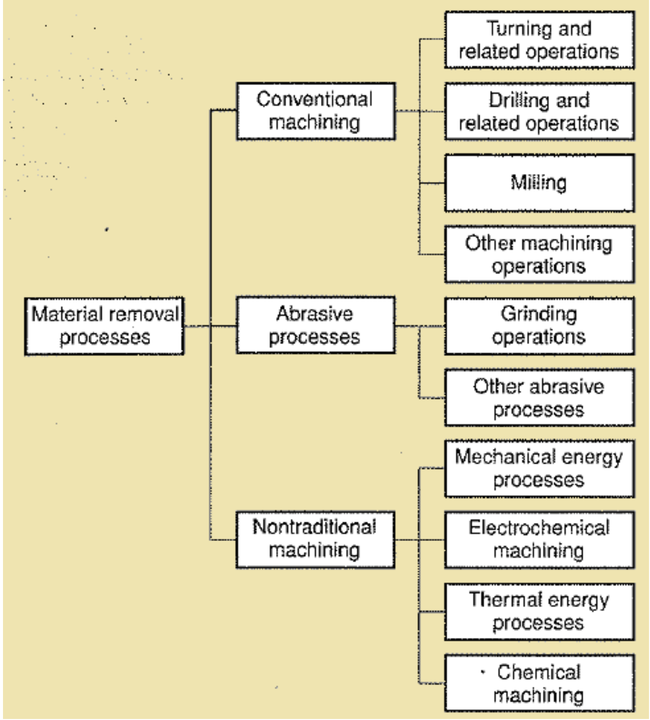
UNIT 3 PRODUCTION PROCESS(MACHINE TOOLS)

3.1 Introduction

Machining is a manufacturing process in which a sharp cutting tool is used to cut away material to leave the desired part shape. Machining is most frequently applied to shape metals.

Conventional machining, the predominant cutting action in machining involves shear deformation of the work material to form a chip, as the chip is removed a new surface is exposed. The three principal machining process turning, drilling and milling. the other machining process includes Shaping, planning, broaching and sawing.



Another group of material removal processes is the abrasive processes, which mechanically remove material by the action of hard, abrasive particles. this process includes Grinding, honing, lapping and superfinishing. Finally, the nontraditional processes which use various energy forms other than a sharp cutting tool or abrasive particles to remove materials. the energy form include mechanical, electrochemical, thermal ad chemical.

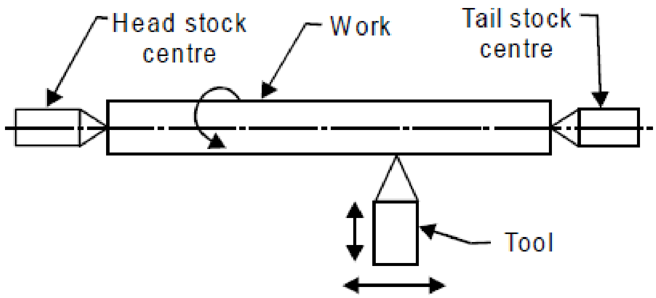
Machining is used to convert casting, forgings or performed blocks of metal in to desired shape, with size and finish specified to fulfill design requirements. Almost every manufacturing product has component that require machining. Most of the engineering components such as gears, bearings, clutches, tools, screws and nuts etc. need dimensional and form accuracy and good surface finish for serving their purposes.

Machining processes are performed on a wide variety of machine tools. Each of the basic machine tool types has many different configuration. Each process is performed on one or more basic machine tools. For example, drilling can be performed on drill presses, milling machine, Lathes and boring machines.

- Turning (boring, facing, cutoff, taper turning, form cutting, chamfering, recessing, thread cutting)
- Shaping (planning, vertical shaping)
- Milling (hobbing, generating, thread milling)
- Drilling (reaming, tapping, spot facing, counterboring, countersinking)
- Sawing(filing)
- Abrasive machining (grinding, honing, lapping)
- Broaching (internal and surface)

3.2 LATHE

Lathe is one of the most versatile and widely used machine tools all over the world. It is commonly known as the mother of all other machine tool. The main function of a lathe is to remove metal from a job to give it the required shape and size. The job is secure1y and rigid1y held in the chuck or in between centers on the lathe machine and then turn it against a single point cutting tool which wi1l remove meta1 from the job in the form of chips. Figure shows the working principle of lathe. An engine lathe is the most basic and simplest form of the lathe. It derives its name from the early lathes, which obtained their power from engines. Besides the simple turning operation as described above, lathe can be used to carry out other operations also, such as drilling, reaming, boring, taper turning, knurling, screwthread cutting, grinding etc.



Working principal of lathe machine

3.2.1 Types of Lathe

Lathes are manufactured in a variety of types and sizes, from very small bench lathes used for precision work to huge lathes used for turning large steel shafts. But the principle of operation and function of all types of lathes is same. The different types of lathes are:

1. Speed lathe
   a) Wood working
   b) Spinning
   c) Centering
   d) Po1ishing

2. Centre or engine lathe
   (a) Be1t drive
   (b) Individual motor drive
   (c) Gear head lathe
3. Bench lathe
4. Tool room Lathe
5. Capstan and Turret 1athe
6. Special purpose lathe
   (a) Whee1 lathe
   (b) Gap bed lathe
   (c) Dup1icating lathe
   (d) T-lathe
7. Automatic lathe

Speed Lathe

Speed lathe is simplest of all types of lathes in construction and operation. The important parts of speed lathe are following-

(1) Bed
(2) Headstock
(3) Tailstock, and
(4) Tool post mounted on an adjustable slide.

