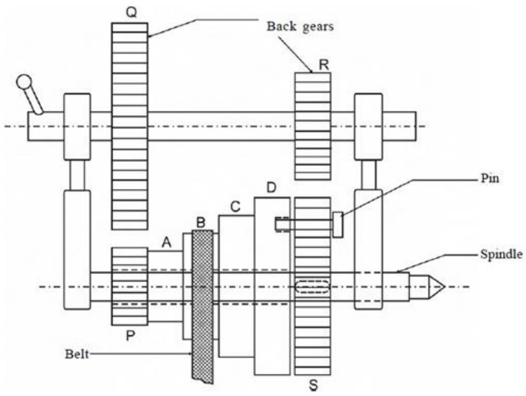


Fig 2: Stepped cone pulley with back gear

Spindle

The spindle rotates on two large bearings housed on the headstock casting. A hole extends through the spindle so that a long bar stock may be passed through the hole. The front end of the spindle is threaded on which chucks, faceplate, driving plate and catch plate are screwed. The front end of the hole is tapered to receive live centre which supports the work. On the other side of the spindle, a gear known as a spindle gear is fitted. Through this gear, tumbler gears and a main gear train, the power is transmitted to the gear on the leadscrew.

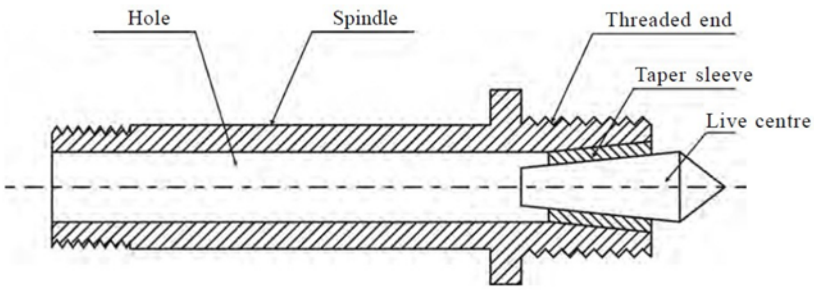


Fig 4: Head stock spindle
Fig 1.3 Spindle

Tailstock

Tailstock is located on the inner guide ways at the right side of the bed opposite to the headstock. The body of the tailstock is bored and houses the tailstock spindle. The spindle moves front and back inside the hole. The spindle has a taper hole to receive the dead centre or shanks of tools like drill or reamer. If the tailstock hand wheel is rotated in the clockwise direction, the spindle advances. The spindle will be withdrawn inside the hole, if the hand wheel is rotated in anti-clockwise direction.

The main uses of tailstock are:

1. It supports the other end of the long workpiece when it is machined between centres.
2. It is useful in holding tools like drills, reamers and taps when performing drilling, reaming and tapping.

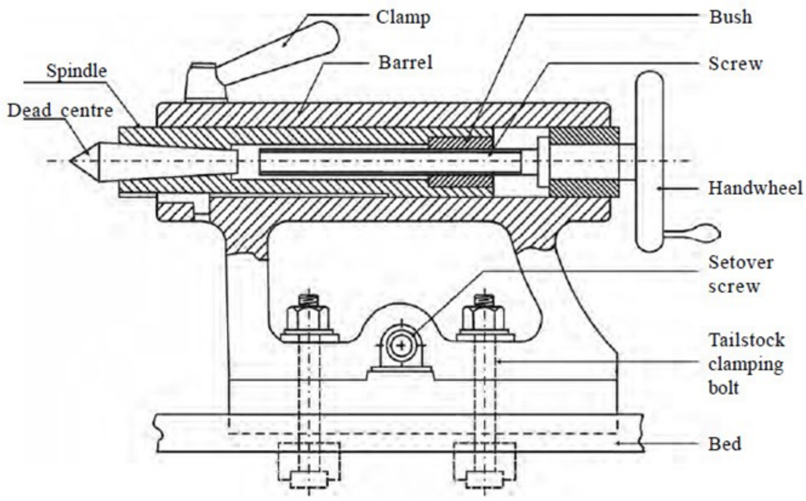


Fig 5: Tail stock

Carriage

Carriage is located between the headstock and tailstock on the lathe bed guide ways. It can be moved along the bed either towards or away from the headstock. It has several parts to support, move and control the cutting tool. The parts of the carriage are:

a) saddle
b) apron
c) cross-slide
d) compound rest
e) compound slide
f) tool post

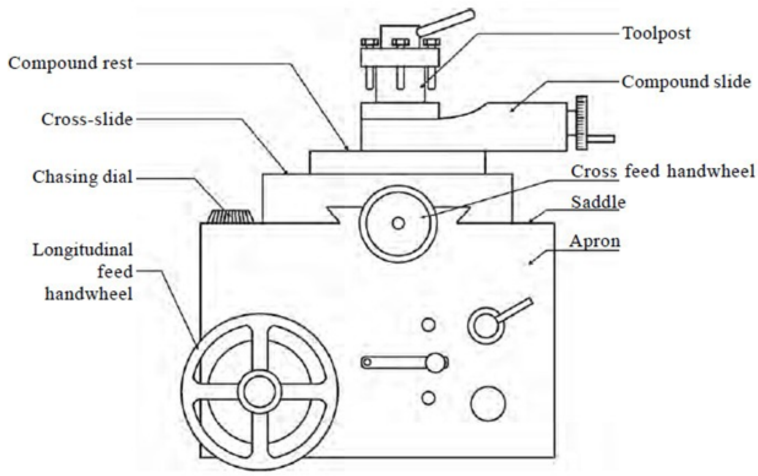


Fig 6: Carriage

Saddle:

It is an "H" shaped casting. It connects the pair of bed guide ways like a bridge. It fits over the bed and slides along the bed between headstock and tailstock. The saddle or the entire carriage can be moved by providing hand feed or automatic feed.

Cross slide:

Cross-slide is situated on the saddle and slides on the dovetail guide ways at right angles to the bed guide ways. It carries compound rest, compound slide and tool post. Cross slide hand wheel is rotated to move it at right angles to the lathe axis. It can also be power driven. The cross slide hand wheel is graduated on its rim to enable to give known amount of feed as accurate as 0.05mm.

Compound rest:

Compound rest is a part which connects cross slide and compound slide. It is mounted on the cross-slide by tongue and groove joint. It has a circular base on which angular graduations are marked. The compound rest can be swivelled to the required angle while turning tapers. A top slide known as compound slide is attached to the compound rest by dove tail joint. The tool post is situated on the compound slide.

Tool post:

This is located on top of the compound slide. It is used to hold the tools rigidly. Tools are selected according to the type of operation and mounted on the tool post and adjusted to a convenient working position. There are different types of tool posts and they are:

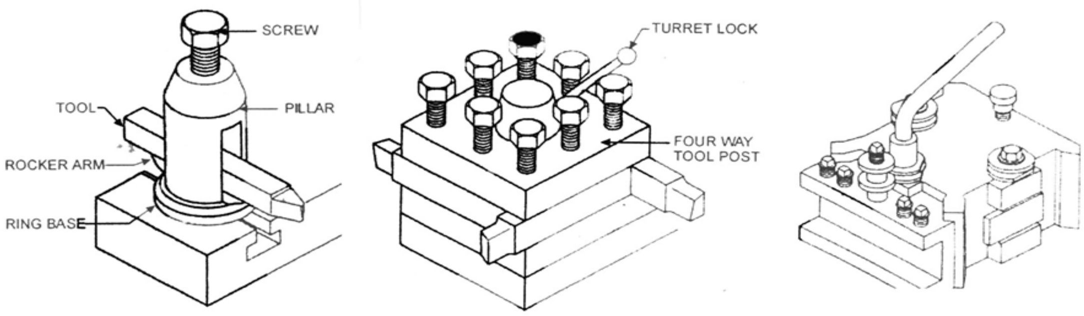
1. Single way tool post
3. Four way tool post
4. Quick change tool post

Single way tool post

The tool is held by a screw in this tool post. It consists of a round bar with a slotted hole in the centre for fixing the tool by means of a setscrew. A concave ring and a convex rocker are used to set the height of the tool point at the right position. The tool fits on the flat top surface of the rocker. The tool post is not rigid enough for heavy works as only one clamping screw is used to clamp the tool.

Four way tool post

This type of tool post can accommodate four tools at a time on the four open sides of the post. The tools are held in position by separate screws and a locking bolt is located at the centre. The required tool may be set for machining by swivelling the tool post. Machining can be completed in a shorter time because the required tools are pre-set.



Single way (Pillar Type) Tool Post | Indexing Type 4 way Tool Post | Quick Change Tool Post

Fig 6: Types of tool posts

Lead screw

The leads crew is a long threaded shaft used as master screw. It is brought into operation during thread cutting to move the carriage to a calculated distance. Mostly lead screw is Acme threaded.

The leadscrew is held by two bearings on the face of the bed. A gear is attached to the lead screw and it is called as gear on leadscrew. A half nut lever is provided in the apron to engage half nuts with the leadscrew.

Feed rod

Feed rod is placed parallel to the leadscrew on the front side of the bed. It is a long shaft which has a keyway along its length. The power is transmitted from the spindle to the feed rod through tumbler gears and a gear train. It is useful in providing feed movement to the carriage except for thread cutting and to move cross-slide. A worm mounted on the feed rod enables the power feed movements.

Types of lathe

Various designs and constructions of lathe have been developed to suit different machining conditions and usage. The following are the different types of lathe:

1. Speed lathe
a. Woodworking lathe
b. Centering lathe
c. Polishing lathe
d. Metal spinning lathe
2. Engine lathe
a. Belt driven lathe
b. Individual motor driven lathe
c. Gear head lathe
3. Bench lathe
4. Tool room lathe
5. Semi automatic lathe
a. Capstan lathe
b. Turret lathe
6. Automatic lathe
7. Special purpose lathe
a. Wheel lathe
b. Gap bed lathe
c. 'T' lathe
d. Duplicating lathe

SIZE OF A LATHE (SPECIFICATION OF LATHE)

The size of a lathe is specified by the following points

1. The length of the bed
2. Maximum distance between live and dead centres.
3. The height of centres from the bed
4. The swing diameter:

The swing diameter over bed - It refers to the largest diameter of the work that will be rotated without touching the bed

The swing diameter over carriage - It is the largest diameter of the work that will revolve over the saddle.

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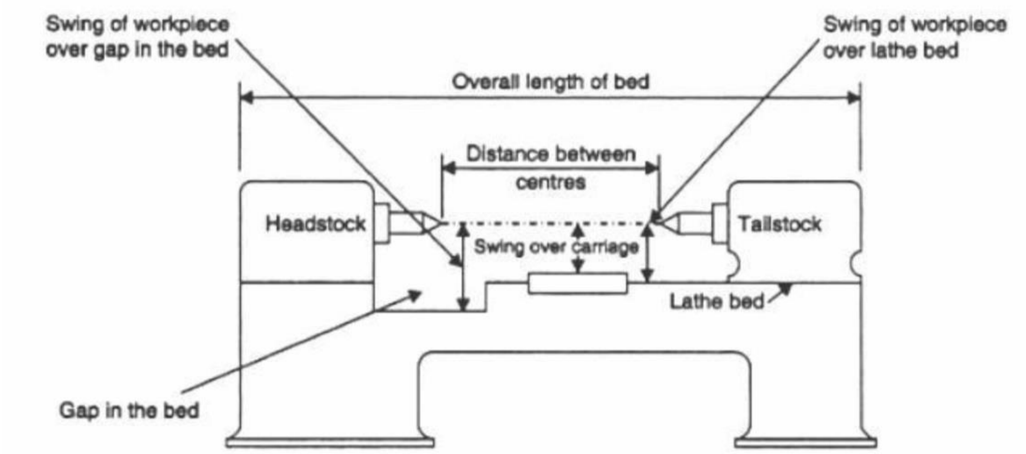

5. The bore diameter of the spindle
6. The width of the bed
7. The type of the bed
8. Pitch value of the lead screw
9. Horse power of the motor
10. Number and range of spindle speeds
11. Number of feeds
12. Spindle nose diameter
13. Floor space required
14. The type of the machine

Work holding devices used in a lathe (accessories)

The work holding devices are used to hold and rotate the workpieces along with the spindle. Different work holding devices are used according to the shape, length, diameter and weight of the workpiece and the location of turning on the work.

They are:

1. Chucks
2. Face plate
3. Driving plate
4. Catch plate
5. Carriers
6. Mandrels
7. Centres
8. Rests

Chucks

Workpieces of short length, large diameter and irregular shapes, which can not be mounted between centres, are held quickly and rigidly in chuck. There are different types of chucks namely, Three jaw universal chuck, Four jaw independent chuck, Magnetic chuck, Collet chuck and Combination chuck.

Three jaw self-Centering chuck

The three jaws fitted in the three slots may be made to slide at the same time by an equal amount by rotating any one of the three pinions by a chuck key. This type of chuck is suitable for holding and rotating regular shaped workpieces like round or hexagonal rods about the axis of the lathe.

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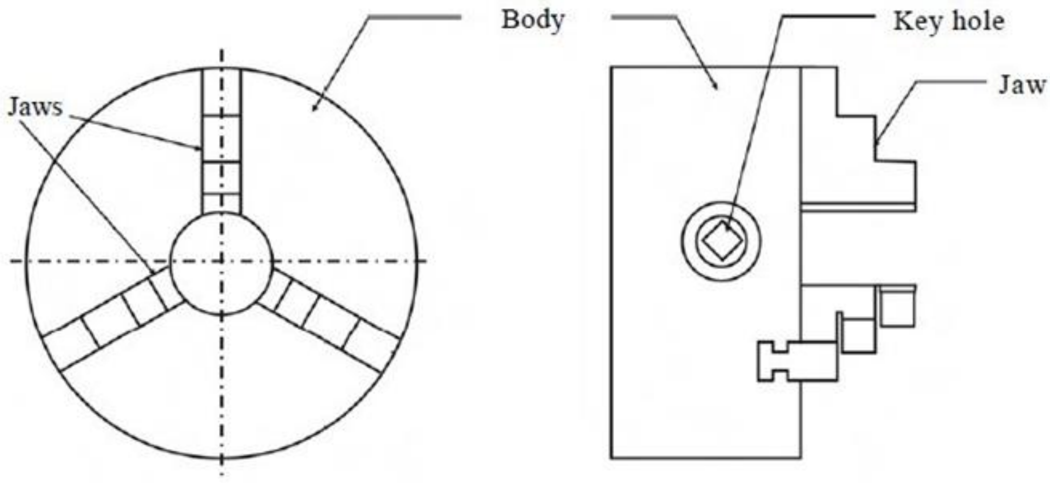
Workpieces of irregular shapes cannot be held by this chuck. The work is held quickly and easily as the three jaws move at the same time.



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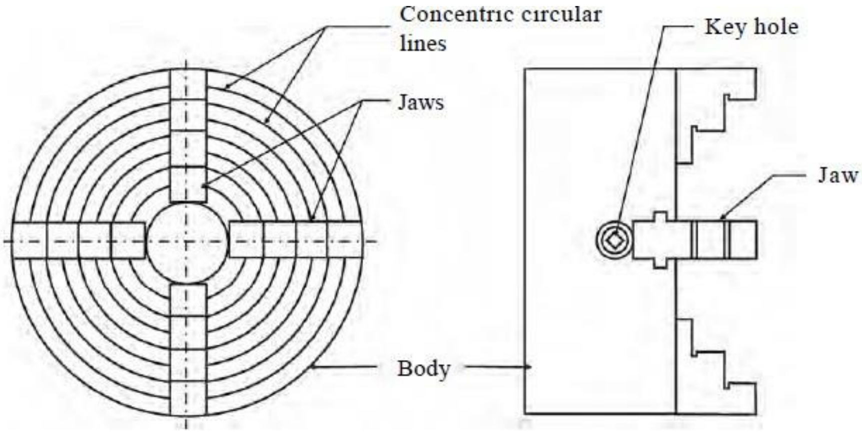
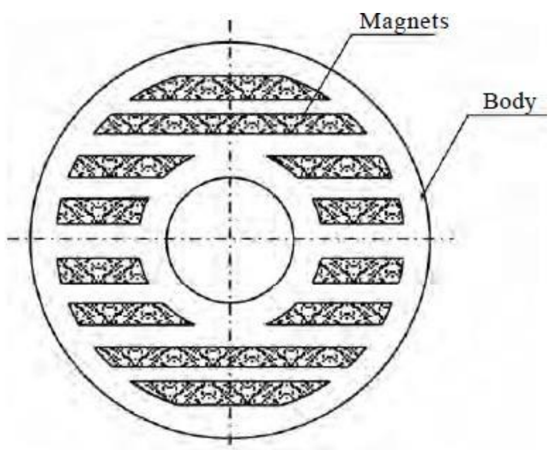
Four jaw independent chuck

There are four jaws in this chuck. Each jaw is moved independently by rotating a screw with the help of a chuck key. A particular jaw may be moved according to the shape of the work. Hence this type of chuck can hold woks of irregular shapes. But it requires more time to set the work aligned with the lathe axis. Experienced turners can set the work about the axis quickly. Concentric circles are inscribed on the face of the chuck to enable quick Centering of the workpiece.



Magnetic chuck

The holding power of this chuck is obtained by the magnetic flux radiating from the electromagnet placed inside the chuck. Magnets are adjusted inside the chuck to hold or release the work. Workpieces made of magnetic material only are held in this chuck. Very small, thin and light works which cannot be held in an ordinary chuck are held in this chuck.



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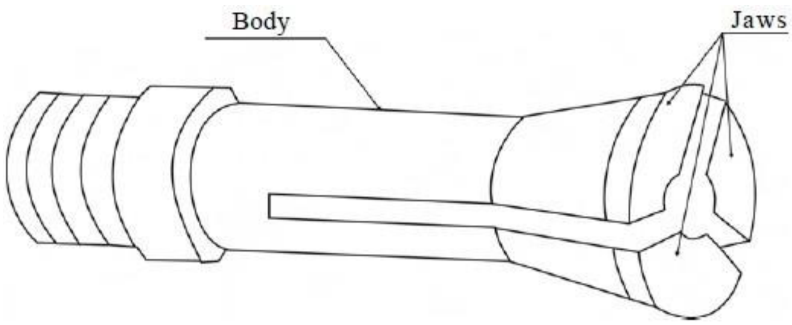
Collet chuck

Collet chuck has a cylindrical bushing known as collet. It is made of spring steel and has slots cut lengthwise on its circumference. So, it holds the work with more grips. Collet chucks are used in capstan lathes and automatic lathes for holding bar stock in production work.



Face plate

Faceplate is used to hold large, heavy and irregular shaped workpieces which can not be conveniently held between centres. It is a circular disc bored out and threaded to fit to the nose of the lathe spindle. It is provided with radial plain and 'T' – slots for holding the work by bolts and clamps.

Driving plate

The driving plate is used to drive a workpiece when it is held between centres. It is a circular disc screwed to the nose of the lathe spindle. It is provided with small bolts or pins on its face. Workpieces fitted inside straight tail carriers are held and rotated by driving plates.

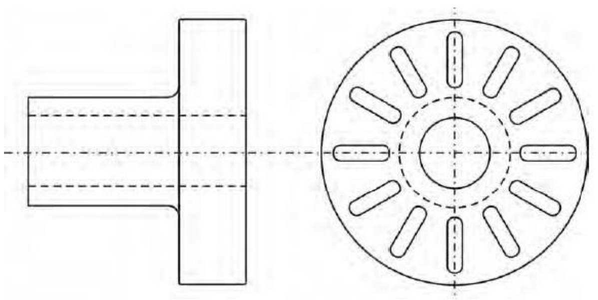


Fig: Face plate

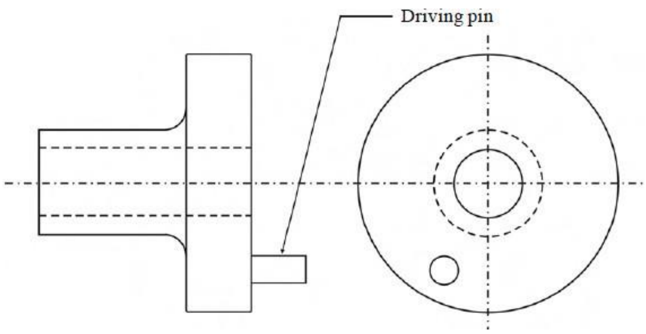


Fig: Driving plate

Catch plate

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When a workpiece is held between centres, the catch plate is used to drive it. It is a circular disc bored and threaded at the centre. Catch plates are designed with ‘U’ – slots or elliptical slots to receive the bent tail of the carrier. Positive drive between the lathe spindle and the workpiece is affected when the workpiece fitted with the carrier fits into the slot of the catch plate.

Carrier

When a workpiece is held and machined between centres, carriers are useful in transmitting the driving force of the spindle to the work by means of driving plates and catch plates. The work is held inside the eye of the carrier and tightened by a screw. Carriers are of two types and they are:

1. Straight tail carrier 2. Bent tail carrier

Straight tail carrier is used to drive the work by means of the pin provided in the driving plate. The tail of the bent tail carrier fits into the slot of the catch plate to drive the work.

Mandrel

A previously drilled or bored workpiece is held on a mandrel to be driven in a lathe and machined. There are centre holes provided on both faces of the mandrel. The live centre and the dead centre fit into the centre holes. A carrier is attached at the left side of the mandrel. The mandrel gets the drive either through a catch plate or a driving plate. The workpiece rotates along with the mandrel.

There are several types of mandrels and they are:

1. Plain mandrel
2. Step mandrel
3. Gang mandrel
5. Collar mandrel
6. Cone mandrel
7. Expansion mandrel

Centres

Centres are useful in holding the work in a lathe between centres. The shank of a centre has Morse taper on it and the face is conical in shape. There are two types of centres namely

(i) Live centre
(ii) Dead centre

The live centre is fitted on the headstock spindle and rotates with the work. The centre fitted on the tailstock spindle is called dead centre. It is useful in supporting the other end of the work. Centres are made of high carbon steel and hardened and then tempered. So the tip of the centres are wear resistant.

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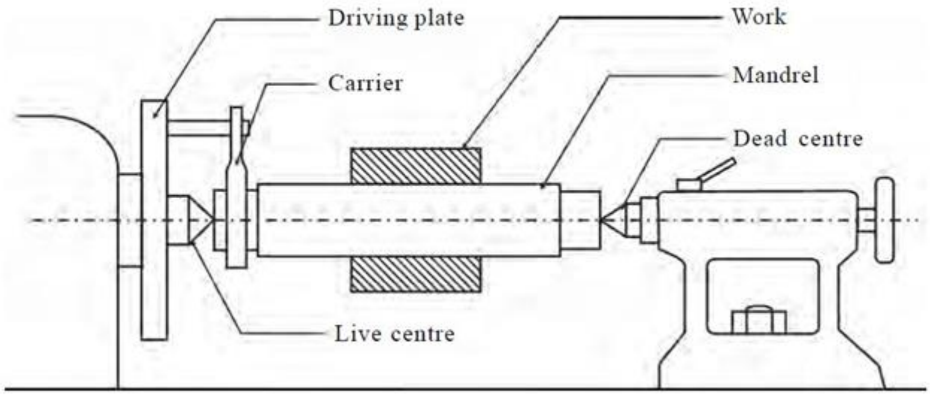

Fig 1.27 Holding a work between centres

Different types of centres are available according to the shape of the work and the operation to be performed. They are:

1. Ordinary centre
2. Ball centre
3. Half centre
4. Tipped centre
5. Pipe centre
6. Revolving centre
7. Inserted type centre

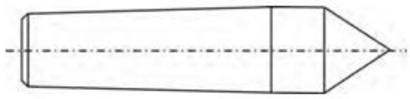

Fig : Ordinary centre

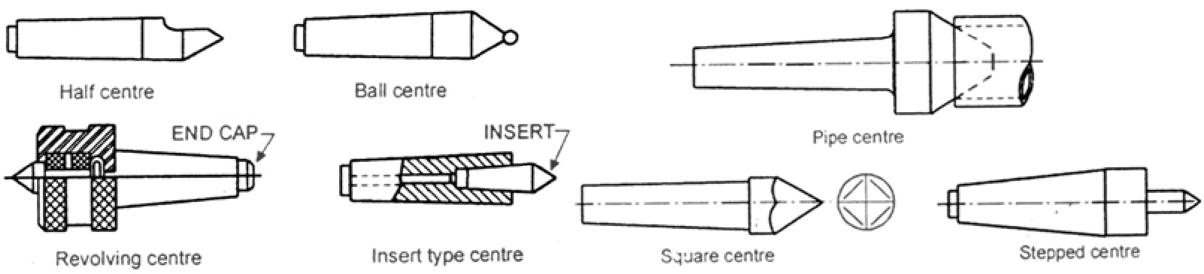

Fig: Types of centres

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Rests

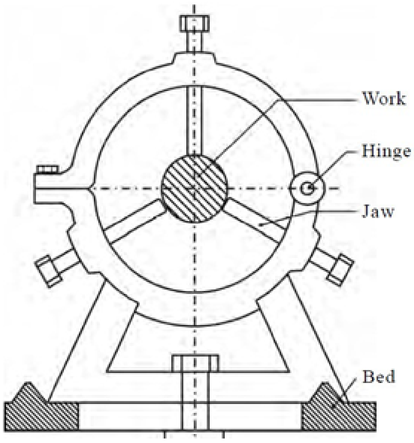
A rest is a mechanical device to support a long slender workpiece when it is turned between centres or by a chuck. It is placed at some intermediate point to prevent the workpiece from bending due to its own weight and vibrations setup due to the cutting force.

There are two different types of rests

1. Steady rest
2. Follower rest

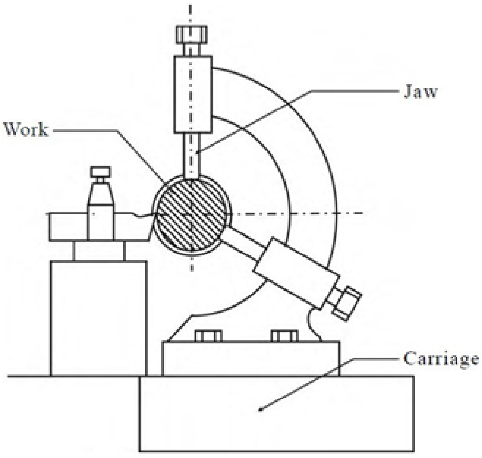
Steady rest

Steady rest is made of cast iron. It may be made to slide on the lathe bed ways and clamped at any desired position where the workpiece needs support. It has three jaws. These jaws can be adjusted according to the diameter of the work. Machining is done upon the distance starting from the headstock to the point of support of the rest. One or more steady rests may be used to support the free end of a long work.



Follower rest

It consists of a 'C' like casting having two adjustable jaws to support the workpiece. The rest is bolted to the back end of the carriage. During machining, it supports the work and moves with the carriage. So, it follows the tool to give continuous support to the work to be able to machine along the entire length of the work. In order to reduce friction between the work and the jaws, proper lubricant should be used.



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Operations performed in a lathe

Various operations are performed in a lathe other than plain turning. They are:

1. Facing
2. Turning
a. Straight turning
b. Step turning
3. Chamfering
4. Grooving
5. Forming
6. Knurling
7. Undercutting
8. Eccentric turning
9. Taper turning
10. Thread cutting
11. Drilling
12. Reaming
13. Boring
14. Tapping

Facing

Facing is the operation of machining the ends of a piece of work to produce flat surface which is square with the axis. The operation involves feeding the tool perpendicular to the axis of rotation of the work.

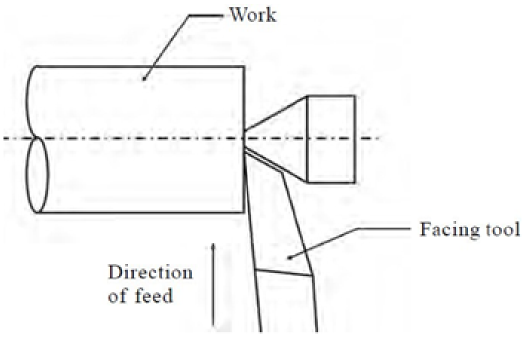

Fig 1.31 Facing

Turning

Turning in a lathe is to remove excess material from the workpiece to produce a cylindrical surface of required shape and size.

Straight turning

The work is turned straight when it is made to rotate about the lathe axis and the tool is fed parallel to the lathe axis. The straight turning produces a cylindrical surface by removing excess metal from the workpieces.

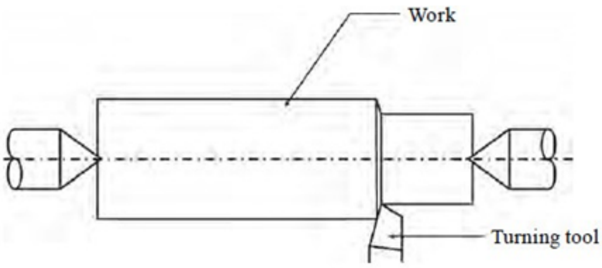

Fig 1.32 Straight turning

Step turning

Step turning is the process of turning different surfaces having different diameters. The work is held between centres and the tool is moved parallel to the axis of the lathe. It is also called shoulder turning.

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Chamfering

Chamfering is the operation of beveling the extreme end of the workpiece. The form tool used for taper turning may be used for this purpose. Chamfering is an essential operation after thread cutting so that the nut may pass freely on the threaded workpiece.

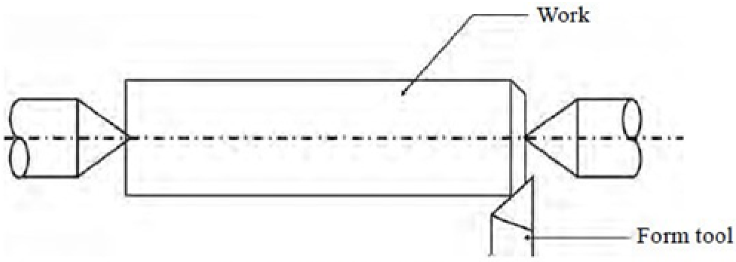
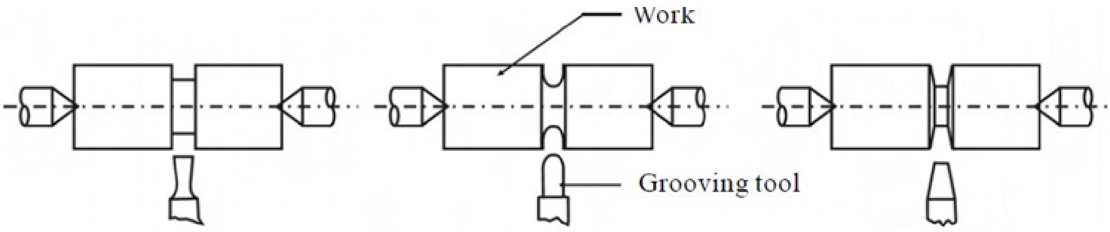


Fig 1.33 Chamfering

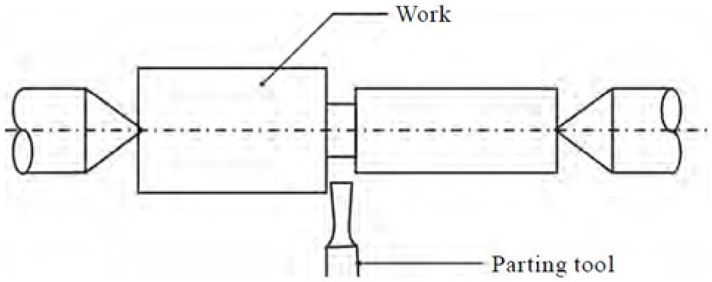
Grooving

Grooving is the process of cutting a narrow groove on the cylindrical surface of the workpiece. It is often done at end of a thread or adjacent to a shoulder to leave a small margin. The groove may be square, radial or beveled in shape.



Undercutting

Undercutting is done (i) at the end of a hole (ii) near the shoulder of stepped cylindrical surfaces (iii) At the end of the threaded portion in bolts. It is a process of enlarging the diameter if done internally and reducing the diameter if done externally over a short length. It is useful mainly to make fits perfect. Boring tools and parting tools are used for this operation.



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Forming

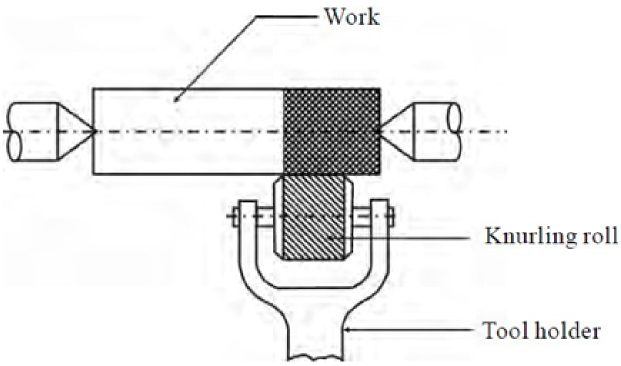
Forming is a process of turning a convex, concave or any irregular shape. For turning a small length formed surface, a forming tool having cutting edges conforming to the shape required is fed straight into the work.

Knurling

Knurling is the process of embossing a diamond shaped pattern on the surface of the workpiece. The knurling tool holder has one or two hardened steel rollers with edges of required pattern. The tool holder is pressed against the rotating work. The rollers emboss the required pattern. The tool holder is fed automatically to the required length. Knurls are available in coarse, medium and fine pitches. The patterns may be straight, inclined or diamond shaped.

The purpose of knurling is

1. To provide an effective gripping surface
2. To provide better appearance to the work
3. To slightly increase the diameter of the work



Taper turning

Taper

A taper may be defined as a uniform increase or decrease in diameter of a piece of work measuredalong its length.

Taper turning methods

1. Form tool method
2. Compound rest method
3. Tailstock set over method
4. Taper turning attachment method
5. Combined feed method

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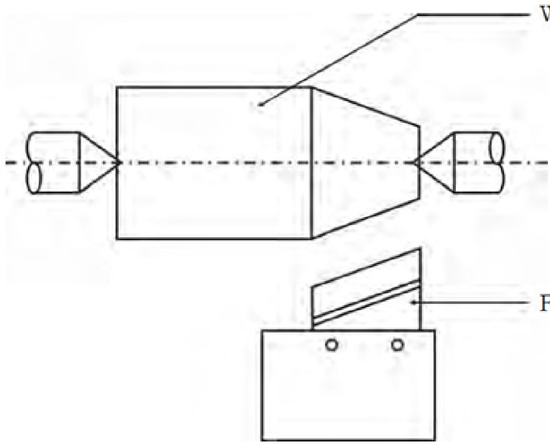
(i) Form tool method

A broad nose tool is ground to the required length and angle. It is set on the work by providing feed to the cross-slide. When the tool is fed into the work at right angles to the lathe axis, a tapered surface is generated. This method is limited to turn short lengths of taper only. The length of the taper is shorter than the length of the cutting edge. Less feed is given as the entire cutting edge will be in contact with the work.



(ii) Compound rest method

The compound rest of the lathe is attached to a circular base graduated in degrees, which may be swivelled and clamped at any desired angle. The angle of taper is calculated using the formula:

$$tan\theta = \frac{D - d}{2l}$$

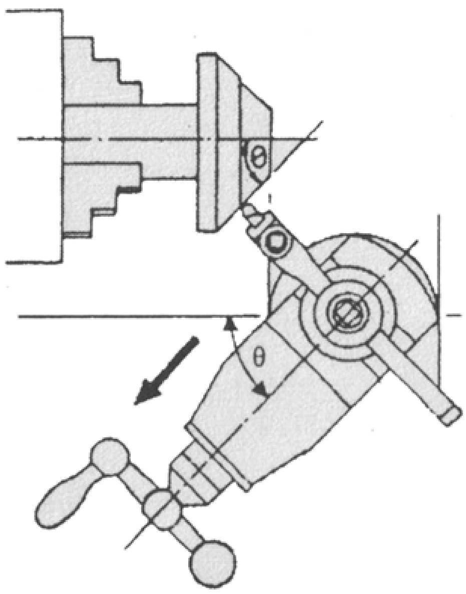
where D = Larger diameter

d = Smaller diameter

l = Length of the taper

θ = Half taper angle

The compound rest is swivelled to the angle calculated as above and clamped. Feed is given to the compound slide to generate the required taper.



Taper turning by swivelling the compound rest

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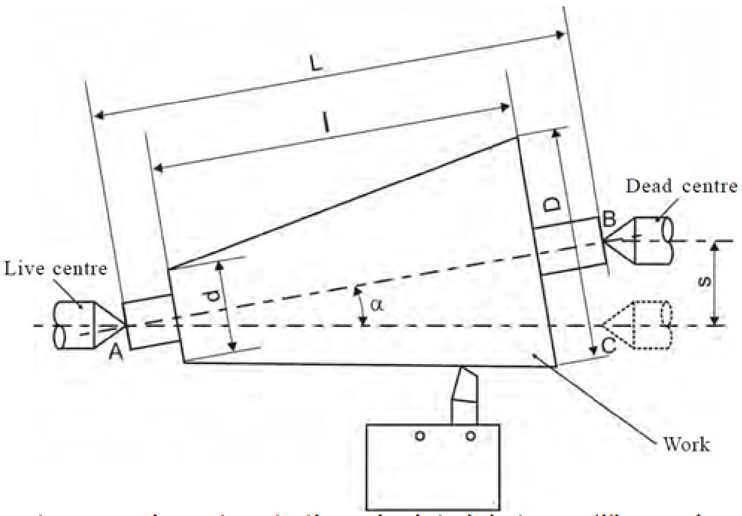
(iii) Tailstock set over method

Turning taper by the set over method is done by shifting the axis of rotation of the workpiece at an angle to the lathe axis and feeding the tool parallel to the lathe axis. The construction of tailstock is designed to have two parts namely the base and the body. The base is fitted on the bed guide ways and the body having the dead centre can be moved at cross to shift the lathe axis.

The amount of set over (s) can be calculated as follows:

$$setover, s = L * \frac{D-d}{2l}$$



The dead centre is suitably shifted from its original position to the calculated distance. The work is held between centres and longitudinal feed is given by the carriage to generate the taper. The advantage of this method is that the taper can be turned to the entire length of the work. Taper threads can also be cut by this method. The amount of set over being limited, this method is suitable for turning small tapers (approx. upto 8°). Internal tapers cannot be done by this method.

(iv)Taper turning by an attachment

The taper attachment consists of a bracket which is attached to the rear end of the lathe bed. It supports a guide bar pivoted at the centre. The bar having graduation in degrees may be swiveled on either side of the zero graduation and set at the desired angle to the lathe axis. A guide block is mounted on the guide bar and slides on it. The cross slide is made free from its screw by removing the binder screw. The rear end of the cross slide is tightened with the guide block by means of a bolt. When the longitudinal feed is engaged, the tool mounted on the cross slide will follow the angular path as the guide block will slide on the guide bar set at an angle of the lathe axis. The depth of cut is provided by the compound slide which is set parallel to the cross-slide. The advantage of this method is that long tapers can be machined. As power feed can be employed, the work is completed at a shorter time. The disadvantage of this method is that internal tapers cannotbe machined.

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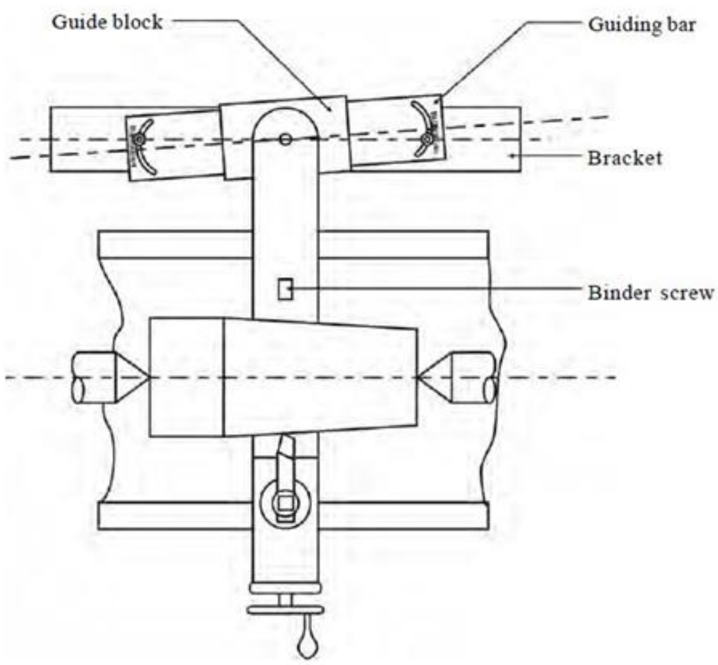
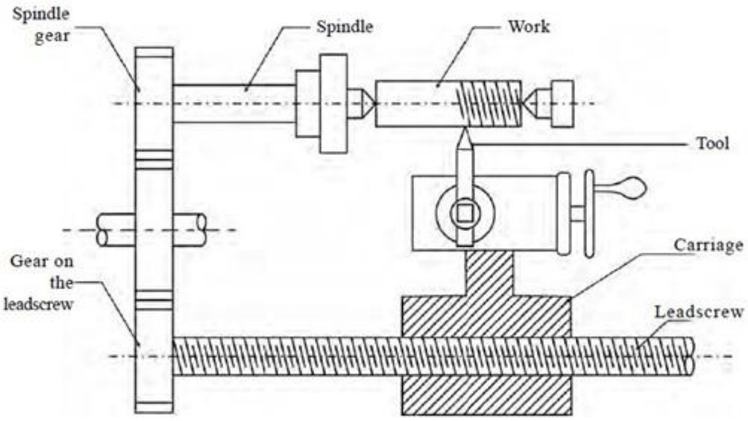


Thread cutting

Thread cutting is one of the most important operations performed in a lathe. The process of thread cutting is to produce a helical groove on a cylindrical surface by feeding the tool longitudinally. The job is revolved between centres or by a chuck. The longitudinal feed should be equal to the pitch of the thread to be cut per revolution of the work piece.



Tools used in a lathe

Tools used in a lathe are classified as follows

A. According to the construction, the lathe tools are classified into three types

1. Solid tool
2. Brazed tipped tool
3. Tool bit and tool holders

B. According to the operation to be performed, the cutting tools are classified as

1. Turning tool
2. Thread cutting tool
3. Facing tool

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4. Forming tool
5. Parting tool
6. Grooving tool
7. Boring tool
8. Internal thread cutting tool
9. Knurling tool

C. According to the direction of feed movement, the following tools are used

1. Right hand tool
2. Left hand tool
3. Round nose tool

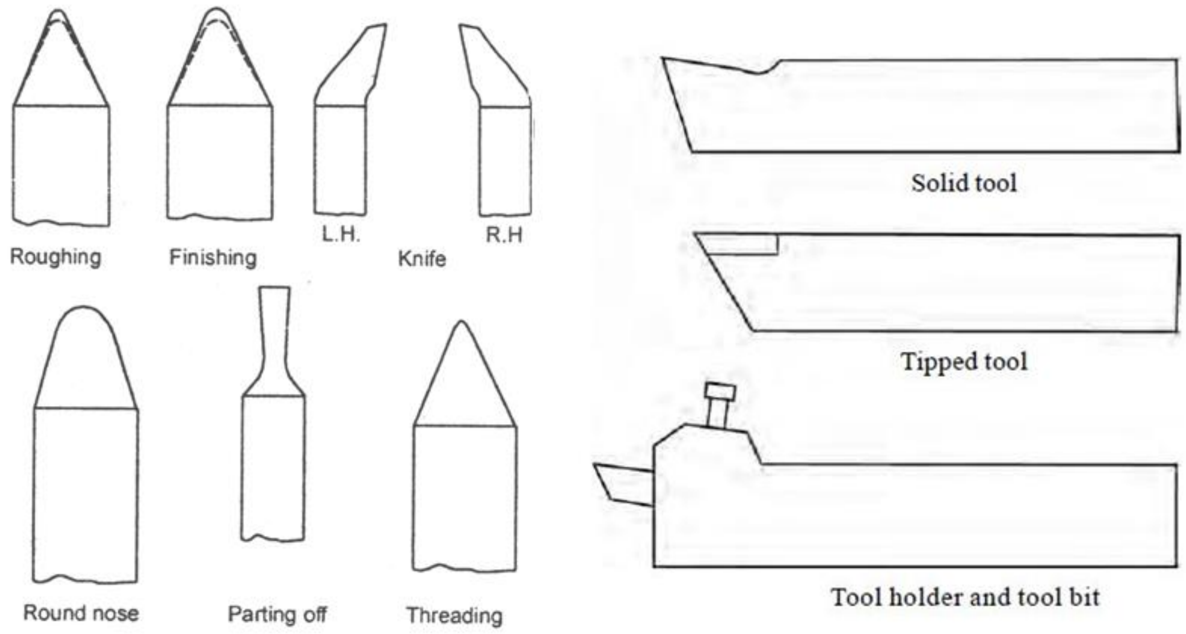

Fig : Types of tools

<u>CLASSIFICATION OF CUTTING TOOLS</u>

All the cutting tools used in metal cutting can be broadly classified as :

1. Single point Tools, i.e., those having only One cutting edge ; such as Lathe tools, Shaper tools, Planer tools, Boring tools, etc.