It has no feed box, 1eadscrew or conventional type of carriage. The tool is mounted on the adjustable slide and is fed into the work by hand contro1. The speed lathe finds applications where cutting force is least such as in wood working, spinning, centering, polishing, winding, buffing etc. This lathe has been so named because of the very high speed of the headstock spindle.

Centre Lathe or Engine Lathe

The term "engine" is associated with this lathe due to the fact that in the very early days of its development it was driven by steam engine. This lathe is the important member of the lathe family and is the most widely used. Similar to the speed lathe, the engine lathe has all the basic parts, e.g., bed, headstock, and tailstock. But its headstock is much more robust in construction and contains additional mechanism for driving the lathe spindle at multiple speeds. Unlike the speed lathe, the engine lathe can feed the cutting tool both in cross and longitudinal direction with reference to the lathe axis with the help of a carriage, feed rod and lead screw. Centre lathes or engine lathes are classified according to methods of transmitting power to the machine. The power may be transmitted by means of belt, electric motor or through gears.

Bench Lathe

This is a small lathe usually mounted on a bench. It has practically all the parts of an engine lathe or speed lathe and it performs almost all the operations. This is used for small and precision work.

Tool Room Lathe

This lathe has features similar to an engine lathe but it is much more accurately built. It has a wide range of spindle speeds ranging from a very low to a quite high speed up to 2500 rpm. This lathe is mainly used for precision work on tools, dies, gauges and in machining work where accuracy is needed.

Capstan and Turret Lathe

The development of these 1athes results from the technological advancement of the engine lathe and these are vastly used for mass production work. The distinguishing feature of this type of lathe is that the tailstock of an engine lathe is replaced by a hexagonal turret, on the face of which multiple tools may be fitted and fed into the work in proper sequence. Due to this arrangement, several different types of operations can be done on a job without re-setting of work or tools, and a number of identical parts can be produced in the minimum time.

Special Purpose Lathes

These lathes are constructed for special purposes and for jobs, which cannot be accommodated or conveniently machined on a standard lathe. The wheel lathe is made for finishing the journals and turning the tread on railroad car and locomotive wheels. The gap bed lathe, in which a section of the bed adjacent to the headstock is removable, is used to swing extra-large-diameter pieces. The T-lathe is used for machining of rotors for jet engines. The bed of this lathe has T-shape. Duplicating lathe is one for duplicating the shape of a flat or round template on to the job.

Automatic Lathes

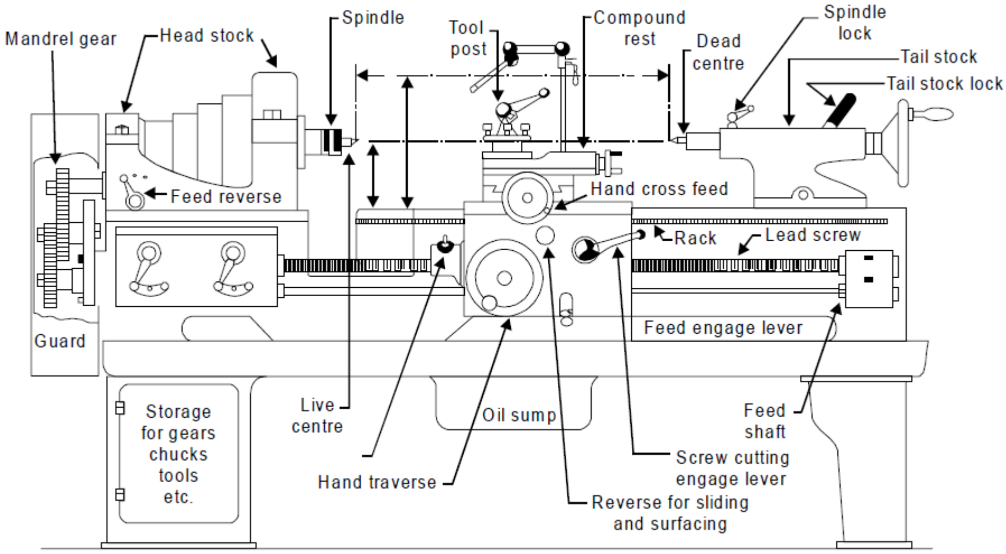
These lathes are so designed that all the working and job handling movements of the complete manufacturing process for a job are done automatically. These are high speed, heavy duty, mass production lathes with complete automatic control

3.2.2 Construction of Lathe Machine

A simple lathe comprises of a bed made of grey cast iron on which headstock, tailstock, carriage and other components of lathe are mounted. Figure shows the different parts of engine lathe or central lathe. The major parts of lathe machine are given as under:

(1) Bed
(2) Head stock
(3) Tailstock
(4) Carriage
(5) Feed mechanism

(6) Thread cutting mechanism



Different parts of engine lathe or central lathe

Bed

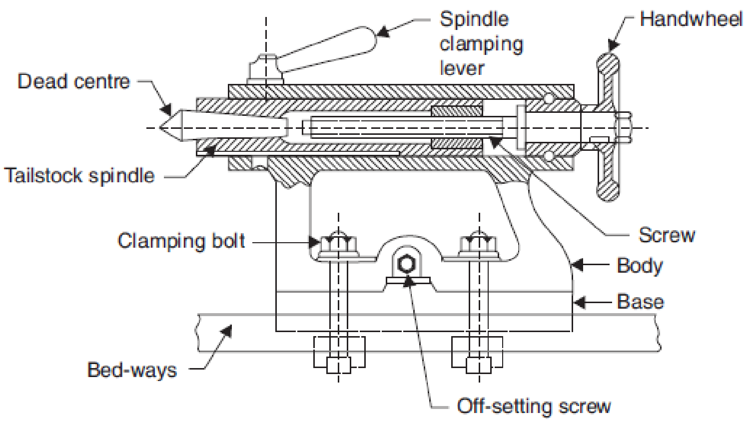
The bed of a lathe machine is the base on which all other parts of lathe are mounted. It is massive and rigid single piece casting made to support other active parts of lathe. On left end of the bed, headstock of lathe machine is located while on right side tailstock is located. The carriage of the machine rests over the bed and slides on it. On the top of the bed there are two sets of guideways-innerways and outerways. The innerways provide sliding surfaces for the tailstock and the outerways for the carriage. The guideways of the lathe bed may be flat and inverted V shape. Generally cast iron alloyed with nickel and chromium material is used for manufacturing of the lathe bed.

Head Stock

The main function of headstock is to transmit power to the different parts of a lathe. It comprises of the headstock casting to accommodate all the parts within it including gear train arrangement. The main spindle is adjusted in it, which possesses live centre to which the work can be attached. It supports the work and revolves with the work, fitted into the main spindle of the headstock. The cone pulley is also attached with this arrangement, which is used to get various spindle speed through electric motor. The back gear arrangement is used

Tail Stock

Figure shows the tail stock of central lathe, which is commonly used for the objective of primarily giving an outer bearing and support the circular job being turned on centers.

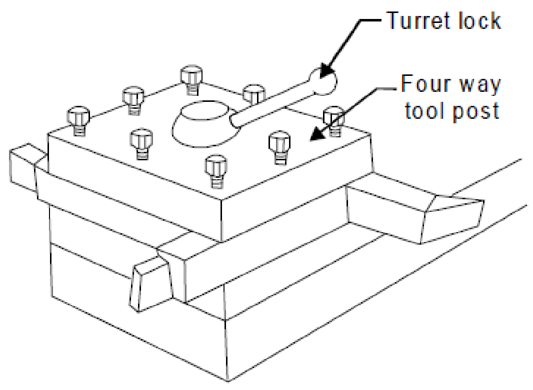


Tailstock

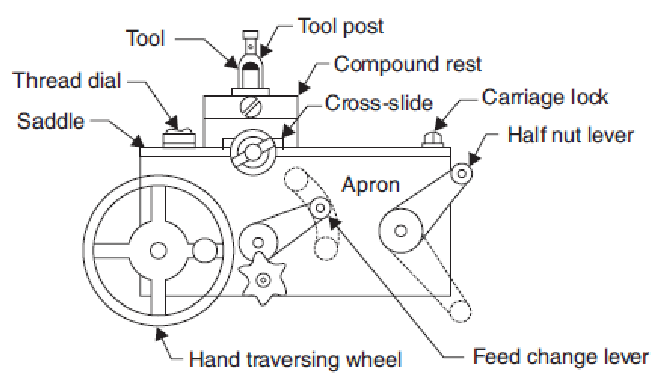
Tail stock can be easily set or adjusted for alignment or non-alignment with respect to the spindle centre and carries a centre called dead centre for supporting one end of the work. Both live and dead centers have 60° conical points to fit centre holes in the circular job, the other end tapering to allow for good fitting into the spindles. The dead centre can be mounted in ball bearing so that it rotates with the job avoiding friction of the job with dead centre as it important to hold heavy jobs.

Carriage

Carriage is mounted on the outer guide ways of lathe bed and it can move in a direction parallel to the spindle axis. It comprises of important parts such as apron, cross-slide, saddle, compound rest, and tool post. The lower part of the carriage is termed the apron in which there are gears to constitute apron mechanism for adjusting the direction of the feed using clutch mechanism and the split half nut for automatic feed. The cross-slide is basically mounted on the carriage, which generally travels at right angles to the spindle axis. On the cross-slide, a saddle is mounted in which the compound rest is adjusted which can rotate and fix to any desired angle. The compound rest slide is actuated by a screw, which rotates in a nut fixed to the saddle. The tool post is an important part of carriage, which fits in a tee-slot in the compound rest and holds the tool holder in place by the tool post screw. Figure shows the tool post of centre lathe.