2. Multi-point Tools, i.e., those having more than one cutting edges ; such as Milling cutters, Drills, Broaches, Grinding wheels, etc. These tools may, for the sake of analysis, be considered as consisting of a number of Single point tools, each forming a cutting edge.

The Cutting tools can also be classified according to the motion as :

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> Linear motion tools ; Lathe, Boring, Broaching, Planing, Shaping tools, etc.

> Rotary motion tools ; Milling cutters, Grinding wheels, etc.

> Linear and Rotary tools ; Drills, Honing tools, Boring Heads, etc.

IMPORTANT TERMS

Before proceeding further, it would be advisable to be acquainted with a few important terms related to the Geometry of Single point tools.

1. **Shank.** It forms the main body of a solid tool and it is this part of the tool which is gripped in the Tool Holder.

2. Face. It is the top surface of the tool between the shank and the point of the tool. In the cutting action, the chips flow along this surface only.

3. Point. It is the wedge shaped portion where the face and flank of the tool meet. It is the cutting part of the tool. It is also called nose, particularly in case of Round nose tools.

4. Flank. Portion of the tool which faces the work is termed as flank. It is the surface adjacent to and below the cutting edge when the tool lies in a horizontal position.

5. Base. It is actually the bearing surface of the tool on which it is held in a Tool holder or clamped directly in a Tool post.

6. Heel. It is the curved portion at the bottom of the tool where the base and flank of the tool meet, as shown in Fig.

7. Nose radius. If the Cutting tip (nose) of a single point tool carries a sharp cutting point, the cutting tip is weak. It is, therefore, highly stressed during the operation, may fail or lose its cutting ability soon and produce marks on the machined surface.

In order to prevent these harmful effects the nose is provided with a radius, called Nose radius. It enables greater strength of the Cutting tip, a prolonged Tool life and a superior Surface finish on the workpiece.

Also, as the value of this radius increases, a higher cutting speed can be used. But, if it is too large it may lead to Chatter. So, a balance has to be maintained. Its value

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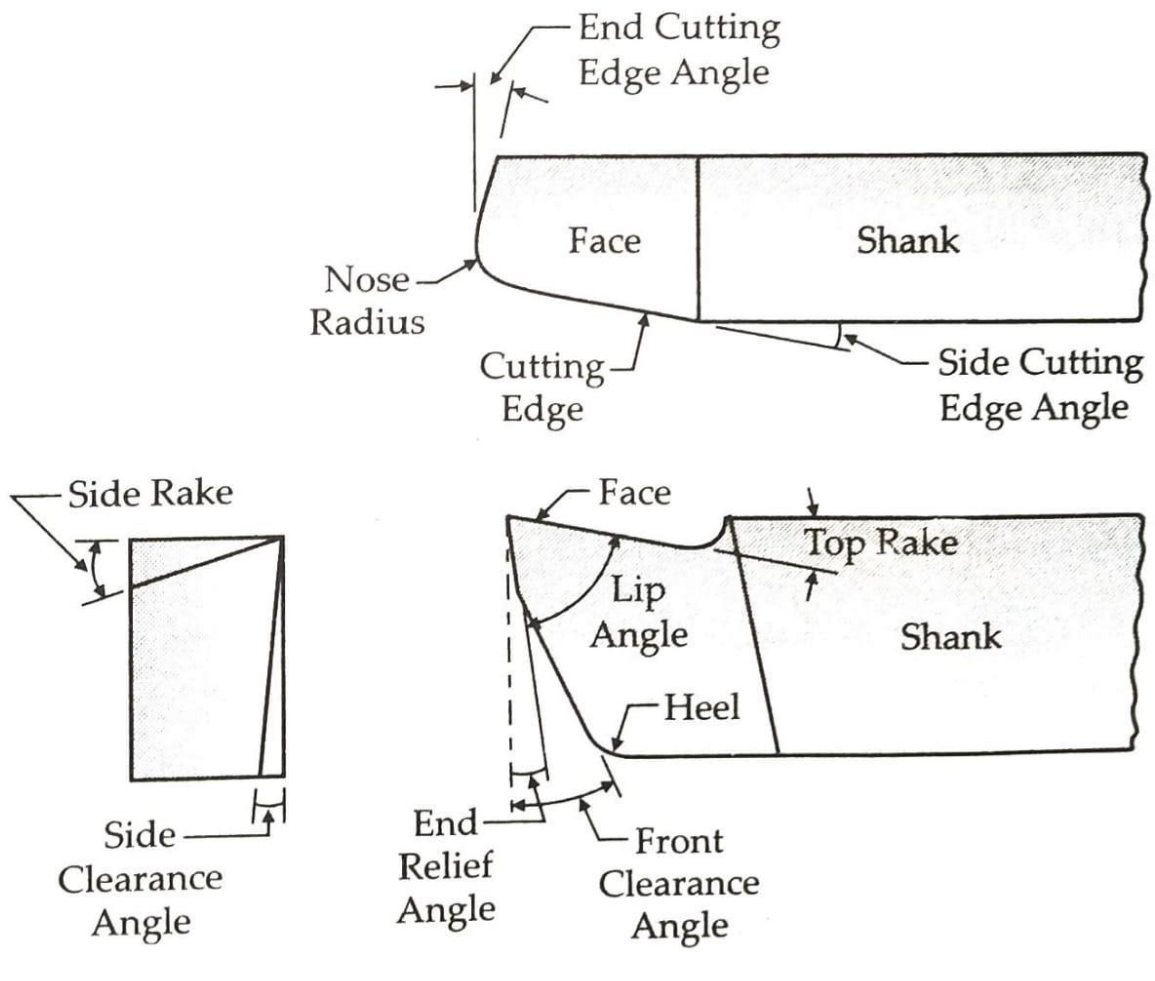
normally varies from 0.4 mm to 1.6 mm, depending upon several factors like depth of cut, amount of feed, type of cutting, type of tool (solid or with insert), etc.

PRINCIPAL ANGLES OF SINGLE POINT TOOLS

The different Angles provided on Single point Tools play a significant role in successful and efficient machining of different metals. A thorough study of these tool angles is, therefore, a must. The main angles provided on these tools are shown in Figure.



1. **Rake angle.**

It is the angle formed between the face of the tool and a plane parallel to its base. If this inclination is towards the shank, it is known as Back Rake or Top Rake. When it is measured towards the side of the tool, it is called the Side rake.

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These rake angles guide the chips away from the cutting edge, thereby reducing the chip pressure on the face and increasing the keenness of the tool so that less power is required for cutting.

It is important to note that an increased Rake angle will reduce the strength of the cutting edge. With the result, the Tools used for cutting hard metals are given Smaller Rake Angles whereas those used for softer metals contain Larger Rakes.

Negative Rake. The rake angles described above are called Positive Rake Angles. When no rake is provided on the tool, it is said to have a **zero rake.** When the face of the tool is so ground that it slopes upwards from the point it is said to contain a Negative Rake.

It, obviously, reduces the keenness of the tool and increases strength of the cutting edge. Such a rake is usually employed on Carbide Tipped Tools when they are used for machining Extra-hard surfaces, Hardened steel parts and for taking Intermittent cuts.

A tool with Negative rake will have a larger Lip angle, resulting in a stronger tool. The value of Negative Rake on these tools normally varies from 5° to 10°.

2. **Lip Angle.** The angle between the face and the flank of the tool is known as Lip angle. It is also sometimes called the **Angle of Keenness** of the tool. Strength of the cutting edge or point of the tool is directly affected by this angle. Larger the lip angle stronger will be the cutting edge and vice versa.
3. **Clearance Angle.** It is the angle formed by the front or side surfaces of the tool which are adjacent and below the cutting edge when the tool is held in a horizontal position. It is the angle between one of these surfaces and a plane normal to the base of the tool.

   When the surface considered for this purpose is in front of the tool, i.e., just below the point, the angle formed is called Front Clearance and when the surface below the side cutting edge is considered the angle formed is known as Side Clearance angle.

   The purpose of providing Front clearance is to allow the tool to cut freely without rubbing against the surface of the job, and that of the Side clearance to direct the cutting thrust to the metal area adjacent to the cutting edge.

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4. **Relief Angle.** It is the angle formed between the flank of the tool and a perpendicular line drawn from the cutting point to the base of the tool.

   Side relief angle: It is the angle between the portion of the side flank immediately below the side cutting edge and a line perpendicular to the base of the tool, and measured at right angle to the side flank.

   End relief angle: It is the angle between the portion of the end flank immediately below the end cutting edge and a line perpendicular to the base of the tool, and measured at right angle to the end flank.

   These angles are provided so that the flank of the tool clears the workpiece surface and there is no rubbing action between the two.

   These angles range from 5° to 15° for general turning.

   Small relief angles are necessary to give strength to the cutting edge when machining hard and strong materials.

   Tools with increased values of relief angles penetrate and cut the workpiece material more efficiently and this reduces the cutting forces.

5. **Side cutting edge angle:** it is the angle between the side cutting edge and the side of the tool shank. It is also known as lead angle.

This angle prevents interference as the tool enters the work material.

For general machining work this angle is kept between 15^0 to 30^0.

6. End cutting edge angle: this is the angle between the end cutting edge and a line normal to the tool shank.

This angle provides a clearance or relief to the trailing end of the cutting edge to prevent rubbing or drag between the machined surface and the trailing part of the cutting edge.

An angle of 8^0 to 15^0 has been found satisfactory for this purpose.

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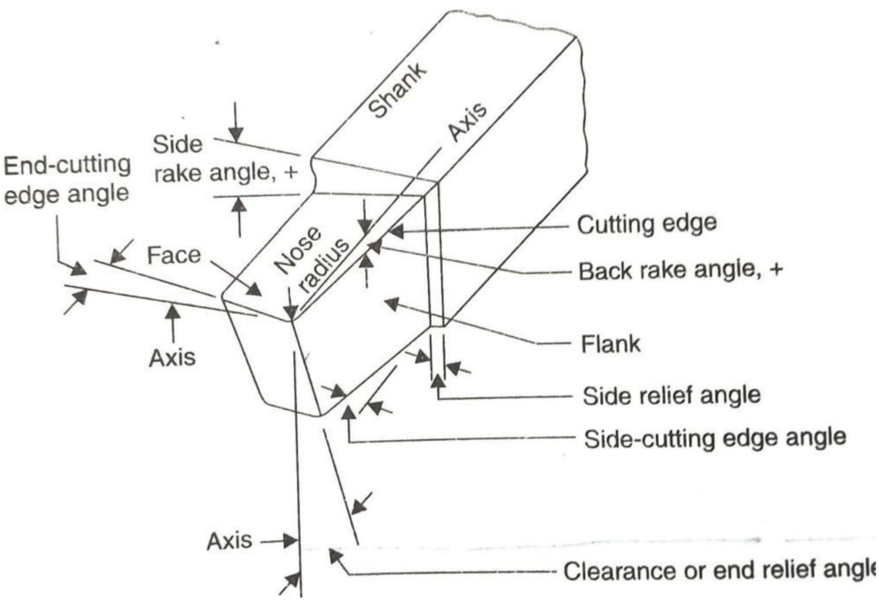

Tool signature:

I. Back rack angle
II. Side rake angle
III. End relief angle
IV. Side relief angle
V. End cutting edge angle
VI. Side cutting edge angle
VII. Nose radius

A typical tool signature:

0-10-6-6-8-90-1mm

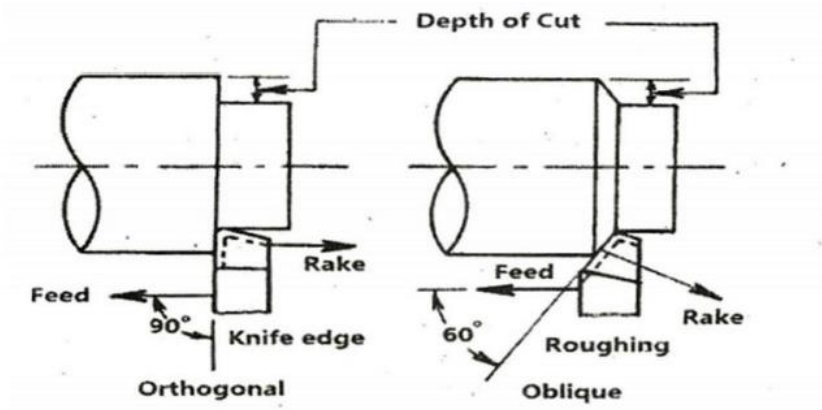

Figure Orthogonal and oblique cutting

CUTTING SPEED, FEED AND DEPTH OF CUT (LATHE WORK)

1. **Cutting speed:** The cutting speed (in a lathe for turning operation) is the peripheral speed of the workpiece past the cutting tool.

   Mathematically, **V= ΠDN / 1000 m/min**

   Where, V = Cutting/peripheral speed, m/min,

   D = Diameter of the job, mm, and

   N = Job or spindle speed, r.p.m.

   The main factors which influence the selection of a proper cutting speed are :

   - Material of the cutting tool.
   - Hardness and machinability of the metal to be machined.
   - Quality of heat treatment, if it is a H.S.S. steel tool.
   - Whether machining is to be done with or without the use of a coolant.
   - Rigidity of the tool and the work.
   - Tool shape.
   - Depth of cut.
   - Feed to be given to the tool.
   - Rigidity of the machine.

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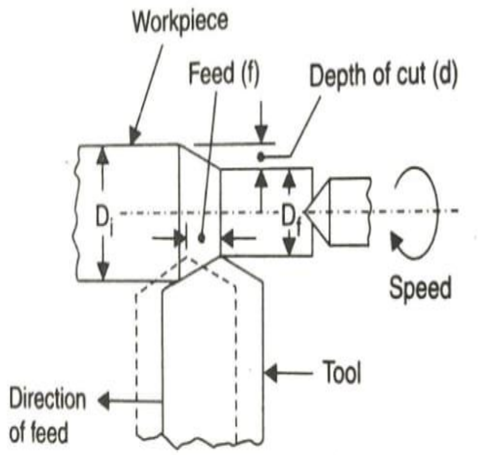

Fig. 9.31. Concept of cutting speed, feed and depth of cut.

2. **Feed (f):**

Feed may be defined as the distance that a tool advances into the work during one revolution of the headstock spindle.

- Feed is expressed in mm/revolution.
- The smaller the feed, the better the finish although a great deal depends on the type of lathe tool used, and a well sharpened tool is necessary.
- Larger feeds reduce machining time, but the tool life is reduced.

Feed may calculated as follows:

$$\mathbf{f = L/N*T_m \text{ mm/rev}}$$

Where, L = Length of cut, mm,

N = r.p.m, and

T_m = Machining/cutting time, min.

3**. Depth of cut (d):**

The depth of cut 'd' is the perpendicular distance measured from the machined surface to the uncut (or previous cut) surface of the workpiece. For turning operations, the depth of cut is expressed as:

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$$d = \frac{Di - Df}{2}$$

Where, D_i= Initial/original diameter of the workpiece, mm, and

D_f = Final diameter of the workpiece, mm.

For rough cutting, the depth of cut should be as large as possible, consistent with the size or capacity of the centre lathe and the material being turned.

The values of speed, feed and depth of cut, in general, depend upon the following factors

- Type of workpiece material
- Type of tool material
- Type of surface finish required

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CHAPTER 2

INTRODUCTION TO BROACHING

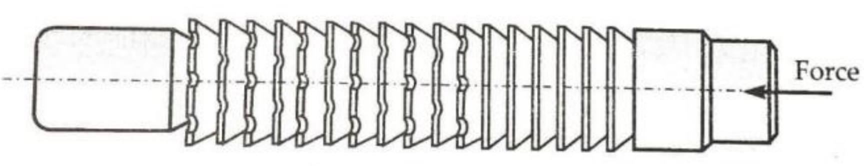
Broaching is a machining operation in which a tool, having a series of cutting teeth, called Broach, is either pulled or pushed by the broaching machine past the surface of a workpiece. In doing so, each tooth of the tool takes a small cut through the metal surface.

The surface to be cut may be external or internal. When the operation is performed on internal surface it is called Internal or Hole Broaching and in case of external surface External or Surface Broaching.

TYPES OF BROACHES

According to the method of operation - **Push, pull or stationary**

- **Push broaches** are shorter in length than the **pull broaches** of the same cross section in order to ensure adequate stiffness to resist bending.
- **Push broaches** are usually employed where a **shorter length** is to be broached and less material is to be removed.
- Where a considerable amount of metal is to be removed and a longer work surface is to be broached a **pull type broach**, which carries **more number of teeth and is longer**, and hence removes more material, is preferred.



A Push Broach.

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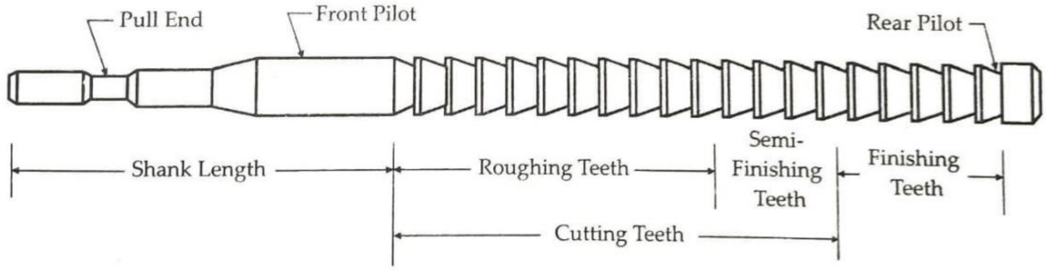
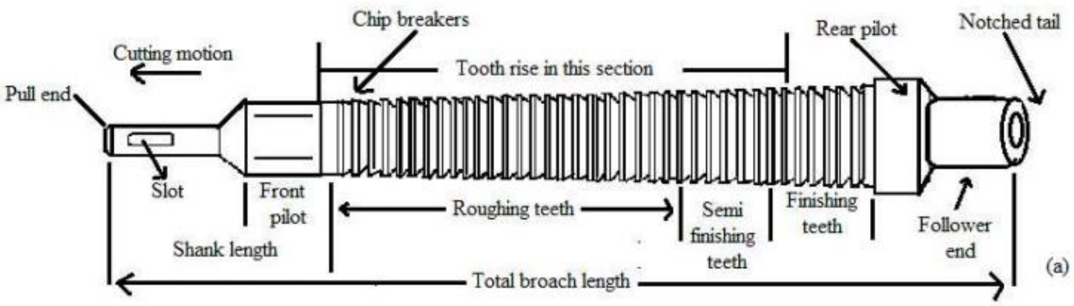


A Pull Broach

The internal broaches which are commonly employed for enlarging and sizing an existing hole and/or providing specific shapes to the existing holes. These holes in the components exist due to earlier operations on them, such as drilling, casting, forging, punching, etc.

DETAILS OF BROACH CONSTRUCTION

Figure illustrates the details of a pull type (internal type broach) for enlarging and sizing a cylindrical hole.

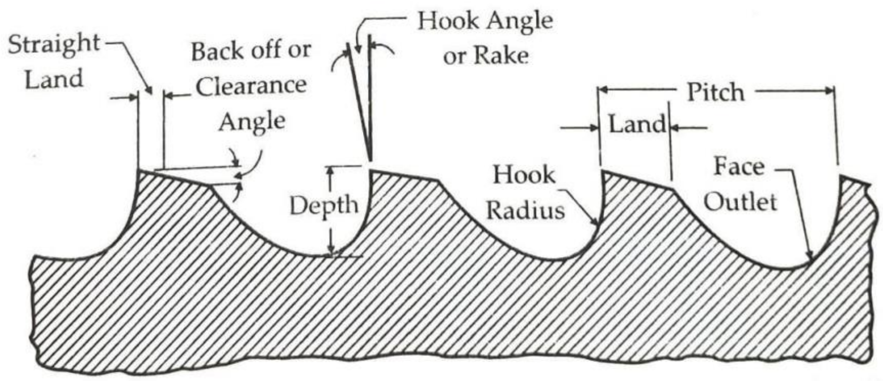


- The pull end grips the broach at the shank end. Before the teeth, the front pilot enters the hole to keep proper alignment.
- The cutting teeth, which follow the front pilot, gradually increase in size. The first set of cutting teeth, called roughing teeth, does most of the cutting. They are followed by semi-finishing teeth, which remove comparatively less material. Their sizes will obviously be smaller than the roughing teeth. They bring the size of the hole to roughly the required size.

- The finishing teeth, do not practically remove any appreciable amount of stock. They are all of the same size and shape as the required size and shape of the hole, so as to produce the hole of required size and shape having a smooth finish.
- The rear pilot supports the broach and keeps it aligned after the cut is over.

ELEMENTS OF A BROACH TOOL

Figure shows the details of broach teeth. It would be interesting to note that each tooth of the tool is larger than the preceding one and smaller than the one that follows **except the finishing teeth**, which are all of the same size.



Broach Teeth details.

The principal elements of a common type of broach are the following

1. **Pull end**. That end of the pull broach, which contains shank, is the pull end. The broaching machine's puller head grips this end of the broach.

2. **Front pilot**. It guides the broach into the hole and keeps it concentric. This helps in starting a straight cut.

3. **Rear pilot**. Its size and shape is same as of the finished hole and provides support to the broach after the cutting process is over. After the operation, this portion of the broach is gripped by the machine to pull back the broach to the starting position.

4. **Land.** It is the extreme top part of the tooth and is normally ground slightly to provide clearance.

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5. **Tooth gullet**. It is also known as **face outlet or chip space**. This provides space for the chips to curl and escape. If this space is not provided, or is too small to accommodate the cut chips, the chips will rub against the hole surface and spoil it. Its size varies directly as the pitch of the teeth.

6. **Pitch**. The linear distance between the cutting edge of one tooth and the corresponding point on the next tooth is called pitch. It should be large enough to allow enough space for the chips to collect. It is more important in case of long holes.

7. **Hook or rake angle**. It is also known as face angle. It is similar to the rake angle provided on a single point tool of a lathe and purpose is also the same.

8. **Hook radius**. It is the radius contained by the bottom of the gullet. It should have a very polished and smooth surface so as to prevent sticking of chips in the gullet

TOOL MATERIAL:

- High carbon steel: light work
- HSS: commonly used for production work, mass production
- Carbide tipped tools: for very hard materials, abrasives

PRINCIPLE OF BROACHING

- The operation of broaching involves the use of a multitooth cutter, called broach, which has already been described earlier. The teeth of the broach are so designed that the height of the cutting edge of the following cutting tooth is slightly more, equal to the **feed per tooth**, than that of the preceding tooth.
- Thus, when the broach is fed in a straight line, either over an external surface or through an internal surface, the metal is cut in several successive layers by successive teeth of the broach.
- The thickness of each layer is same and is known as feed per tooth. The sum of thicknesses of all the layers taken together is called the depth of cut.
- During the operation, either the broach is fed past the stationary workpiece or the workpiece past a stationary broach, the former practice being more common.

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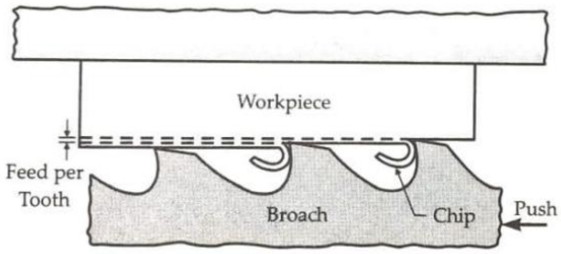
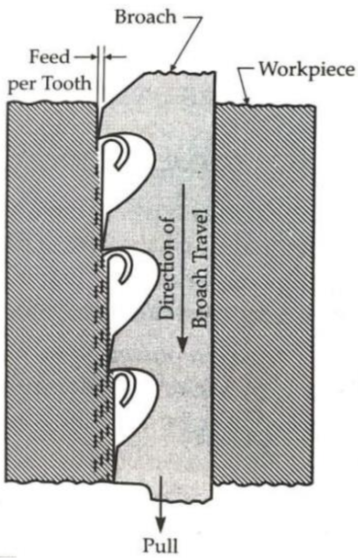
- A specific point regarding broaching is that out of all the basic machining processes it is the only process in which the feed is in-built in the tool (broach). This feed is equal to the chip thickness.





- Figure 1 shows a push type broach being fed past the stationary work, on a horizontal broaching machine, to machine an external surface on the workpiece.
- Figure 2 shows a pull type broach being fed into a hollow workpiece, on a vertical pull-down type machine, to machine an internal surface of the workpiece. In this case also, the workpiece will remain stationary.
- Both the operations are performed in a single linear stroke of the broach.
- The broaching process is used to machine internal and external surfaces such as holes of circular, square, or irregular shapes, key-ways and teeth of internal gears.

TYPES OF BROACHING MACHINES

1. According to the power employed - manually operated or power driven.

2. According to the direction of broach movement in cutting - **Horizontal or vertical.**

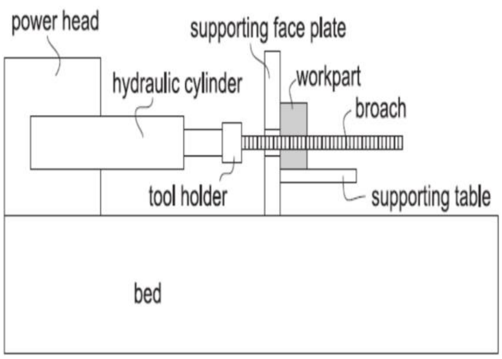
3. According to the method of cutting- **Pull, push or continuous.**

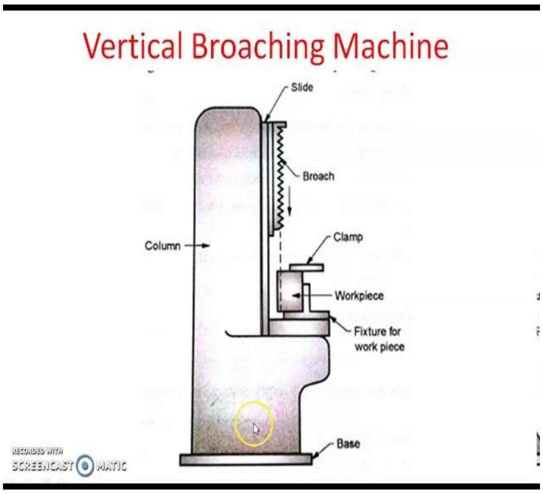
4. According to the condition of movement of the tool relative to the work - Moving or Stationary broach.

5. According to the type of drive - Mechanical or hydraulic drive.

6. According to the number of pull heads - Single or multiple pull-head.

A broaching machine is made up of an appropriate frame, a driving mechanism, a work-holding device (fixture), and a broaching tool. The main slide of the broaching machine is typically where the broach is fixed and moves together with the slide.





Horizontal broaching machine

Depending on whether the slide moves in the horizontal or vertical planes, a broaching machine (see Fig.) may be either horizontal or vertical.

Horizontal broaching machine:

- ❖ Any area of it is easily accessible from the floor, particularly the work station.
- ❖ A lengthy slide can be levelled and supported at several spots to maintain it in place.

Vertical broaching machine:

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- ❖ It takes up less space on the floor
- ❖ A pit or a platform for the operator to access the workstation should be sunk for a machine with a long stroke.

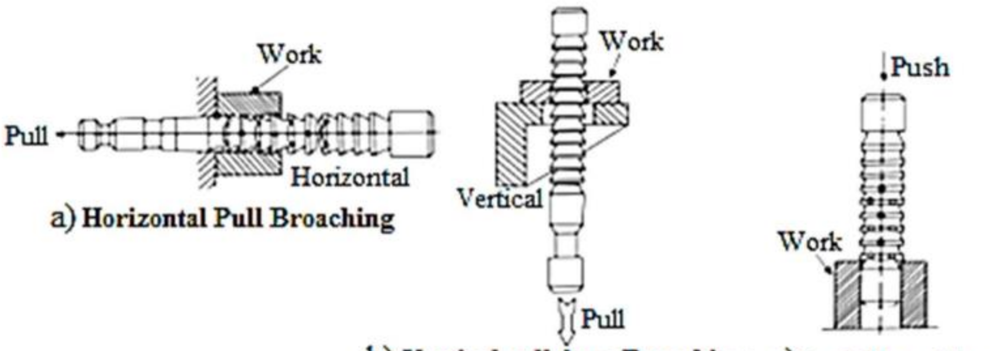
push and pull internal broaching machines:

- ➢ **May be either horizontally or vertically oriented.**

pull broaching machines: the shank receives the force while the body of the broach is under strain.

It is a **"push broach"** and is in compression if the force is applied to the back of the broach. A push broach should be shorter than a pull broach and typically does not expand in length by more than 15 times of diameters in order to prevent buckling.

- ✧ Internal broaching, such as hole sizing and key-way cutting, is typically done on a vertical push broaching machine.



a) Horizontal Pull Broaching b) Vertical pull down Broaching c)Push Broaching

In vertical pull down broaching machines, the broach is dragged through the work rather of being pushed. The machine's base houses the pulling mechanism. An upper carriage suspends the broach above the work surface. The broach is lowered through the workpiece that is being held in a fixture on the worktable to begin the broaching operation.

vertical pull up broaching machines: The pulling mechanism is located above the worktable, while the broach is located at the machine's base. The broach is dragged

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upward and enters the work. The work is released at the end of the process and drops into a container.

Single Ram Horizontal Broaching Machine

Construction:

- Has **one ram (or slide)** which carries the broach tool.
- The ram is powered hydraulically or mechanically to pull/push the broach through the workpiece.
- Workpiece is clamped on a fixed fixture.

Working Principle:

- The single ram pushes/pulls the broach in one direction to complete the machining (internal or external broaching).
- After machining, the ram retracts, and the broach returns to its initial position.

Applications:

- Used for **medium-scale production**.
- Suitable for **internal splines, slots, keyways, round holes**, etc.

Advantages:

- Simple design, easy to operate.
- Cost-effective for general use.

Limitations:

- Only **one workpiece** can be machined at a time.
- Idle time during return stroke reduces productivity.

Duplex Ram Horizontal Broaching Machine

Construction:

- Has **two rams (slides)** arranged in parallel.
- Each ram carries its own broach and operates alternately.
- Work holding fixtures are positioned for each ram.

Working Principle:

- While **one ram is performing the cutting stroke**, the **other ram is in the return stroke** (idle).
- This overlapping action reduces non-productive time.
- Workpieces can be loaded/unloaded alternately in each fixture.

Applications:

`

- Used for **high-volume production**.
- Suitable for **automobile parts, gears, turbine components**, etc.

Advantages:

- **Higher productivity** than single ram machines.
- Reduced idle time since one ram is always cutting.
- More efficient for mass production.

Limitations:

- More complex design and higher cost.
- Requires more floor space.

Advantages and limitations of broaching process

- Due to its exceptional qualities and benefits, broaching has become a popular metal cutting technique for tasks requiring mass production. With the right broaches, fittings, and machinery, production rates are quite high. High precision and good surface finish is feasible, both roughing and finishing cuts are carried out in a single tool pass. Any profile might be machined by providing the tools various forms, and the process is appropriate for both internal and exterior surface finishing.

- Despite the foregoing benefits, it has certain drawbacks, such as the high cost of tooling, which makes it uneconomical for small-scale work. It is not appropriate for the removal of huge amounts of stock because it necessitates sturdy machinery to handle the high forces generated during cutting.

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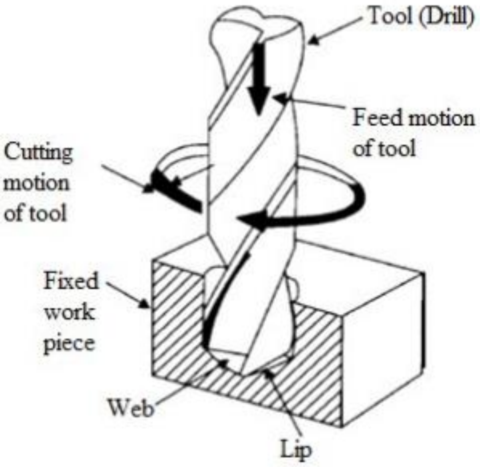
INTRODUCTION TO DRILLING

- Drilling is the process of creating a hole for a job. This is a sizeable portion of the machining operations carried out by the multi-point drilling tool's rotary and axial feed movements.



- Round holes are machined in drilling machines, boring machines, engine lathes, vertical boring mills, turret lathes, semi-automatic and automatic lathes, broaching machines and grinders.
- Whereas, drilling machines are used **to originate or cut a hole** in none previously existed one. The boring machines, broaching machines and grinders are mainly used to enlarge/ finish the existing holes.

Generally, holes should meet the following requirements:

- ✓ The diameter size must be restricted to the predetermined range.
- ✓ The hole's axis or cylindrical surface must be straight and meet the requirements.

`

- ✓ The hole needs to have a true cylindrical shape, meaning there must be no taper, ovality, or lobed edges.
- ✓ The part's faces and the hole must be square to one another.

Basic nomenclature of drill tool and their functions

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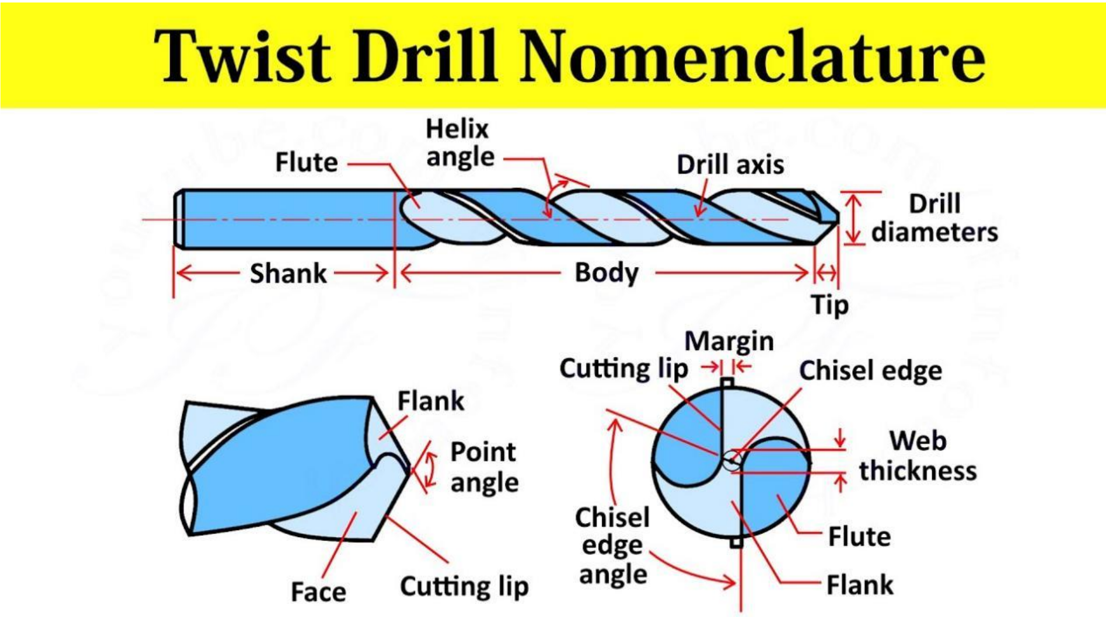
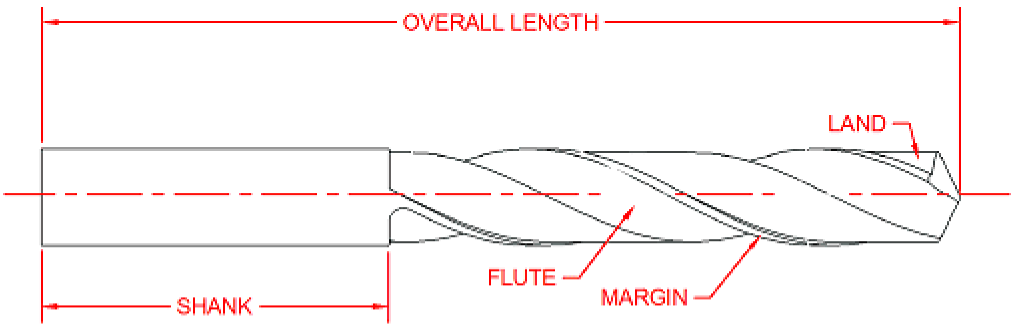
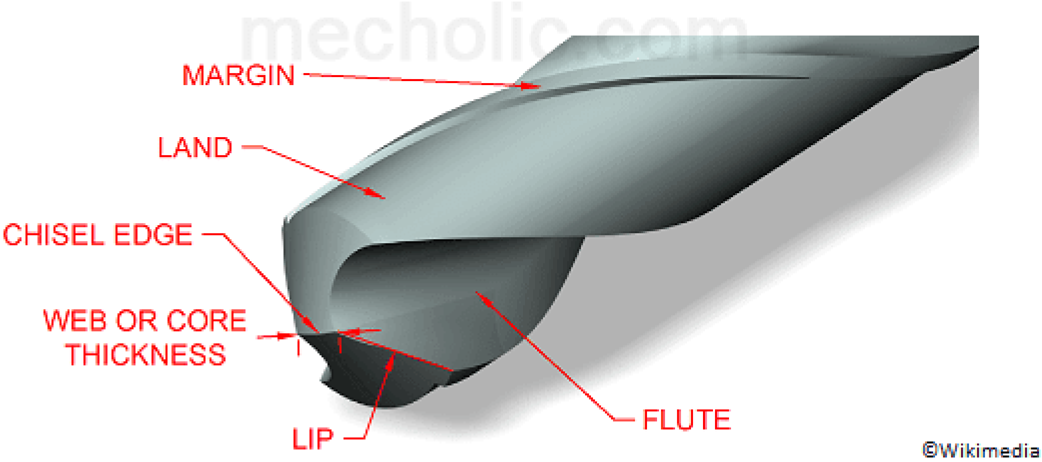
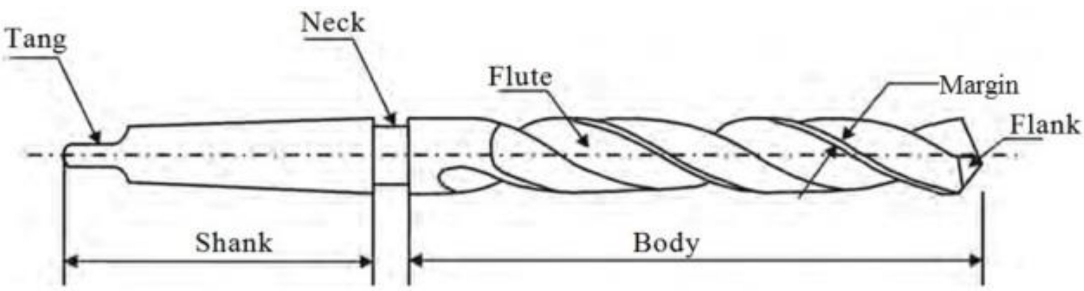
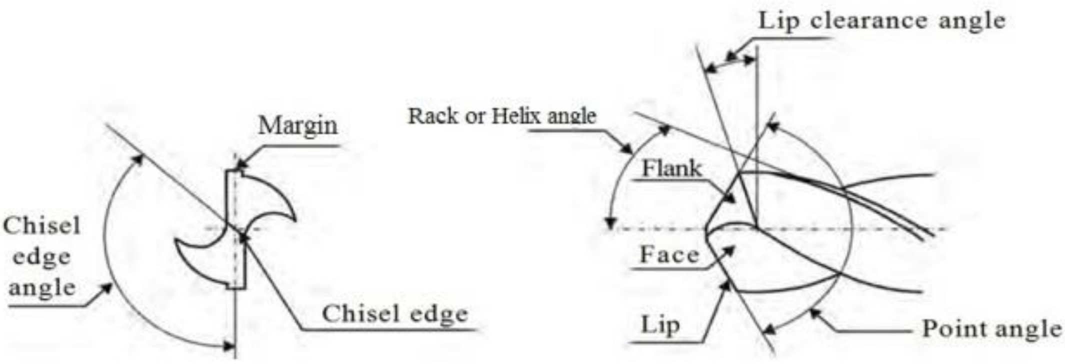



OVERALL LENGTH
LAND
FLUTE
MARGIN
SHANK


mecholic.com
MARGIN
LAND
CHISEL EDGE
WEB OR CORE
THICKNESS
LIP
FLUTE
©Wikimedia


Tang
Neck
Flute
Margin
Flank
Shank
Body


Lip clearance angle
Rack or Helix angle
Margin
Chisel
edge
angle
Flank
Face
Lip
Chisel edge
Point angle

1. Shank

`

Definition: The part of the drill by which it is held in the machine (chuck, taper socket, or spindle).

Function: Transmits torque and rotation from the machine to the drill.

Types:

- ✓ straight shanks (standard cylindrical)
- ✓ Hexagonal shanks (for non-slipping grip)
- ✓ SDS shanks (for quick-release)
- ✓ Taper shanks (for heavy-duty applications)
- ✓ Reduced shanks (to fit larger bits into smaller chucks)

2. Tang

Definition: A flattened end provided on taper shank drills.

Function: Engages with the slot in the spindle or sleeve to prevent slipping and helps in easy removal.

3. Body

Definition: The portion of the drill extending from the shank

Function: Contains the cutting edges, flutes, and margins for cutting and guiding the drill.

4. Flutes

Definition: Helical or straight grooves cut along the body of the drill.

Function:

- ✓ Provide cutting edges at the drill point.
- ✓ Allow chips to escape from the hole.
- ✓ Permit coolant/lubricant to reach the cutting edges.

5. Point (or Drill Point)

Definition: The sharpened end of the drill that performs the cutting.

Function: Penetrates the material and removes material in the form of chips.

6. Cutting Edges (Lips)

Definition: The sharp edges formed at the intersection of the flutes and the drill point.

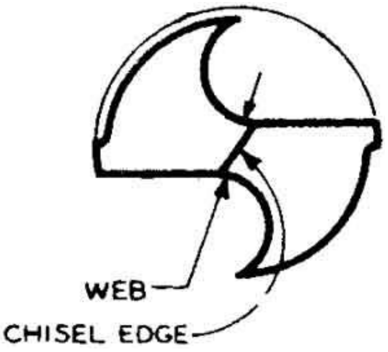
`

Function: Perform the actual cutting action of the material.