Tool post of centre lathe



Carriage

Feed Mechanism

Feed mechanism is the combination of different units through which motion of headstock spindle is transmitted to the carriage of lathe machine. Following units play role in feed mechanism of a lathe machine-

1. End of bed gearing
2. Feed gear box
3. Lead screw and feed rod
4. Apron mechanism

The gearing at the end of bed transmits the rotary motion of headstock spindle to the feed gear box. Through the feed gear box the motion is further transmitted either to the feed shaft or lead screw, depending on whether the lathe machine is being used for plain turning or screw cutting. The feed gear box contains a number of different sizes of gears. The feed gear box provides a means to alter the rate of feed, and the ration between revolutions of the headstock spindle and the movement of carriage for thread cutting by changing the speed of rotation of the feed rod or lead screw. The apron is fitted to the saddle. It contains gears and clutches to transmit motion from the feed rod to the carriage, and the half nut which engages with the lead screw during cutting threads.

Thread Cutting Mechanism

The half nut or split nut is used for thread cutting in a lathe. It engages or disengages the carriage with the lead screw so that the rotation of the leadscrew is used to traverse the tool along the workpiece to cut screw threads. The direction in which the carriage moves depends upon the position of the feed reverse lever on the headstock.

3.2.3 Accessories and Attachments of Lathe

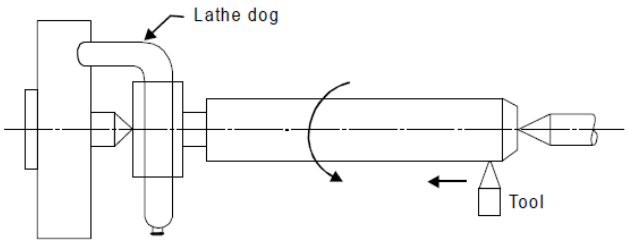
There are many lathe accessories provided by the lathe manufacturer along with the lathe, which support the lathe operations. The important lathe accessories include centers, catch plates and carriers, chucks, collets, face plates, angle plates, mandrels, and rests. These are used either for holding and supporting the work or for holding the tool. Attachments are additional equipments provided by the lathe manufacturer along with the lathe, which can be used for specific operations. The lathe attachment include stops, ball turning rests, thread chasing dials, milling attachment, grinding attachment, gear cutting attachment, turret attachment and crank pin turning attachments and taper turning attachment.

Lathe centers

The most common method of holding the job in a lathe is between the two centers generally known as live centre (head stock centre) and dead centre (tailstock centre). They are made of very hard materials to resist deflection and wear and they are used to hold and support the cylindrical jobs.

Carriers or driving dog and catch plates

These are used to drive a job when it is held between two centers. Carriers or driving dogs are attached to the end of the job by a setscrew. A use of lathe dog for holding and supporting the job is shown in Figure. Catch plates are either screwed or bolted to the nose of the headstock spindle. A projecting pin from the catch plate or carrier fits into the slot provided in either of them. This imparts a positive drive between the lathe spindle and job



Lathe dog

Chucks

Chuck is one of the most important devices for holding and rotating a job in a lathe. It is basically attached to the headstock spindle of the lathe. The internal threads in the chuck fit on to the external threads on the spindle nose. Short, cylindrical, hol1ow objects or those of irregular shapes, which cannot be conveniently mounted between centers, are easily and rigidly held in a chuck. Jobs of short length and large diameter or of irregular shape, which cannot be conveniently mounted between centers, are held quickly and rigidly in a chuck.

There are a number of types of lathe chucks, e.g.

(1) Three jaws or universal
(2) Four jaw independent chuck
(3) Magnetic chuck
(4) Collet chuck
(5) Air or hydraulic chuck operated chuck
(6) Combination chuck
(7) Drill chuck.

Face plates

Face plates are employed for holding jobs, which cannot be conveniently held between centers or by chucks. A face plate possesses the radial, plain and T slots for holding jobs or work-pieces by bolts and clamps. Face plates consist of a circular disc bored out and threaded to fit the nose of the lathe spindle. They are heavily constructed and have strong thick ribs on the back. They have slots cut into them, therefore nuts, bolts, clamps and angles are used to hold the jobs on the face plate. They are accurately machined and ground.

Angle plates

Angle plate is a cast iron plate having two faces machined to make them absolutely at right angles to each other. Holes and slots are provided on both faces so that it may be clamped on a faceplate and can hold the job or workpiece on the other face by bolts and clamps. The plates are used in conjunction with a face plate when the holding surface of the job should be kept horizontal.

Mandrels

A mandrel is a device used for holding and rotating a hollow job that has been previously drilled or bored. The job revolves with the mandrel, which is mounted between two centers. It is rotated by the lathe dog and the catch plate and it drives the work by friction. Different types of mandrels are employed according to specific requirements. It is hardened and tempered steel shaft or bar with 60° centers, so that it can be mounted between centers. It holds and locates a part from its center hole. The mandrel is always rotated with the help of a lathe dog; it is never placed in a chuck for turning the job. A mandrel unlike an arbor is a job holding device rather than a cutting tool holder. A bush can be faced and turned by holding the same on a mandrel between centers. It is generally used in order to machine the entire length of a hollow job

Rests

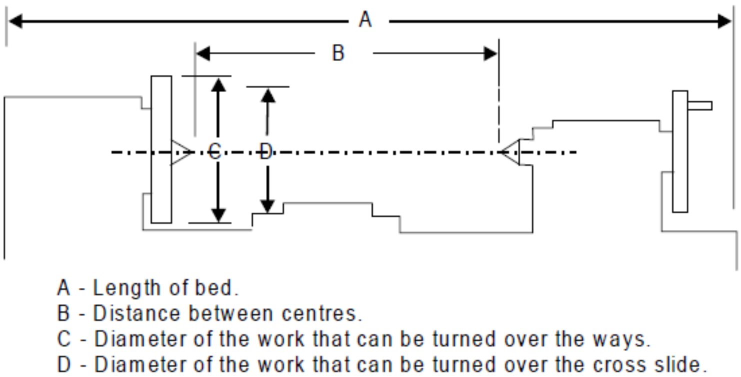
A rest is a lathe device, which supports a long slender job, when it is turned between centers or by a chuck, at some intermediate point to prevent bending of the job due to its own weight and vibration set up due to the cutting force that acts on it. The two types of rests commonly used for supporting a long job in an engine lathe are the steady or centre rest and the follower rest.

3.2.4 Specification of Lathe

The size of a lathe is generally specified by the following means:

(a) Swing or maximum diameter that can be rotated over the bed ways
(b) Maximum length of the job that can be held between head stock and tail stock centers
(c) Bed length, which may include head stock length also
(d) Maximum diameter of the bar that can pass through spindle or collect chuck of capstan lathe.

Figure illustrates the elements involved in specifications of a lathe. The following data also contributes to specify a common lathe machine.



Specifications of a lathe

(1) Maximum swing over bed
(2) Maximum swing over carriage
(3) Height of centers over bed
(4) Maximum distance between centers
(5) Length of bed
(6) Width of bed
(7) Morse taper of center
(8) Diameter of hole through spindle
(9) Face plate diameter

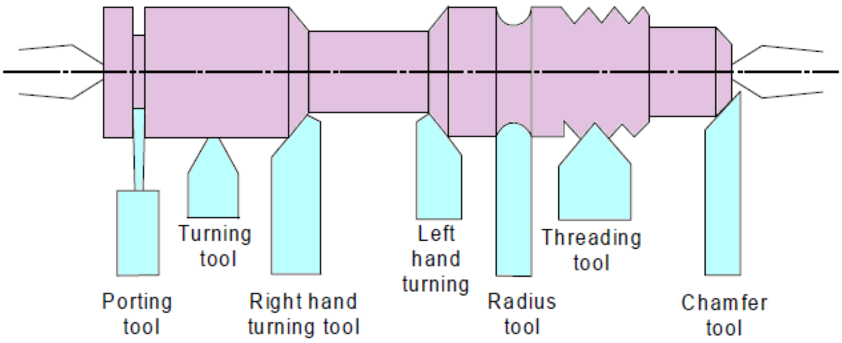
(10) Size of tool post
(11) Number of spindle speeds
(12) Lead screw diameter and number of threads per cm.
(13) Size of electrical motor
(14) Pitch range of metric and inch threads etc.

3.2.5 Lathe Operations

For performing the various machining operations in a lathe, the job is being supported and driven by anyone of the following methods.

1. Job is held and driven by chuck with the other end supported on the tail stock centre.
2. Job is held between centers and driven by carriers and catch plates.
3. Job is held on a mandrel, which is supported between centers and driven by carriers and catch plates.
4. Job is held and driven by a chuck or a faceplate or an angle plate.

The above methods for holding the job can be classified under two headings namely job held between centers and job held by a chuck or any other fixture. The various important lathe operations are depicted through Figures. The operations performed in a lathe can be understood by three major categories



Lathe operation

(a) Operations, which can be performed in a lathe either by holding the workpiece between centers or by a chuck are:

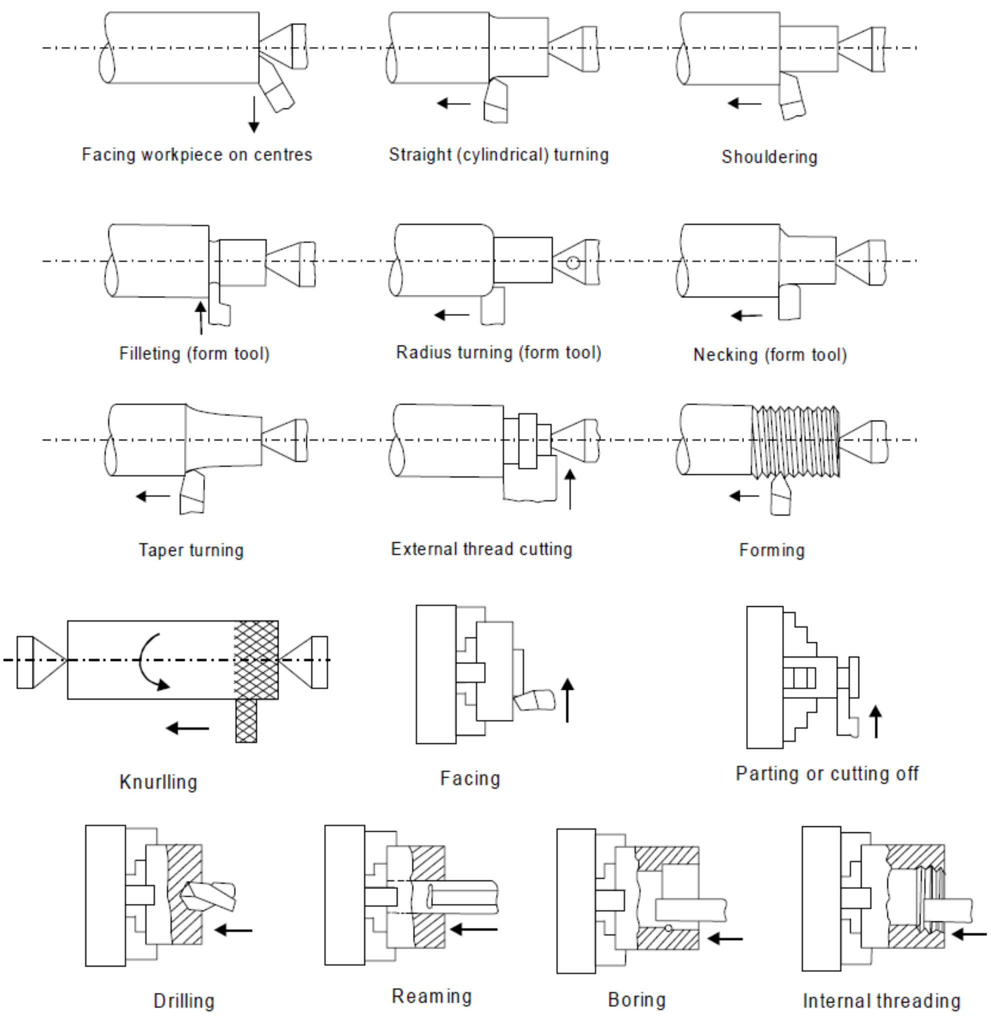
1. Straight turning 2. Shoulder turning
3. Taper turning 4. Chamfering
5. Eccentric turning 6. Thread cutting
7. Facing 8. Forming
9. Filing 10. Polishing
11. Grooving 12. Knurling
13. Spinning 14. Spring winding

(b) Operations which are performed by holding the work by a chuck or a faceplate or an angle plate are:

1. Undercutting 2. Parting-off
3. Internal thread cutting 4. Drilling
5. Reaming 6. Boring
7. Counter boring 8. Taper boring
9. Tapping

(c) Operations which are performed by using special lathe attachments are:

1. Milling 2. Grinding



Lathe operations

Tapers and Taper Turning

A taper is defined as a uniform increase or decrease in diameter of a piece of work measured along its length. In a lathe machine, taper turning means to produce a conical surface by gradual reduction in diameter from a cylindrical job. Taper in the British System is expressed in taper per foot or taper per inch.

Taper per inch = (D – *d*) /*l*

Where,

D = is the diameter of the large end of cylindrical job,

d = is the diameter of the small end of cylindrical job, and

l = is the length of the taper of cylindrical job, all expressed in inches,

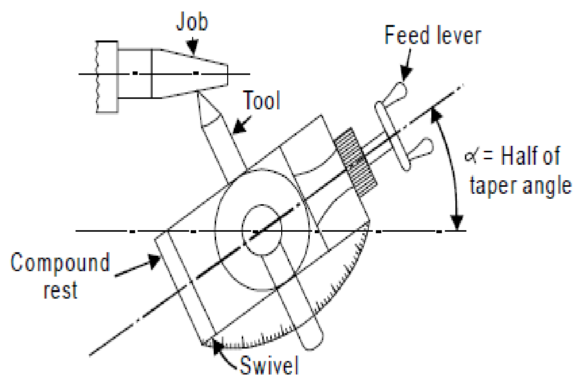
When the taper is expressed in taper per foot, the length of the taper l is expressed in foot, but the diameters are expressed in inches. A taper is generally turned in a lathe by feeding the tool at an angle to the axis of rotation of the workpiece. The angle formed by the path of the tool with the axis of the workpiece should correspond to the half taper angle. A taper can be turned by anyone of the following methods:

1. By swiveling the compound rest,
2. By setting over the tailstock centre,
3. By a broad nose form tool,
4. By a taper turning attachment,
5. By combining longitudinal and cross feed in a special lathe and
6. By using numerical control lathe

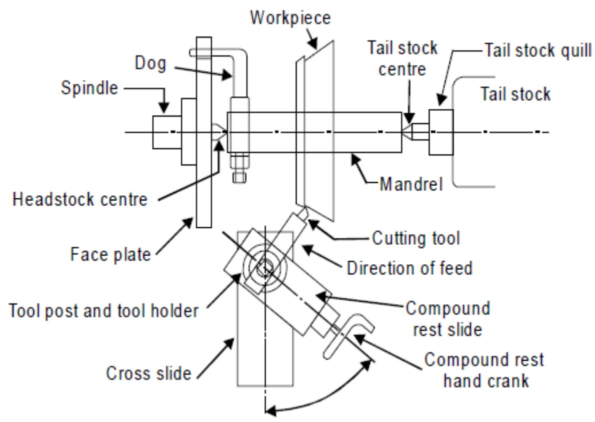
Some of the important taper turning methods are discussed as under.