7. Chisel Edge and Web thickness

Definition: The central portion of the drill point (where the two cutting edges meet).

Function: Acts like a wedge to push material aside but does not cut efficiently—mainly responsible for thrust force.



- ✓ A **thicker web** provides greater rigidity and strength, making the drill better for tough materials and high-force applications.
- ✓ A **thinner web** reduces cutting resistance and improves chip disposal in softer materials.
- ✓ The ideal web thickness is a balance between strength and cutting efficiency, with a typical range for standard high-speed steel drills being 10-20% of the drill diameter.

8. Margin

Definition: The narrow strip running along the length of the drill body, at the outermost edge of the flutes.

Function:

Guides the drill inside the hole.

Maintains hole diameter and prevents wobbling.

9. Body Clearance

Definition: The portion of the drill body slightly reduced in diameter behind the margin.

Function: Reduces friction between drill body and workpiece hole.

`

10. Helix Angle

Definition: The angle of the flutes relative to the drill axis.

Function: Affects chip flow and cutting efficiency (higher angle → better chip removal in soft materials, lower angle → suitable for hard materials).

✓ The rear rake angle of a single point cutting tool is the same as this helix angle and most drills operate between 24° and 30°.

11. Point Angle

Definition: Angle included between the two main cutting lips at the tip.

Function: Determines cutting efficiency depending on work material:

Small point angle (60°–90°) → soft materials.

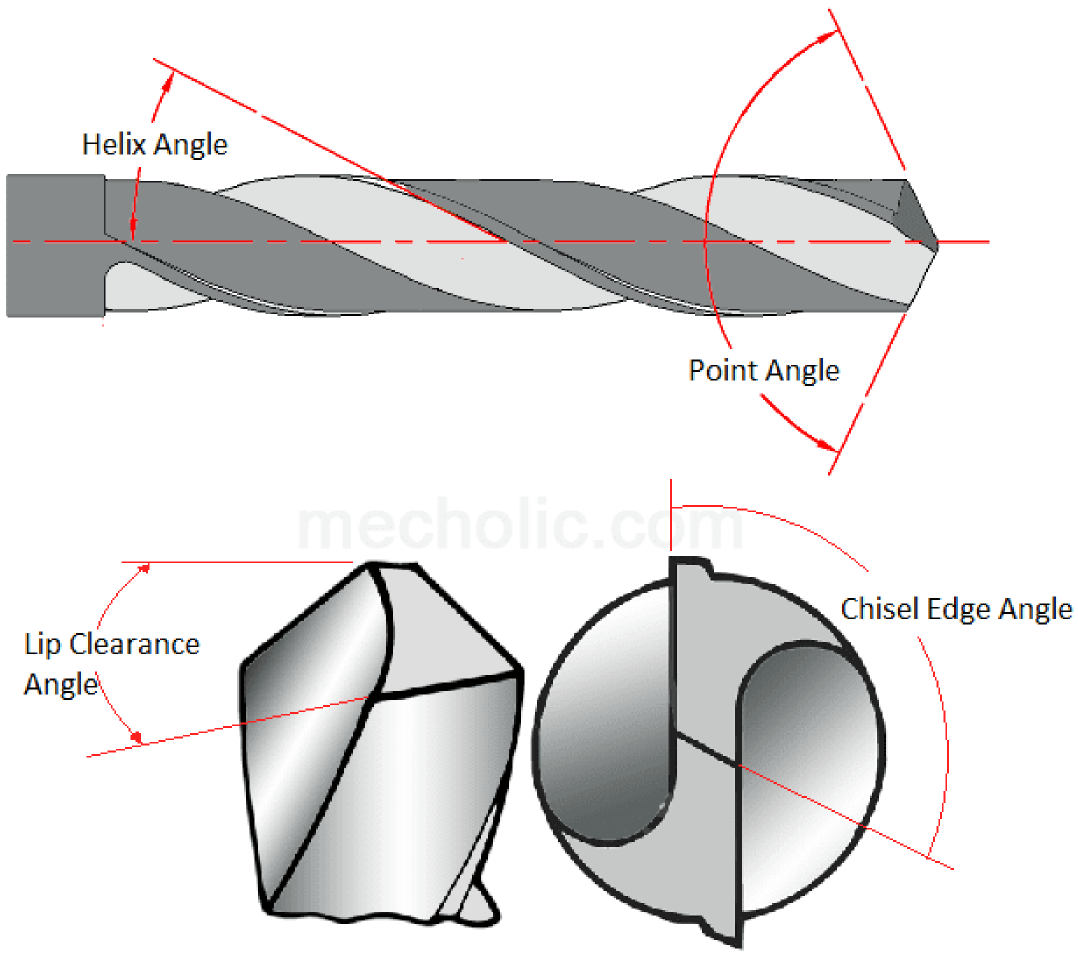
Normal point angle (118^0) →soft to medium hard steel.

Large point angle (135°) → hard materials.

12. Lip clearance Angle

Definition: Angle between the flank surface and a plane perpendicular to the drill axis.

Function: Provides clearance behind the cutting edge to avoid rubbing and reduce friction.



Materials of drill

- ✓ Although drills made of carbon tool steel have a cheap initial cost, they should only be used infrequently and at medium speeds.
- ✓ The most widely used and strong drills are made of high speed steel.
- ✓ Drills with cemented carbide tips are mostly used for drilling malleable iron castings as well as nonferrous metals and alloys including copper, brass, aluminum, magnesium, and zinc as well as plastics and hard rubber, etc. Due to the possibility of breaking from high tip pressure, these should not be used for steel components.

RADIAL DRILLING MACHINE

- ➢ Its principal use is in drilling holes on such work which is difficult to be handled frequently.
- ➢ With the use of this machine, the tool is moved to the desired position instead of moving the workpiece for drilling.

`

- This machine consists of a Base, on which is mounted a cylindrical Vertical column. A typical type of Radial Drill is shown in Fig.
- The Column carries a Radial Arm, as shown. A separate motor is provided for elevating and lowering the arm. Clamping levers are used for locking the arm at a desired height.
- Apart from this, the arm can be swung round the column to any desired angle. The Drilling Head or Spindle Head is mounted on the arm, along which it can slide horizontally.
- Different other controls for the spindle speed and feed, etc. are shown in the diagram. All the above adjustments collectively contribute towards minimizing the setting time.
- Many Radial drills are provided with a Swiveling head instead of the Fixed type. This enables drilling of holes at any desired angle.
- Also, in these machines it will not be possible to clamp the arm while the elevating mechanism is in operation. This ensures safety of one against the other.
- Some machines are fitted with an second spindle for High speed drilling. A hole depth strip mechanism is incorporated in modern Radial drills to stop the machine automatically as soon as the required depth of hole is obtained.

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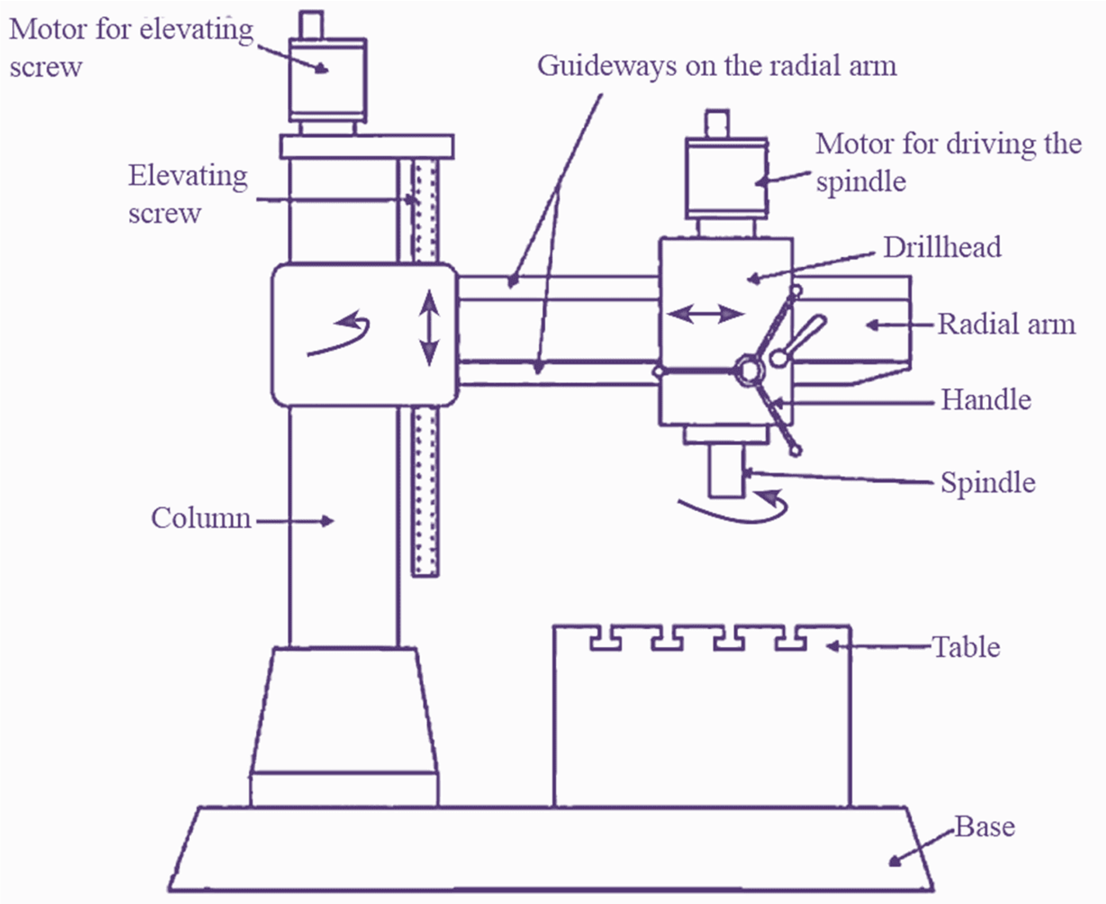

Figure: Radial Drilling Machine

- Apart from the Fixed column type of Radial drills many other forms are also used. Sometimes, these drilling machines are mounted on a Trolley base to have a greater degree of mobility in order to move the machine to any position on or around the work and drill holes at any desired angles. These machines are known as **Universal Portable Radial Drills**.

Based on the type and number of movements possible the Radial Drills can be broadly grouped as:

1. Plant Radial Drills. Three principal movements are possible in this type of machine, viz., ***Vertical movement of the Arm along the Column***, ***horizontal Sliding movement of the Drilling Head*** or Spindle Head along the Arm and ***Radial Swinging of the Arm in a horizontal plane.***

`

2. Semi-universal Radial Drills. These machines, in addition to the above three basic movements, carry provision for ***swinging of the Spindle Head about a horizontal axis*** which is normal to the arm. Thus, the Head, and hence the Spindle, can be inclined to a suitable angle enabling drilling of holes at desired inclinations.

3. Universal Radial Drills. In this machine ***the Arm itself can be rotated through a desired angle along a horizontal axis***. This is in addition to the four possible movements available on a Semi-universal Machine. This makes this machine highly versatile and facilitates drilling at any desired inclination and location.

https://youtu.be/hRTE4Rpf6Pg?si=4Y64258zex9zcFfq

Types of operations

1. **Core drilling -**

Core drilling is a **hole-making process** used to remove a cylindrical portion of material (called a *core*) from a workpiece. It is widely used in construction, mining, and manufacturing for creating precise, large-diameter holes.

Core drilling is the process of cutting or drilling a solid cylindrical specimen (core) from a material using a **hollow drill bit (core drill)** with cutting edges at its tip.

Features of Core Drilling

- Produces **accurate, large-diameter holes** (up to several hundred mm).
- Extracts a **solid core** for inspection/testing (e.g., concrete strength tests).
- Can be done in **metal, rock, or concrete**.
- Can drill **deep holes** with less power compared to solid drilling.
- Uses **coolants/lubricants** (like water) to reduce heat and dust.

Applications

- **Civil/Construction**
  - Drilling holes in reinforced concrete for pipelines, cables, anchor bolts.
  - Extracting cores for strength testing of concrete structures.
- **Mining/Geology**
  - Extracting rock samples for mineral exploration.

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Enlarging existing drilled holes.

Creating hollow components like bushes or bearings.

2. **Step drilling -**The "Step drill" or "combination drill" is an operation that involves creating a hole of two or more diameters with a single drill.

Step Drilling is a hole-making operation in which multiple diameters are produced in a single hole using a special drill bit called a **step drill**. Instead of drilling with separate drills of increasing sizes, the step drill combines them into one tool.

Applications:

- Sheet metal work (to drill holes of different diameters).
- Electrical panels and switchboards.

3. **Boring -** Boring is the process of completely completing and widening the hole using a single point cutting instrument. Although the lathe group of machine tools can also be used, boring machines are often used for this activity. By boring, the hole's location is adjusted and brought into alignment with the spindle's axis of rotation.

4. **Reaming -** Reaming, which often comes after drilling or core drilling, uses a multipoint cutting tool called a "reamer" to eliminate all coarse remnants of earlier machining processes.

`

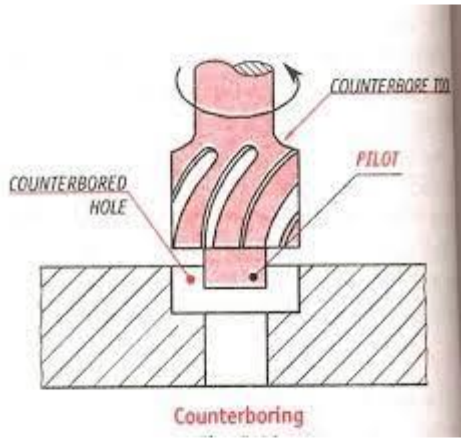
A hole that has been reamed is precise in size and has a smooth surface. Since the reamer only follows the previously drilled hole, reaming cannot change the location of the hole.

5. **Counter boring - Counter Boring** is a hole-enlarging machining operation used in manufacturing and fitting work. It involves enlarging the upper portion of a previously drilled hole to a specific diameter and depth, while keeping the bottom portion of the hole the same size as originally drilled.

Tool Used

Counterbore Tool: A multi-fluted, straight or piloted cutting tool.

It has a pilot (a smaller diameter portion) that fits into the drilled hole, ensuring concentricity.



Applications

- Machine parts where bolts/screws must not project.
- Automobile, aerospace, and assembly industries.
- Fitting precision parts with socket head screws.

6. **Countersunk -** is carried out after a hole has been drilled in order to chamfer the entry or to create a conical recess or seat for a screw or rivet so that the heads are flush or below the main surface. Standard countersinks have an incorporated angle of 60, 82, or 90°.

`

7. **Spot facing -**

Spot facing is a machining operation performed to produce a **flat, smooth, and accurately located surface around a hole**. This is usually done on castings or rough surfaces where a **bolt head, nut, or washer** is to be seated properly.

Key Points:

Purpose:

- ➢ To provide a true and even bearing surface for nuts, bolt heads, or washers.
- ➢ To remove rough, uneven, or inclined surfaces around a drilled hole.

Tool Used:

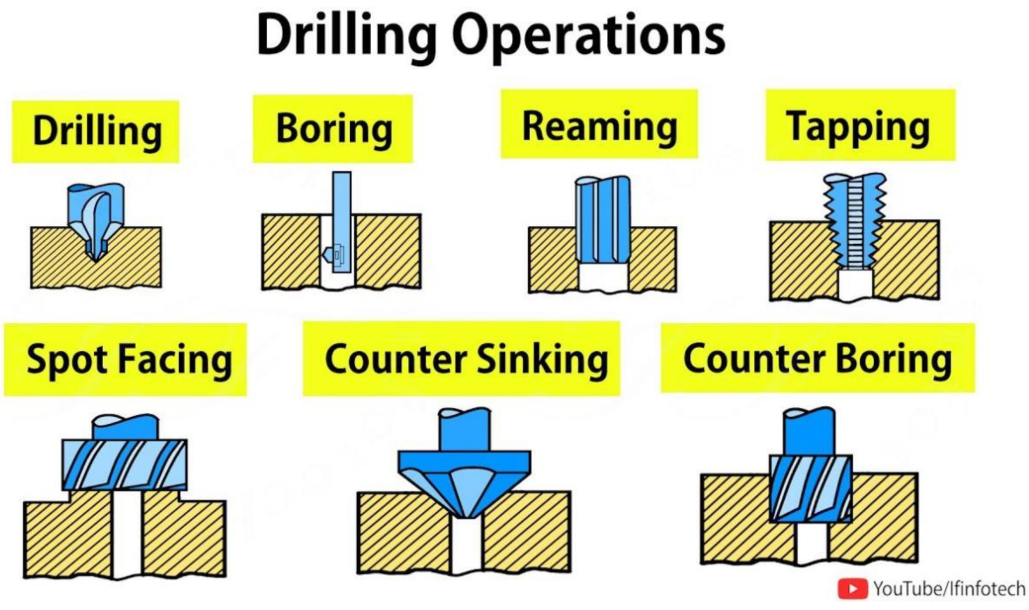
Spot facing cutter (similar to a counterbore tool but with flat cutting lips).

Operation:

- ➢ Performed after drilling the hole.
- ➢ Cutter is aligned with the hole axis and removes a small amount of material around the hole mouth.
- ➢ Depth is usually shallow — just enough to create a flat seating surface.

Applications:

- ➢ In machine components where bolt tightening is required.
- ➢ Wherever an accurate seating surface is necessary.



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SPECIFICATIONS OF A DRILLING MACHINE

1. General Information

- **Type of drilling machine**: (Bench, Pillar, Radial, Sensitive, Gang, CNC, etc.)
- **Model / Make**: (if applicable)

2. Capacity Specifications

- **Maximum drilling diameter** (in steel/cast iron) → e.g., 25 mm
- **Spindle taper** (e.g., MT 2, MT 3)
- **Spindle travel (stroke)** → e.g., 125 mm
- **Drilling head travel** (for radial types)

3. Spindle Details

- **Spindle speed range** → e.g., 80 – 2500 RPM (number of speed steps)
- **Spindle feed range** → e.g., 0.05 – 0.3 mm/rev
- **Spindle nose taper**

4. Table Specifications

- **Table size (working surface)** → e.g., 300 × 300 mm
- **Table travel (vertical / horizontal)**
- **Table tilting / swiveling range**

5. Drive & Power

- **Motor power** → e.g., 1.5 kW (2 HP)
- **Type of drive** → Belt drive / Gear drive

6. Dimensions & Weight

- **Overall height** → e.g., 1650 mm
- **Floor space required** → e.g., 800 × 600 mm
- **Net weight** → e.g., 300 kg

7. Special Features (if any)

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- Auto feed / manual feed
- Coolant system provision
- Guarding and safety features
- Digital depth readout or DRO (for advanced/CNC types)

TYPES OF DRILLS

Flat Drill

A **flat drill** (also called **spade drill** or **flat bit**) is one of the simplest forms of cutting tools used for drilling. It has a flat cutting portion with a sharp edge and is used mainly for drilling relatively shallow holes in softer materials.

Features of Flat Drill:

- **Shape**: Flat, paddle-like blade with a cutting edge at the end.
- **Cutting Edge**: Ground at an angle to provide clearance and cutting action.
- **Point Angle**: Usually around 90° to 120°, depending on the application.

Uses:

- Suitable for **wood, plastics, and soft metals**.
- Often used in carpentry for boring larger diameter holes.

Advantages:

- Simple design and low cost.
- Easy to manufacture and resharpen.

`

Limitations:

- Poor accuracy compared to twist drills.
- Cannot drill deep holes efficiently (poor chip removal).
- Produces rough hole surface finish.

Straight Fluted Drill

A **Straight Fluted Drill** is a type of drill bit where the flutes (grooves along the body of the drill) run **parallel to the drill axis** instead of being helical. **Point angle:** Usually ranges between **90°–120°**, depending on the material.

Functions / Applications:

Drilling soft materials – such as brass, copper, plastics, and some composite materials.

In these materials, helical flutes tend to "dig in" or cause the drill to pull into the workpiece aggressively. Straight flutes prevent this.

Short-hole drilling – since chip evacuation is less effective than in helical flutes.

Advantages:

- Prevents "self-feeding" in soft, ductile materials (like brass).
- Produces a more accurate hole in short-depth drilling.
- Simpler design and easier to grind.

Limitations:

- Poor chip removal compared to twist drills → unsuitable for deep holes.

`

- Generates more heat if used on hard materials.

TWIST DRILL

A **twist drill** is the most common type of cutting tool used for producing round holes in solid materials like metal, wood, and plastic. It is called a *twist drill* because of the **helical flutes** running along its body.

Main Features of a Twist Drill:

- **Shank** – The part held in the drilling machine (straight shank or taper shank).
- **Body** – The main cutting part with spiral flutes.
- **Flutes** – Helical grooves that help in:

- Cutting edge formation,
- Chip removal,
- Coolant passage.

- **Point/Tip** – The end of the drill where cutting starts, usually at a **118° point angle** (general purpose).
- **Lips/Cutting Edges** – Two sharp edges formed at the tip for cutting material.
- **Chisel Edge** – The edge at the center that does not cut efficiently but helps in guiding the drill.
- **Margin/Land** – Narrow strip along the outer edge that guides the drill inside the hole.

Materials:

- High Speed Steel (HSS) – Common for general drilling.
- Carbide tipped – For hard materials.

Common Sizes:

- Diameters: 0.25 mm to 80 mm (standard ranges).

Advantages:

- Versatile and inexpensive.

`

- Can produce accurate holes with good surface finish.
- Available in a wide range of sizes.

Applications:

- Used in **drilling machines, lathes and hand drills**.
- Suitable for drilling steel, cast iron, non-ferrous metals.

DOUBLE FLUTED DRILL

A **Double Fluted Drill** is the most commonly used type of twist drill, designed with **two helical grooves (flutes)** running along its body.

Applications:

- General-purpose drilling in metals, wood, and plastics.
- Most widely used in **hand drills, drilling machines, lathes, and CNC machines**.
- Suitable for producing round, straight holes in a wide range of materials.

Compared to single-flute drills or multi-flute drills, the **double fluted drill offers the best balance of cutting efficiency and chip removal**.

MULTI-FLUTED DRILL

A **Multi-Fluted Drill** is a type of cutting tool used for drilling operations that has **more than the conventional two flutes** (commonly 3, 4, or even 6 flutes). It is designed to improve cutting efficiency, hole quality, and tool life in specific applications.

`

Applications:

- Used in **deep hole drilling.**
- **High precision hole making** where surface finish and accuracy are important.
- Common in **aerospace, automotive, and die/mould industries**.
- Suitable for **harder materials** where two-flute drills might wear quickly.

CENTRE DRILL

It is sometimes referred to as a combination drill. It has a cutting edge on both of its ends, and its midsection is plain. With this drill, countersinking and drilling may be done concurrently. It is used to drill the centre of a rod during turning operation.

A **Centre Drill** is a special type of cutting tool used in machining operations, mainly for producing a small, precise starting hole at the end of a workpiece. This hole guides larger drills and also provides a seat for the lathe **live center** or **dead center** when turning.

COUNTER SINKING DRILL

A **Countersinking Drill** (or simply *countersink*) is a cutting tool used to create a conical-shaped enlargement at the top of a drilled hole. This operation allows the head of a screw, bolt, or rivet (especially flat-head or countersunk types) to sit flush with or below the surface of the workpiece.

This drill has four flutes and is multi-fluted. At 60° or 82°, the cutting point is ground.

COUNTER BORING DRILL

A **Counter boring drill (Counter bore)** is a **special cutting tool** used in machining operations to enlarge the upper portion of an existing drilled hole, creating a **flat-bottom recess**. This allows the head of a bolt, screw, or fastener (such as socket head cap screws) to sit flush with or below the surface of the workpiece.

One interesting difference between counter boring and countersinking is that with counter boring, the hole is drilled deeper and larger.

Guiding Pilot: Often provided with a **pilot (guide)** at the end to fit the pre-drilled hole and maintain concentricity.

Applications

- To seat **bolt heads, nuts, and screws** flush with the surface.
- Used in **automobile, aerospace, and mechanical assemblies** where smooth surfaces are required.

OIL HOLE OR TUBE DRILL

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An **Oil Hole Drill (or Tube Drill)** is a **special type of twist drill** designed with one or two internal holes running through its body to allow the continuous flow of cutting fluid (oil or coolant) directly to the cutting edges during drilling.

Key Features:

- **Internal Coolant Holes**: Extend from the shank to the cutting lips.
- **Direct Cooling**: Supplies coolant right at the cutting zone.
- **Material**: Usually made of **HSS (High-Speed Steel)** or **Carbide**.
- **Shank Type**: Often taper shank for rigidity in deep hole drilling.

An **oil hole drill (tube drill)** is just like a normal twist drill but with **internal coolant channels**, making it ideal for **deep, accurate holes with better cooling and chip evacuation**.

<u>SPIREC DRILL</u>

These drills are extremely fine. These are used to drill very small holes in items like the spray pump nozzle.

`

These are **precision micro drills** designed for **PCB drilling, watch-making, medical instruments, electronics, and aerospace components** where **tiny holes (down to a few microns)** are required.

STEP DRILL

A **step drill (step drill bit)** is a special type of drilling tool designed to drill holes of different diameters using a single bit. Instead of having a uniform cutting edge like a conventional twist drill, a step drill has a **conical shape with stepped cutting edges**, each step corresponding to a specific hole diameter.

A **step drill bit** is mainly used in **sheet metal fabrication, electrical work (for switchboards, panels), plumbing, and HVAC ducting** where different hole sizes are needed quickly and cleanly.

MASONRY BIT

A **Masonry Bit** is a type of cutting tool specifically designed for drilling into hard, brittle construction materials such as **brick, stone, concrete, and masonry blocks**.

`

Material: Usually made of high-speed steel (HSS) with a **tungsten carbide tip** for hardness and durability.

Applications:

- Drilling holes in **walls for plugs, anchors, and fasteners**.
- Creating passage holes for **pipes, conduits, and wiring** in construction work.
- Suitable for **bricklaying, masonry fixing, and concrete installations**.

<u>AUGER BIT</u>

A drill bit called an auger can be used to create a hole in thick, dry wood. One doesn't need to exert as much pressure since a hole may be made in the trees relatively quickly.

These have a screw tip that both drills the hole and aids in pulling out the bit to produce a tidy hole. Since several of these bits are up to 18 inches in length, they may be used on thicker wood.

<u>REAMING AND TYPES OF REAMERS</u>

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- **Reaming** is a finishing operation performed after drilling or boring to enlarge and accurately size an existing hole with a smooth surface finish.
- It removes a very small amount of material (typically **0.2–0.5 mm**) from the drilled hole.
- The tool used for reaming is called a **reamer**.

Purpose of Reaming

- To achieve **accurate hole size** within close tolerances.
- To improve **surface finish** of the hole.
- To correct **minor misalignments** or inaccuracies caused by drilling.

When viewed from either end of the reamer, the flutes of the reamer exhibit a right hand helix, which twists away from the viewer in a clockwise motion. Alternatively, when they twist in a counterclockwise manner, they have a Left hand helix.

Types of Reamers

Reamers can be classified based on **construction**, **operation**, and **application**:

A. According to Construction

Solid Reamers

- Made from a single piece of high-speed steel (HSS) or carbide.
- Strong and rigid, used for small and medium holes.

Shell Reamers

- Cutting part (shell) is separate and mounted on an arbor.
- Economical for larger hole sizes, as only the shell is replaced when worn.

Adjustable Reamers

- Blades are adjustable within a small range.
- Used when exact hole tolerance is needed or when holes vary slightly.

Expandable Reamers

- Have a screw mechanism to expand the diameter slightly.
- Useful for compensating wear or achieving precise size.

B. According to Operation

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Hand Reamers

- Have a square end for applying torque with a wrench.
- Used in manual finishing operations.
- Taper lead for easy alignment.

Machine Reamers

- Designed for use in drilling/boring machines.
- Have a short taper lead.
- Provide higher accuracy and productivity.

C. According to Application / Shape

Straight Flute Reamers

- Simple design with straight cutting edges.
- Used for reaming through holes in softer materials.

Helical (Spiral) Flute Reamers

- Flutes are helical (right-hand or left-hand).
- Provide smoother cutting, better chip removal.
- Used in harder materials and blind holes.

Taper Reamers

Used to finish tapered holes (e.g., Morse taper holes in machine spindles).

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Chucking Reamers

High precision machine reamers used in lathes, drilling, or milling machines.

Masonry Reamers

Used for enlarging or cleaning out holes in stone/concrete.

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CHAPTER 3

INTRODUCTION TO WELDING

❖ Welding is the process of permanently connecting two metallic parts together using heat and/or pressure.

❖ Welding is a fabrication process that permanently joins metals, by applying heat, pressure, or both, causing them to fuse together and form a strong bond when they cool.

❖ The parts being joined are called parent materials, the resulting connection is a weldment, and a filler material may be added to strengthen the joint.

❖ Welding is the art of joining metals and plastics by such methods which do not employ fasteners and adhesives.

Advantages and limitations of welding

Welding is becoming increasingly popular due to the following benefits:

1. Welded joints are inexpensive to produce.

2. Welded constructions are often lighter in weight.

3. Welding joints provide optimal efficiency, which other types of joints do not.

4. Additional and alternative structures can be readily added to the existing structure. A welded joint provides very rigid joint and has a great strength.

5. The welding procedure is faster than other types of joints.

6. Welding can also be used to repair cracked, worn, or defective metal parts.

Some limitations are: stress concentration, residual stresses, and numerous welding defects such as cracks, incomplete fusion, slag inclusions, and so on.

`

CLASSIFICATION OF WELDING PROCESSES

FUSION WELDING

To join metal pieces by raising their temperature to the **fusion point** so that they form a sort of pool of molten metal at the ends to be joined, and then allow the said pool to solidify at the ends to form a Weld. This is known as Fusion Welding process. If needed, supplement this pool with Filler Metal which normally has nearly the same composition as that of the parent Metals.

The following are some of the most frequent welding methods in this category:

1. Gas welding 2. Arc welding 3. Thermit fusion welding

PRESSURE WELDING (NON FUSION)

An alternative process of welding is to heat the ends of the metal pieces to be joined to **plastic state** (fusion may occur to a limited amount) and then apply some external pressure to join them and complete the weld. It is known as Pressure Welding.

Some of the most prevalent processes in this category are listed below: **1. Forge welding 2. Thermit Pressure Welding 3. Pressure Gas Welding 4. Electric Resistance Welding**

Heat for the above purpose can be obtained from many sources, such as

- Fire of a Smith's Forge:- Forge welding
- Electric arc:- Metal arc, Carbon arc, Argon arc, etc.
- Gas flame:- Oxy-acetylene, Water-gas Welding, etc.
- Gas plus Electric arc:- Atomic Hydrogen Welding.
- Electrical resistance:- Resistance welding.
- Chemical reaction:- Thermit Welding
- Energy ray:- Electron Beam and Laser Weldings.
- Mechanical Energy:- Friction and Ultrasonic Welding.

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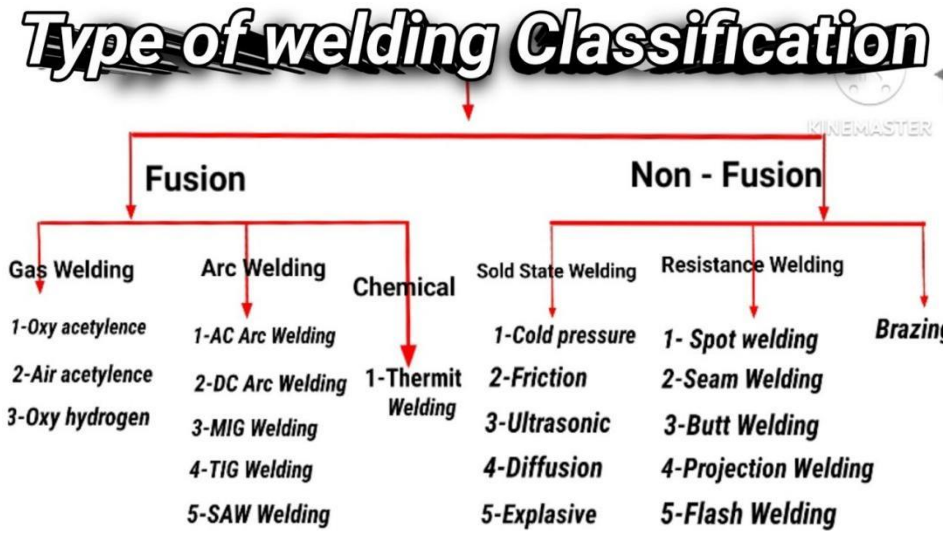
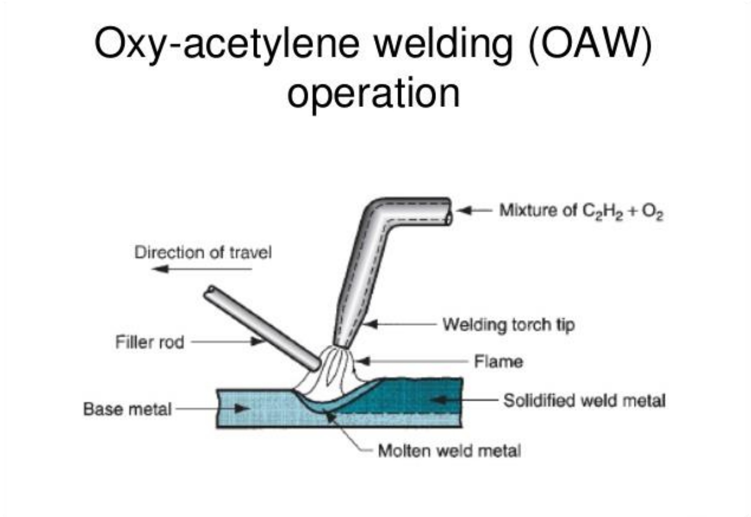


GAS WELDING

- It is a Fusion or Non-pressure welding method in which **a strong gas flame** is used to raise the temperature of the ends of the metal pieces to be joined.
- A filler metal may be added to the flowing molten metal to fill up the cavity made during the joint preparation.
- The filler rod or welding rod which provides the additional metal required is of the same or nearly same composition as that of the base metal.
- So many different combinations of gases can be used to obtain a heating flame, but the most common of these are **Oxygen and Acetylene**, oxygen and hydrogen and oxygen with coal gas, of which the first one is very extensively used.



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OXY-ACETYLENE WELDING:

- The process of Oxy-Acetylene Welding can be used for welding almost all metals and alloys used in engineering practice.

- The advantage of using Acetylene, instead of other fuels, with Oxygen is that it produces a comparatively **higher temperature** and also an **Inert gas Envelope**, consisting of carbon dioxide and water vapours, which prevents the molten metal from oxidation.

- The highest temperature that can be produced by a flame of oxygen and acetylene is nearly **3200°C**. There are two systems of Oxygen-Acetylene Welding.

(i) High Pressure System. In this method both oxygen and acetylene are derived for use from High Pressure Cylinders.

(ii) Low Pressure System. In this system oxygen is taken as usual from a high pressure cylinder but acetylene is generated by the action of water on carbide (usually calcium carbide), in a Low Pressure Acetylene Generator.

OXY-ACETYLENE WELDING EQUIPMENTS:

Cylinder:

The High Pressure Oxy-acetylene Welding and Cutting Equipment consists of two large steel strong Cylinders; one containing oxygen at high pressure (13.8MPa to 18.2MPa) and the other Dissolved Acetylene, also at high pressure.

- **Oxygen Cylinder in Black colour**

- **Acetylene cylinder in Maroon colour**

Free acetylene is highly explosive, if stored at a pressure more than 200 kPa, where it becomes very unstable and is likely to explode. Hence, acetylene needs to be carefully stored in a strong cylinder, filled with 80 to 85% porous material such as calcium silicate and then filled with acetone which can absorb upto 420 times its volume of acetylene.

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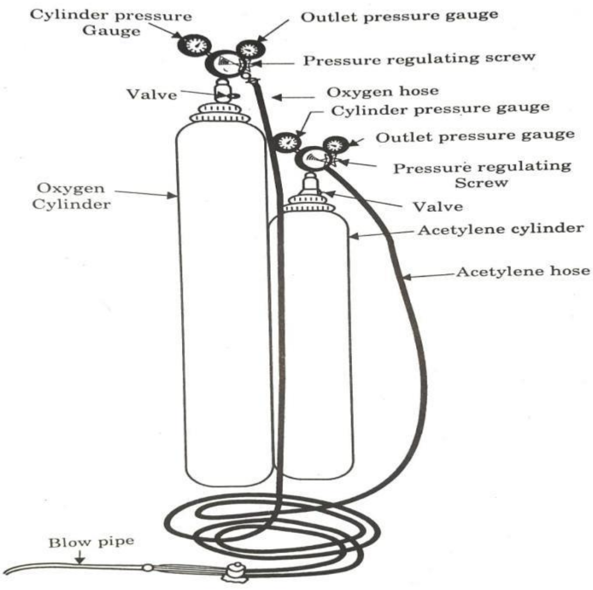


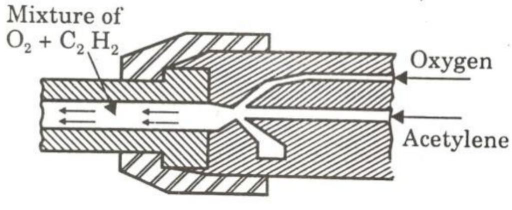
In the low pressure equipment we use oxygen as usual from a high cylinder but acetylene is drawn from a low pressure acetylene generator.

Acetylene is normally produced by a reaction between calcium carbide and water which is instantaneous as shown below:

$$CaC_2 + 2H_2O = C_2H_2 + Ca(OH)_2$$

Blowpipes Or Torches:

The High Pressure Blow Pipe, shown in Fig. consists of different passages (connected to hoses) which mix in a chamber. One of these passages is for oxygen and the other for acetylene. Both these gases are mixed in the chamber and then driven out through the Orifice of the Blowpipe Nozzle with the desired velocity. These nozzles are usually known as tips and are made interchangeable so that the same blow pipe can be used for different sizes of the tips.



Tips with smaller orifices produce Smaller Flames and those with larger size orifices Larger Flames. The former should be chosen for fine work and welding of thin sections whereas the latter for heavier work and thick sections.

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Welding rods (filler rod)

- Always the best available quality of the rods should be selected as the cheaper qualities are likely to contain more impurities and they will result in the production of an unsound Joint.
- However, it is reckoned that **a welding rod will possess the same or nearly same composition of its constituents as that of the metal which is to be welded.**

Fluxes

- Except for the common grades of mild-steel, a Flux is always necessary for successfully welding of different metals and alloys.
- **It dissolves the scale (oxide) present on the surface of the metal and forms slag.**
- Also, the **flux should be lighter in comparison to the molten metal so that the slag formed may float on the top of this metal** during the operation so as to be chipped off after this.
- **It should be stored in a dry place and should not be allowed to mix with other types of fluxes.**
- **Borax and Sodium Carbonate** are good fluxes for ferrous metals.

Other equipments

The other equipment needed in oxy-acetylene working includes

- keys for cylinder valves,
- hoses for oxygen and acetylene with connections and spanners,
- safety equipment like goggles, screens, leather hand gloves and leather apron,
- chipping hammer, wire brush and spark lighter, etc.

In addition a Trolley is needed to carry the oxygen and acetylene cylinders from one work place to the other.

Gas welding techniques

1. Leftward (Forehand) Welding Technique

- In this method, welding starts from the right-hand side and proceeds towards the left.

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Features:

- **Welding direction:** Right → Left
- **Torch position:** Inclined at about **60–70°** to the work surface
- **Filler rod position:** Held at about **30–40°** to the work
- **Used for: Thin plates (up to 5 mm thick)**

Advantages:

- Better visibility of the weld pool
- Easier control of molten metal for beginners
- Uniform heat distribution in thin sheets
- Smooth and clean weld appearance

Disadvantages:

- Less penetration compared to rightward welding
- Slower welding speed
- More gas consumption

Applications:

- Sheet metal work
- Light fabrication
- Small-diameter pipes
- Automobile body repairs

2. Rightward (Backhand) Welding Technique

- In this method, welding starts from the left-hand side and proceeds towards the right.
  The torch flame is directed toward the deposited weld metal (i.e., opposite to the direction of travel).

Features:

- **Welding direction:** Left → Right

`

- **Torch position:** Inclined at about **40–50°** to the work surface
- **Filler rod position:** Held at about **30–40°** ahead of the flame
- **Flame direction:** Toward the finished weld bead
- **Used for: Thicker plates (more than 5 mm)**

Advantages:

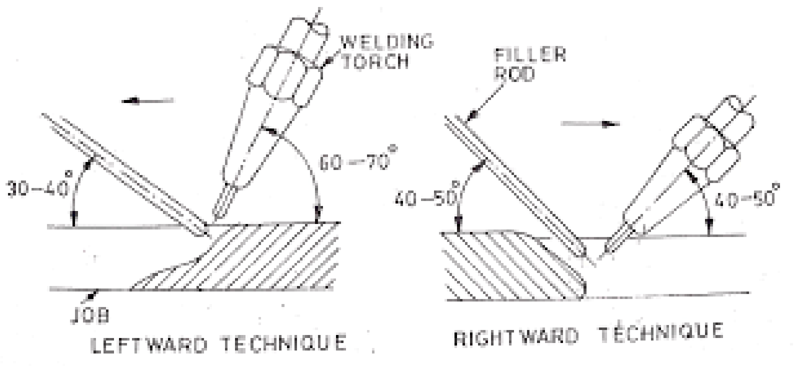
- Greater penetration and stronger weld
- Less gas consumption
- Higher welding speed
- Better fusion at the root of the joint

Disadvantages:

- Harder to observe and control the molten pool
- Not suitable for thin sheets

Applications:

- Heavy fabrication work
- Welding of thick plates and sections
- Structural and pressure vessel welding



TYPES OF FLAMES:

1. <u>Neutral flame:-</u>

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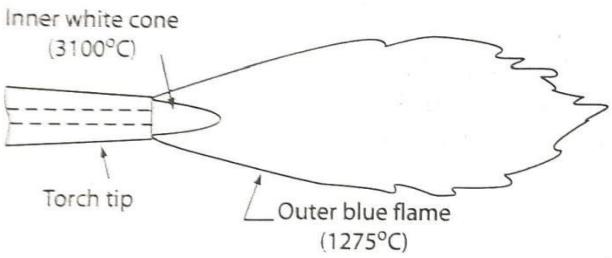
- In all the oxy-fuel gas welding processes, the combustion takes place in **two stages.** The first reaction takes place when the fuel gas such as acetylene and oxygen mixture burn releasing intense heat. This is present as **a small white cone** as shown in Fig.



Neutral flame

- For the oxy-acetylene welding, the following reaction takes place in this zone.

$C_2 H_2 + O_2 = 2CO + H_2 + 448$ kJ/mol **(first stage-inner white cone)**

- The carbon monoxide (CO) and hydrogen produced in the first stage further combine with the atmospheric oxygen and give rise to the outer bluish flame, with the following reaction.

$4CO + 2H_2 + 30_2 = 4CO_2 + 2H_2 O + 812$ kJ/mol **(second stage- outer bluish flame)**

- Though higher amount of heat is produced in the **second stage**, since it is distributed over a larger area, the temperature achieved is small (of the order of 1200 to 2000°C) in the flame, which may be used for **preheating the steels.**

- The inner white cone temperature is of the order of 3100°C, which is used for **directly melting the joint.**

- Above Figure shows the ideal condition, i.e. the complete combustion, called neutral flame. In neutral flame, all the acetylene present is completely burned and thus all the available heat in the acetylene is released. Thus, this is the most desirable flame to be used in oxy-acetylene welding.

2. <u>Carburising flame:-</u>

- When **less oxygen is provided**, part of the combustible matter is left as it is and it results in a reducing or carburising flame.

- This flame is similar to the neutral flame, only with the addition of **a third phase** in between the outer blue flame and the inner white cone as shown in Fig. It is called **'intermediate flame feather' which is reddish in colour.**

`

- **The length of the flame feather is an indication of the excess acetylene present. This excess carbon causes the steel to become extremely hard and brittle.**

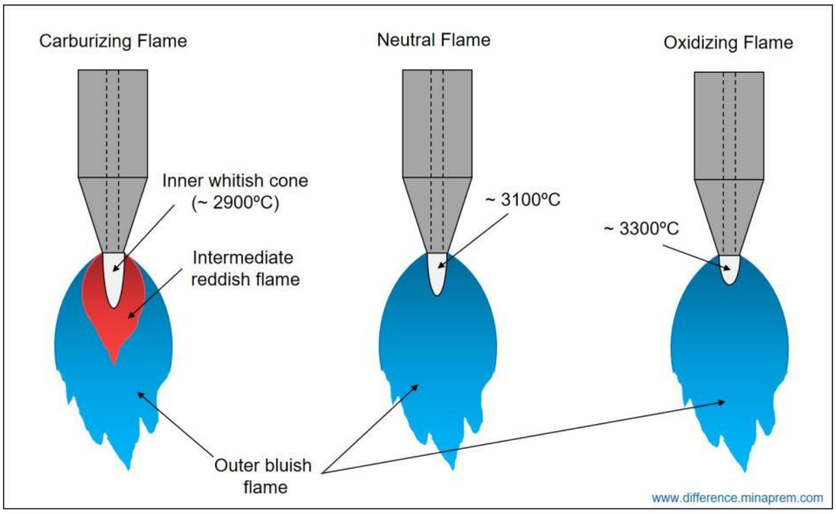
- The carburising flame is not suggested for general use. However, since this flame provides **a strong reducing atmosphere** in the welding zone, it is useful for those materials, **which are readily oxidised**, for example, oxygen-free copper alloys. It is also used for high-carbon steels, cast irons and cemented carbides.

3. Oxidising flame:-

- When **oxygen is in excess**, it is called the oxidising flame whose appearance is shown in Fig. The flame is similar to the neutral flame with the exception that the **inner white cone is somewhat small**, giving rise to higher tip temperatures (3300°C).

- There is an excess amount of oxygen present in the flame, which badly oxidises the weld metal. This flame would be useful for welding some **nonferrous alloys** such as **copper-base alloys and zinc-base alloys.**

- The presence of excess oxygen in the oxidising flame causes an oxide film to form quickly which provides a protective cover over the base metal pool.



ELECTRIC ARC WELDING

In welding, generation of heat by an electric arc is one of the most efficient methods. The electric-arc welding process makes use of the heat produced by the electric arc to fusion weld metallic pieces.

This is one of the most widely used welding process, mainly because of the ease of use and high production rates that can be achieved economically.

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Principle of Arc:

- An arc is generated between two conductors of electricity, **cathode and anode** (considering direct current, dc), **when they are touched** to establish the flow of current and then separated by a small distance.
- An arc is a **sustained electric discharge** through the **ionised gas column** between the two electrodes.
- Electrons liberated from the **cathode (-ve) move towards the anode (+ve)** and are accelerated in their movement. When these electrons strike the anode at high velocity, a large amount of heat is generated.
- Also, when the electrons are moving through the air gap between the electrodes, they collide with the **ions (+ve charge particles)** in the ionised gas column between the electrodes. Also the positively charged ions, **moving from the anode** and would be impinging on the cathode, thus ‘liberating heat.
- About 65 to 75% of the total heat is liberated at the anode by the striking electrons. A temperature of the order of 6000°C is generated at the anode.
- In case of A.C welding, **cathode and anode would change continuously.** As a result, the temperature across the arc would be more uniform, compared to a dc arc.

Advantages of arc welding

The advantages of Arc welding mainly include the following.

- Arc welding offers a high welding efficiency and speed.
- It comes with a basic welding setup.
- Arc welding creates a physically strong link between the welded metals.
- It ensures consistent welding quality.
- This welding's power source is not expensive.
- This welding method is quick and consistent.
- The welder can work with standard household current.

Disadvantages of arc welding

The disadvantages of Arc welding include the following.

i. Arc welding necessitates the use of a skilled operator.

ii. The rate of deposition may be insufficient.

`

iii. The electrode length is 35mm, and the electrode must be changed frequently.

iv. These are not suitable for reactive metals like titanium and aluminium.

Applications of arc welding

Arc Welding applications include the following:

- Used in sheet metal welding
- For welding thin, ferrous, and non-ferrous metals
- Used to design pressure and pressure vessels
- Industrial piping developments
- Used in the automobile and home furnishing industries
- Shipbuilding industries
- Aircraft and aerospace manufacturers
- Construction, automotive, mechanical, and other industries

ELECTRIC ARC WELDING

- ✓ It is a **Fusion Welding Process** in which **no mechanical pressure** is applied for joining the metals.
- ✓ In this, the metal pieces to be joined are **heated locally to the melting temperature,** by creating an Electric Arc, and then allowed **to solidify** to form the Welded Joint.
- ✓ In some cases only the metal of the pieces to be joined is made to form the joint while in the others **additional filler metal** is provided by melting a wire into the weld metal.

The Electric Arc Welding processes are divided into the following two main kinds:

1. Metallic arc welding 2. Carbon arc welding

1. METAL ARC WELDING

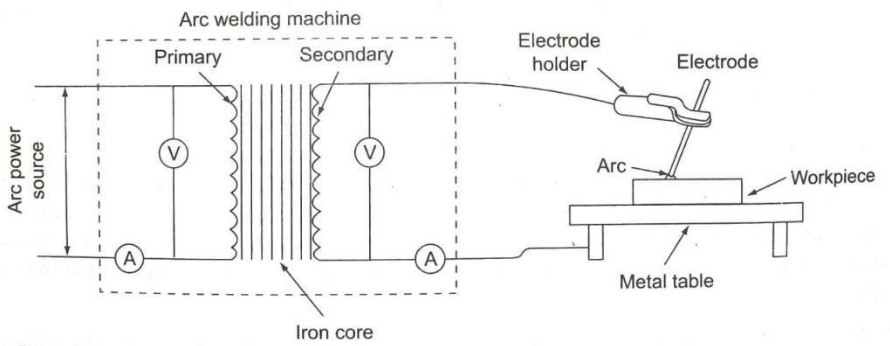
- In this process **a Metal Electrode** is used and the Arc is maintained between this electrode and the workpiece, which respectively form the two terminals.
- The electrode used can be either **bare or coated** type.
- Bare electrodes have the **same or nearly the same composition** as that of the parent metal.
- Coated electrodes may either have a **light coating** of some material, which prevents their surface from being oxidised, or may carry a **strong coating** of Flux.

`

- For **welding of-ferrous metals** the core of the electrodes is usually made of **mild steel** and the **coating** around it is made such that it acts a as **a flux** as well as **provides the necessary constituents to the weld metal.**

SHIELDED METAL ARC WELDING/MANUAL METAL ARC WELDING

- The Principle of Shielded Metal Arc Welding consists of establishing an Electric Arc between **a metal electrode and the workpiece** to be welded.
- The metal of the workpiece to be joined is called **Base Metal or Parent Metal.**
- The manual metal arc welding (MMAW) also called the Shielded Metal Arc Welding **(SMAW)** is the most extensively used **manual welding process,** which is **done with stick (coated) electrodes.**
- This process is highly **versatile** and can be used extensively, for both simple as well as sophisticated jobs. Further, the equipment is **least expensive** than most of the arc-welding processes. Welds by this process can be made in any position.



- Job of any thickness can be welded by shielded metal arc welding. But very small thicknesses, **below 3 mm**, may give rise to difficulty in welding because of their lack of rigidity. Similarly, very large thicknesses, **above 20 mm**, may take a long time for filling up the joint groove.
- The shielded metal arc welding can be done with either **ac or dc power source.** The typical range of the current usage may vary from **50 to 500 A** with voltages from **20 to 40 V.**
- The main disadvantage of the shielded metal arc-welding process is the **slow speed.**
- Further, a lot of electrode material is wasted in the form of **unused end**, slag and gas. There are more chances of slag inclusions in the bead.

The essential factor in high quality hand arc welding is the selection of welding conditions, which are governed by the electrode diameter, welding current, and voltage

(a) Electrode diameter. the diameter of the electrode will depend upon **the thickness of the metal being welded** and **the type of the joint.**

`

Electrode diameter, according to the thickness of the metal to be welded, is given below:

Metal thickness, mm:	Upto 2	2 to 4	4 to 6	6 to 8	over 8
Electrode diameter, mm:	2	3	4	5	5-6

(b) Welding current. For practical reasons, the welding current is governed by the **electrode diameter (d)** chosen, as shown below:

Welding current, $\boldsymbol{I = k.\, d}$**,** amperes; d is in mm,

where k = a constant = 45 to 60 for ordinary steel electrodes

In general practice, welding is performed with currents **over 50 A.**

(c) Voltage: The arc voltage depends only upon the arc length (l)

It is given by the relation: $V = (k1 + k2\, l)$ volts,

Where l is the arc length in mm and $k1$ and $k2$ are constants,

$k1$ = 10 to 12 and

$k2$ = 2 to 3

The minimum Arc voltage is given by $Vmin = (20 + 0.04\, I)$ Volt

(d) Arc length: It is the distance between the end of the electrode and the surface of the molten metal on the work. A short arc length is required for good welding.

An arc length of 0.6 to 0.8 times the electrode diameter can be used to provide the stable arc required for high quality welding.

- **Except for pure copper, aluminium, and several low melting point and reactive metals, SMAW is applicable to practically all metals and alloys.**

ARC WELDING EQUIPMENTS:

- Both Alternating Current **(A.C)** and Direct Current **(D.C.)** are used for Arc Welding.
- When D.C. arc welding is to be employed the current is generated by a **D.C. Generator.**

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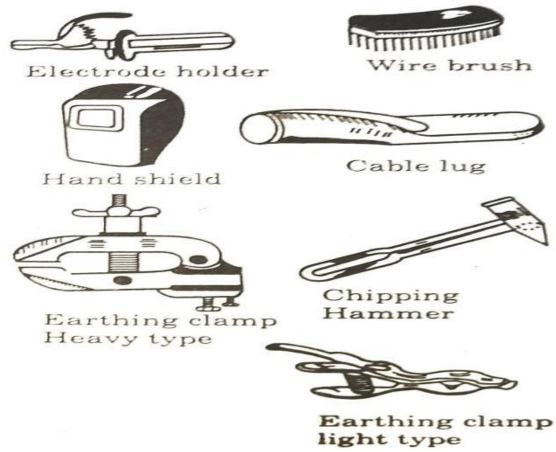
- For A.C. Arc Welding a **step down Transformer** is used which receives current from the supply mains at 400-440 Volts and transforms it to the required voltage for welding, i.e., 80-100 Volts.
- Apart from the above main equipment a number of other equipments, particularly for safety and clamping the work, holding the electrodes etc. are required as illustrated in Fig. A brief list of this equipment is given below:



List of Equipments:

1. Well insulated electrode Holders.
2. Wire cables and cable connectors.
3. Welding Helmet and Hand Screen or Shield.
4. Safety goggles.
5. Welder's Chipping Hammer.
6. Earthing Clamps.
7. Hand Gloves.
8. Aprons and Sleeves, etc.
9. Wire Brush

- we receive **A.C.** supply from power mains at 400-440 volts whereas we require a much less voltage for welding. We, therefore, use a **Step Down Transformer** which lowers the voltage to about **80-100 volts.**
- This voltage is actually required **only for striking the arc** and for **maintaining the same we require a still lower voltage, say about 30 to 40 volts.** This is accomplished by means of the **Current Regulator.**

POLARITY

- There is **no fixed polarity** at the terminals when using **A.C.** and they interchange in every cycle.

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- But in D.C. welding, the electrode acts as one terminal and the job the other terminal (either +ve or -ve).
- The potential difference can be so adjusted that the heat developed at the **positive terminal is higher, (nearly 2/3 rd)** and that on the negative terminal lower, (nearly 1/3 rd) of the total heat evolved.
- The voltage required in case of D.C. welding is **60 to 80 Volts for striking the arc and 15 to 25 Volts for maintaining the arc.**

Polarity is a very significant factor in all D.C. welding works. This polarity can be of two types:

1. **Straight Polarity (DCEN).** In this, the **electrode** forms the **negative** terminal and the **workpiece positive**.
2. **Reverse Polarity (DCEP).** In this, the **electrode** forms the **positive** terminal and the **workpiece negative**.

ELECTRODES:

1. Consumable electrodes

- With a consumable electrode, the weld metal under the arc and **the tip of the electrode, both melt**.
- The **molten metal from the electrode** and that obtained from the base metal gets intimately **mixed** under the arc and provides the necessary joint after solidification.
- So in this process, once the arc is initiated, the electrode is continuously consumed and hence, the electrode should be moved continuously towards the workpiece to maintain the constant arc length.
- They may be made of steel, cast iron, copper, brass, bronze or aluminium.

2. Non consumable electrodes

- It is also possible to use non-consumable electrodes made of **carbon, graphite or tungsten.**
- The **carbon and graphite** electrodes are used **only in dc welding**, whereas **tungsten** electrodes are used for **both ac and dc** welding.
- The filler metal required has to be deposited through **a separate filler rod**.

A consumable electrode, used in welding, can be either **bare or coated**. The coated electrode also called **stick electrode**, is used for the manual-arc-welding process.

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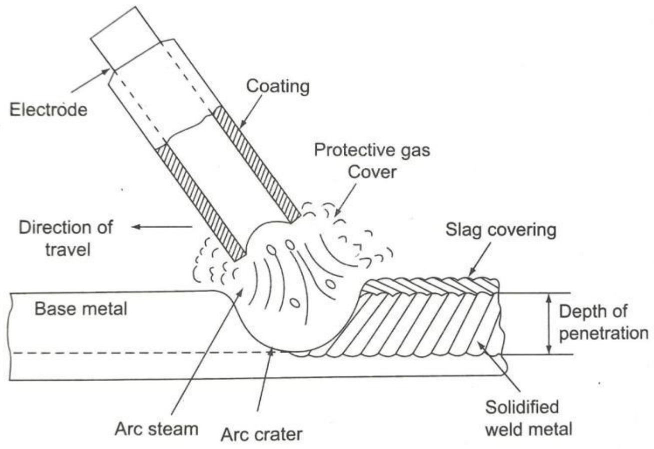

The coatings on the electrodes serve a number of purposes which are detailed as follows:

1. The coatings give off **inert gases** such as **carbon dioxide** under the arc heat, which **shields the molten metal pool** and protects it from the atmospheric oxygen, hydrogen, and nitrogen, thus **reducing contamination** of the weld metal.
2. The coatings **provide flux** to the molten metal pool, which mixed with the oxides and other **impurities** present in the puddle, **forms a slag.** The slag being **lighter,** floats on the top of the pool and **protects** it against the surrounding air during the weld bead solidification. The slag covering also helps the metal to **cool slowly**.
3. Some elements that are required for **stabilisation of the arc** are also added in these coatings.
4. Special **alloying elements** can be introduced through these coatings to improve the strength and physical properties of the weld metal.
5. The coatings are normally **insulators of electricity** and thus, permit the electrode to be used in narrow grooves and other difficult locations without causing any short circuits.

<u>Electrode Holder:</u>

The electrode holder is the piece of equipment used to keep the electrode **at a proper angle.**

<u>Leads or Cables:</u>

The electric current is carried by the cables from the welding machine to the work-piece. The cables used in the welding process are flexible and constructed of copper or aluminium.

<u>Lugs or Cable Connectors:</u>

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The cable connections are used to connect machine switches to the welding electrode holder. Mechanical connectors are commonly utilised because they are easily assembled and disassembled. The cable connectors used in welding procedures are developed based on the current rating of the cable.

SUBMERGED ARC WELDING

Submerged Arc Welding (SAW) is an **automatic or semi-automatic arc welding process** in which the arc is struck **beneath a blanket of granular flux**. The flux completely covers the arc and molten metal, preventing spatter and oxidation.

An electric arc is formed between a **continuously fed bare wire electrode** and the **workpiece**. The heat of the arc melts the base metal and electrode, forming a molten weld pool. The **granular flux** covers the arc zone, melts partially, and forms a protective **slag layer** that solidifies over the weld bead.

Equipment Used:

- **Power Source** – DC or AC supply
- **Electrode Wire** – Bare metal wire (1.6 mm to 6.4 mm diameter)
- **Flux Hopper** – Feeds flux over the weld zone
- **Wire Feed Unit** – Feeds wire at a controlled rate
- **Travel Mechanism** – Moves torch along the joint
- **Workpiece and Fixtures**

How it works:

- An electric arc is generated between a consumable wire electrode and the workpiece.
- A continuous supply of granular flux is fed to the weld area, covering the arc and molten metal completely.
- The flux melts, forming a protective gas shield and a slag layer, which also adds alloying elements to the weld pool and insulates the molten metal.
- The unfused flux is collected and can be reused.

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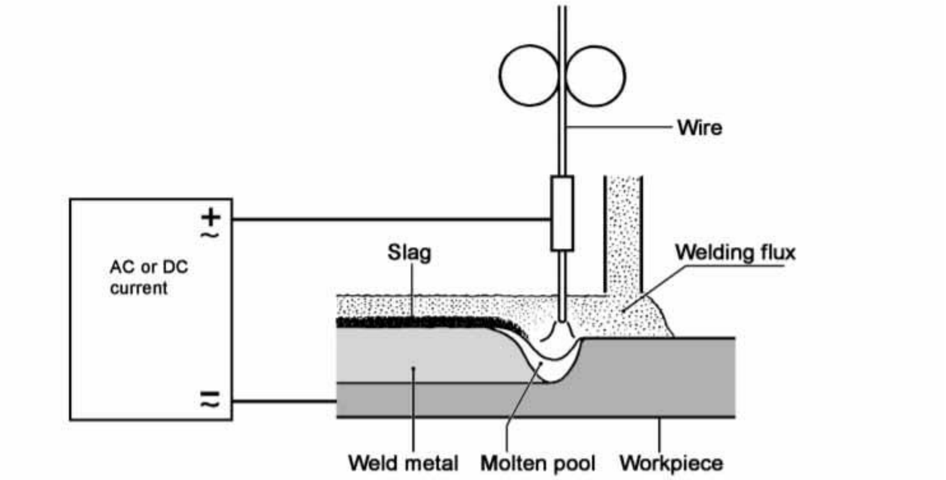
- The arc is "submerged" beneath the flux, making it invisible and suppressing sparks and ultraviolet radiation.

Advantages:

- Deep weld penetration and high deposition rate
- Smooth, uniform weld bead
- No arc glare or spatter (arc covered by flux)
- Suitable for long welds and thick sections
- Excellent weld quality
- Automation

Disadvantages:

- Limited to **flat and horizontal positions**
- Not suitable for **thin sheets (< 5 mm)**
- **Flux handling and recovery** required
- Equipment is **bulky** and less portable
- The lack of a visible arc



Applications:

- Since the **granular flux must cover the joint** to be welded, this method is **restricted** for making straight welds in the flat position.

- Thus it is suitable for steel line pipes, boiler pressure vessels, railroad tank cars, structural shapes and cylinders etc. and also for circular welds if the workpiece is rotated under the welding head.

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- Submerged arc welding can be used to weld low C- steels, high strength low alloy steels, chromium steels.

INERT GAS TUNGSTEN ARC WELDING (TIG)

- It is basically an Arc welding process in which the arc is struck between a **non-consumable tungsten electrode** and the base metal.
- The electrode is held in a special type of Electrode-holder which is so designed that apart from holding the electrode, it also carries a passage around the electrode for **flow of Inert gas (argon or helium)** to provide the protective shield around the arc.
- This **gaseous shield** protects the electrode, molten metal, the arc and adjacent heated areas of base metal from atmospheric contamination.
- The Electrode Holder also carries a provision for **water cooling or air cooling.** This process can be adopted for both manual and automatic operations.
- This process is capable of producing **continuous, intermittent or spot welds.**
- **Additional filler metal** can be provided from outside by fusing a **filler rod.**
- This process is suitable for welding in all positions.
- Thin Metal Foils upto a **minimum thickness of 0.125 mm** can be easily welded with this process.
- It is suitable for welding of **most metals and alloys** except lead and zinc, which have very low melting points.
- Its specific applications include welding of **Al-alloys, Mg-alloys, Nickel alloys, Zirconium alloys, Titanium alloys, Beryllium alloys, Refractory metals, Carbon steels, alloy steels and Stainless steels.**

TIG Welding Equipment:

The following equipment is required in TIG Welding

1. An inert gas cylinder. (Ar/He)
2. An inert gas regulator and flowmeter.
3. Inert gas hoses and hose connections.
4. An arc welding machine
5. Welding cables for electrode and ground connections.

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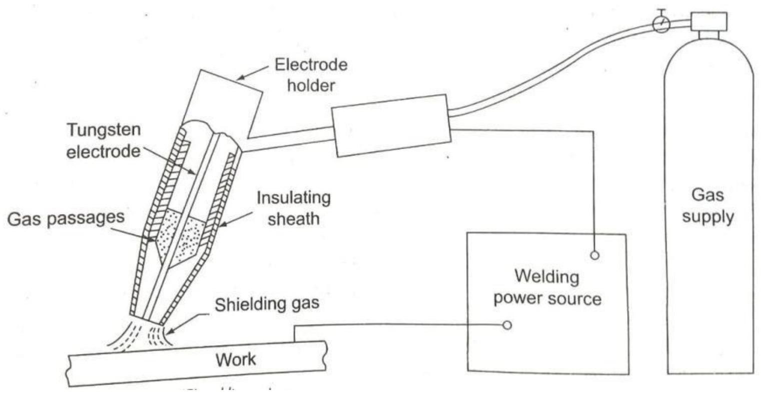
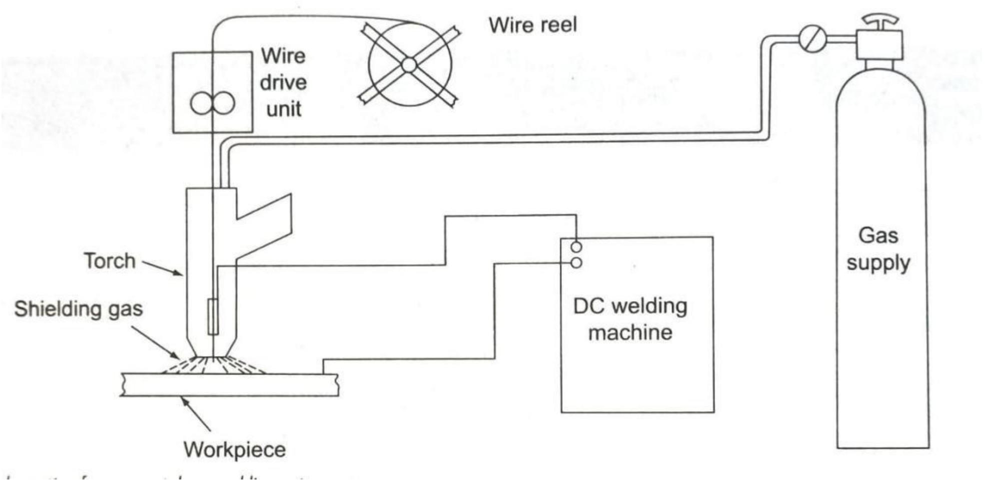
6. Electrode holder (water cooled or air cooled).
7. Non-consumable Tungsten Electrode.



- **Both A.C. and D.C**. are used in TIG Welding.
- The electrode should be held at an angle of **60° to 80°** with the workpiece and the filler metal (if used) at **15° to 20°** with the workpiece.
- The inert gas flow should be continued till the electrode cools down.

INERT GAS METAL-ARC WELDING (MIG WELDING)

- The arc is struck between a **consumable metal electrode** and the workpiece.
- The electrode is in the form of **a continuous wire** which is fed into the arc, by an **Adjustable Speed Electric Motor**, at the same speed at which it is melted and deposited in the weld.
- A **specially designed Electrode Holder** is used to supply of Inert Gas for shielding and for supply of cooling water.
- A schematic diagram of MIG Welding Torch is shown in Fig.



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- This method can be employed for welding **carbon steels, low alloy steels, stainless steels, aluminium and al-alloys, heat resisting alloys, magnesium alloys, copper and Cu-alloys, cast iron, titanium and its alloys, refractory metals, manganese bronze also.**
- It is not suitable for welding of low melting point metals.
- Economically welded metal thicknesses with this method range from **0.5 mm to 12.5 mm.**

The main equipment needed in this process is as follows :

- An Inert gas cylinder.
- Gas regulator and Flowmeter.
- Gas hoses and connections.
- MIG welding gun.
- A spool of electrode wire.
- Electrode wire feeder.
- Water supply with water hoses.

- Usually, **D.C. with Reverse Polarity** is used in MIG Welding. **A.C. is not used** in this method. Even D.C. with Straight Polarity is not often used.
- In MIG Welding, inert gases like argon, helium, carbon-dioxide or a mixture of these gases are used for providing the inert gas shield.

Advantages of MIG Welding:

1. It is faster
2. There is no slag formation.
3. It provides higher deposition rate.
4. Deeper penetration is possible.
5. More suitable for welding of thick sheets.
6. Welds produced are of better quality.

Disadvantages:

1. Equipment used is costlier and less portable.

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2. It is less adaptable for welding in difficult to reach portions.

DIFFERENCES BETWEEN TIG AND MIG

Feature	TIG Welding	MIG Welding
Full Form	Tungsten Inert Gas	Metal Inert Gas
Electrode	Non-consumable tungsten electrode	Consumable wire electrode
Shielding Gas	Usually argon or helium	Usually argon or argon-CO_2 mixture
Filler Material	Optional (manual rod can be added)	Automatically fed wire acts as filler
Material Thickness	Best for thin materials	Suitable for both thin and thick materials
Weld Quality	High-quality, precise, clean welds	Faster but slightly lower precision; more spatter
Speed	Slower process	Faster process
Skill Level	Requires high skill	Easier to learn
Applications	Aerospace, automotive, stainless steel, aluminum, precision jobs	General fabrication, automotive repair, construction, structural steel
Cost	Usually higher due to slower speed and equipment	Lower for large-scale production due to speed
Appearance	Very clean, neat, visually appealing weld	May need post-cleaning; spatter can occur

- **TIG** :- Precision, high-quality, controlled, slower, skilled labor.
- **MIG** :- Fast, easier, suitable for production, may have more cleanup.

RESISTANCE WELDING

✧ It is the process of joining metal pieces together by raising the temperature of the pieces to fusion point and **applying a mechanical pressure** to join them.

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- In this, the pieces to be joined are held together and a strong Electric Current (A.C.) of **high amperage and low voltage** is passed through them.

- This current comes across a certain resistance in passing from one piece to the other and it is this resistance offered to the flow of current which results in raising the temperature of the two pieces. The mechanical pressure applied at this moment completes the weld.

(In resistance welding, a low voltage **(1 volt)** and very high current **(15000A)** is passed through the joint for a very short period of time.)

The heat generated in resistance welding can be expressed as $H = k I^2 R t$

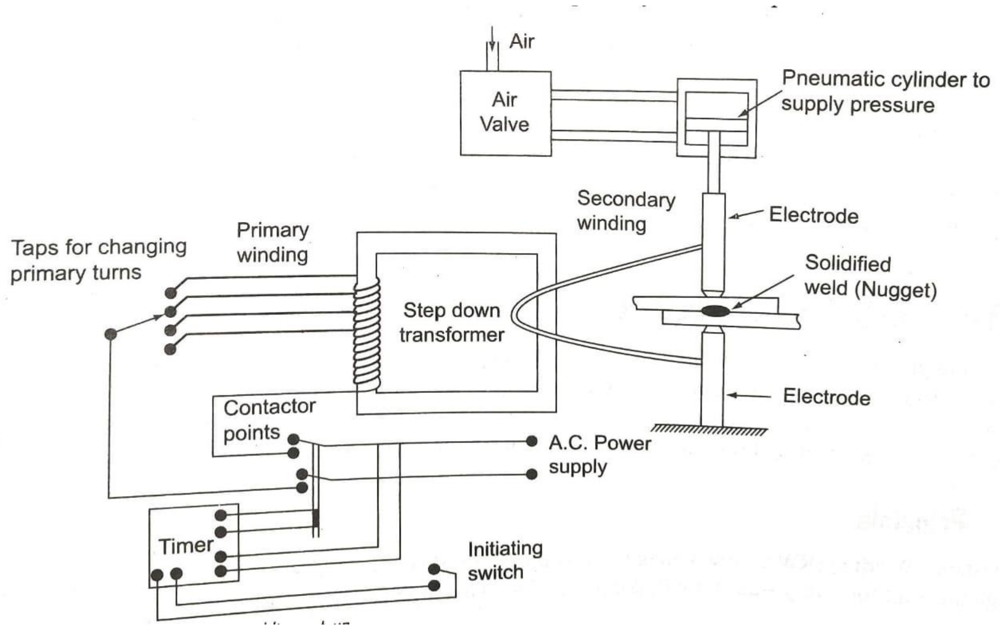
Where H =Total heat generated in the work,

I = Electric current, A

t = Time for which the electric current is passing through the joint, s

R= Resistance of the joint, ohms, and

k = Constant to account for the heat losses from the welded joint.



RESISTANCE SPOT WELDING

- It is the simplest and probably the most commonly used method of making Lap Welds in thin sheets (upto a maximum thickness of 12.7 mm) using the principle of Resistance Welding.

- It owes its popularity to the fact that it can quite suitably replace riveting in sheet metal products.

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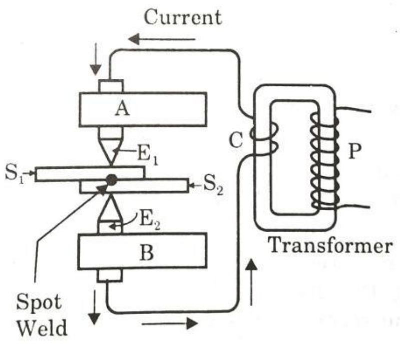
- ❖ The Principle of Spot Welding is illustrated in Fig.where a Transformer Core is shown having primary and secondary windings P and C respectively. One end of the secondary windings is connected to the upper Electrode E_1 carried in the movable copper or bronze arm A and the other end to the lower Electrode E_2 mounted on the fixed arm B.



In operation, the metal sheets S_1 and S_2 are held and pressed between the electrodes and a strong current at low voltage is switched on.

Due to the resistance offered by the sheet metal to the flow of this current the temperature at the contact surfaces rises to fusion point and the weld is completed under the Contact pressure of the Electrodes.

SPOT WELDING ELECTRODES

Functions:

1. They conduct the electric current to the workpieces.

2. They hold the workpieces together and transmit the required amount of force to the work area to complete the weld.

3. They have to dissipate heat from the weld zone as quickly as possible.

Properties:

- They should be good conductors of heat and electricity.
- They should possess high mechanical strength and hardness.
- They should not have a tendency of alloying with the metal of the workpieces.

Electrode Materials:

- ➢ Copper-base Alloys, Cu-tungsten mixture, pure tungsten, pure molybdenum, etc

<u>RESISTANCE SEAM WELDING</u>

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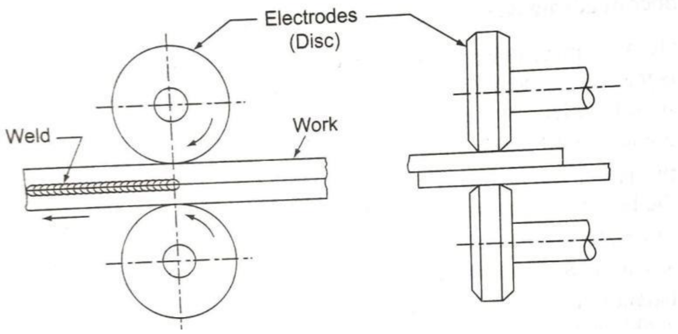
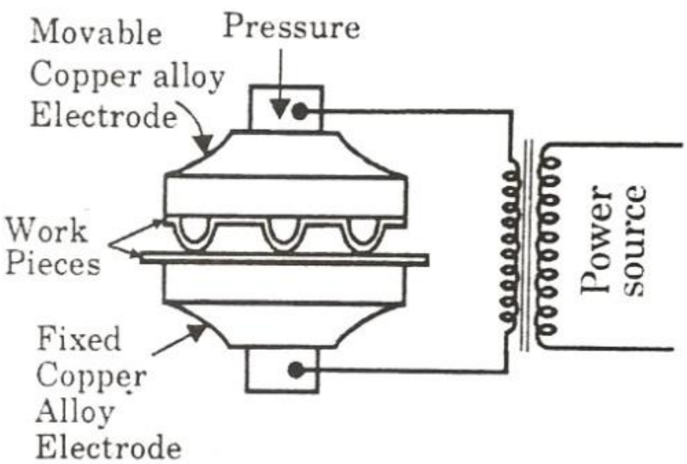
- In principle it is very similar to Spot Welding except that in this process the Spot Welding Tips are replaced by **continuously rotating Wheel** Type Electrodes. With the result, the weld produced is continuous instead of being intermittent.
- A continuous series of spot welds produced by passing the workpieces between the revolving electrodes.
- The metal between the electrodes gets heated to welding heat and welded continuously under the constant pressure of rotating electrodes as it passes between them.
- This is a quicker operation than spot welding and gives a stronger joint than that.



RESISTANCE PROJECTION WELDING

- This process is similar to Spot Welding, but differs from the latter in that the spots at which welding takes place are previously located by providing **projections at the desired locations** on the surface of one of the work-pieces, as shown in Fig.



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- Thus, the surfaces of the workpieces are in contact with each other only at the projections. As current is switched on the projections are melted and the workpieces pressed together to complete the weld.
- This method enables production of several spot welds simultaneously. However, this process is economical **only for large-scale production**.

WELDING DEFECTS

Welding defects are imperfections or irregularities in a welded joint that reduce its strength, appearance, or performance. These defects can occur due to **improper welding techniques, faulty equipment, or any incorrect parameters**.

Types of Welding Defects:

1. Porosity: Presence of gas pockets or voids inside the weld metal.

Causes:

- Moisture or oil on base metal or electrode
- Excessive welding speed
- Contaminated shielding gas

2. Slag Inclusion: Entrapment of non-metallic slag particles in the weld metal.

Causes:

- Improper cleaning between passes
- Low welding current
- Incorrect electrode angle

3. Incomplete Penetration: Weld metal does not extend through the joint thickness.

Causes:

- Low current
- Incorrect joint preparation
- Improper root gap

4. Lack of Fusion: Weld metal fails to fuse completely with base metal or previous pass.

Causes:

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- ❖ Low heat input
- ❖ Wrong electrode angle or speed
- ❖ Oxidized surfaces

5. Undercut: Groove formed at the weld toe reducing cross-sectional area.

Causes:

- ❖ High current or travel speed
- ❖ Wrong electrode manipulation

6. Overlap: Excess weld metal flows onto the surface without fusing.

Causes:

- ❖ Low travel speed
- ❖ Excessive current

7. Cracks: Fractures in weld or base metal.

Types

Hot cracks – occur during solidification

Cold cracks – occur after cooling

Causes:

- ❖ High residual stress
- ❖ Rapid cooling
- ❖ Improper electrode or material
- ❖ Use proper welding sequence and filler

8. Spatter: Small metal droplets sticking around the weld area.

Causes:

- ❖ High current
- ❖ Wrong polarity or arc length

9. Distortion: Warping or change in shape due to uneven heating and cooling.

Causes:

- ❖ Excessive heat input
- ❖ Poor clamping or restraint

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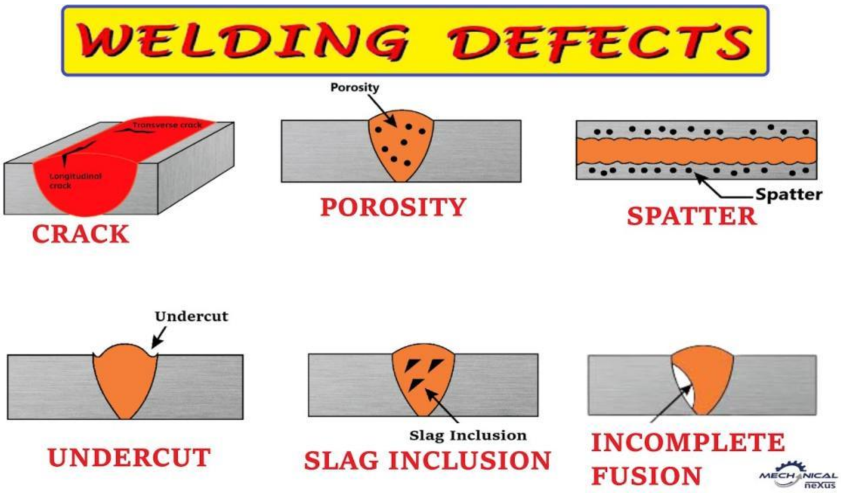

BRAZING AND SOLDERING

Brazing and soldering are metal-joining processes that create a permanent bond by melting a filler metal into a joint, without melting the base materials. They are distinguished primarily by the melting temperature of the filler material.

Brazing

Brazing uses a filler metal that melts at a temperature above 450°C (840°F) but below the melting point of the base metals being joined.

Principles

- ➢ **Capillary action:** The molten filler metal is drawn into the narrow gap of the joint by capillary action, creating a strong, sealed bond.
- ➢ **Minimal distortion:** Because the base metals do not melt, there is minimal thermal distortion or residual stress, preserving their metallurgical properties.
- ➢ **Flux:** A flux is used to remove surface oxides from the base metals, prevent oxidation during heating, and promote the wetting and flow of the filler metal.

Types of brazing

- ❖ **Torch brazing:** A common manual method that uses a gas torch to heat the joint.
- ❖ **Furnace brazing:** A mass-production process where assemblies with pre-placed filler metal and flux are heated in a furnace with a controlled atmosphere.
- ❖ **Induction brazing:** Uses a high-frequency alternating current and induction coils to quickly and precisely heat the joint area.
- ❖ **Vacuum brazing:** Performed in a vacuum furnace, this method is used for high-integrity joints and eliminates the need for flux.
- ❖ **Dip brazing:** The parts to be joined are dipped into a bath of molten flux, which serves as both the heat source and fluxing agent.

Applications

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- **HVAC and refrigeration:** Joining copper and copper alloys for leak-proof piping.
- **Automotive:** Manufacturing radiators, exhaust systems, and air conditioning parts.
- **Aerospace:** Joining critical components like jet engine blades.
- **Tool manufacturing:** Attaching carbide tips to steel tool holders.
- **Jewelry:** Creating strong, clean, and often invisible joints.

<u>Soldering</u>

Soldering uses a filler metal, called solder, that melts at a temperature below 450°C (840°F). This process creates weaker but easily disassembled joints compared to brazing.

Principles

- **Low temperature:** The low heat input minimizes thermal stress and is ideal for joining heat-sensitive electronic components.
- **Wetting:** The molten solder spreads over the heated base metal and forms an intermetallic bond.
- **Flux:** A flux is essential for cleaning the metal surface and preventing oxidation, which ensures good wetting and a quality joint. Rosin-based flux is standard for electronics, while more aggressive acid-based flux is used for plumbing.

Types of soldering

- ❖ **Soft soldering:** The most common type, using tin-lead or lead-free alloys with low melting points (typically 90–450°C).
- ❖ **Wave soldering:** An industrial process for mass-producing printed circuit boards (PCBs). Boards are passed over a wave of molten solder to join all components at once.
- ❖ **Reflow soldering:** Another automated technique for surface-mount components, where solder paste is applied and then melted in a reflow oven.
- ❖ **Hard (silver) soldering:** Uses a silver-based alloy that melts at higher temperatures (above 450°C) to create stronger joints than soft soldering, often considered a form of brazing.

Applications

- ➢ **Electronics:** Assembling and repairing printed circuit boards (PCBs), joining wires, and creating electrical connections.
- ➢ **Plumbing:** Joining copper pipes and fittings, though brazing is often used for higher-pressure applications.
- ➢ **Stained glass:** Joining individual pieces of glass with solder to create decorative art.

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- **Jewelry and metalwork:** Repairing and creating smaller items.

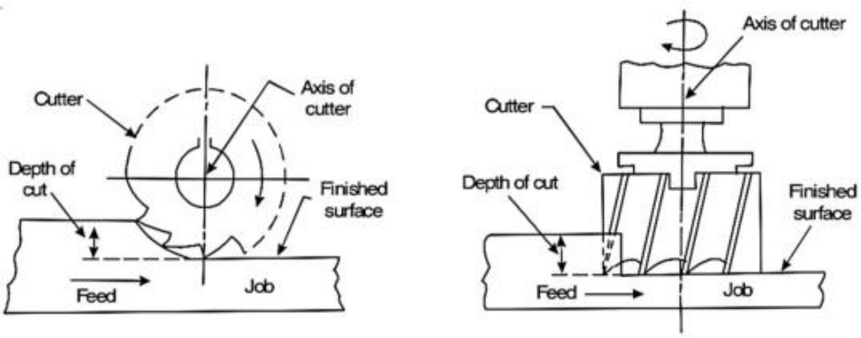
MILLING

INTRODUCTION

- It is a machining process in which the removal of metal takes place due to the cutting action of a **Revolving Cutter** when the work is fed past it.
- The Revolving cutter is held on a **Spindle or Arbor** and the work is clamped on the Machine Table, **fed past the milling cutter**. In doing so, the teeth of the cutter remove the metal, in the form of Chips, from the surface of the work to produce the desired shape.
- For **small and medium jobs**, the Milling machine gives probably the **fastest production with very high accuracy**.
- The milling process is used to create **flat, curved, or helical surfaces, threads, toothed gears, and helical grooves**. In general, all milling processes can be classified into two types:

Peripheral milling or horizontal milling

Here, the **finished surface is parallel to the axis of the cutter** and is machined by cutter teeth located on the periphery of the cutter as shown in Fig



(a) Peripheral milling (b) Face milling (Shell end Mill)

Face milling or vertical milling

The final **surface in face milling is at right angles to the cutter axis** and is obtained by the teeth on the **cutter's periphery and the flat end.**

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TYPES OF MILLING MACHINES

1. COLUMN AND KNEE TYPE MILLING MACHINES (General purpose milling machines)

These machines are all **General purpose machines** and have **a Single Spindle** only. They derive their name 'Column and Knee' type from the fact that the **work table is supported on a knee like Casting**, which can slide in vertical direction along a Vertical Column. These machines, depending upon the spindle position and table movements, are further classified as follows :

(a) Hand milling machine,

(b) **Plain or Horizontal milling machine,**

(c) **Vertical Milling machine,**

(d) **Universal Milling machine**, and

(e) Omniversal Milling machine.

2. FIXED BED TYPE OR MANUFACTURING TYPE MILLING MACHINES

It differs from the Column and Knee type Plain Milling Machine in that the table is mounted on a fixed bed instead of the saddle and knee and has a longitudinal travel only. It can neither move up and down nor crosswise.