Taper Turning by Swivelling the Compound Rest

This method uses the principle of turning taper by rotating the workpiece on the lathe axis and feeding the tool at an angle to the axis of rotation of the workpiece. The tool is mounted on the compound rest which is attached to a circular base, graduated in degrees. The compound rest can easily be swiveled or rotated and clamped at any desired angle as shown in Figure. Once the compound rest is set at the desired half taper angle, rotation of the compound slide screw will cause the tool to be fed at that angle and generate a corresponding taper. This method is limited to turn a short but steep taper because of the limited movement of the cross-slide. The compound rest can be swiveled at 45° on either side of the lathe axis enabling it to turn a steep taper. The movement of the single point cutting tool in this method is being purely controlled by hand. Thus it provides a low production capacity and poor surface finish. The positioning or setting of the compound rest is accomplished by swiveling the rest at the half taper angle, if this is already known. If the diameter of the small and large end and length of taper are known, the half taper angle can be calculated. The complete setup for producing a taper by swelling the compound rest is given in Figure.



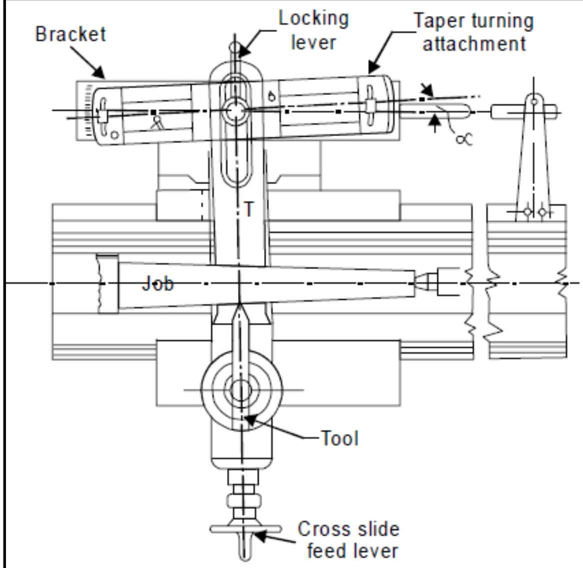
Taper turning by swiveling compound rest



Swiveling compound rest set-up

Taper Turning Attachment Method

This method is commonly employed for generating external tapers only. In this method, the taper turning attachment is bolted back of the lathe machine as shown in Figure. It has guide bar which may be set at any desired angle or taper.

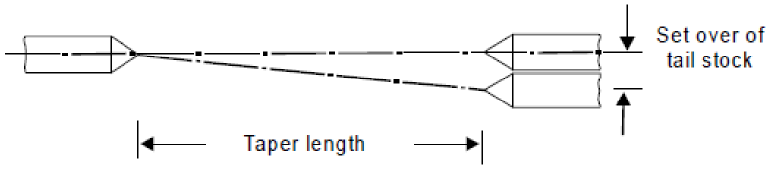


Taper turning attachment

As the carriage moves along the bed length aside over bar causes the tool to move in and out according to setting of the bar. The taper setting on the bar is duplicated on the job or work. The merit of this method is that the lathe centres are kept in alignment.

Taper Turning with Tailstock set over Method

This method is basically employed for turning small tapers on longer jobs and is confined to external tapers only. In this method, the tailstock is set over is calculated using Figure by loosening the nut from its centre line equal to the value obtained by formula given below.



Tailstock set over

Tail stock set over = Taper length × Sine of half of taper angle

$(D - d) / 2 = l \times \sin(a/2)$

Where, D = is the diameter of the large end of cylindrical job,

d = is the diameter of the small end of cylindrical job, and

l = is the length of the taper of cylindrical job, all expressed in inches,

a = taper angle

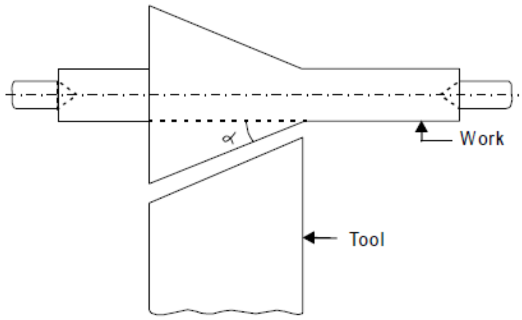
When a part length of the job is to be given taper then tail stock set

= ((D – *d*)/2)) × (total length of the cylindrical job/length of taper)

= l × sin (*a*/2) × (total length of the cylindrical job/length of taper)

Form Tool Method

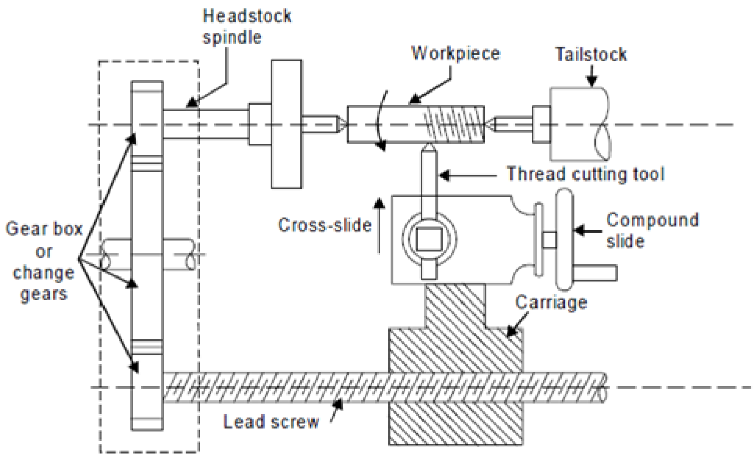
Figure shows this method in which a taper form is used to obtain tapers. It is limited to short external tapers. The edge tool must be exactly straight for accurate work.