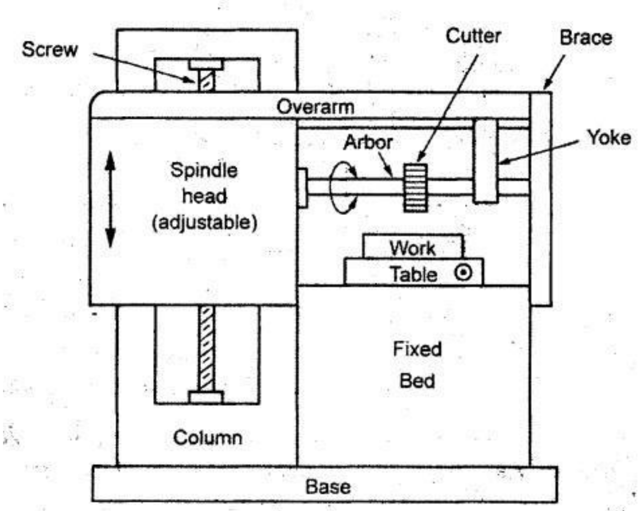

Figure 3.94 Fixed bed type plain milling machine

Their further Classification is as follows ;

(a) Plain Type (having Single Horizontal Spindle).

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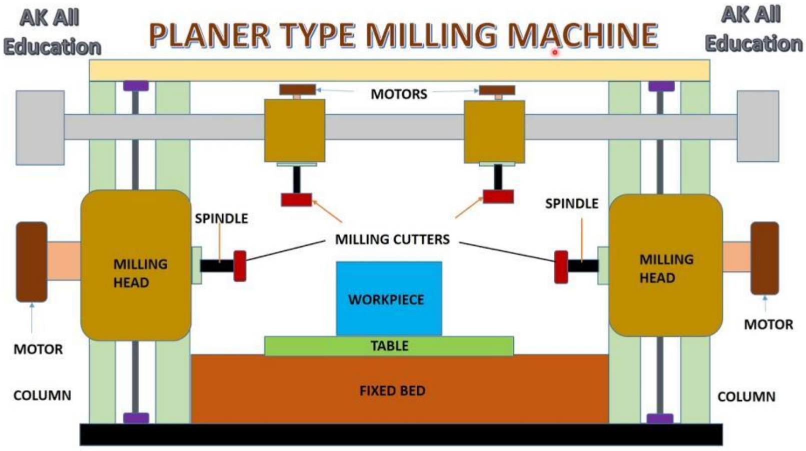
(b) Duplex Head (having Double Horizontal Spindles).

(c) Triplex Head (having two Horizontal and one Vertical Spindle).

(a) Rise and Fall type (for Profile Milling)

3. PLANER TYPE MILLING MACHINES

They are used for heavy work. Upto a maximum of Four Toolheads can be mounted over it, which can be adjusted vertically and transverse directions. It has a robust and massive construction like a Planer. In this case spindle carriers are mounted in place of the planer tool post, which are operated by individual motors.



4.PRODUCTION MILLING MACHINES

They are also Manufacturing Machines but differ from the above described machines in that they do not have a fixed bed. They include the following machines :

(a) Rotary Table

(b) Drum Type, and

(c) Tracer Controlled.

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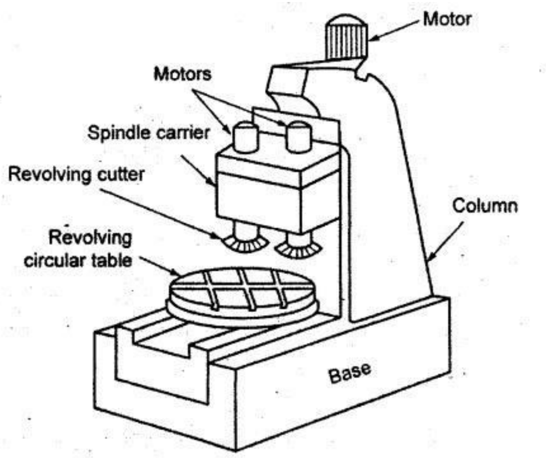

Figure 3.97 Rotary or continuous milling machine

5.SPECIAL PURPOSE MILLING MACHINES

These machines are designed to perform a specific type of Operation only. They include the following machines :

(a) Thread Milling Machine,
(b) Profile Milling Machine,
(c) Gear Milling or Gear Hobbing Machine,
(d) Cam Milling Machine,
(e) Planetary Type Milling Machine,

COLUMN AND KNEE TYPE MILLING MACHINES

Plain or Horizontal Milling Machine

- Its principal parts are shown by means of a block diagram in Fig. The Vertical Column serves as Housing for Electricals, the Main drive, Spindle bearings, etc.

- The knee acts as a support for the Saddle, Worktable and other accessories like Indexing Head, etc.

- Overarm provides support for the **arbor support** which in turn, supports the free end of the Arbor. **The arbor carrying the Cutter rotates about a horizontal axis.**

- The Table can be given straight motions in three directions ; **longitudinal, cross and vertical (up and down) but cannot be swivelled.**

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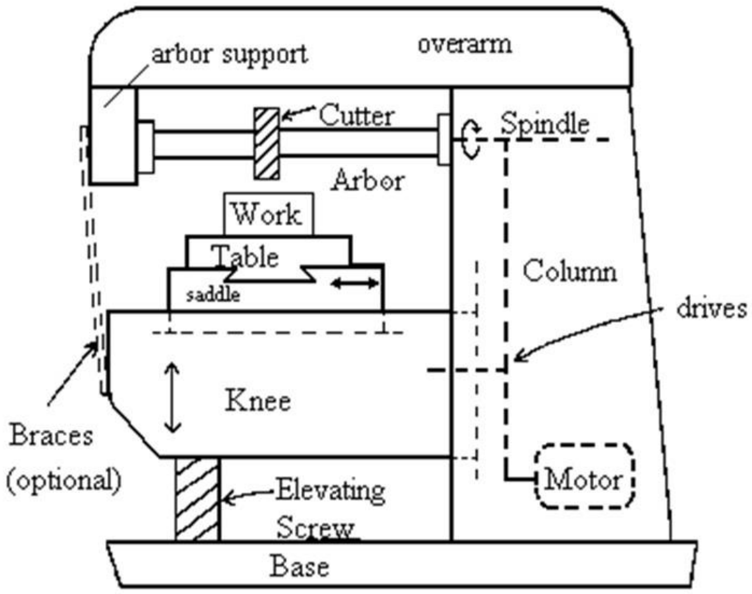

Horizontal Milling machine

- For giving vertical movement to the table the knee itself, together with the whole unit above it, slides up and down along the ways provided in front of the Column.
- For giving **cross movement** to the table, the **saddle is moved** towards or away from the column along with the whole unit above it.
- A **Brace** is employed to provide **additional support and rigidity** to the arbor when a long arbor is used. Both hand and power feeds can be employed for the work.

Vertical Milling Machine

- It derives its name from the vertical position of the Spindle. It carries a Vertical Column on a heavy base.
- The Overarm in this machine is made integral with the column and carries a head at its front. This **Head, can be Fixed type or Swiveling type**.
- In Fixed type, the spindle always remains vertical and can be adjusted up and down. In Swiveling type, the Head can be swiveled to any desired angle to machine inclined surfaces.

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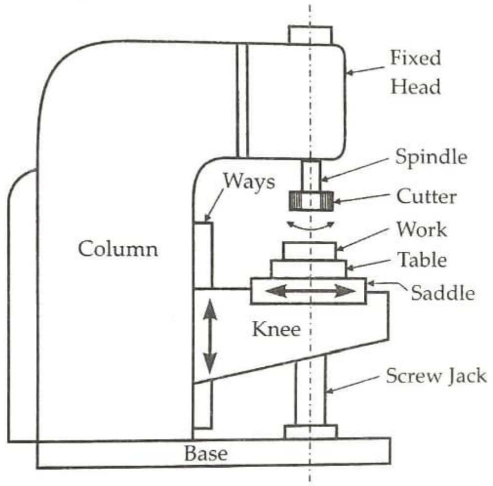

Fig. 11.3 Vertical Milling Machine with Fixed Head.

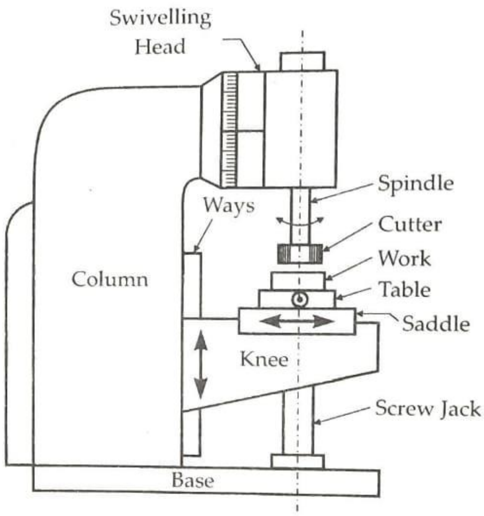

Fig. 11.4 Vertical Milling Machine with Swivelling Head.

- The Knee carries an Screw jack, by means of which, it is moved **up and down** along the Vertical Guideway provided on the front side of the Column.
- The Saddle is mounted on the knee and can be moved towards or away from the column. This enables the Table to move in **cross direction**.
- The Table is mounted on guideway, provided on the saddle. By means of a Lead screw, provided under the table, the table can be moved in the **longitudinal direction.**

Thus, the work gets up and down movement by the knee, cross movement by saddle and longitudinal movement by the table.

Universal Milling Machine

It differs from the Plain milling machine only in that the table can be given one more additional movement. **Its table can be swiveled (45^0) on the saddle in a horizontal plane.** For this, **Circular guideways** are provided on the saddle along which it can be swiveled.

This special feature **enables the work to be set at an angle** with the cutter for milling **helical grooves.** (e.g. the helical flutes of twist drills or the teeth of helical gears)

Its Overarm can be pushed back or removed and **a Vertical milling head can be fitted** in place of the arbor to use it as a Vertical Milling Machine. Detailed parts and various controls of a Universal milling machine are shown in Fig.

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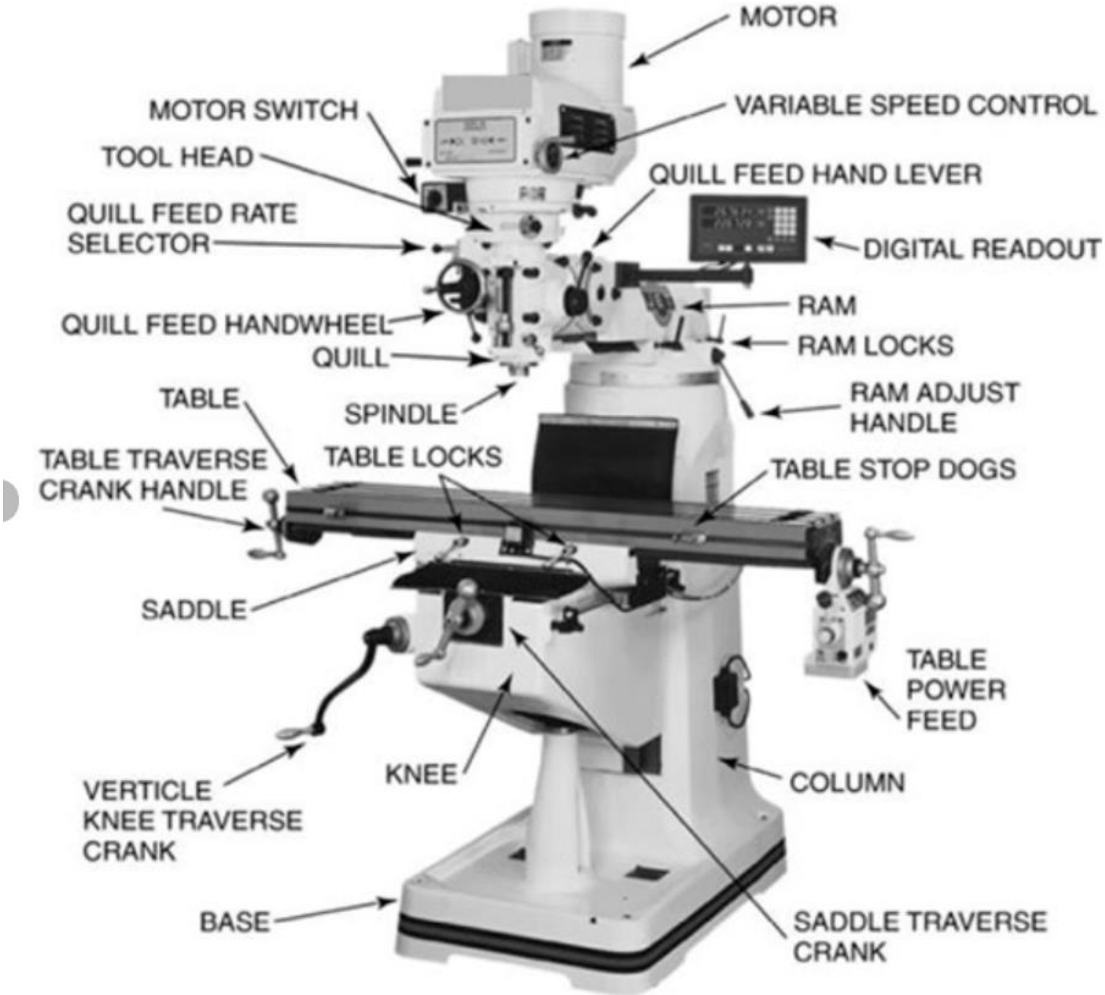

CONSTRUCTIONAL DETAILS OF COLUMN AND KNEE TYPE MILLING MACHINE:

1. Base

- It is a heavy Casting provided at the bottom of the machine.
- It actually acts as load bearing member for all other parts of the machine.
- Column of the machine is secured to it.
- Also, it carries the Screw jack which supports and moves the Knee.
- In addition to this, it also serves as a Reservoir for the coolant.

2. Column

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- On the front face of the column vertical parallel ways are made in which the knee slides up and down.
- At its rear side, it carries the enclosed motor drive.
- Top of the column carries the Over arm.

3. Knee

- It is a rigid Casting, which is capable of sliding up and down along the vertical ways on the front face of the column.
- This enables the adjustment of the table height or the distance between the cutter and the job by operating the Elevating jack, provided below the knee, by means of hand wheel or application of power feed.

4. Saddle

- It is the intermediate part between the knee and the table and acts as a support for the table.
- It can be adjusted crosswise, along the guideways provided on the top of the knee, to provide cross feed to the table.
- At its top, it carries horizontal ways, along which the table moves during the longitudinal traverse.

5. Table

- It acts as a support for the workpiece. It is made of cast iron, with its top surface accurately machine.
- Its top carries longitudinal T-slots to accommodate the Clamping bolts for fixing the work or securing the Fixtures. Also, the cutting fluid, after it is used, drains back to the Reservoir through these slots and then the pipe fitted for this purpose.
- Longitudinal feed is provided to it by means of a hand wheel.
- Cross feed is provided by moving the saddle and Vertical feed by raising or lowering the knee.
- In Universal milling machines the table can be swiveled in a horizontal plane.

6. Overarm

- It is the heavy support provided for the arbor on the top of milling machines.
- If further support is needed, to have additional rigidity, Braces can be employed to connect the Overarm and the Knee.

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SPECIFICATIONS OF PLAIN, UNIVERSAL, AND VERTICAL MILLING MACHINES

Specification	Plain Milling Machine	Universal Milling Machine	Vertical Milling Machine
Spindle orientation	Horizontal	Horizontal (table swivels ±45°)	Vertical
Table size (L × W)	1250 × 250 mm	1500 × 300 mm	1200 × 300 mm
Longitudinal travel (X-axis)	600 mm	700 mm	600 mm
Cross travel (Y-axis)	200 mm	250 mm	250 mm
Vertical travel (Z-axis)	400 mm	400 mm	500 mm
Table swivel	Fixed	±45°	Fixed
Spindle speed range	35 – 1200 rpm	40 – 1600 rpm	50 – 2000 rpm
Feed range	20 – 500 mm/min	20 – 500 mm/min	20 – 600 mm/min
Spindle taper	ISO 40	ISO 40	ISO 40
Main motor power	3 HP	5 HP	4 HP
Floor space (L × W × H)	2000 × 1500 × 1600 mm	2200 × 1600 × 1700 mm	1900 × 1500 × 1800 mm
Approx. weight	1200 kg	1500 kg	1300 kg
Special feature	Suitable for plain and slab milling	Suitable for helical and angular milling	Suitable for face, end, and slot milling

`

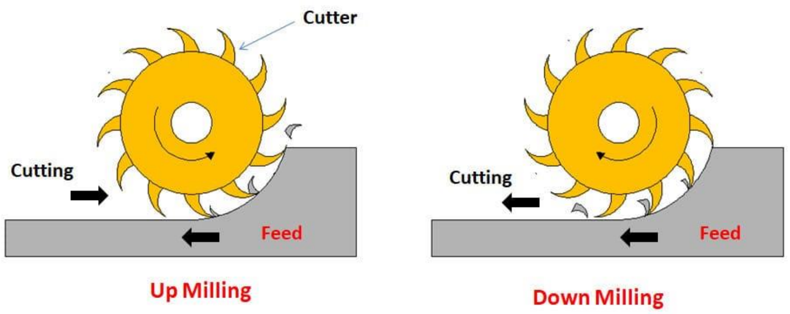
MILLING OPERATIONS

UP MILLING (CONVENTIONAL MILLING)

- In up milling, the cutter rotates against the direction of feed of the workpiece.
- The cutter teeth start from zero thickness and gradually increase to the maximum.
- The chip thickness increases during the cut.

Characteristics:

- Cutter rotates opposite to feed direction.
- The cutting starts with a rubbing action, leading to **poor surface finish**.
- **More tool wear** because of friction.
- Requires **more power**.
- **Suitable for rough machining** and hard materials.



DOWN MILLING (CLIMB MILLING)

- In down milling, the cutter rotates in the same direction as the feed of the workpiece.
- The cutter teeth start cutting at maximum thickness and end at zero.
- The chip thickness decreases during the cut.

Characteristics:

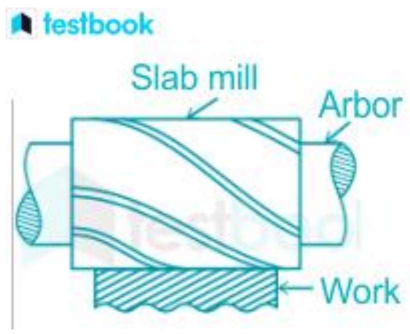
- Cutter rotates in the same direction as feed.
- Less friction, giving **better surface finish**.
- **Longer tool life**.
- Requires **rigid machine setup** to avoid backlash.
- **Suitable for finishing operations** and soft materials.

`

PLAIN OR SLAB MILLING (PERIPHERAL MILLING)

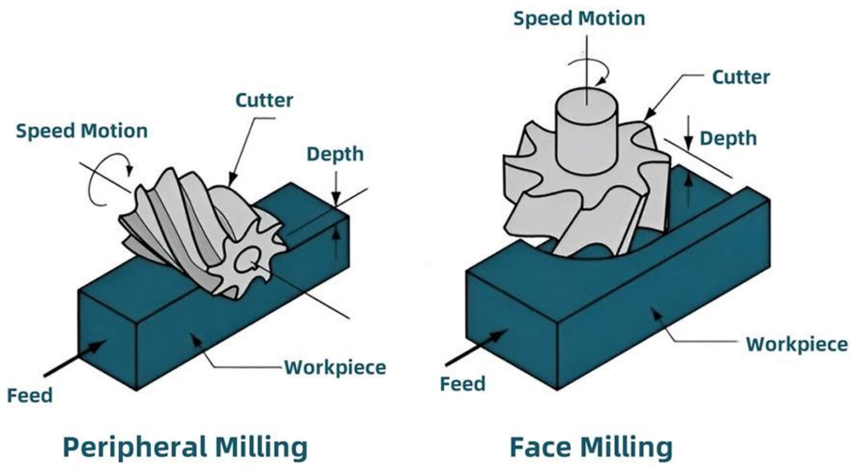
It is the process which is employed for **machining a flat surface**, parallel to the axis of the cutter, by using a **Plain or slab milling cutter**, as shown in Fig.

When the breadth of the cutter exceeds the width of the workpiece, it is referred to as a **"slab cutter".**



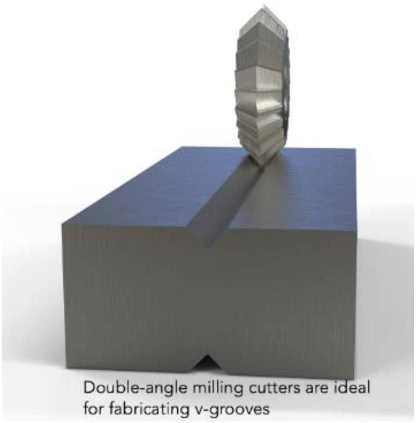
FACE MILLING

This milling process is also employed for machining a flat surface but the work surface is at **right angles to the axis of the rotating cutter**. The cutter used in this process is the **face milling cutter.**



ANGULAR MILLING

It is the milling process which is used for machining a **flat surface at an angle, other than a right angle to the axis of the revolving cutter**. The cutter used may be a Single or Double Angle Cutter, depending upon whether a single surface is to be machined or two mutually inclined surfaces simultaneously.

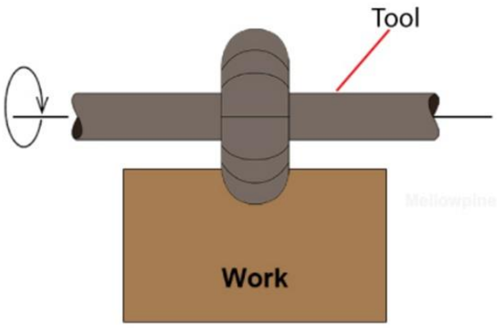


FORM MILLING

The cutter used, called a **Form Milling Cutter**, will have the shape of its cutting teeth conforming to the profile of the surface to be produced.

Form milling is a **milling operation** used to produce **irregular contours, curved surfaces, or complex profiles** on a workpiece using a **form cutter**.

Example: Milling pulleys or sprocket rims, Milling cams or roller surfaces, keyways, splines, or special slots.



SIDE MILLING

In this operation, a **plain Milling Cutter** is used to machine **a flat vertical surface on a side of the workpiece**.

The milling cutter used in side milling is **cylindrical and features cutting edges along its periphery**. It moves laterally across the workpiece, with its axis remaining parallel to the surface.

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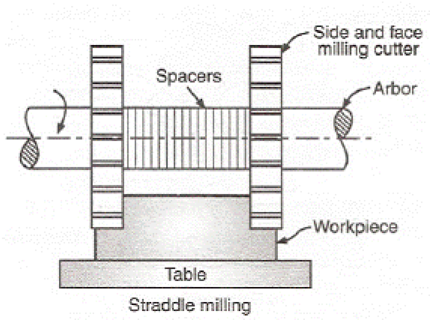
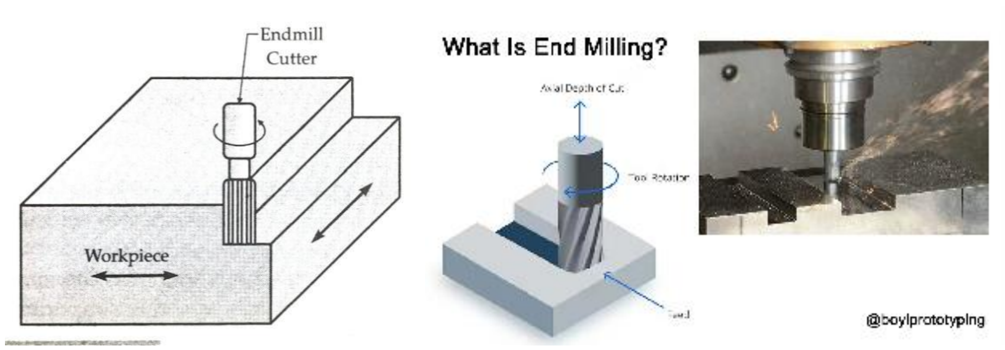


When two parallel vertical flat surfaces are required to be machined, the usual time saving practice is to use a pair of two Side Milling Cutters to machine **both the surfaces simultaneously**. The space between the two cutters can be easily adjusted as per requirement by using the Spacers. This operation is then known as **'Straddle Milling'.**

END MILLING

End milling is a versatile machining process that uses a rotating, multi-fluted tool called an end mill to remove material from a workpiece. An **end mill** has **cutting teeth on its end (face)** as well as **along its periphery**. It can perform **both peripheral and face milling** operations.

The end mill cuts with both its sides and end, allowing for a wide range of operations like creating **slots, pockets, contours, and precise cuts.**



End milling

GANG MILLING

It involves the use of **a combination of more than two cutters, mounted on a common arbor,** for milling a number of flat horizontal and vertical surfaces of a work-piece simultaneously.

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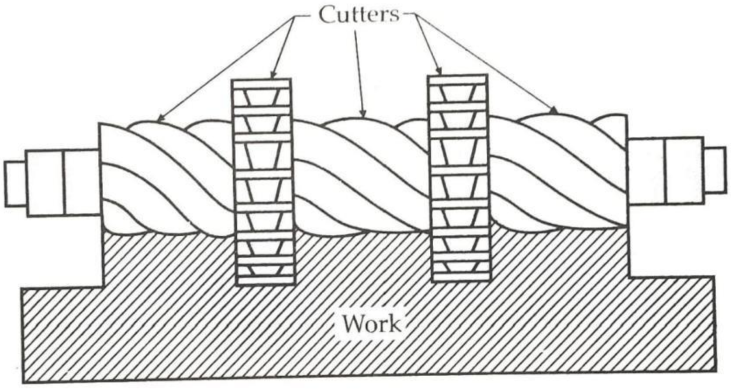
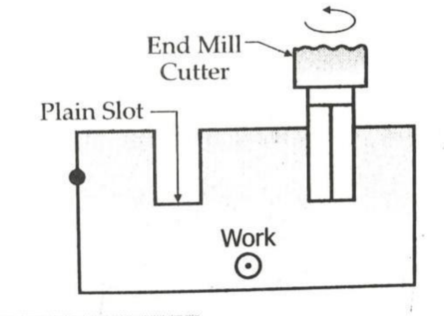
Gang milling is a type of milling process where **several cutters of different sizes or shapes** are fixed on the same arbor and are used together to machine **different surfaces** of a workpiece in **one setup**.



Gang milling

SLOT AND GROOVE MILLING

Slot Milling is the operation of **producing slots in solid work pieces** on a Milling machine. These slots can be of varied shapes, such as **Plain slots, T-slots, Dovetail slots,** etc.



Cutters Used: End mill (for narrow slots), T-slot cutter (for T-shaped slots), Woodruff cutter (for keyways)

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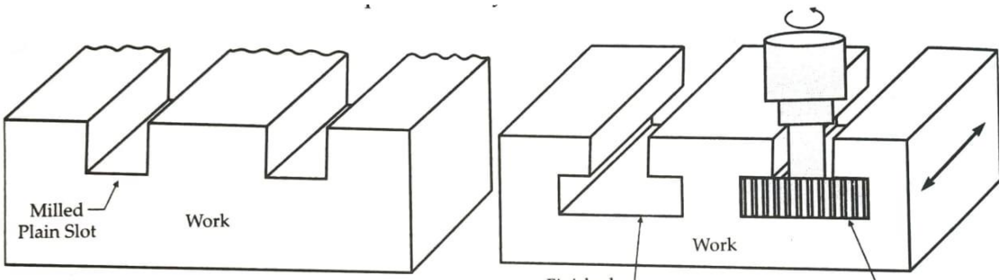
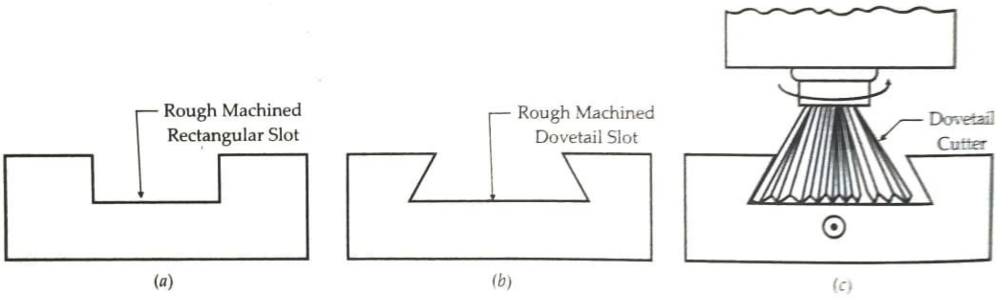
Woodruff cutter T-slot cutter



(a) Work having Milled Plain Slots. (b) Milling T-slots with T-slot Milling Cutter

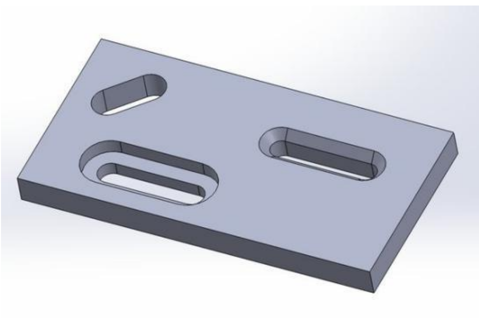
Production of a Dovetail slot:



11.71 Milling a Dovetail Slot. (a) Rough machined rectangular slot (b) Rough machined Dovetail Slot (c) Finish machining the Dovetail Slot with the help of a Dovetail Milling Cutter.

Groove Milling is the operation of producing Grooves of different shapes, such as **Plain grooves, Curved grooves, V-grooves,** etc.

A groove is a **narrow channel or depression** cut into the surface of a workpiece. It May be **circular, semicircular, V-shaped, or U- shaped.**



Cutters Used: Side and face cutters, Formed milling cutters

<u>STRING MILLING</u>

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In “String milling”, two or more workpieces are mounted on the milling machine table in a line, so that they are successively fed to one or more milling cutters. String milling results in a substantial reduction in handling time, as it is overlapped by the machining time.

ABREAST MILLING

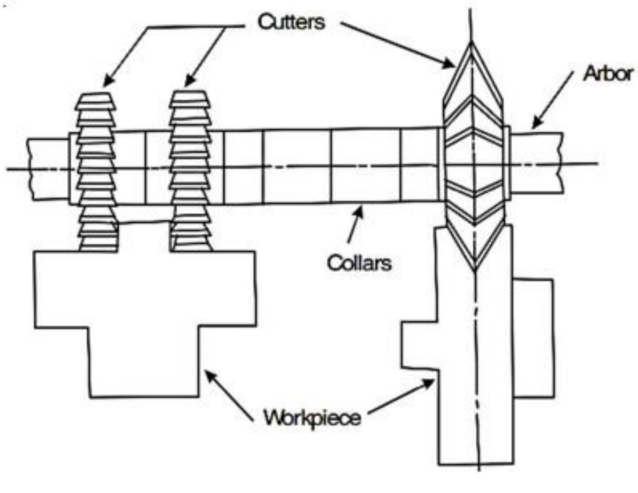
Abreast Milling (also called Side-by-Side Milling) is a type of gang milling operation in which two or more cutters are mounted on the same arbor and are used simultaneously to machine two or more surfaces of a workpiece that lie parallel to each other.

Abreast milling is a milling operation in which **multiple cutters** are arranged **side by side on a single arbor**, each performing a separate cut on the workpiece at the same time.

PROGRESSIVE MILLING

Here, two or more similar or different operations are performed either simultaneously/

successively, on separate workpieces on the same machine and are progressively moved from one fixture station to the next, until all the desired operations are performed.



TYPES OF MILLING CUTTERS

MILLING CUTTERS

Plain milling cutters

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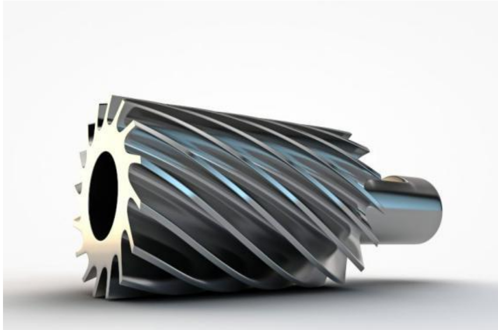
- These cutters have cutting teeth just on the periphery and are cylindrical in shape.
- They are used to grind flat or plain surfaces.
- Straight or helical teeth can be found on a simple milling cutter.

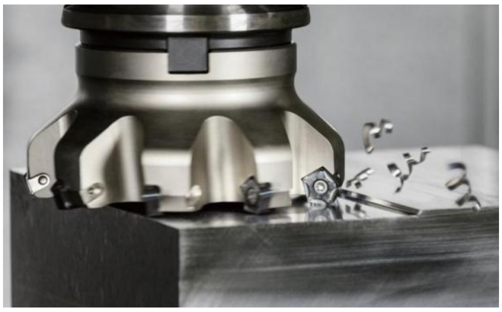


- When a cutter with straight teeth is used, each tooth enters the cut simultaneously along its entire length. This causes huge loads to act on the machine, lowering the quality of the surface produced.
- Cutters with helical teeth run more smoothly because the teeth enter the cut gradually and the machine load is more homogeneous.

Used for **face milling, slab milling.**

Face milling cutters

- For machining large, flat surfaces, face milling cutters with teeth on the end face are utilized.



- They are intended to machine flat surfaces perpendicular to the spindle's rotational axis.

`

- Face milling cutters are similar to end mills but much larger in diameter. (diameter from 140 mm to 380 mm).

Profile or form milling cutters

Profile or form milling cutters are cutters with a curved tooth outline and has the same shape as the profile to be produced on the workpiece.

Concave, convex, and corner rounding cutters are among of the most popular shapes. Gear milling cutters are form milling cutters used to machine any conventional gear tooth.

Use: Used for **contour milling** such as semicircular or concave/convex forms.

End Milling Cutters:

- Teeth on both **periphery and face**.
- Used for **slotting, profiling, and contouring**.

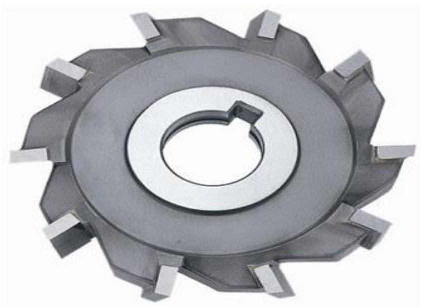
Examples: Square end mill, ball nose end mill.

Shell end mill with a hole at centre

Their sizes range from roughly 3 mm to 50 mm. Shell end mills range in diameter from 30 mm to 150 mm.

Side milling cutters

- Comparatively narrow cylindrical milling cutters with teeth on one or both sides and on periphery.
- It is designed to **cut slots, grooves, and shoulders**, or **finish the vertical surface** of a workpiece.



- These cutters are available in widths ranging from roughly 5 mm to 25 mm and diameters ranging from 50 to 200 mm.
- "Half-side milling cutters" have teeth just on one side and all the way around the diameter.

Angular milling cutters

These cutters are available in single-angle or double-angle configurations and are used to machine angles other than 90°. The 45° and 60° single angle cutters, as well as the 45°, 60°, and 90° double-angle cutters, are popular.

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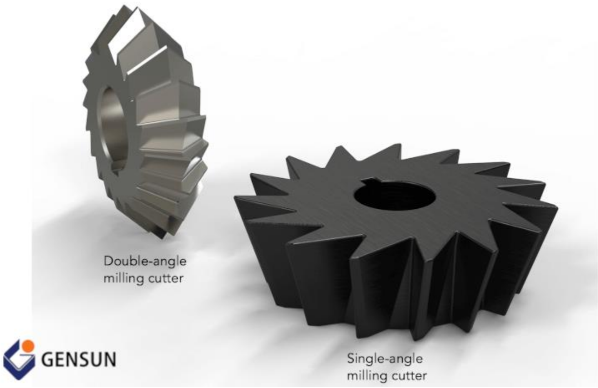


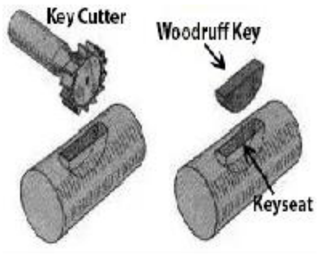
Use: For **milling angular grooves** such as V-slots and dovetails.

<u>T-slot milling cutters, Woodruff key slot milling cutters, and dove tail cutters</u>

A T-slot milling cutter is used to produce **T-shaped slots** in a workpiece, commonly found on **machine tables** for holding workpieces with T-bolts.

Woodruff key cutter is used to cut **semi-circular keyways** (Woodruff key slots) in shafts, where **Woodruff keys** fit for torque transmission between a shaft and a hub.

A dovetail milling cutter is used to cut **dovetail grooves**, which are trapezoidal-shaped slots used for **sliding or fitting components** together.



<u>Fly Cutter</u>

A **Fly Cutter** is a **single-point cutting tool** used on a **milling machine** for machining flat surfaces. It is one of the simplest types of milling cutters.

Applications

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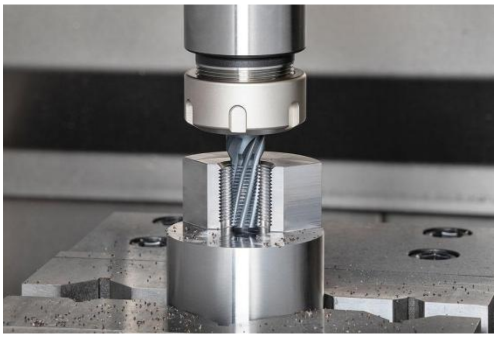
- ✧ Facing large plates or blocks.
- ✧ Producing smooth, flat surfaces.

Thread Milling Cutter

The **teeth profile** corresponds to the thread form.It Can cut **right-hand or left-hand** threads.

Thread milling cutter **gradually cuts threads** by moving in a helical path.



Slitting Saw

A **slitting saw** is a **thin, circular milling cutter** used for cutting narrow slots or for parting off (slitting) workpieces in a milling machine.

TEETH MATERIALS

Milling cutters are made from materials that can withstand **high cutting temperatures, wear, and impact forces** during machining.
The most common materials used are:

High-Speed Steel (HSS)

`

- ✧ **Composition:** Iron with tungsten, molybdenum, chromium, vanadium, and cobalt.
- ✧ **Applications:** Slotting, end milling, and light-duty operations.

Carbide (Cemented Carbide)

- ✧ **Composition:** Tungsten carbide (WC) + Cobalt binder.
- ✧ **Applications:** High-speed, heavy-duty, and production milling.

Carbide-Tipped Cutters

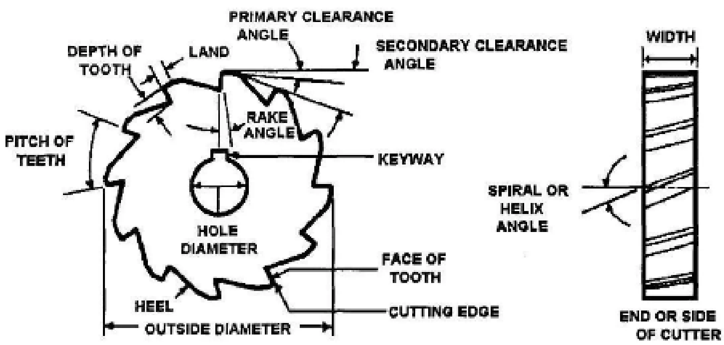
- ✧ **Description:** Steel body with carbide tips brazed or mechanically clamped.
- ✧ **Applications:** Heavy-duty and mass production work.

Other materials: ceramic, cermets, CBN, Diamond.

NOMENCLATURE OF TEETH AND TOOL SIGNATURE OF MILLING CUTTER

The **nomenclature of a milling cutter** refers to the **names and meanings of various parts, angles, and elements** that define the geometry and cutting performance of the cutter.

NOMENCLATURE OF MILLING CUTTER



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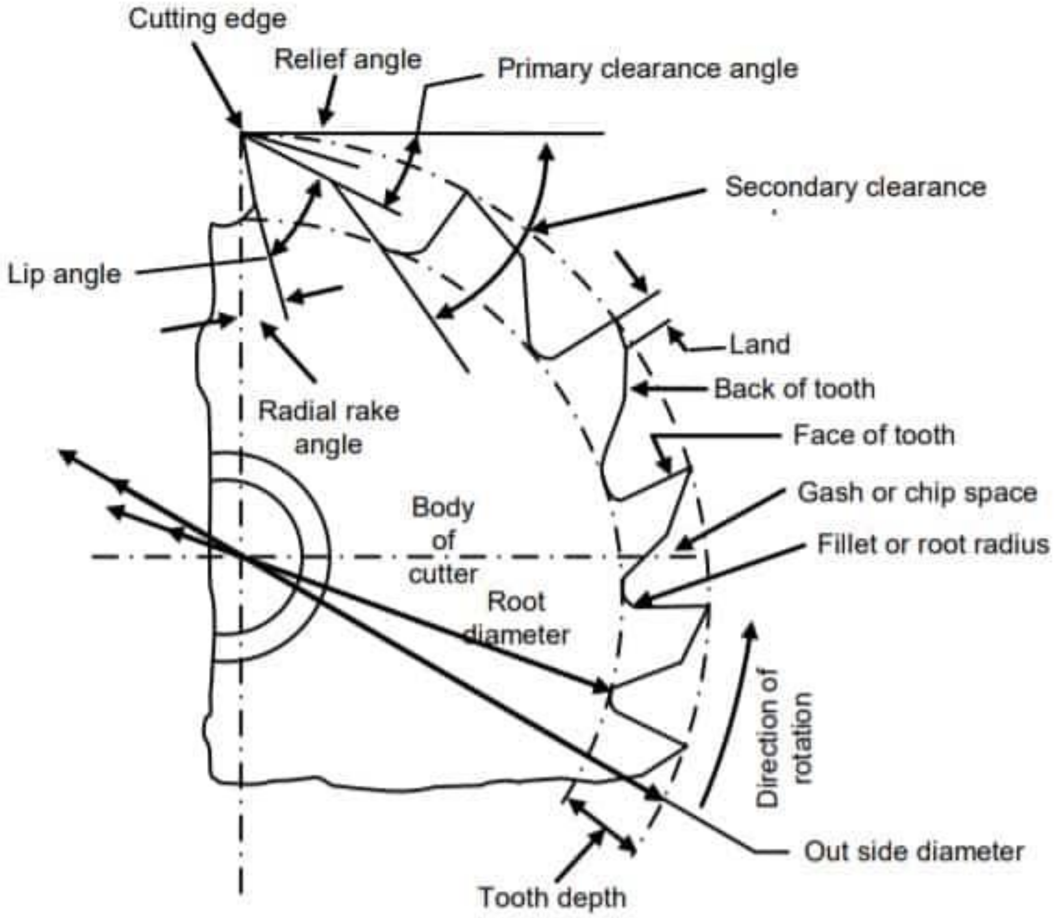


Plain Milling Cutter and its Elements

Body of Cutter – The main part of the cutter that holds the cutting edges (teeth).

Teeth – The tooth is the part of the cutter starting at the body and ending with the peripheral cutting edge. Replaceable teeth are called inserts. The cutting edges are on the periphery or face of the cutter that remove material.

Face – The surface of the tooth over which the chip slides.

Flute – The space between two teeth that allows chip removal and provides rake face.

Fillet - The fillet is the radius at the bottom of the flute, provided to allow chip flow and chip curling.

Pitch:- Distance between corresponding points on adjacent teeth.

Land – The surface behind the cutting edge that provides relief.

Tooth Face – The surface against which the chip bears while being cut.

`

Tooth Back – The surface opposite the face of the tooth.

Cutting Edge – The sharp edge formed by the intersection of the face and the relief surface.

Key Slot – A slot on the cutter's bore for fixing it to the arbor.

Arbor Hole (Bore) – The central hole by which the cutter is mounted on the arbor.

Outside diameter - The diameter of a circle passing through the peripheral cutting edges.

Root diameter - This diameter is measured on a circle passing through the bottom of the fillets of the teeth.

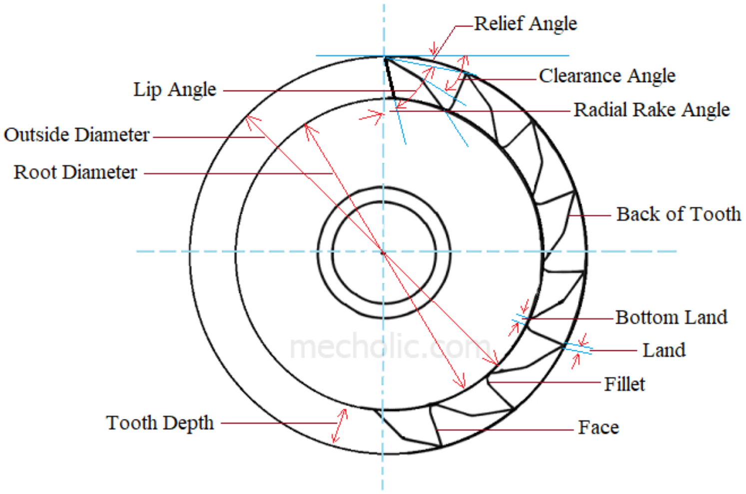
Peripheral cutting edge - The cutting edge which is aligned in the direction of the cutter axis is called the peripheral cutting edge. In peripheral milling, it is this edge that removes the metal.

Face cutting edge - The face cutting edge is the metal removing edge aligned primarily in a radial direction.

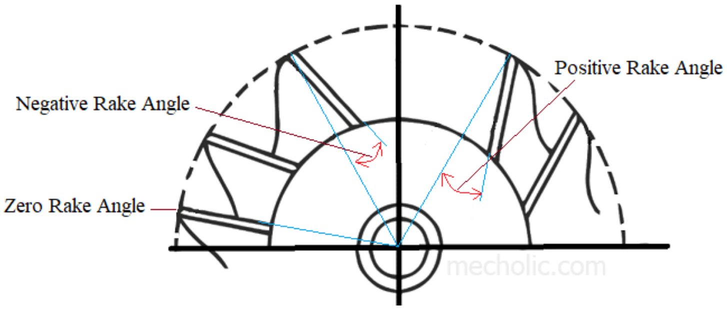
Wedge Angle (β):- The angle between the rake face and relief face.

Relief angle (α) - This angle is measured between the land and a tangent to the cutting edge at the periphery.

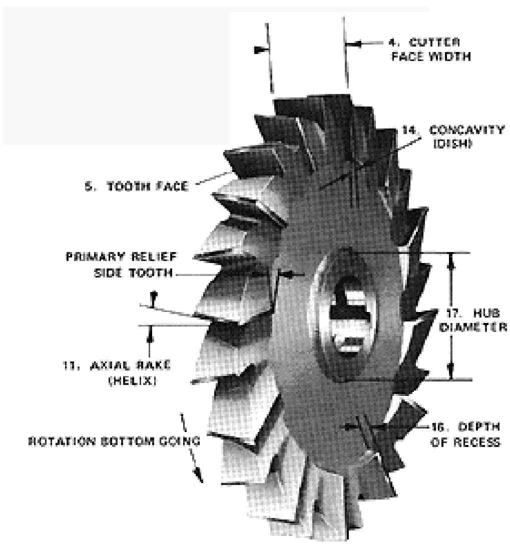
Clearance angle (θ) - This angle is measured between the back of the tooth and a tangent to the cutting edge at the periphery. It is provided to make room for chips, thus forming the flute.



Radial rake angle (γ) - This is the angle between the tooth face and a radial line extending from the cutter's center to the cutting edge. It can be positive, negative, or zero and is critical for smooth chip flow.



Axial rake angle:- This is the angle of the cutting edge relative to the cutter's axis. It is usually positive to give the teeth a helical shape, which promotes a shearing action and smoother cutting.



Helix Angle (λ) - The angle between the cutting edge and the axis of the cutter.

The tool signature of a plain milling cutter is generally written as:

$$N - \alpha - \gamma - \beta - \lambda - \theta - D$$

Example of a Plain Milling Cutter Signature

$$12 - 10^\circ - 5^\circ - 75^\circ - 25^\circ - 60^\circ - 100\text{mm}$$

Meaning:

`

12 teeth

Radial relief angle = 10°

Radial rake angle = 5°

Wedge angle = 75°

Helix angle = 25°

Tooth angle = 60°

Cutter diameter = 100 mm

INDEXING AND DIVIDING HEADS

The heads help in changing angular position of the work in relation to the cutter. With their use it is possible to divide the periphery of the workpiece into any number of equal parts.

1. Plain Dividing Heads for direct indexing

❖ These Dividing Head carries the **Indexing Plate** directly mounted on its Spindle. It is the simplest of all the dividing heads and is used in Direct Indexing.

❖ The Index Plate carries **12 or 24 equispaced Slots on its periphery**. Figure shows such a Dividing head. The job is held between two centres, one on the Dividing head Spindle and the other on the Tailstock.

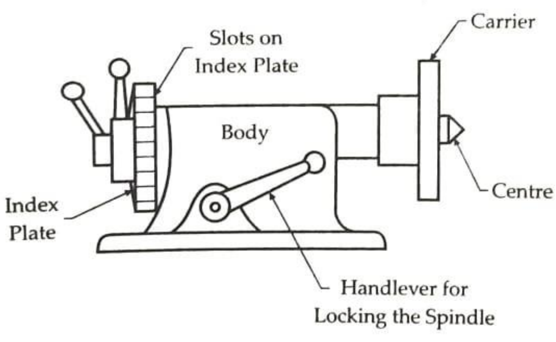


Fig. Plain Indexing Head for Direct Indexing.

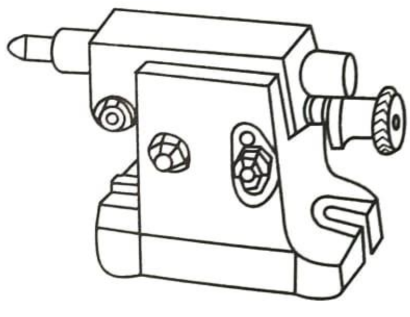


Fig. Tail Stock.

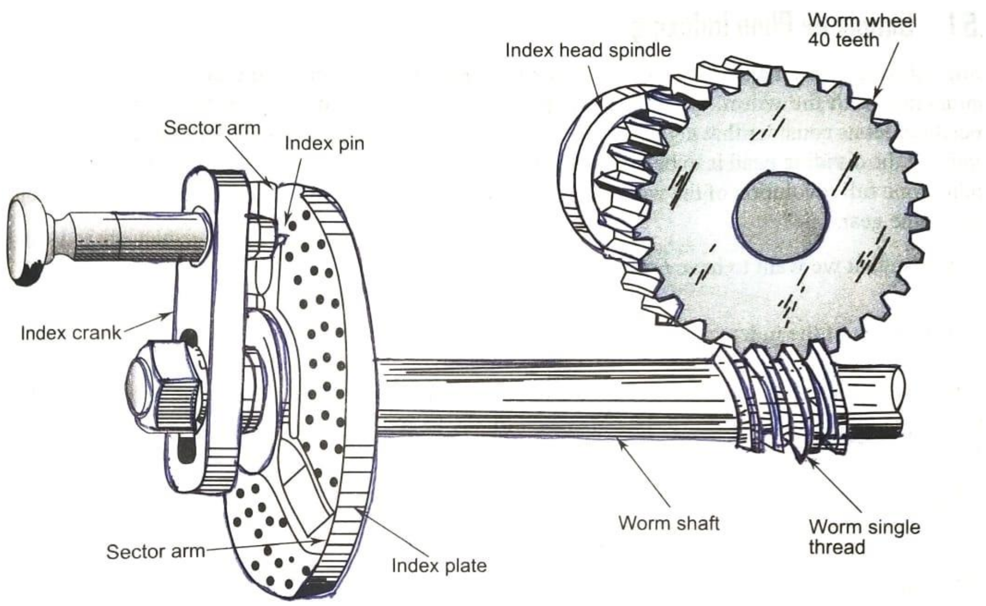
❖ The Hand lever is used for locking the spindle in position so that the index plate, spindle and worpiece rotates simultaneously when index plate is rotated by a hand wheel.

`

❖ In operation, a lug engages the desired slot of the Indexing plate. By means of this Dividing heads 2, 3, 4, 8, 12 and 24 division can be obtained when 24 Slots index Plate is used and 2, 3, 4, 6 and 12 divisions when a 12 Slots plate is used.

2. Universal Dividing Heads

The main spindle of the dividing head drives the workpiece.



Indexing method of the dividing head

❖ The index plate of a dividing head consists of a number of holes with a crank and a pin.

`

- The index crank drives the spindle, hence the worpiece through a worm gear, which generally has 40 teeth as shown in Fig. As a result, a full rotation of the workpiece is produced by 40 full revolutions of the index crank.

- Further indexing is made possible by having the index plates with equi-spaced holes around various circles. This would allow for indexing the periphery of the workpiece to any convenient number of divisions.

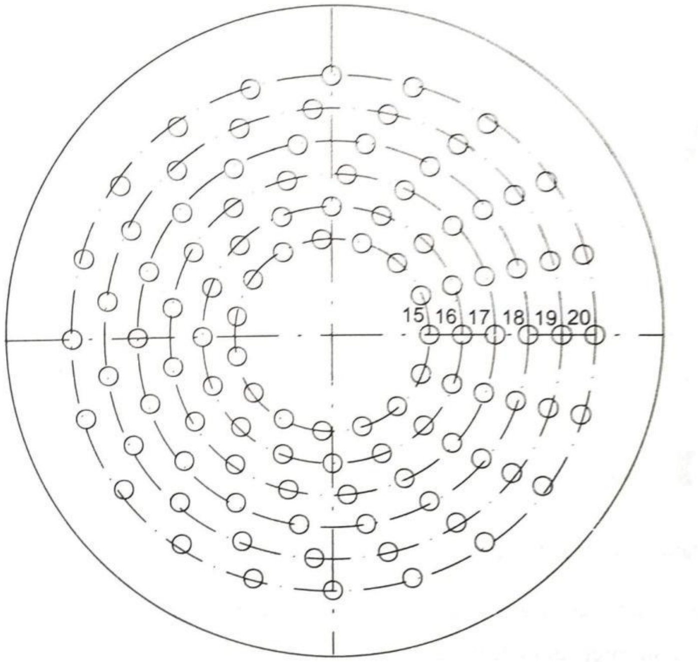
- Dividing Head provides support to the job, holds it in position and rotates it through a desired angle after each cut is over.

The index plates available with the **Brown and Sharpe milling machines** are

Plate no. 1: 15, 16, 17, 18, 19, and 20 holes

Plate no. 2: 21, 23, 27, 29, 31, and 33 holes

Plate no. 3: 37, 39, 41, 43, 47, and 49 holes



Index plate no. I of Brown and Sharpe dividing head

- When the Crank is rotated, the worm rotates which, in turn, rotates the worm wheel. Since this worm wheel is mounted directly on the spindle the spindle rotates so also the workpiece.

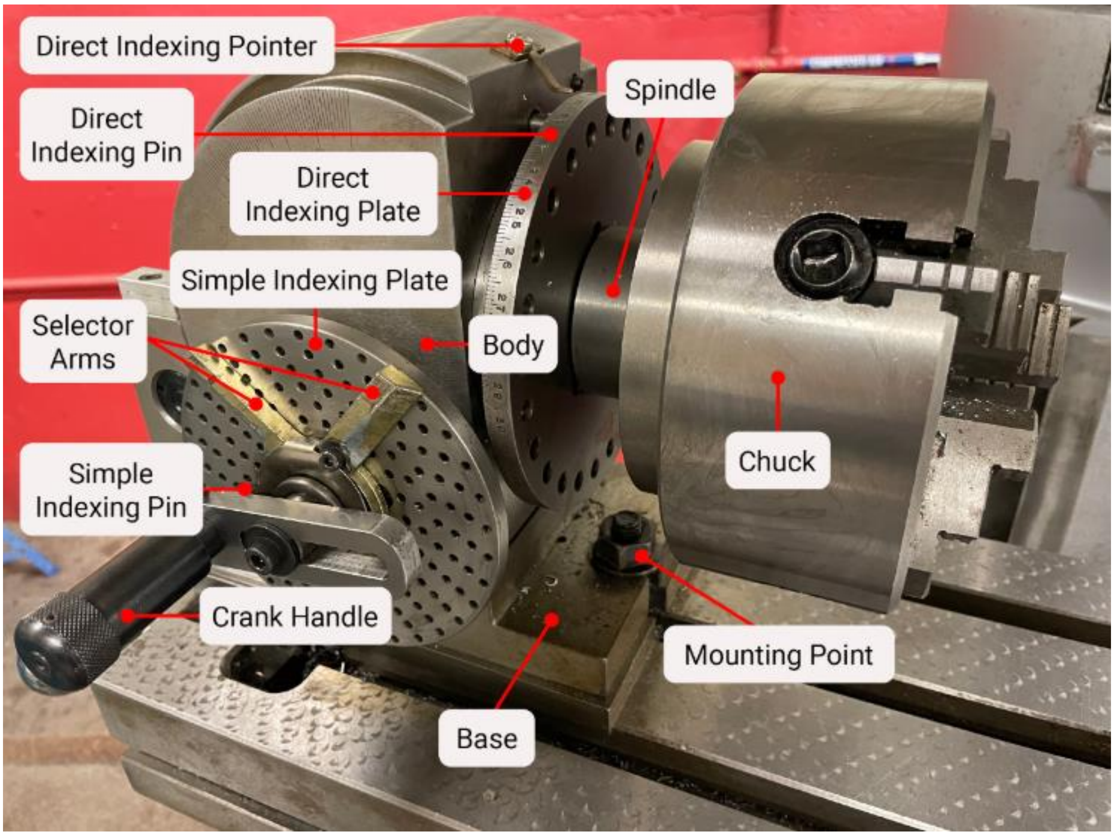
`

- The angle through which the job will rotate, for each revolution of the crank, depends upon the Velocity ratio between the worm and worm-wheel. **i.e., for 40 revolutions of the worm, or of the Crank, the job will make one revolution.**

INDEXING METHODS

By Indexing we mean **division of the job periphery into a desired number of equal divisions**. It is done by a controlled movement of the Crank such that the **Job rotates through a definite angle after each cut is over.** The following methods of Indexing are commonly used:

- Direct-indexing
- Simple Indexing
- Compound Indexing
- Differential Indexing
- Angular Indexing



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Direct indexing

It is the simplest case of Indexing in which a Plain Dividing Head is used.

N = No. of slots on the index plate (usually 12 or 24)

n= No. of divisions required to be obtained on workpiece.

The Indexing ratio is obtained by:

Index ratio = N/n

For example, if the circumference of a job has to be divided into 6 equal divisions and the Index plate has 24 slots, then the required ratio will be:

= 24/6 = 4/1

i.e., the index plate will be required to move through 4 slots after each cut is over.

Simple Indexing

If the work is required to be divided into 22 equal divisions the Direct Indexing cannot be used, because 22 is not divisible into any of the hole circles on the Direct Indexing Plate. For such cases, Simple Indexing can easily be used.

For this, **a Universal Dividing Head** can be used. When the Crank pin is pulled outwards and the Crank is rotated, the worm will rotate which, in turn, will rotate the worm wheel, and hence the spindle and the work.

Since the Worm has single start thread and the Worm wheel 40 teeth, with one turn of the crank (i.e., of the worm) the worm wheel will rotate through one pitch distance, i.e., equal to 1/ 40 of a revolution. Thus, the Crank will have to be rotated through 40 turns in order to rotate the work through one complete turn.

The **holes in the Index plate serve to subdivide the rotation of the Index crank.**

Now suppose we want to divide the work into a number of divisions, the corresponding Crank movements will be as given:

For **two divisions** on the Work, the **Crank will make 40/2 = 20 turns for each division**

`

For **four divisions** on the Work, the Crank will make 40/4 = **10 turns for each division**

Similarly for **n divisions on the Work**, the Crank will make **40/n turns.**

Suppose that we want to have 6 equal divisions to be made.

The rotation of the index crank = 40/6 = $6\frac{2}{3}$ turns

This means that the index crank should be rotated **6 full turns** followed by **two thirds of a rotation.** The fraction of a rotation required is to be obtained with the help of the index plates as given above. This can done as follows using any of the Brown and Sharpe plates.

Plate no. 1: 10 holes in a 15-hole circle

12 holes in an 18-hole circle

Plate no.2: 14 holes in a 21-hole circle

18 holes in a 27-hole circle

22 holes in a 33-hole circle

Plate no.3: 26 holes in a 39-hole circle

EXAMPLE 1 Indexing 28 divisions.

Solution The rotation of the index crank = $\frac{40}{28} = 1\frac{3}{7}$ turns.

This can be done as follows using any of the Brown and Sharpe plates.

One full rotation + 9 holes in a 21-hole circle in Plate no. 2.

One full rotation + 21 holes in a 49-hole circle in Plate no. 3.

EXAMPLE 2 Indexing 62 divisions.

Solution The rotation of the index crank = $\frac{40}{62} = \frac{20}{31}$ turns.

This can be done as follows using any of the Brown and Sharpe plates.

20 holes in a 31-hole circle in Plate no. 2.

`

Compound Indexing

This method of Indexing is employed when the number of divisions required on workpiece is outside the range that can be obtained by Simple Indexing. It involves the use of two separate simple indexing movements and is performed in **two stages**:

1. By turning the Crank a definite amount in one direction in the **same way as in Simple indexing. (**n1 holes in N1 hole circle**)**

2. By adding or subtracting a further movement **by rotating the crank and the index plate together** forward or back ward. (through n2 spaces in the N2 circle)

Let *n1* be the number of holes to be indexed in N1 hole circle and n2 the number of holes to be indexed in N2 hole circle.

Then,

$$\frac{n1}{N1} \pm \frac{n2}{N2} = \frac{40}{z}$$

From here, n1 and n2 are found out by trial and error. Then the total indexing will be, n1 holes in N1 hole circle by rotation of the crank ± ***n2* holes in *N2* hole circle by rotating the crank and index plate together.**

Example.

Indexing 87 divisions

Let *N1* = 29 and *N2* = 33

Now, indexing equation is :

$\frac{n1}{29} \pm \frac{n2}{33} = \frac{40}{87}$ or $33\, n_1 \pm 29\, n_2 = 440$

By trial and error $n_1 = 23$ and $n_2 = 11$ with minus sign.

That is, $33 \times 23 - 29 \times 11 = 440$

∴ Indexing equation will be: 23/29 - 11/33 = 40/ 87

That is, mmovement of crank by 23 holes in 29 hole circle forwards and movement of crank and index plate both by 11 holes in 33 hole circle backwards.

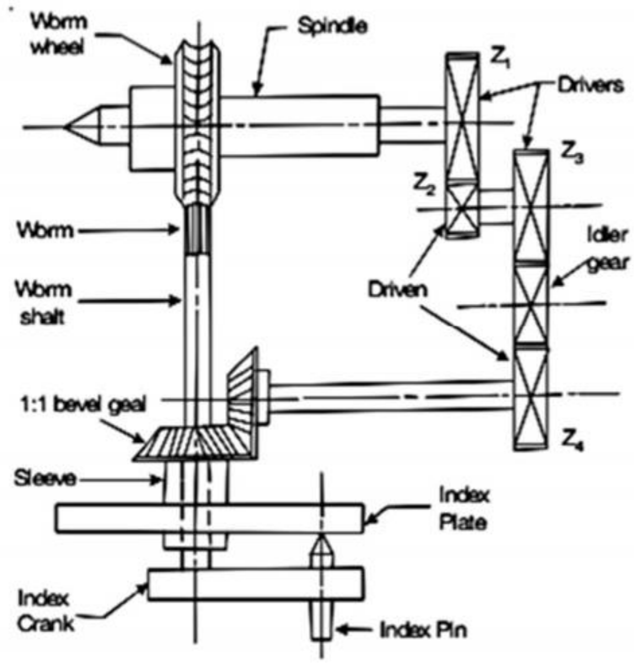
`

Differential indexing

- In differential indexing, **the index plate is connected to the head stock spindle by means of a gear train.** Fig. shows one such design where *z1, z2, z3* and *z4* are interchangeable gears.
- As the index crank is turned for indexing, rotating the spindle through worm and worm gear in a same way as that of simple indexing, **the index plate will receive power through the change gears, equal bevel gear and the sleeve, and will rotate slowly.**
- The index plate can be made to rotate either in the same direction or in the opposite direction to the index crank (by gear train design).
- Indexing is performed in the same manner as that for simple indexing except that the required movement of the index plate is calculated and taken care of by the gear train.

Procedure

Let z = number of divisions required to be indexed for one complete revolution of the spindle and hence the work-piece



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k = A number very nearly equal to z and which can be used in simple indexing method.

∴ Number of crank turns for each simple indexing, $n = 40 / k$

∴ Number of crank turns needed for z indexings,

$$N = \frac{40}{k} \times z$$

But, we know that the crank must make only 40 turns for the spindle (and hence the work) to turn through one complete circle. So,

(i) If $N > 40$, then $(N - 40)$ turns have to be subtracted. This is achieved through the change gears so that while the spindle makes one turn, the index plate makes $(N - 40)$ turns in the opposite direction to that of the crank.

(ii) (ii) If $N < 40$, then the index plate should rotate $(40 - N)$ turns in the same direction as that of the crank. The gear ratio will be :

(iii) $I = \frac{40}{k} \times (k - z)$

Thus, the movement of the index handle (crank) operates according to the principle of simple indexing and the gear ratio makes it possible to find gears which take care of residual divisions.

Example. Do differential indexing for 93 divisions.

Solution. z = 93,

∴ Simple indexing = 40 / 93

It is clear from the available index plates, that 93 cannot be simple indexed.

So, let $k = 90$, which can be simple indexed each indexing = $\frac{40}{90} = \frac{4}{9} = \frac{8}{18}$, that is, 8 holes in an 18 hole circle. ∴ for 93, indexings, $N = \frac{8}{18} \times 93 = 41\frac{1}{3}$ turns of the crank

Since N > 40, the index plate must rotate 4/ 3 turns backwards, that is, in the opposite direction.

$$i = \frac{40}{k} \times (k - z) = \frac{40}{90} \times 3 = \frac{4}{3}$$

In the Brown and Sharpe dividing head, the gears supplied are: 24 (2), 28, 32, 40, 44, 48, 56, 64, 72, 86 and 100 teeth.

$$\therefore i = \frac{4}{3} = \frac{32}{24} = \frac{Drivers}{Driven}$$

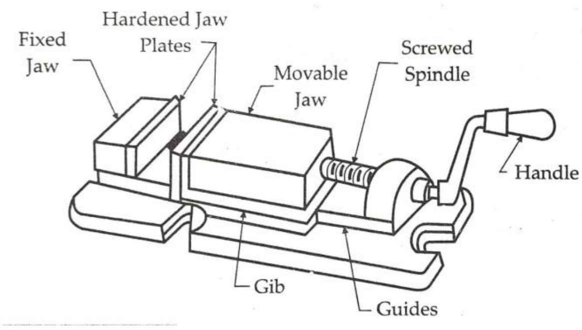
It is a simple gear train.

`

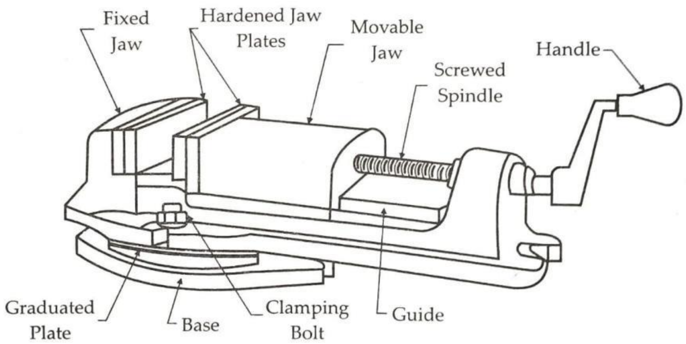
WORK HOLDING DEVICES

i. The work may be clamped on the table by means of T-bolts, strap clamps and pads.

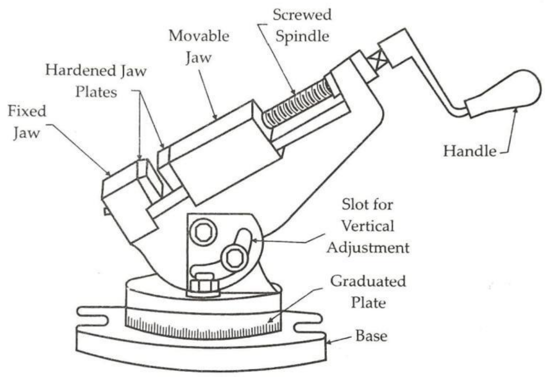
ii. *Plain vise.* On a milling machine, this is the most typical work holding device. T-bolts can be used to secure it to the table



iii. *Swivel vise.* The vise is made in two parts. The top part can be turned in a complete circle. The base is divided into 360°. The jaws can be set to any angle.



iv. *Universal Vise.* If the vise, apart from being swivelled in the horizontal plane, can also be tilted in the vertical plane, it is called as "Universal Vise". It is used for milling compound angles.



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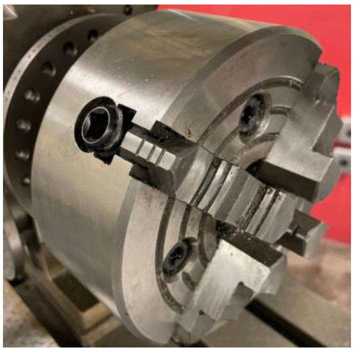
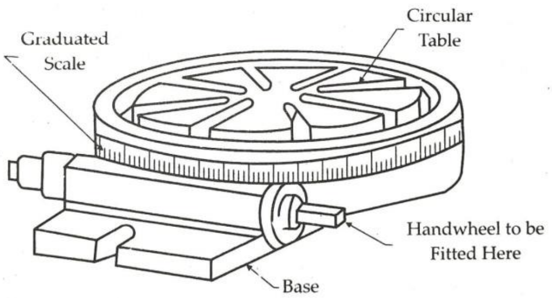
v. *Universal chuck.* It is used to hold round workpieces and is used mostly on the dividing head.



vi. *Rotary table.* The rotary table is constructed of two pieces and is attached to the machine table via T-bolts. The base is divided into sections that allow the workpiece to rotate in a complete circle.



vii. *Dividing head.* The dividing head is a device that holds and turns the workpiece in order to make a series of evenly spaced divisions or cuts around it.

viii. Work may also be held in various types of milling fixtures.

CLAMPS

Many Jobs, on account of their shape, size and weight, etc., cannot be conveniently held in Vices. Such components are directly secured to the machine table by means of **Clamps, Straps, Jacks, Step blocks and clamping bolt etc**. All these Straps and Clamps carry a long hole, through which passes the clamping bolt.

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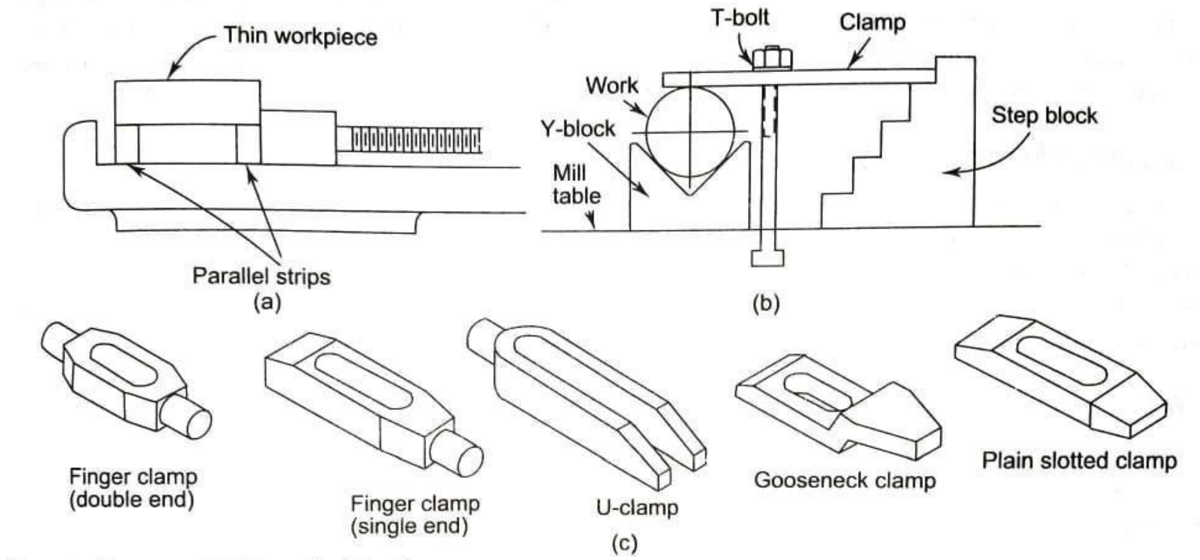


Fig. *Common work-holding methods in milling*

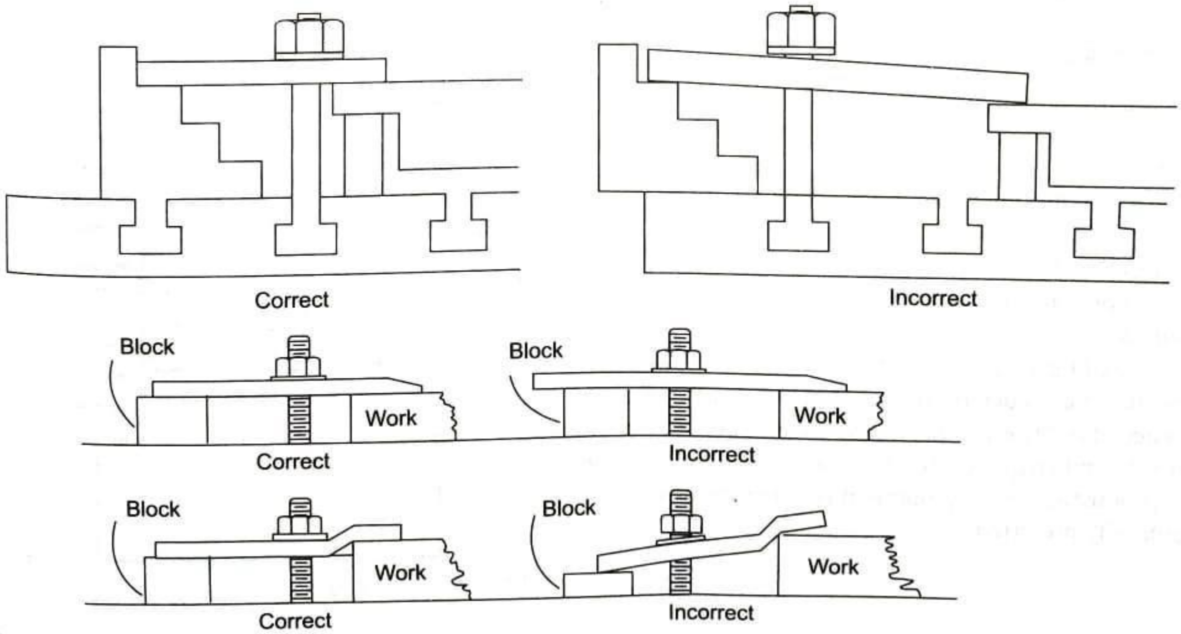


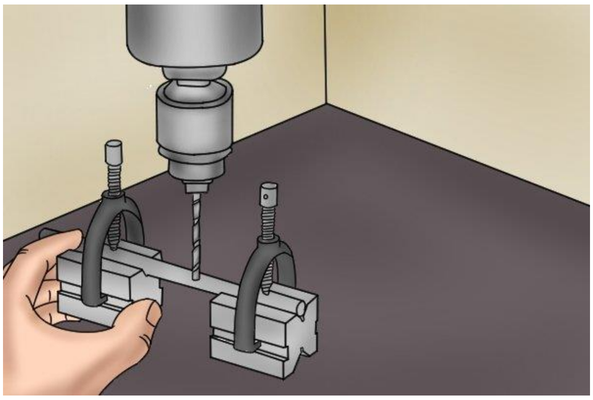
Fig. *Work-holding principles in milling*

ANGLE PLATES AND V-BLOCKS

Occasionally it may be required to mill the surfaces of a work piece at right angles. This operation can be very conveniently performed by holding the work piece on an Angle plate, which is secured to the machine table.

`

Solid cylindrical work which is not centred, such as a Shaft, can be held in V-blocks for milling Keyways, Slots and Flats, etc., on it. Usually two or more V-blocks are used simultaneously to support the work, depending upon the latter’s length. The work is firmly held in position by means of the Strap clamps and Blocks.



CHAPTER 4

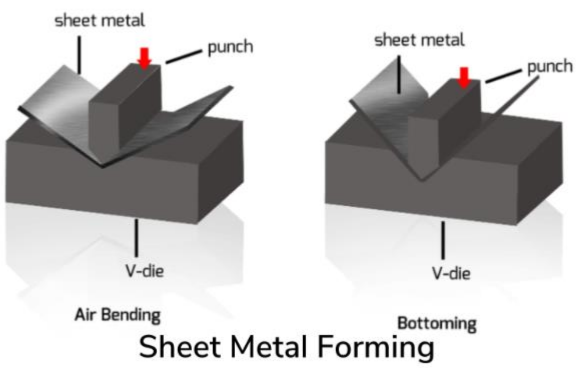
PRESS WORKING

- Press working refers to applying pressure or force to metal workpieces (usually sheet metals) to cause them to deform to the required size. The press is a metal-forming device that can cut or shape metal using pressure or force.
- A press machine uses a ram to push a punch down onto a workpiece placed on a die, applying force to cut or form the metal.

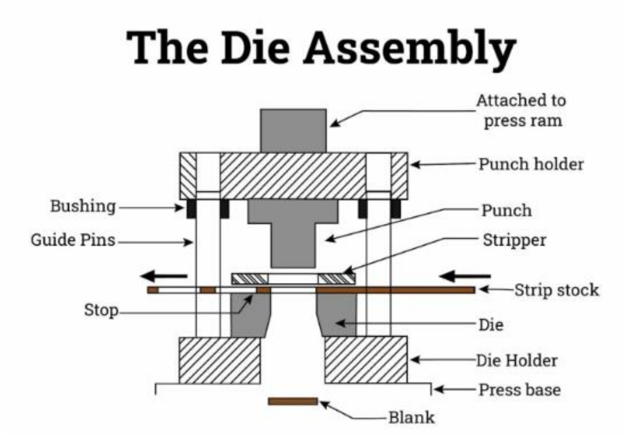
Common operations:

- **Cutting:** Blanking, punching, piercing, notching, and lancing.
- **Forming:** Bending, drawing, and squeezing.

- Basically, the process of press working consists of shearing out and plastically deforming the metal to the desired finished shape and size through a few quick strokes under heavy loads.



- Presses are generally employed in mass production of identical components.
- It is a metal working process, where each new dissimilar component required a new shape of tools.



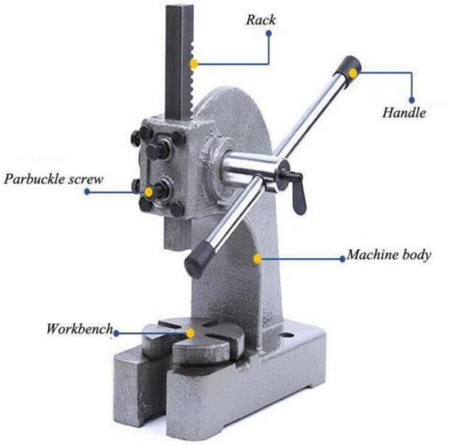
- One of the manufacturing techniques that is virtually chip-free is metal shaping.
- Tools used are costlier. So press working is suitable for mass production.
- Usually avoided where the production of items are small in numbers and particularly when they are dissimilar.
- Much faster production than metal cutting .
- Widely used in telephone industries, aircraft industries, radio industries, electrical goods manufacturing industries, etc.

TYPES OF PRESSES

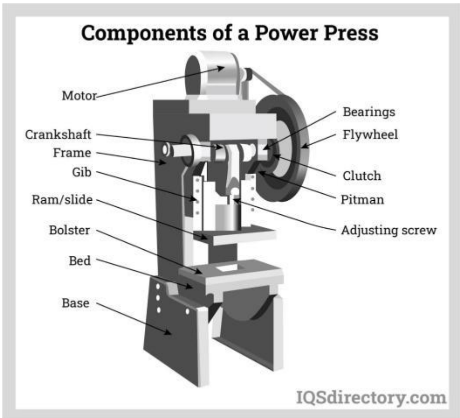
Presses classified on the basis of source of power

(i). **Mechanical presses**. A **mechanical press** is a machine tool used to **shape or cut metal** by applying mechanical force with the help of a **mechanical drive mechanism** (such as a flywheel, crankshaft, or eccentric). It converts the **rotary motion of a motor** into **reciprocating motion of a ram or slide**, which performs the pressing operation. (5 to 100 tons capacity)

(ii). **Manual Presses.** These are either hand or foot operated through levers, screws or gears. A common press of this type is the arbor press used for assembly operations. Capacity ½ to 10 tons.



(iii). **Hydraulic Presses.** A **hydraulic press** is a machine that uses **hydraulic pressure** to generate a **compressive force** for shaping, forming, pressing, or assembling materials.These presses have better performance and reliability than mechanical Presses.



(iv). **Pneumatic/Power Presses.** These presses utilize air cylinders or motor power to exert the required force. These are generally smaller in size and capacity than hydraulic or mechanical presses, and therefore find use for light duty operations only.

Comparison between **mechanical presses** and **hydraulic presses**

S.No.	Mechanical Press	Hydraulic Press
1	Power is transmitted mechanically through **crank, eccentric, or mechanisms**.	Power is transmitted by **hydraulic pressure** using fluid in cylinders.

S.No.	Mechanical Press	Hydraulic Press
2	Stroke length is usually **short.**	Stroke length is **long**, **variable and adjustable**.
3	Delivers **maximum force near the bottom** of the stroke. (50MN Max)	Delivers **maximum force throughout** the stroke. (500 MN or more)
4	**Faster operation**, suitable for high-speed production.	**Slower operation**, suitable for deep drawing and forming.
5	Limited control over speed and pressure.	Precise control over **force, speed, and stroke**.
6	Best for **blanking, punching, and shallow forming** operations.	Best for **deep drawing, molding, and forging** operations.
7	Generally **less expensive** for small sizes.	**More expensive** due to hydraulic components.

Presses classified on the basis of number of slides

(i) **Single Action Presses**: A **Single Action Press** is a type of mechanical press in which the **ram (or slide)** moves through one complete stroke — **one downward and one upward motion** — for each operation. It performs **one pressing action per stroke**.

(ii) **Double Action Presses**: A double-action press is an industrial machine featuring two independent slides or rams that apply force to a workpiece, typically in opposite or sequential directions. The two actions provide greater control and precision, making them ideal for complex metal-forming operations like deep drawing.

- **The outer ram (blank holder):** First, this ram descends to hold the sheet metal blank securely against the die. This controlled clamping action prevents the material from wrinkling or tearing as it is stretched.
- **The inner ram (punch):** While the outer ram holds the blank, the inner ram descends to press the material into the die cavity, forming it into the desired shape.

(iii). **Triple Action Presses:** There are **three moving slides** in a triple action press. **The third or lower slide moves upward** through the fixed bed in a direction opposite to that of the other two slides.

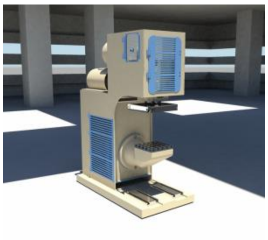
<u>Presses classified on the basis of frame and construction</u>

(i). **Arch-Frame Presses**. The frames of these presses are shaped like arches

(ii). **Gap Frame Presses**. The frame of these presses is C-shaped.

(iii). **Straight Side Presses**. These presses are more durable because the large side frame can support huge weights in a vertical direction.

(iv). **Horn Presses**. Instead of the typical bed, these presses typically feature a large shaft protruding from the machine frame. This press is mostly used to punch, rivet, emboss, and flange edges on cylindrical items.



<u>Presses classified on the basis of the drive mechanism</u>

(i) Crank (ii) Eccentric (iii) Rack and pinion (iv) Screw (v) Toggle drive

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Presses classified on the basis of the uses

(i) Shearing (ii) Punching (iii) Coining (iv) Stretching (v) Extruding (vi) Straightening (vii) Bending etc.

SPECIFICATION OF PRESSES

For selection of a press, specification is needed. The specification of a press involves the following parameters:

(i). **Length of stroke.** The length of stroke is defined as the distance between up and down position the ram

(ii). **Shut height.** The shut height is defined as the distance between the top of the bed to the bottom of the ram.

(iii). **Die space.** The die space is defined as the available area for mounting the punch and dies components in the press.

(iv). **Press adjustment.** The press adjustment means the capability of press to adjust the length of stroke as per need.

(v). **Number of ram head.** The number of ram heads provided for simultaneous operations i.e. single- acting, double-acting or multiple-acting.

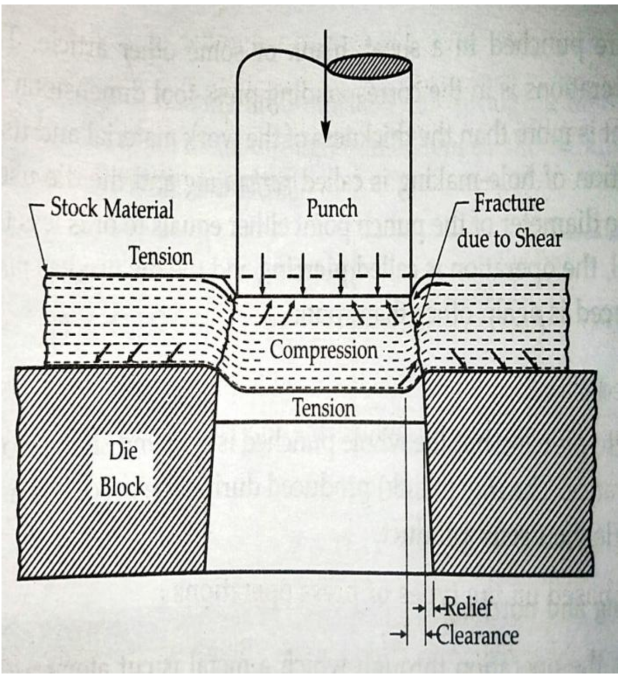
(vi). **Amount force or press.** The size of any press is determined by the maximum force or pressure that can be exerted by the ram on the work piece without any failure.

(vii). **Capacity of working.** The capacity of mechanical presses ranges from 50 tons to 4000 tons. The capacity of a hydraulic press ranges from 100 tons to 40,000 tons

There are many factors for selection of a Press based on the application :(i) Work piece material, (ii) Work piece size, (iii) Work piece thickness, (iv) Operations to be performed, (v) Operational speed required, (vi) Production rate, (vii) Power required, (viii) Dimensional tolerances and accuracy required for parts, (ix) Die types i.e., single, compound or progressive type etc.

PRESS WORKING OPERATIONS

- When the punch is forced into the die, the metal between the two cutting edges is stressed in shear to the fracture point, resulting in the separation of the blank from the parent metal.
- Both tensile and compressive stresses act on the metal, stretching it to beyond its elastic limit. This results in plastic deformation and reduction of area and ultimately fracture of metal along the planes in the reduced area.



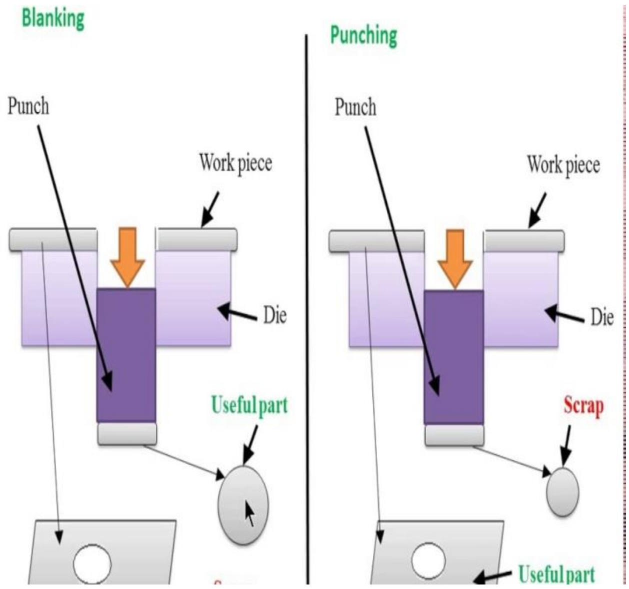
- The maximum concentration of the stresses is at the edges of the punch and the die. If the clearance between the punch and the die is correct, the cracks emanating from the edges of the two will meet and a clean edge will be produced, otherwise a ragged edge will result on the blank.
- Optimum clearance. It is that value of the clearance which is just sufficient to enable production of a blank with a clean edge. The clearance between two shears is one of the major factors controlling a shearing process. This clearance depends on the material and thickness of sheet metal.

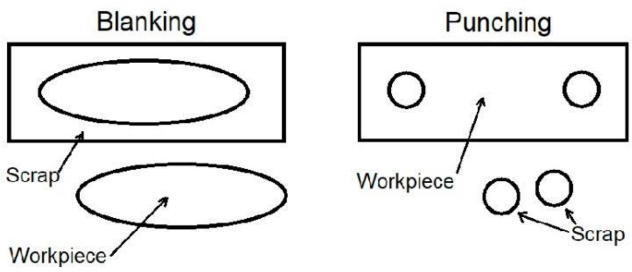
SHEET METAL CUTTING OPERATIONS

In this press work process, the sheet metal is subjected to tensile and compressive stresses to break/shear its structure and separate it into different parts.

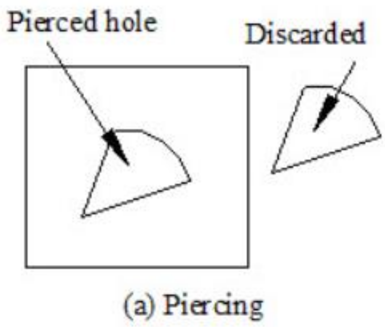
1. **Blanking**: It is a process in which the punch removes a portion of material from the stock, which is a strip of sheet metal of the necessary thickness and width. The removed portion is called a blank and is usually further processed to be of some use. The sheet metal carrying the hole is a waste.

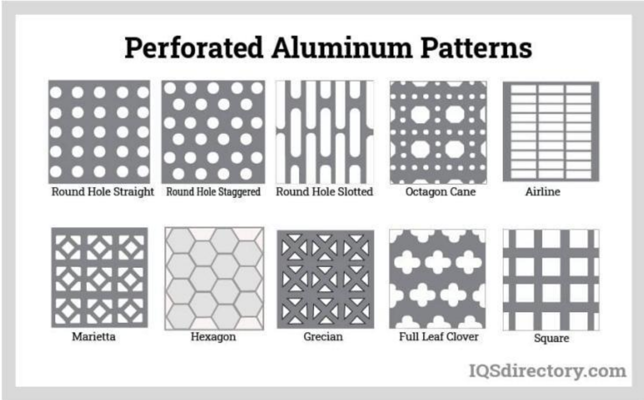
2. **Punching:** It is similar to piercing but the **hole punched is of round shape**. The blank produced during the process is a waste and the metal carrying the hole is the useful product.





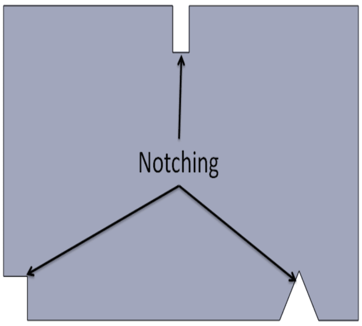
3. **Perforating and piercing:** They both are similar operations in that they are used for producing holes. The metal punched out (blank) in this manner is the scrap.

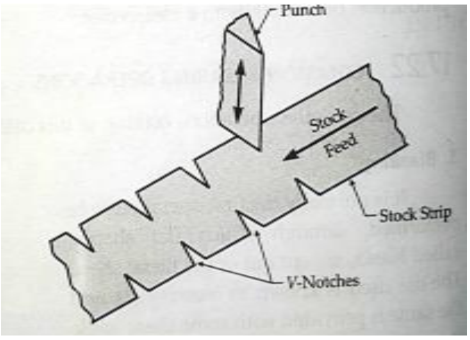




- When the diameter of the punch point is more than the thickness of the work material and its shape is other than round, the operation of hole-making is called **perforating.**
- Against this, if the diameter of the punch point either equals to or is less than the thickness of the work material, the operation is called **piercing.**

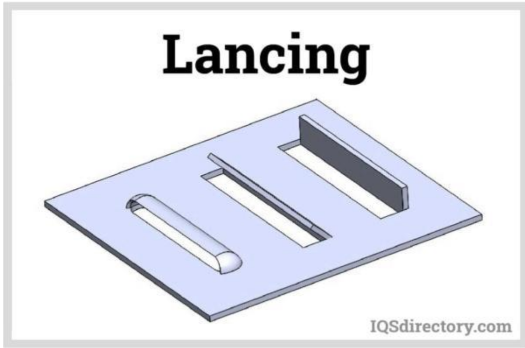
4. **Notching:** Notching is a **sheet metal cutting operation** in which a **small portion or notch is removed from the edge or corner of a metal or workpiece**. It is usually done **before bending or forming**, to allow clearance or to create specific shapes in the finished component.





5. **Lancing Operation**

   Lancing is a sheet metal cutting and forming operation in which the metal is **partially cut and bent in a single stroke of the press without removing any material from the sheet.**



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Process Description:

- ✓ The sheet metal is placed between the **die** and **punch**.
- ✓ The **punch descends**, shearing part of the material along a defined line.
- ✓ The **uncut portion acts as a hinge**, allowing the sheared section to **bend or lift** out of the plane of the sheet.
- ✓ The metal is **not completely separated** from the sheet.

Key Features:

- ❖ No scrap is produced.
- ❖ Combination of **shearing and bending**.
- ❖ Done in a **single press stroke**.
- ❖ Produces **dimensional accuracy** and **clean edges**.

Applications:

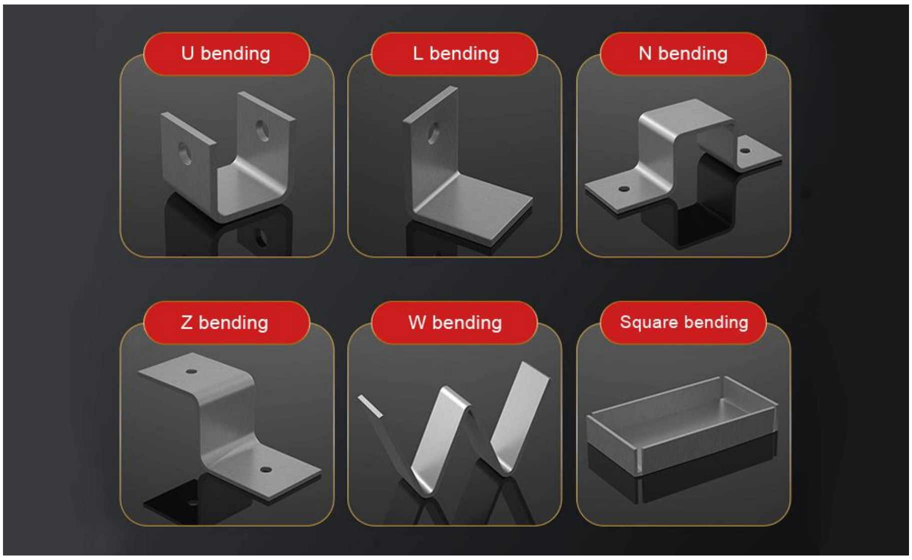
- ❖ Manufacturing **louvers**, **air vents**, and **locking features**.
- ❖ Used in **electrical panels**, **automotive components**, **air-conditioning covers**, and **machine guards**.

SHEET METAL FORMING OPERATIONS

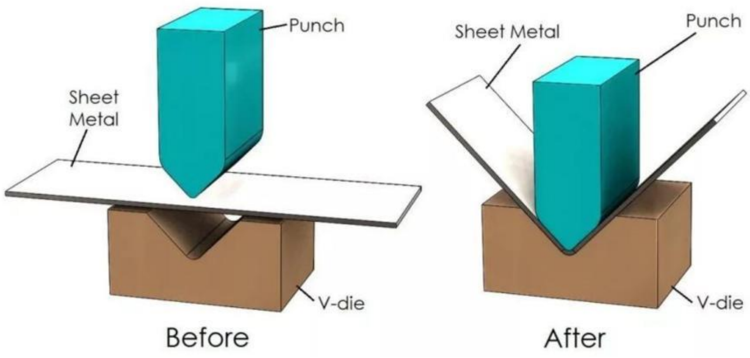
It is one of the most widely used processes that cause stress below the ultimate strength of the metal, which results in distortion.

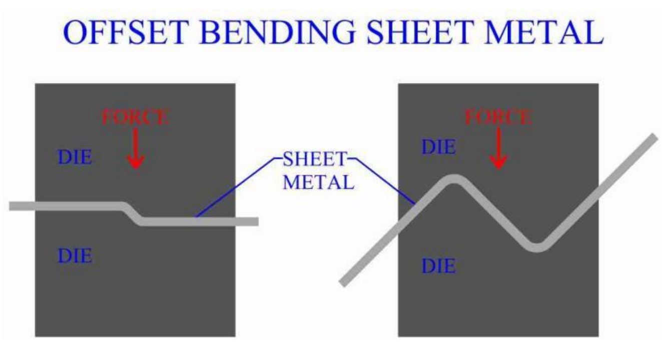
BENDING OPERATION

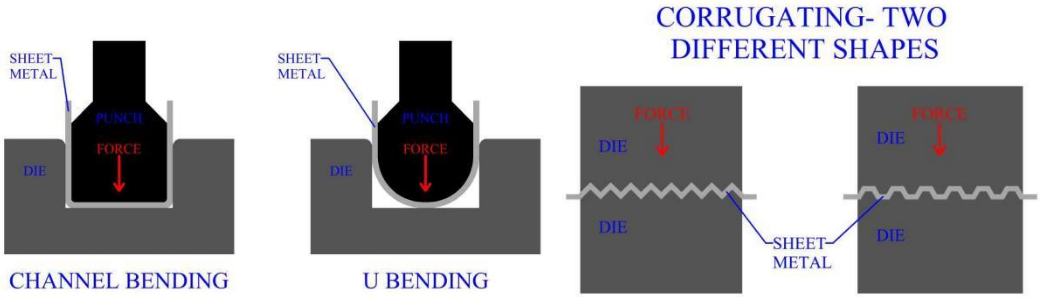
A sufficient amount of force is used in this operation **to bend the sheet metal into a curved shape**. **The metal's volume is kept constant** while its shape is altered during bending.



Bending is a **metal forming process** in which a force is applied to a sheet or strip of metal, causing it to **bend at an angle** and form a desired shape such as a **"V", "U", or channel.**







Different techniques can be used to bend sheet metal. Among the most common varieties are **v-bending, offset bending, channel bending, and edge bending.**

Objectives of Bending

- To change the shape of a workpiece without changing its volume.
- To produce components such as brackets, enclosures, channels, angles, and frames.

When a bending force is applied:

- The **outer surface** of the material is **stretched (tension)**.
- The **inner surface** is **compressed**.

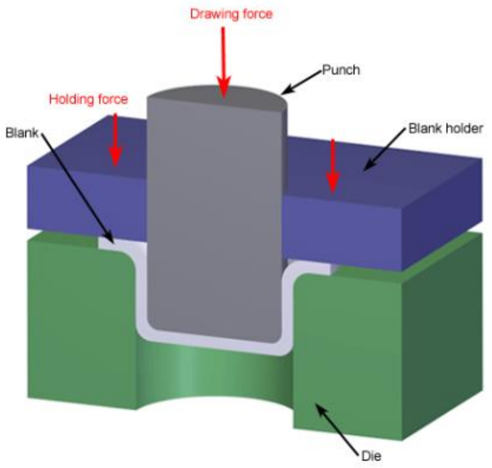
DRAWING OPERATION

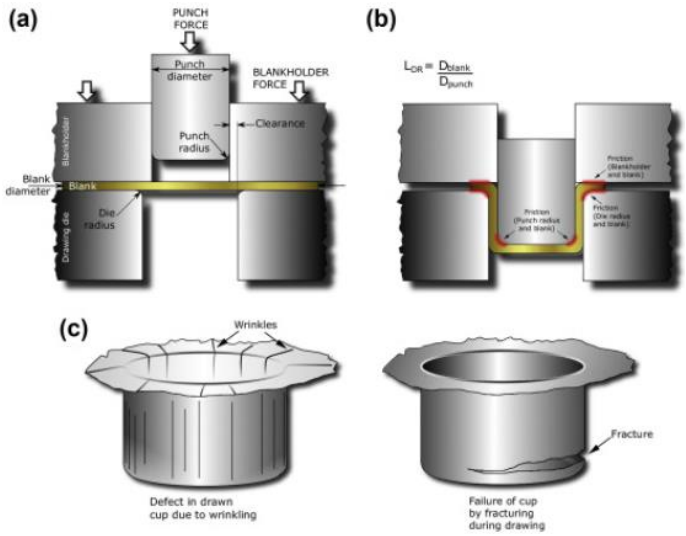
In the drawing process, a **blank** (flat circular metal sheet) is placed over a **die cavity**, and a **punch** pushes the sheet into the die. The material flows plastically over the die radius and forms the desired shape without wrinkling or tearing.

It is mainly used to produce **hollow, cup-shaped, or cylindrical parts** from flat sheets.

A simple **deep drawing setup** consists of:

- **Blank** – the flat sheet metal piece.
- **Punch** – pushes the blank into the die cavity.
- **Die** – provides the desired shape.
- **Blank holder (or pressure pad)** – prevents wrinkling of the flange.
- **Press machine** – provides the required force.





- **Shallow Drawing:**

  Depth of the part ≤ diameter of punch

  Used for cups, pans, etc.

- **Deep Drawing:**

  Depth > diameter of punch

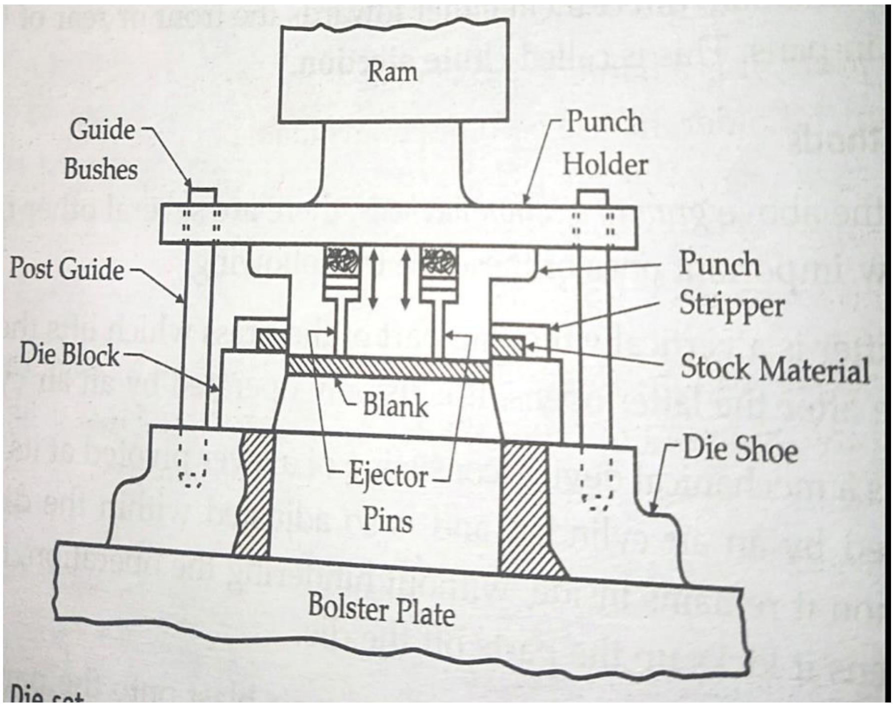
  Used for cans, shells, automotive panels, etc

DIE SET COMPONENTS

The commonly used tools on presses are punches and dies. A punch is usually that part of the unit which is fastened to the ram and is forced into the die. The die, which can be termed as the female part of the assembly, is normally rigidly held on the bed of the press. It carries an opening in perfect alignment with the punch, through which the punch enters into It. Both these parts work together as a unit and they known as a die set.

Die details and accessories:-

1. **Punch holder.** It is directly fastened to the ram of the punch press and holds the punch below it. It is also sometimes known as **upper shoe**.
2. **Punch.** The male member of the die assembly is called punch. It is made sufficiently strong and rigid from a hard and wear resistant material and accurately finished to provide just the required clearance between it and the die. It is secured to the ram or slide of the press.
3. **Die shoe.** It acts as a support for the die block and is fastened to the bolster plate of the press. It is also known as the **lower shoe** of the die set.
4. **Stops/Stock guide.** They are used for restricting the feed of the stock material to a pre-determined length each time, so that correct spacing may always occur. It used to **guide and position the strip (sheet metal stock)** accurately as it is fed into the tool during each stroke of the press.
5. **Guide posts.** They help in obtaining correct alignment of the punch and die shoe.
6. **Stripper.** It helps in freeing the punch from the blank in the return stroke, as the latter tries to cling to the former.



8. **Knock out pins.** They help in knocking away the sheared blank from the face of the punch.

9. **Punch plate**. It holds the punch in proper alignment with the die and is secured to the punch holder.

10. **Pilot**. A pilot is a hardened pin used in a **progressive press tool** to **locate the strip or sheet accurately** in each station of the die.
It enters the previously pierced hole in the strip to ensure proper alignment before the next operation (such as blanking) takes place. It also **Maintains pitch distance** between successive operations.

11. **Feed stock** is the **strip or sheet metal** that is **fed into the press tool** from which components are produced through cutting or forming operations.

PUNCH AND DIE CLEARANCES

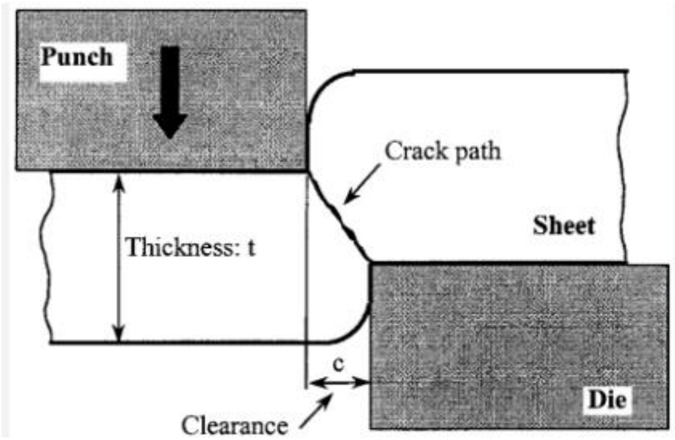
Clearance is the intentional gap provided between the **punch** and **die cutting edges** to ensure proper shearing of sheet metal during **blanking or piercing** operations.

Proper clearance is essential to:

- ✓ Produce **clean and accurate edges**
- ✓ Reduce **burrs and tool wear**
- ✓ Ensure **longer die and punch life**
- ✓ Avoid **excessive force** and **sheet distortion**

Clearance depends mainly on:

- ➢ **Type of material**
- ➢ **Material thickness**
- ➢ **Material hardness**



Determination of the punch and die clearance value

1. **The** value of ***c*** can be calculated according to the following punch and die clearance formula

$$c = (t - h_0)\tan\beta = t(1 - h_0/t)\tan\beta.$$

Where, h_0 – Punch penetration depth;

β - The angle between the maximum shear stress direction and the vertical direction.

The gap c is related to the material thickness t, the relative penetration depth h_0/t and the crack direction β.

The die clearance value increases with the hardness or thickness of the material.

2. Punch and die clearance is the distance between the punch and die cutting edges, calculated as a percentage of the material's thickness.

How to calculate clearance

Use the formula:

A common formula is **Clearance = Material Thickness × Clearance Coefficient.**

Find the clearance coefficient:

This value depends on the material.

- For softer materials like aluminum and brass, the coefficient is typically between 5% and 10% of the material thickness.
- For mild steel, a common range is 8% to 10% of the material thickness.
- For harder materials like stainless steel, it's higher, often around 18% to 24%.

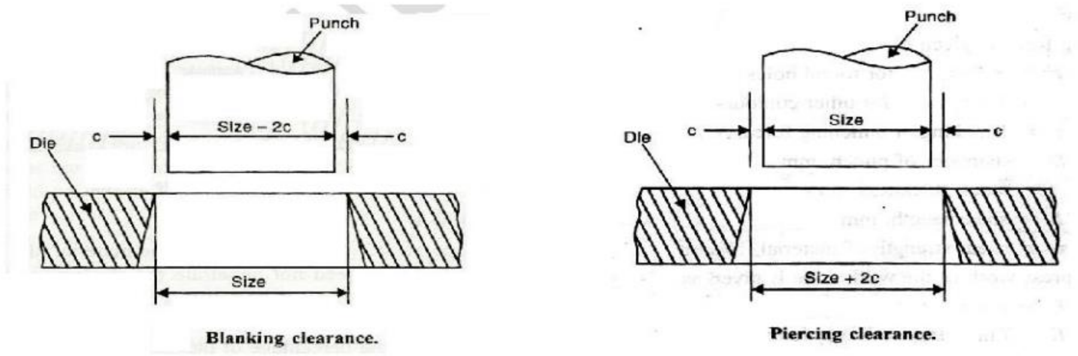
Use a chart:

Many manufacturers provide charts with specific clearance values for different materials and thicknesses, which can simplify the process.

Punch vs. die clearance in blanking and piercing

In blanking, the die is the final size, clearance is provided on the punch and punch size is obtained by subtracting the clearance from the die opening size

- Die Size = Blank Size
- Punch Size = Die Size - (2 × Clearance)



In piercing, the punch is the final size, clearance is provided on the die and the die opening size is obtained by adding clearance to the punch size

- Punch Size = Hole Size
- Die Size = Punch Size + (2 × Clearance)

EFFECT OF CLEARANCE IN BLANKING AND PIERCING

Correct clearance ensures a smooth shear, reduces burrs, and lowers the blanking force, extending tool life and improving part accuracy.

The consequences of inadequate clearing include: (i) secondary shearing (ii) an increase in punching force and (iii) a reduction in mould life.

Clearance Condition	Effect on Edge Quality
Too Small Clearance	High cutting force, rapid punch wear, rough and burred edge
Optimum Clearance	Smooth cut, minimal burr, best dimensional accuracy
Too Large Clearance	Poor edge quality, tapered hole or blank, large burr

Effect on Cutting Force

- ✧ **Small clearance → higher cutting force** required.
- ✧ **Large clearance → lower cutting force**, but **poorer edge quality**.

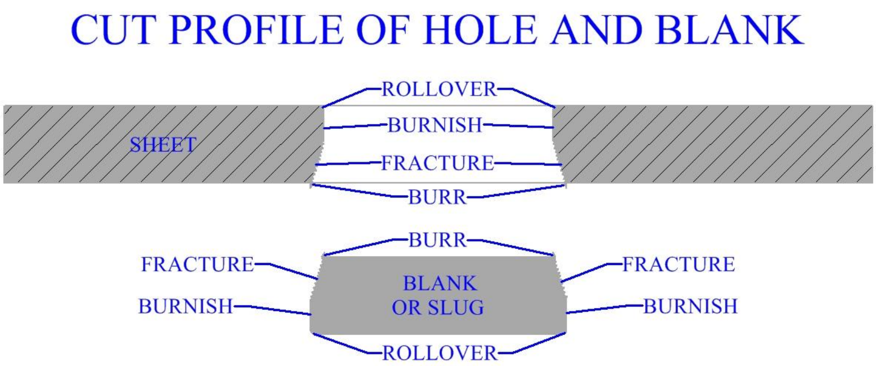
Effect on Tool Life

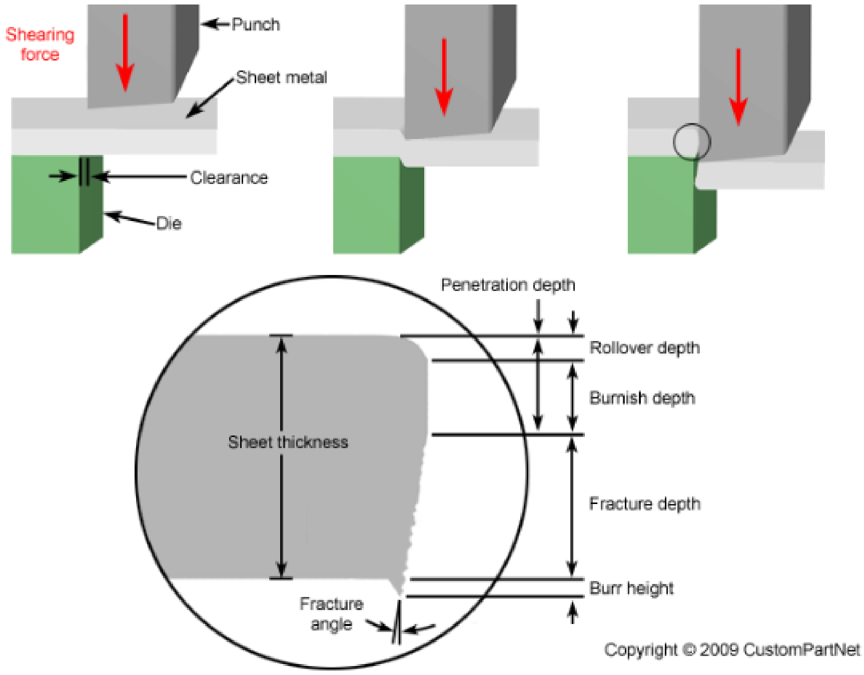
- ✧ **Too small clearance** causes high friction → **tool wear and chipping**.

- ✧ **Optimum clearance** ensures long **tool life**.
- ✧ **Too large clearance** → uneven load → **edge damage** and **distortion**.

Parameter	Too Small Clearance	Optimum Clearance	Too Large Clearance
Cutting Force	High	Moderate	Low
Edge Finish	Rough	Smooth	Rough
Burr	Medium	Minimum	Large
Tool Life	Short	Long	Short
Dimensional Accuracy	Poor	Good	Poor

secondary shearing: When the clearance is too small, the fracture lines do not align and meet. The remaining material between the misaligned fracture lines must then be subjected to further stress and a second shearing action as the tooling continues to move through the material. This extra work creates the secondary shear defect.




Shearing force
Punch
Sheet metal
Clearance
Die
Penetration depth
Rollover depth
Burnish depth
Sheet thickness
Fracture depth
Burr height
Fracture angle
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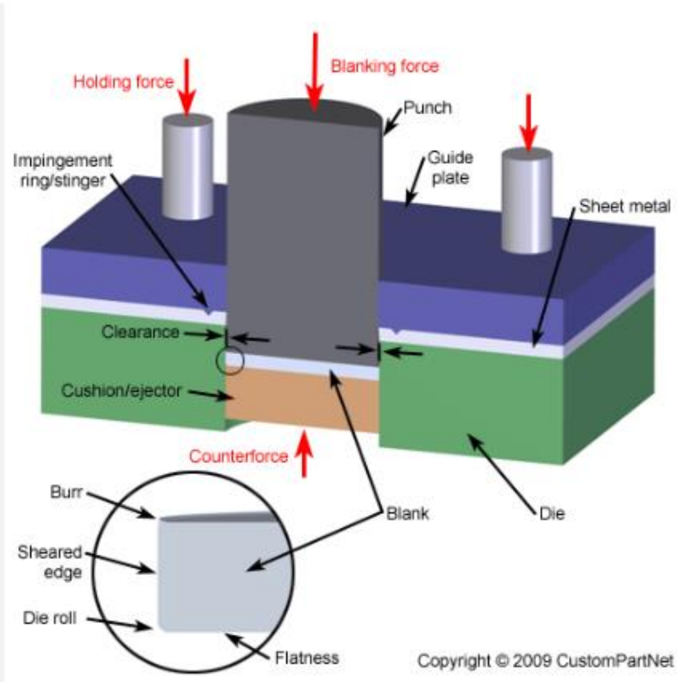
Holding force
Blanking force
Punch
Impingement ring/stinger
Guide plate
Sheet metal
Clearance
Cushion/ejector
Counterforce
Burr
Sheared edge
Die roll
Blank
Die
Flatness
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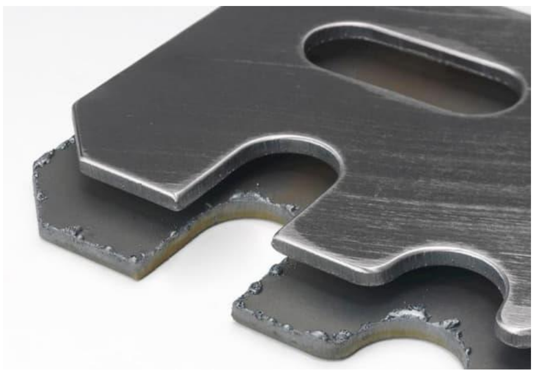


CHAPTER 5

GRINDING AND FINISHING PROCESSES

PRINCIPLES OF METAL REMOVAL BY GRINDING

- Grinding is a process of removing material by the **abrasive action of a revolving wheel** on the surface of a workpiece, in order to bring it to the **required shape and size.**
- The wheel used for performing the grinding operation is known as **'Grinding Wheel'**. It consists of **sharp crystals, called abrasive**s, held together by a **binding material or bond**.
- The wheel may be a **single piece** or solid type or may be composed of several segments of **abrasive blocks joined togethe**r.
- In most cases, Grinding is a **finishing operation** and a very small amount of material is removed from the surface during the operation.

THE GRINDING WHEEL

A grinding wheel is a **multitooth cutter** made up of **many hard particles** known as abrasives which **have sharp edges which do the cutting.**

The abrasive grains are mixed with a **suitable bond**, which acts as **a holder** when the wheel is in use. The abrasive wheel is usually mounted on some form of machine adapted to a particular type of work.

ABRASIVES

An abrasive is a substance that is used for **grinding and polishing** Operations. Abrasives may be classified in two groups :

1. Natural. 2. Artificial

1. **Natural:** The natural abrasives include **sandstone or solid quartz, emery, corundum, and diamonds.**

- Both emery and corundum have a greater hardness and better abrasive action than quartz.

- Diamonds of less than gem quality are crushed to produce abrasive grains for making grinding wheels to grind cemented carbide tools.
- As a result of the impurities in and lack of uniformity of these natural abrasives, only a very a small percentage of grinding wheels are produced from natural abrasives.

2. Artificial: Artificial or manufactured abrasives include chiefly (a) silicon carbide, and (b) aluminium oxide.

Silicon carbide (SiC) abrasive is manufactured by heating silicon sand, powdered coke, salt, and saw dust in an electric furnace.

- Silicon carbide follows the diamond in order of hardness, but it is not as tough as aluminium oxide.
- It is used for grinding materials of **low tensile strength** such as **cemented carbides, stone and ceramic materials, gray cast iron, brass, bronze, copper, aluminium,** etc.
- The abrasive wheels are denoted by **'S'.**

Aluminium oxide (Al_2O_3) manufactured by heating mineral bauxite, a hydrated aluminium oxide clay containing silica, iron oxide, titanium oxide, etc., mixed with ground coke in an electric furnace.

- Aluminium oxide is tough and not easily fractured.
- so it is better adopted to grinding materials of high tensile strength, such as most **steels, carbon steels, high speed steels, malleable iron, wrought iron, tough bronzes.**
- The wheels are denoted by **'A'**.

BONDS AND BONDING PROCESSES

A bond is an adhesive substance that is employed to hold abrasive grains together. Bonding materials and processes are :

1. **Vitrified bond used for making verified grinding wheels.**
2. **Silicate bond for making silicate wheels.**

3. **Shellac bond for making elastic wheels.**
4. **Resinoid bond used for making resinoid wheels.**
5. **Rubber bond used for making vulcanized wheels.**

These bonds may be used with either silicon carbide or aluminium oxide.

<u>Vitrified bonding process</u> : Verified wheels are made by bonding **clay melted to a glass like consistency with abrasive grains**.

✧ The **clay and abrasive grains** are thoroughly **mixed together with sufficient water** to make the mixture uniform. The fluid mixture is then poured into sandmould and allowed to dry.

✧ When it has dried to a point where it can be handled, the material is cut to more perfect size and shape. It is then heated or **burned in a furnace** in much the same manner as brick or tile is burnt.

✧ When the burning proceeds, **the clay vitrifies** ; that is, **it fuses and forms a porcelain or glasslike substance** that surrounds and connects the abrasive grains.

✧ Vitrified bond gives a wheel good strength as well as porosity to allow high stock removal while cutting.

✧ About 75 per cent of the wheels now manufactured are made with this bond. A vitrified bonded wheel is denoted by the letter **'V'**.

<u>Silicate bonding process</u> : Silicate wheels are made by mixing abrasive grains with **silicate of soda or water glass.**

➢ The mixture is packed into moulds and allowed to dry. The moulded shapes are then backed in a furnace at a temperature of 260°C for several days.

➢ The silicate bond **releases the abrasive grains more readily** than the vitrified bond and silicate wheels are **waterproof.**

➢ These characteristics make silicate wheels valuable for **grinding edged tools** and other operations **where heat must be held to a minimum** with or without the aid of a coolant.

➢ A silicate bonded wheel is denoted by the letter **'S'.**

Shellac bonding process : Shellac bonded wheels are also known as **elastic bonded wheels**.

- In this process, the abrasive and shellac are mixed in heated containers and pressed in heated moulds. Later the shapes are backed a few hours at a temperature of approximately 150^0C.
- The elasticity of this bond is greater than in other types and it has considerable strength.
- It is not intended for heavy duty. Shellac bond is used for finishing chilled iron, cast iron, aluminum pistons, and in very thin sections.
- A shellac bonded wheel is denoted by the letter **'E'**.

Resinoid (Bakelit) bonding process: Resinoid wheels are produced by mixing abrasive grains **with synthetic resins**.

- The mixture is placed in moulds and heated at about 200^0C. At this temperature, the resin sets to hold the abrasive grains.
- Wheels bonded with synthetic resin, such as Bakelite are used for purposes which require a strong and high speed wheel. They can remove stock very rapidly.
- A resinoid bonded wheel is denoted by the letter '**B**'.

Rubber bonding process : Rubber bonded wheels are prepared by mixing abrasive grains with pure rubber and sulphur.

- The mixture rolled into sheets, and wheels are punched out of the sheets on a punch press. Following that, the wheels are vulcanized.
- Rubber bonded wheels are less heat resistant and more dense. They are strong and tough enough to make extremely thin wheels.
- They are used where good finish is primary requisite.
- A rubber bonded wheel is denoted by the letter '**R**'.

Oxychloride bonding process : This process consists of mixing abrasive grains with oxide and chloride of magnesium. The mixing of bond and abrasive is performed in the same way as for vitrified bonded wheel.

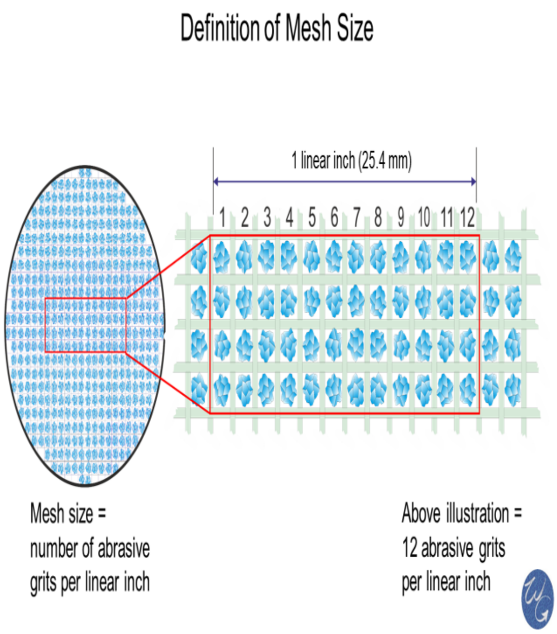
An oxychloride bonded wheel is denoted by the letter 'O'.

GRIT, GRADE AND STRUCTURE OF WHEELS

GRITS:

The grain or grit number indicates **the size of the abrasive grain**s used in making a wheel.

Grain size is denoted by a number indicating **the number of meshes per linear inch** (25.4 mm) of the screen through which the grains pass when they are graded after crushing.



The following list ranging from very coarse to very fine, includes all the ordinary grain sizes commonly used in the manufacture of grinding wheels:

COMMON ABRASIVE GRAIN TYPE AND SIZE

	Grain size or grit						
Coarse	10	12	14	16	20	24	
Medium	30	36	46	54	60		
Fine	80	100	120	150	180		
Very fine	220	240	280	320	400	500	600

The size of abrasive grain required in a grinding wheel depends on the amount of material to be removed, the finish desired, and the hardness of the material being ground.

In general, **coarse wheels are used for fast removal of materials**. Fine grained wheels are used for soft, ductile materials and can be used to grind hard, brittle materials.

GRADE:

The term 'grade' as applied to a grinding wheel refers to the **tenacity or hardness** with which the bond holds the cutting points or abrasive grains in a place. It does not refer to the hardness of the abrasive grain.

The grade shall be indicated in all bonds and process by a letter of the English alphabet, **A denoting the softest and Z the hardest grade**. The term 'soft' or hard' refers to the resistance a bond offers to disruption of the abrasives.

A wheel from which the abrasive grains can easily be dislodged is called soft, whereas one which holds the grains more securely is called hard, the grades are denoted as:

GRADE OF GRINDING WHEELS

Soft	A	B	C	D	E	F	G	H		
Mediums	I	J	K	L	M	N	O	P		
Hard	Q	R	S	T	U	V	W	X	Y	Z

The grade of the grinding wheel depends on the hardness of the material being ground, the wheel and work speeds and the condition of the grinding machine. **Hard wheels are recommended for soft materials and soft wheels for hard materials.**

STRUCTURE:

Abrasive grains are not packed in the wheel but are distributed through the bond. The relative spacing is referred to as the Structure and denoted by the number of cutting edges per unit area of wheel face as well as by number and size of void spaces between grains.

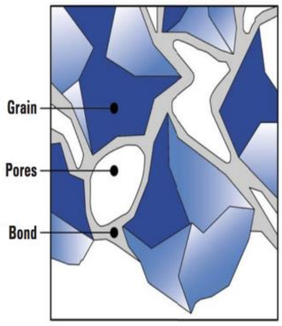


Figure 1: Structure of a grinding wheel

The primary purpose of structure is to provide chip clearance and it may be **open or dense.** The structure commonly used is denoted by numbers as follows

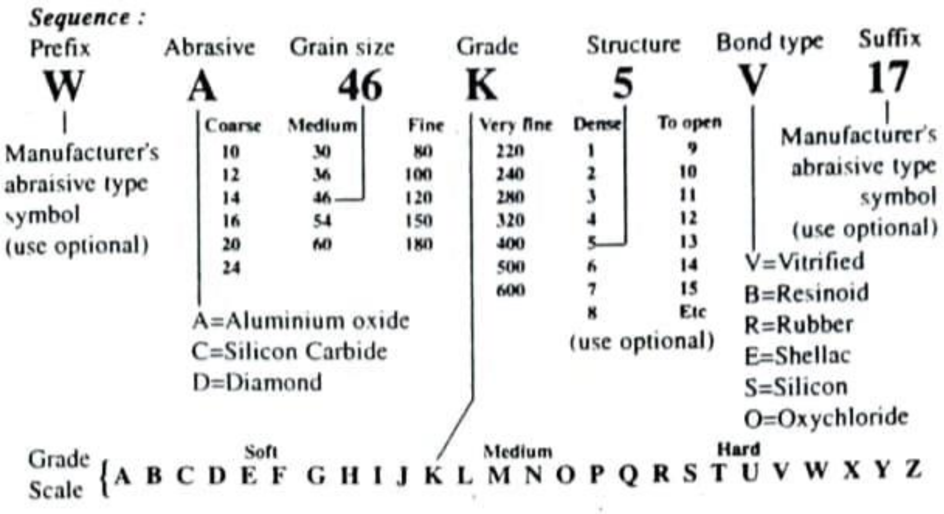
STRUCTURE OF GRINDING WHEELS

Dense	1	2	3	4	5	6	7	8
Open	9	10	11	12	13	14	15	higher

The structure of a grinding wheel depends on the hardness of the material being ground, the finish required, and the nature of the grinding operation.

Soft, tough and ductile materials and heavy cuts require an open structure, whereas hard and brittle materials are finishing cuts required a dense structure.

SPECIFICATION OF A GRINDING WHEEL:



Example:

250 x 25 x 32 W A 46 L 4 V 17

Wheel dia = 250 mm

Thickness of wheel = 25mm

Bore dia = 32mm

SELECTION OF GRINDING WHEELS

In selecting a grinding wheel there are four constant factors and four variables.

Constant factors	**Variable factors**
1. Material to be ground	1. Wheel speed
2. Amount of stock to be removed	2. Work speed
3. Area of contact Personal	3. Condition of the machine
4. Type of grinding machine	4. Personal factors

CONSTANT FACTORS:

1. **The material to be ground:** This influences the selection of (a) abrasive, (b) grain size, (c) grade, (d) structure, and (e) bond.

- Aluminium Oxide abrasive is recommended for materials of high tensile strength and silicon carbide for low tensile strength.
- **Fine grain is used for hard and brittle materials and coarse grain for soft ductile metals.**
- **Hard wheel is used for soft materials and soft wheel for hard materials.**
- Generally, **close spacing is required for hard and brittle materials and wide for soft and ductile.**

[Why Fine Grain for Hard & Brittle Materials?

1. Hard materials require small cutting edges

Hard materials (like hardened steel, carbide, glass) resist penetration.
A *large* coarse abrasive cannot easily dig into a hard surface → it will **glaze**, slide, or fracture.

A **fine grain** has:

- more cutting points per unit area
- smaller, sharper edges that can penetrate hard surfaces

2. Prevents cracking in brittle materials

Brittle materials crack under high cutting forces.
Coarse grains remove large chips → high stress → crack propagation.

Fine grains:

- produce small chips
- apply low cutting force

- avoid crack formation on the surface

Why Coarse Grain for Soft & Ductile Materials?

Soft metals (aluminium, mild steel, copper) **can be removed faster,** produce long, ductile chips.
Fine grains produce many small chips.

Coarse grains have larger chip space]

2. **Amount of stock to be removed:**

- **Coarse grain is used for fast cutting and fine grain for fine finish;**
- **Wide spacing for rapid removal and close for fine finish ;**
- **Select a vitrified bond for the highest rate of metal removal and a resinoid, rubber, or shellac bond for a good finish.**

3. **Area of contact:**

Fine grain and close grain spacing are useful where the area of contact involved is small, and coarse grain and higher grain spacing are employed where a large area of contact is concerned.

4. **Type of grinding machine:**

Heavy rigidly constructed machines take softer wheels.

VARIABLE FACTORS:

Wheel speed:

The higher the wheel speed with relation to work speed, the softer the wheel should be.

[When the wheel rotates faster, **more abrasive grains pass over the workpiece per second**. Since the workpiece speed remains the same, each grain removes **less material** per pass. Therefore, the individual cutting forces on each abrasive grain become **smaller**. When forces become too low, **dull grains remain stuck.]**

Work speed:

The higher the work speed with relation to the wheel speed, the harder the wheel should be.

(At higher work speed, the wheel encounters more force per grain. Increased cutting force tends to pull abrasive grains out of the wheel. A harder wheel holds grains more firmly.)

Condition of the grinding machine: The condition of the grinding machine has a hearing on the grade of the wheel to be selected. **Spindle loose in their bearings, and insecure or shaky foundations would necessitate the use of harder wheels.**

Personal factor: The skill of workman is another variable factor which should be considered in selecting the wheel, as, for instance on off-hand grinding, it can vary the grinding costs considerably on the same work in the same factory.

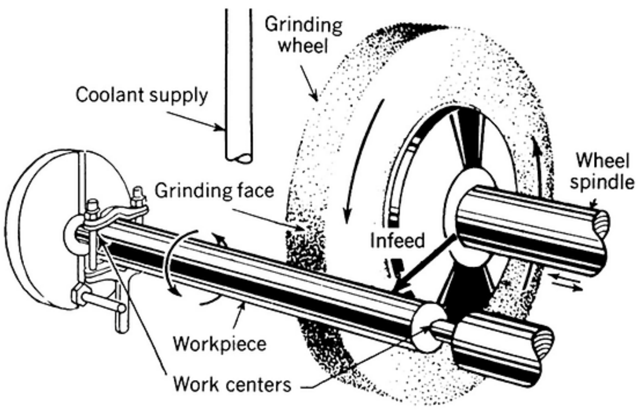
TYPES OF GRINDING MACHINES

An abrasive wheel-equipped machine tool known as a grinding machine is used to produce fine finishes or make slight cuts in metals and other materials. Machines for industrial grinding come in many different varieties. There are five different types of grinding machines: **cylindrical, internal, centerless, surface, and special.**

CYLINDRICAL GRINDERS

The principle of cylindrical grinding, involves holding the workpiece rigidly on centres, in a chuck or in a suitable holding fixture, rotating it about its axis and feeding a fast-revolving grinding wheel against the same.

If the **work surface is longer than the face width of the grinding wheel**, the **work is traversed past the wheel or the wheel past the work.** Traversing of wheel or work is done either by hydraulic or mechanical power or by hand.



Feed is given to the work or the wheel at the end of each traversing movement.

In case the width of wheel face is more or equal to the length of the work surface to be ground, the wheel may be fed in with no traversing movement of it or that of the work. This is known as **plunge grinding.**

Cylindrical grinding machines are mainly of the following three types:

1. Plain cylindrical grinders

2. Universal cylindrical grinders

3. Centreless grinders.

They all work on the common principle of cylindrical grinding, involving the following necessary basic movements:

1. The work must revolve.

2. The grinding wheel must revolve.

3. Either the wheel or the work must have a traversing movement past the other.

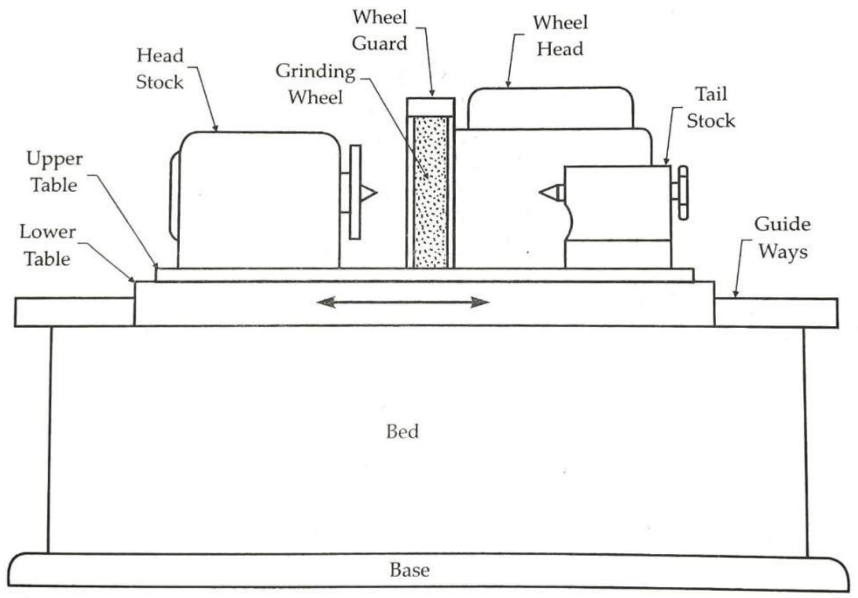
4. Either the wheel should be fed into the work or the work on to the wheel.

PLAIN CYLINDRICAL GRINDERS

- On these grinders, the workpiece is usually held between two centres. One of these centres is in the headstock and the other in the tailstock.
- In operation, the rotating work is traversed across the face of the rotating grinding wheel. At the end of each traverse, the wheel is fed into the work by an amount equal to the depth of cut.
- Tailstock and headstock both can be moved along the table to suit the work.
- The table is usually made in two parts. The upper table carries the tailstock, headstock and the workpiece

and can be swiveled in a horizontal plane, to a maximum of 10° on either side, along the circular ways provided on the lower table. This enables grinding of tapered surfaces.

- The lower table is mounted over horizontal guideways to provide longitudinal traverse to the upper table, and hence the work.
- The **wheel** head is usually mounted on horizontal cross ways **on the bed** and travels along these to feed the wheel to the work.



Block diagram of a Plain Cylindrical Grinder.

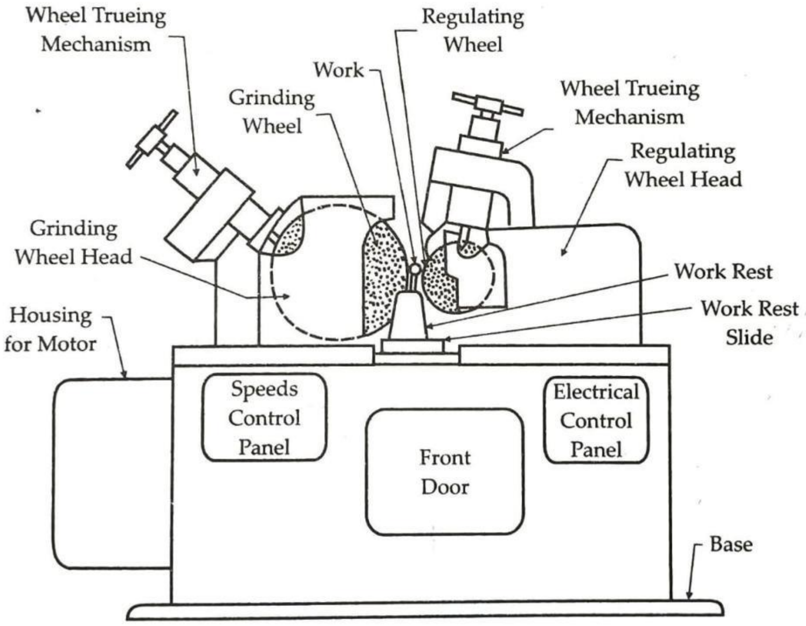
UNIVERSAL CYLINDRICAL GRINDERS

A Universal cylindrical grinder carries all the parts and movements of a plain cylindrical grinder and, in addition, carries the following advantageous features:

- Its headstock can be made to carry a live or dead spindle, as desired.
- The headstock can itself be swiveled in a horizontal plane.
- Its wheel head can be raised or lowered and can also be swiveled to 90° to grind tapered surfaces.

CENTRELESS GRINDERS

Here the work, instead of being mounted between centres, is supported by a combination of **a grinding wheel, a regulation wheel and a work rest blade**. The relative movements of the work-piece and the two wheels are shown in Fig.



Simplified diagram of a Centreless Grinder.

- It carries a heavy base and two wheel heads, one carrying the grinding wheel (larger one) and the other regulating wheel (smaller one).
- The workpiece rests on the blade of the work rest between these two wheels.
- Each head carries a separate wheel truing mechanism for the wheel it carries.
- Housing is provided on one side of the machine body to house the main driving motor. There are two control panels on the front. The left hand panel carries controls for speed adjustments of the two truing mechanisms and the infeed grinding mechanism. The right hand panel carries controls for hydraulic mechanism, speed adjustment of regulating wheel, start and stop switches, etc.
- In operation, grinding operation is performed by the grinding wheel only while the function of the regulating wheel is to provide the required support to the workpiece while it is pushed away by the cutting pressure of the grinding wheel.

✧ This helps the workpiece to remain in contact with the grinding wheel. At the same time, required support from bottom is provided by the workrest, as the workpiece while rotating, rests on the blade of the workrest.

✧ The directions of rotation of the two wheels are the same. The common methods used for feeding the work are :

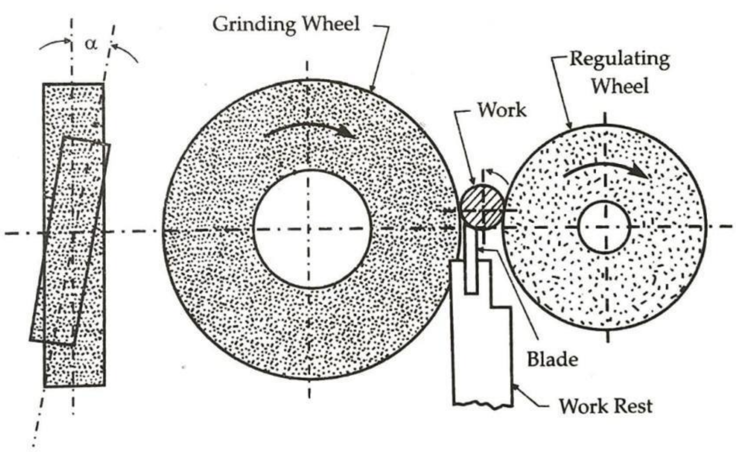
> Through feed

> Infeed

> End feed

1. Through feed grinding

In this method of centreless grinding, the workpiece is supported and revolved as described above but is simultaneously **given an axial movement** by the regulating wheel so as to pass between the wheels. For this, **the axis of the regulating wheel is inclined at 2 to 10 degrees with the vertical** (See angle α in Fig). The amount of stock to be removed determines as to how many time a workpiece has to pass between the wheels. This method is used for straight cylindrical objects.



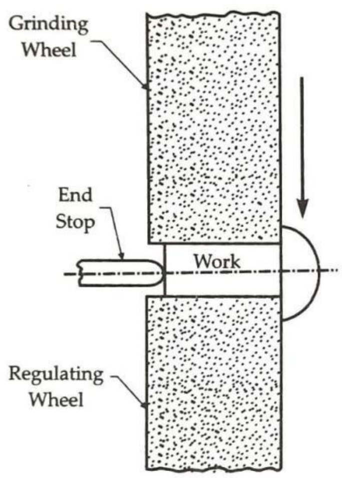
Principle of Through feed Centreless Grinding.

2. Infeed grinding

This method is similar to the plunge cut grinding method used on cylindrical grinders. **Both regulating and grinding wheels are more in width than the work length to be ground.**

Axis of the regulating wheel is inclined a little, say about **half a degree**, from the horizontal. This method is used for grinding shouldered or formed components.

In this operation, the workrest does not carry guides. Instead, it is made to have an end stop at the rear end, as shown in Fig.



Infeed Centreless Grinding.

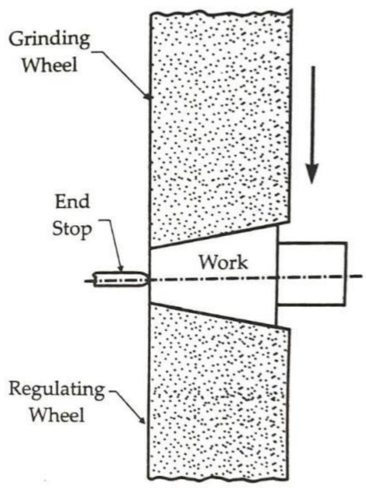


Fig. 12.20 End-feed Centreless Grinding.

3. End feed grinding

This method is, in a way, a sort of form grinding. It is because both the wheels, i.e., the grinding wheel and the regulating wheel, have the required shape or form. The workpiece is fed longitudinally from the side of the wheels. As it advances between the revolving wheels, its surface is ground till its farther end touches the end stop. This method can be used for grinding of both spherical and tapered surfaces.

Advantages of centreless grinding

i. Its high productivity, which is far higher than cylindrical grinding between centres, is the key benefit.

ii. The operator must possess less expertise.

iii. There is no noise or deflection of the work, and it is firmly supported.

iv. The work's size is reasonably manageable.

v. Less grinding set up is needed since a real floating state obtains during the grinding process.

Disadvantage of centreless grinding

i. Keyways and work with flats cannot be ground.

ii. Work with various diameters is difficult to handle.

iii. There is no guarantee that the exterior diameter and internal diameter of hollow work will be concentric.

iv. Changing over a centerless grinder to grind different diameters takes a lot of time. As a result, it may be used to large lot production more quickly

SURFACE GRINDERS

Surface grinders do almost the same operation as the planers, shapes or milling machines, but with more precision. Primarily they are intended to machine flat surfaces, although irregular, curved or tapered surfaces can also be ground on them. The common classification of surface grinders can be made as follows :

1. According to the table movement :

(a) Reciprocating table type.

(b) Rotary table type.

2. According to the direction of wheel spindles:

(a) Vertical spindle type.

(b) Horizontal spindle type.

3. Special type and single purpose machines :

(a) Face grinders.

(b) Way grinders.

(c) Wet belt grinders.

1. Reciprocating Table Type Surface Grinders

The principle of grinding, as applied to reciprocating table type surface grinders, is illustrated by means of the diagrams of relative movements in Figs. A reciprocating table type surface grinder may have a horizontal spindle of the grinding wheel or a vertical spindle of the same, as shown in Fig. The former will carry a straight wheel and the latter a cup type wheel. Hydraulic drives are commonly used in all such grinders. Cutting is done on the periphery of the straight wheel, in case of horizontal spindle type, and on the revolving edge of the cup wheel on vertical spindle machines. The horizontalspindle machines are widely used in toolrooms. The workpiece is usually held on a magnetic chuck on these machines. They are vastly used for grinding flat surfaces. The machine size is designated by the dimensions of the working area of the table.

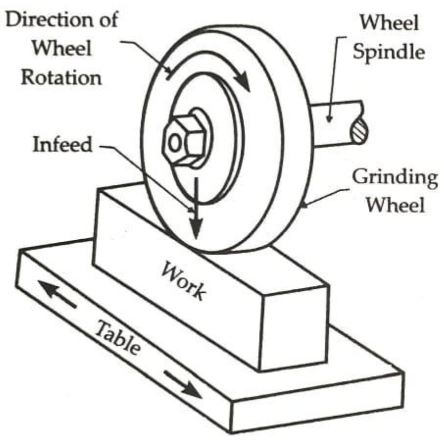


Fig. 12.21 Working principle of a Horizontal Spindle Reciprocating Table Surface Grinder.

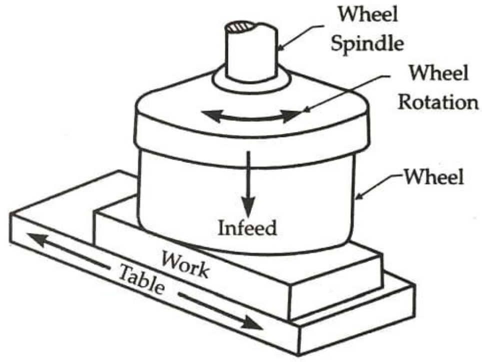


Fig. 12.22 Working principle of a Vertical Spindle Reciprocating Table Surface Grinder.

The longitudinal feed to the work is given by reciprocating the table. For giving crossfeed, there are two methods. One is to mount the table on a saddle and given the crossfeed by moving the saddle. Alternatively, the crossfeed can be given by moving the wheel-head in and out.

In case of vertical spindle reciprocating table grinders the table, alongwith the workpiece, reciprocates under the wheel. The wheel covers all or a major portion of the width of the job, as shown in Fig. 12.22. Crossfeed to the work can be given as usual by moving the saddle. A manual or power feed can be employed to feed the wheel-head vertically. An individual motor drive is usually provided to rotate the wheel.

2. Rotary Table Surface Grinders

Rotary table surface grinders are also made in two types, ie., either having a horizontal wheel spindle or a vertical wheel spindle. The relative movements of the wheel and table of a horizontal spindle type are shown in Fig. 12.24. Usually a circular shaped magnetic chuck is mounted on the circular table to hold the jobs. The workpieces are normally arranged in a circle, concentric with the round chuck. If it is a single piece, it can be mounted centrally on the chuck. The table is made to rotate under the revolving wheel, both rotating in opposite directions. The vertical feed to the wheel is given by moving the wheel-head along a column and the crossfeed by the horizontal movement of the wheel spindle. A straight wheel is used on these machines, which cuts on its periphery. Some machines carry the provision to raise or lower the table also, and also to incline the same.

Figure 12.25 illustrates the relative movements of the wheel and table of a Rotary table vertical spindle surface grinder. A cup wheel has to be used on these machines, as shown in the diagram. Vertical feed to the wheel is given by moving the wheel-head. The workpieces are mounted on the round chuck in the same way as in the horizontal spindle type. The table rotates in a direction

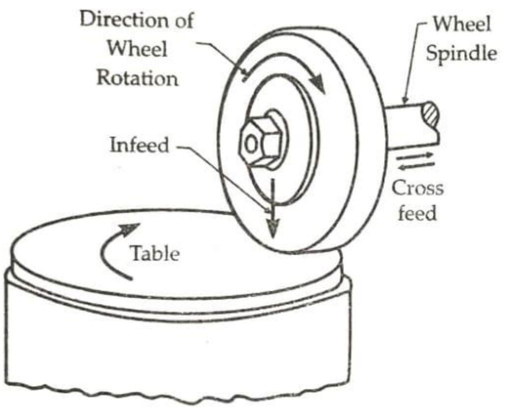


Fig. 12.24 Relative movements of different parts of a Horizontal Spindle Rotary Table Surface Grinder.

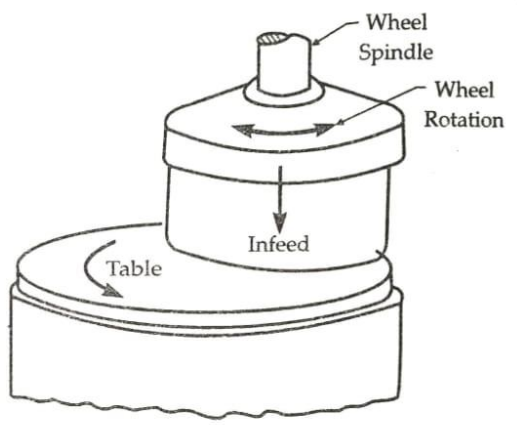


Fig. 12.25 Relative movements of different parts of a Vertical Spindle Rotary Table Surface Grinder.

opposite to that of the wheel and brings the workpieces one after the other under the rotating wheel. The table is usually mounted on a slide so as to give crossfeed.

Some rotary table surface grinders are provided with two tables instead of one so that, while the workpieces are being ground on the table, the other table can be used for loading the fresh batch of workpieces.

TOOL & CUTTER GRINDING MACHINES

A **Tool & Cutter Grinder** is a precision machine used to sharpen and recondition various cutting tools like drills, end mills, and milling cutters used in machining operations. These machines restore the cutting edges of tools to their original geometry, ensuring accurate machining and longer tool life.

They are used in aerospace, automotive, and tool manufacturing industries, where precision and consistency are important. They enable the reconditioning of worn-out tools and the creation of custom tool geometries, contributing significantly to the efficiency and accuracy of machining operations.

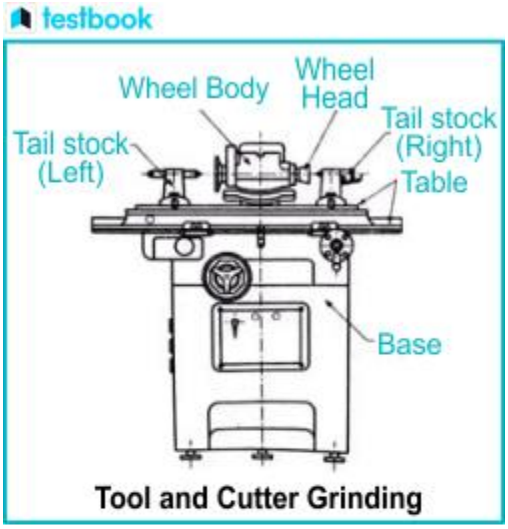
Tool & cutter grinders are used for:

- Sharpening milling cutters (end mills, side mills, face mills)
- Sharpening drills, reamers, taps, hobs
- Reconditioning lathe tools
- Forming special cutting tools

Parts of a Tool and Cutter Grinder

1. Base

- The foundation of the machine.
- Provides support to all other components.
- Made of cast iron for rigidity and vibration damping.



2. Column

- ✧ Vertical structure mounted on the base.
- ✧ Supports the grinding head and other upper components.

3. Work Table / Table

Consists of two parts:

- ✧ **Longitudinal Table** (moves forward–backward)
- ✧ **Swivel Table** (rotates to set required angles)

Carries the work-holding fixtures and allows precise positioning.

4. Saddle

- ✧ Mounted between the table and the base.
- ✧ Allows transverse (left–right) movement.
- ✧ Helps in accurate feed of the workpiece towards the wheel.

5. Grinding Head / Wheel Head

- ✧ Contains the **spindle** on which the grinding wheel is mounted.
- ✧ Can be **swiveled** and **tilted** to grind different angles on tools.
- ✧ Provides high-speed rotation for grinding.

6. Work Head

- ✧ Used to hold and rotate cylindrical tools (e.g., end mills, drills, reamers).
- ✧ Can be indexed, tilted, and rotated for accurate relief angles.

7. Tailstock

- ✧ Usually has two tailstocks which Support the free ends of long cutting tools between two centers.
- ✧ Works with the work head for cylindrical tool grinding.

8. Tool Rest / Tool Holder

- ✧ Adjustable support for the cutting tool.
- ✧ Helps maintain accurate positioning during grinding operations.

9. Universal Vice

Adjustable vice used to hold cutting tools at the required angle for grinding the cutting edges.

10. Control Panel

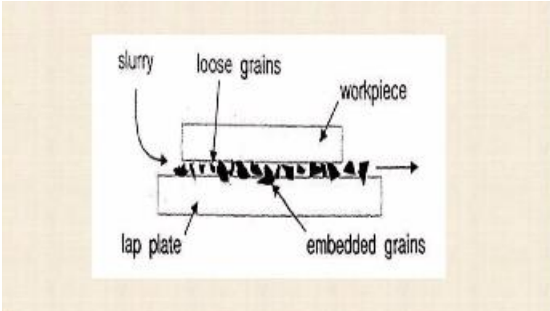
Contains switches, knobs, and speed controls.

Used to operate the machine safely.

FINISHING BY GRINDING

LAPPING

The lapping process is a precision finishing method that uses a loose abrasive slurry between a workpiece and a rotating lap plate to achieve a very smooth, flat, and accurate surface.



It involves placing a workpiece on a slowly rotating plate, applying light pressure, and using a liquid-based abrasive slurry (Aluminum oxide or SiC or Diamond mixed with Oil or water) to remove microscopic irregularities, resulting in a high-precision finish without generating excessive heat.

Principle of Lapping

Lapping works on the principle of:

Abrasive + Relative Motion + Pressure

1. The lap tool (made of cast iron, copper, lead, ceramic, etc.) is coated with fine abrasives and also charged with abrasive slurry.
2. When the workpiece and lap move relative to each other under light pressure, the abrasives create tiny cutting actions. They are pressed between the plate and the workpiece, removing microscopic layers of material from the high points of the surface.
3. This results in the removal of peaks on the work surface → producing a smooth and precise finish.

Types of lapping process

A. **Hand Lapping**

Performed manually with a flat lap plate. Palm movement resembles english letter 8.

Used for small and delicate components.

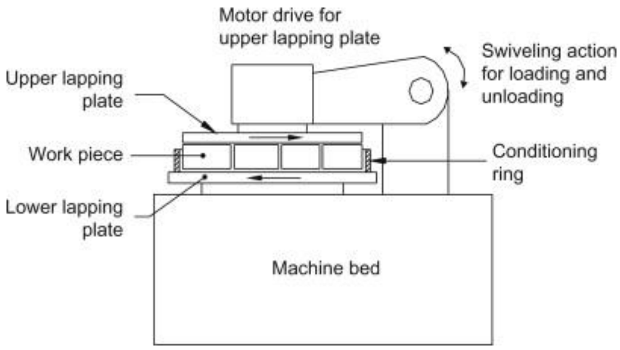
B. Machine Lapping

Single-side lapping machine

Workpiece is placed on one rotating lap plate.

Double-side lapping machine

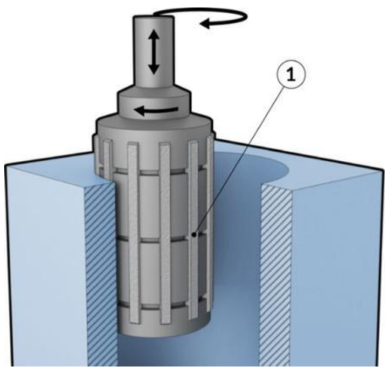
Both sides of the workpiece are simultaneously lapped between two plates.



This process is used for applications requiring tight tolerances, such as in optics, aerospace, and automotive parts.

HONING

The honing process is a precision machining technique that uses abrasive stones or tools to refine the internal surfaces of workpieces. It is a low-stock removal process, typically removing less than 0.25mm, though it can be used to remove up to 3mm in some cases.



It uses **abrasive stones** mounted on **a mandrel** which **rotate and reciprocate** simultaneously**,** removing small amounts of material to improve the surface finish, geometry (like roundness and straightness), and dimensional accuracy.

Honing works by:

✓ Rotating the honing tool (mandrel)

- ✓ Reciprocating it up and down inside the bore
- ✓ Abrasive stones apply outward pressure on the workpiece surface

  This combined motion cuts very fine chips and produces a controlled surface texture.

A typical honing tool consists of:

- **Abrasive stones** (3 to 8 stones)
- **Expander mechanism** to apply pressure
- **Mandrel** to hold stones
- **Coolant/oil** to carry away chips

Applications:-

This is a finishing operation used for parts that require high precision, such as engine cylinders, hydraulic components, gun barrels and gears.

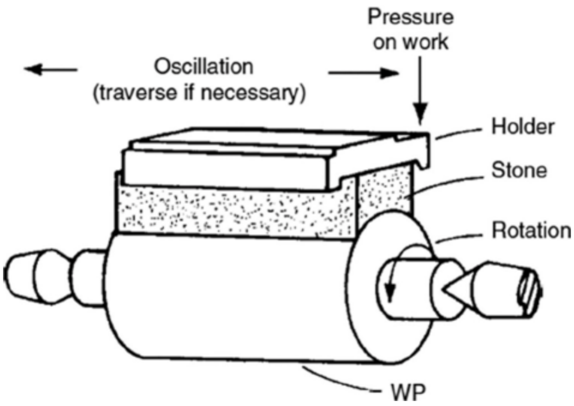
Difference Between Honing and Lapping

Feature	Honing	Lapping
Tool	Abrasive stones	Loose abrasive slurry
Motion	Rotation + reciprocation	Oscillating or circular
Material removed	More than lapping	Very little
Surfaces	Mainly internal cylindrical	Flat or cylindrical
Accuracy	High	Very high

SUPERFINISHING

Super-finishing is a **precision finishing process** used to improve the surface finish, accuracy, and geometry of a workpiece by removing a very thin layer of material using **abrasive stones** at low pressure and low speed.

It produces extremely smooth surfaces with **surface finish as fine as 0.01–0.1 µm Ra**.



Superfinishing uses:

- ❖ **Abrasive stone** (fine-grit)
- ❖ **Oscillatory motion** + slow rotational motion of the workpiece
- ❖ **Light pressure**

The stone is pressed against the rotating workpiece while it oscillates back and forth. This removes the peaks (asperities) from the surface without affecting geometry.

Applications

Used when **very high surface finish and accuracy** are required on following parts:

- ❖ Automobile crankshafts & camshafts
- ❖ Gear teeth
- ❖ Bearing journals
- ❖ Hydraulic spools and valves
- ❖ Fuel injection parts

ELECTROPLATING

Electroplating is a process of depositing a thin layer of a metal onto the surface of another metal (called the base metal) using **electrical current**. The main purpose is to improve **appearance, corrosion resistance, wear resistance, and surface properties**.

Electroplating works on the principle of **electrolysis**. When an electric current passes through an electrolyte containing metal ions, the metal ions get **reduced** and deposit on the cathode (the workpiece).

Setup / Components

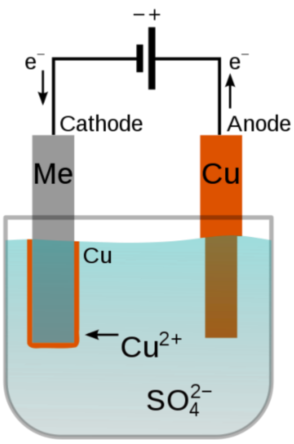
I. **Power supply (DC source)** : Provides direct current.

II. **Cathode (−)** : The workpiece on which metal is to be deposited.

III. **Anode (+)** : Metal to be plated (e.g., copper, nickel, chromium).

IV. **Electrolyte** : A solution containing dissolved metal salts (e.g., $CuSO_4$ for copper plating).

V. **Container / Bath** – Holds the electrolyte solution.



<u>Process Steps</u>

Cleaning the Workpiece

Removal of oil, dirt, rust by alkaline cleaning, acid pickling, or ultrasonics. Ensures proper adhesion.

Setting the Circuit

- The workpiece is connected to the **negative terminal** → becomes the **cathode**.
- The plating metal is connected to the **positive terminal** → becomes the **anode**.

Electrolysis Begins When DC current flows:

- Metal atoms from the anode dissolve into the electrolyte as **positive ions**.
- These metal ions move toward the cathode.
- At the cathode, ions gain electrons (reduction) and **deposit as a thin metal coating**. Process continues until required coating thickness is obtained.

At anode (+):
$Cu \rightarrow Cu^{2+} + 2e^-$

At cathode (−):
$Cu^{2+} + 2e^{-} \rightarrow Cu$ (metal deposit)

Applications

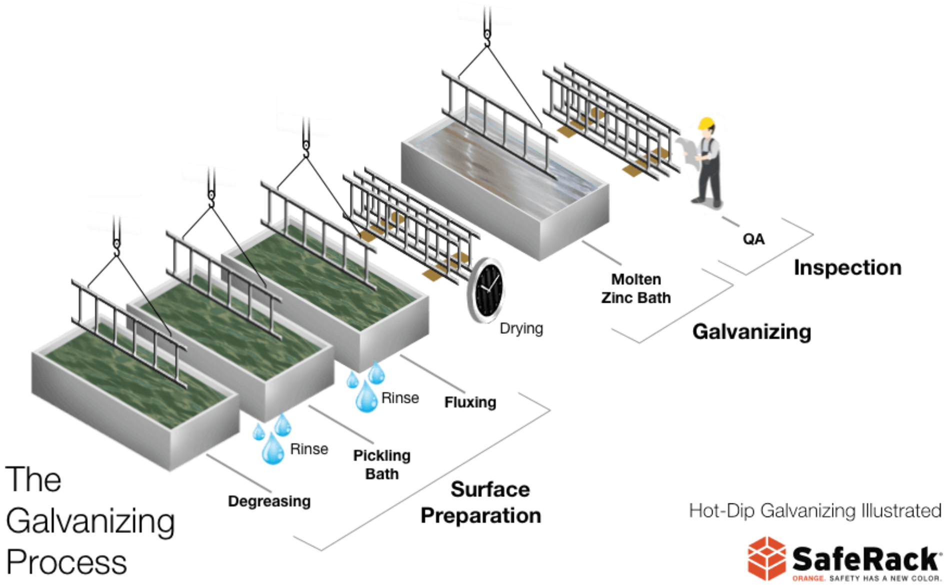
- ✓ **Automobile parts:** bumpers, handles, engine components
- ✓ **Electronics:** PCB tracks, connectors, contacts
- ✓ **Jewellery:** gold/silver coating
- ✓ **Household items:** taps, door handles (chrome plating)
- ✓ **Corrosion protection:** zinc plating on steel (galvanizing)

HOT DIPPING

The hot dipping method involves coating steel with a **protective layer of zinc**, which is essential for shielding steel from all types of corrosion and also known as **Hot dip Galvanizing.**

Galvanizing

- ❖ The galvanization method involves coating steel with a protective layer of zinc which is essential for shielding steel from all types of corrosion.
- ❖ The base metal in this case, steel, is immersed in a bath of molten zinc during this operation.
- ❖ Preparing the surface of the steel to be galvanised is the most crucial step in the hot dip galvanization process.
- ❖ The steel that will be hotdip galvanised must be entirely **clean** in order for the molten zinc to develop **a strong and full metallurgical bond** with the steel, which is of the utmost importance.



The steps for cleaning and preparing the surface of steel:-

1. **Pickling.** In this stage, hydrochloric acid at a proper temperature is used to remove scale and rust off the steel's surface. □□

2. **Rinsing.** Following the completion of the chemical cleaning procedure, the steel that will be galvanised is thoroughly rinsed in water.

3. **Fluxing.** Fluxing eliminates all oxides and prevents their further production, which is essential for promoting the strongest bond between the zinc coating and the steel.

After the entire process of steel's surface preparation is finished, it **is completely immersed in a bath of molten zinc that is around 450^0 C in temperature and contains about 98 percent pure zinc**. After that the steel is removed and cooled to get the final product.

<u>TITANIUM NITRIDE (TiN) COATING</u>

Titanium nitride (TiN) coating is a durable, hard, and inert ceramic coating applied to metal parts to improve their surface properties like wear resistance, abrasion resistance, and corrosion resistance.

Properties and advantages

1) **Hardness:** TiN is an extremely hard material, which significantly improves the wear resistance of the underlying substrate.

2) **Corrosion and abrasion resistance:** It protects against wear, corrosion, and chemical attack.

3) **Low friction:** It reduces friction, which is beneficial for moving parts.

4) **Biocompatibility:** TiN coatings are biocompatible and used in medical implants, although applications require careful consideration of potential delamination issues.

5) **Inertness:** It is chemically stable and resistant to etching solutions.

Application methods

- **Physical Vapor Deposition (PVD):** A common method where titanium is vaporized and deposited onto the workpiece in a vacuum chamber.
- **Chemical Vapor Deposition (CVD):** Involves reacting titanium tetrachloride with ammonia at high temperatures.

Applications

- ✓ **Metalworking:** Cutting tools, drills, blades, and punches to increase lifespan and performance.
- ✓ **Plastics and molding:** Injection molds and parts used in plastic processing.
- ✓ **Orthopedics:** Coated surgical implants like hip and knee replacements.

PARKERISING

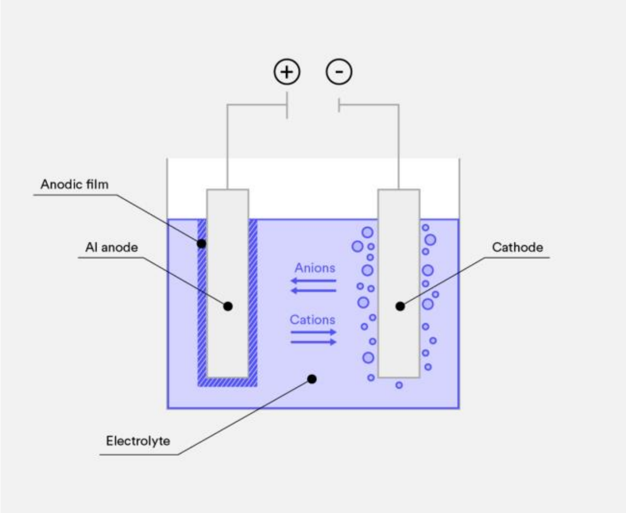
Parkerizing is a chemical process that coats steel **with a protective phosphate layer** to prevent corrosion and improve wear resistance. The process involves cleaning steel parts and then submerging them in a heated solution of **phosphoric acid with additives like zinc or manganese.**

The Parkerizing process

1. **Cleaning:** Metal parts must be thoroughly cleaned with acid and degreased before the process begins.
2. **Immersion:** The clean parts are then submerged in a heated phosphate solution, typically **a mixture of phosphoric acid with manganese or zinc** and other chemicals like nitrates. The solution is usually heated to around 90^0C.
3. **Coating:** As the part heats, it will start to bubble. This is the reaction where the iron in the steel reacts with the solution, creating a phosphate coating on the surface. The part is left in the solution until the bubbling stops, which typically takes between 5 and 45 minutes.
4. **Rinsing:** Once the coating is complete, the part is removed from the solution and thoroughly rinsed with water to remove any remaining chemicals.
5. **Drying and Oiling:** After rinsing, the parts are dried, often with an oil or degreasing agent to displace any water.
6. **Final Oil Coat:** Finally, a light oil is applied to the finished part. The porous phosphate coating absorbs the oil, which is crucial for providing long-term corrosion resistance.

ANODIZING

Anodizing is an electrochemical process that builds a durable, corrosion-resistant oxide layer on a metal's surface, most commonly aluminum.



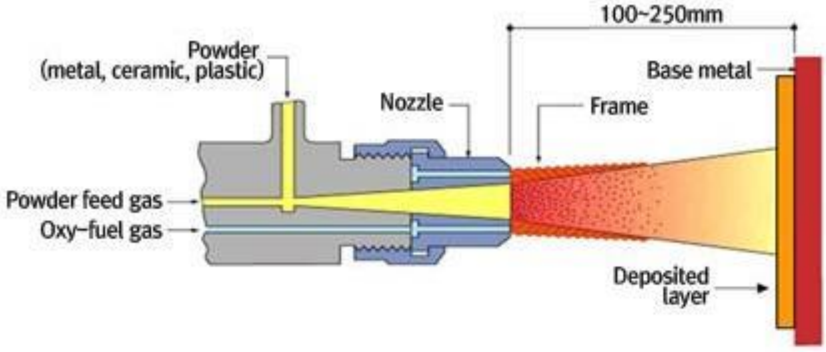
The cleaned part is placed in an electrolytic solution, typically a dilute sulfuric acid bath, and acts as the anode. An electric current is passed through the solution, causing oxygen to form on the surface of the part. This oxygen then reacts with the base metal to form a porous aluminum oxide layer. The thickness of this layer is controlled by the time, temperature, and current used in this stage.

METAL SPRAYING

A procedure known as metal spraying involves applying molten metal or softened particles to a prepared surface (substrate) with spray equipment to improve its qualities (hardness, anti-corrosion, wear, dielectric, restoring dimensions etc.)

Flame powder spraying

Flame powder spraying is a thermal spray coating method in which **powdered coating material** is heated by a **fuel–oxygen flame** and then propelled onto a surface to form a protective coating.



How the Process Works

- **Powder Feeding:**
  Metal, alloy, or ceramic powder is fed into a flame spray gun.
- **Combustion Flame Creation:**
  A mixture of **oxygen + fuel gas** (acetylene, propane, or hydrogen) is burned to produce a hot flame.
- **Melting of Powder:**
  The powder enters the flame, where it is **heated and softened or melted**.
- **Propulsion Onto Workpiece:**
  Compressed air accelerates molten particles toward the surface.
- **Coating Formation:**
  When the molten particles strike the surface, they **flatten, solidify, and bond**, forming a coating layer.

Materials Used

- **Metals:** Aluminium, Zinc, Copper, Molybdenum
- **Alloys:** Nickel-based, stainless steel
- **Ceramics:** Alumina, Zirconia

Applications

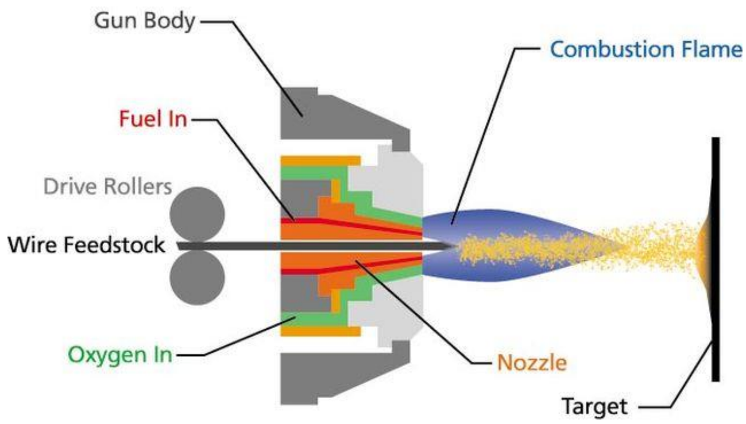
- Corrosion protection (Zn, Al coating on steel)
- Wear resistance
- Rebuilding worn machine parts
- Coating shafts, bearing surfaces, piston rings
- Protective coatings in chemical and marine environments

Flame wire spraying

It is a method of depositing a **metal coating** by feeding a metal wire into an **oxy-fuel flame** (usually oxy-acetylene). The flame melts the wire tip, and **compressed air** blows the molten metal droplets onto the surface being coated.

Basic Principle

1. A metal **wire** (coating material) is continuously fed into the gun.
2. The wire tip is melted by a **high-temperature flame**.
3. **Compressed air** atomizes the molten metal into small droplets.
4. These droplets strike the surface and **form a dense coating layer**.



Applications

- Corrosion protection (zinc, aluminum coatings)
- Repair of worn parts (shafts, bearing seats)
- Building up material thickness
- Electrical conductivity coatings
- Surface hardening

PROBABLES

1. Selection criteria of cutting fluids

2. Methods of applications of cutting fluid

3. Functions and properties of lubricants

4. Basic parts and their functions of a lathe with diagram

5. Describe various operations performed in lathe

6. Specification of a lathe machine

7. Elements of broach tool; broach teeth details; Nomenclature

8. Pull and push type broaching machine.

9. Classification of drilling machine, their parts and functions.

10. Radial drilling machine- parts, functions with figure

11. Forehand and backhand welding

12. Types of flames in gas welding

13. MMAW/SMAW welding process

14. Submerged arc welding process

15. TIG/MIG difference

16. Resistance spot welding

17. Any four welding defect- cause and remedies

18. Brazing and soldering- short notes

19. Milling machine parts, universal milling machine.

20. Milling operations- up milling, down milling, side milling, face milling, end milling, straddle milling

21. simple, compound and differential indexing methods (only theory)

22. Nomenclature of teeth, Tool signature

23. Press working operations - Cutting, bending, Drawing, punching, blanking, notching, lancing

24. Die set components- parts and functions

25. Punch and die clearances for blanking and piercing

26. Factors affecting the selection of grind wheels

27. Grinding wheel specification

28. Cylindrical and surface grinding machine

29. Lapping and honning process

30. Short notes- Electroplating, super finishing, hot dip galvanizing, parkerizing, anodizing.

31. Metal spraying: wire process, powder process