Form tool taper turning

Thread Cutting

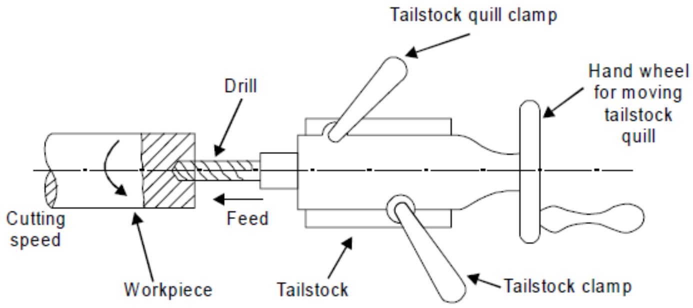
Figure shows the setup of thread cutting on a lathe. Thread of any pitch, shape and size can be cut on a lathe using single point cutting tool. Thread cutting is operation of producing a helical groove on spindle shape such as V, square or power threads on a cylindrical surface. The job is held in between centres or in a chuck and the cutting tool is held on tool post. The cutting tool must travel a distance equal to the pitch (in mm) as the work piece completes a revolution. The definite relative rotary and linear motion between job and cutting tool is achieved by locking or engaging a carriage motion with lead screw and nut mechanism and fixing a gear ratio between head stock spindle and lead screw. To make or cut threads, the cutting tool is brought to the start of job and a small depth of cut is given to cutting tool using cross slide.



Thread cutting

Drilling on a Lathe

For producing holes in jobs on lathe, the job is held in a chuck or on a face plate. The drill is held in the position of tailstock and which is brought nearer the job by moving the tailstock along the guide ways, the thus drill is fed against the rotating job as shown in Figure.



Drilling on lathe

3.2.6 Cutting Speed

Cutting speed for lathe work may be defined as the rate in meters per minute at which the surface of the job moves past the cutting tool. Machining at a correct cutting speed is highly important for good tool life and efficient cutting. Too slow cutting speeds reduce productivity and increase manufacturing costs whereas too high cutting speeds result in overheating of the tool and premature failure of the cutting edge of the tool. The following factors affect the cutting speed:

(i) Kind of material being cut,
(ii) Cutting tool material,
(iii) Shape of cutting tool,
(iv) Rigidity of machine tool and the job piece and
(v) Type of cutting fluid being used.

3.2.7 Feed

Feed is defined as the distance that a tool advances into the work during one revolution of the headstock spindle. It is usually given as a linear movement per revolution of the spindle or job. During turning a job on the center lathe, the saddle and the tool post move alone.

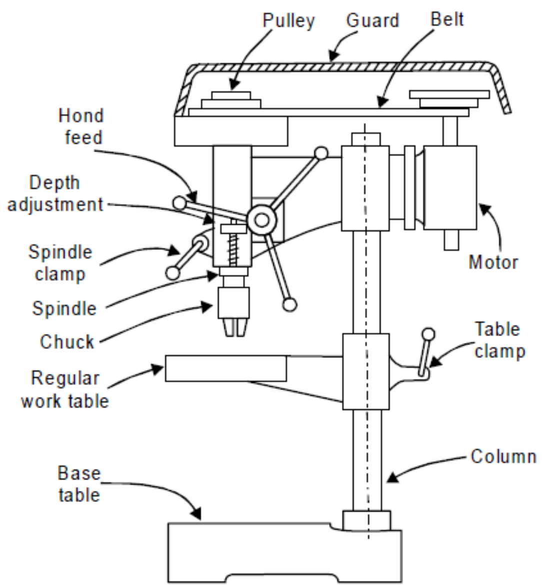
3.3 DRILLING

Drilling is an operation of making a circular hole by removing a volume of metal from the job by cutting tool called drill. A drill is a rotary end-cutting tool with one or more cutting lips and usually one or more flutes for the passage of chips and the admission of cutting fluid. A drilling machine is a machine tool designed for drilling holes in metals. It is one of the most important and versatile machine tools in a workshop. Besides drilling round holes, many other operations can also be performed on the drilling machine such as counter- boring, countersinking, honing, reaming, lapping, sanding etc.

3.3.1 Construction of Drilling Machine

In drilling machine the drill is rotated and fed along its axis of rotation in the stationary workpiece. Different parts of a drilling machine are shown in Figure and are discussed below: (*i*) The head containing electric motor, V-pulleys and V-belt which transmit rotary motion to the drill spindle at a number of speeds. (*ii*) Spindle is made up of alloy steel. It rotates as well as moves up and down in a sleeve. A pinion engages a rack fixed onto the sleeve to provide vertical up and down motion of the spindle and hence the drill so that the same can be fed into the workpiece or withdrawn from it while drilling. Spindle speed or the drill speed is changed with the help of V-belt and V-step-pulleys. Larger drilling machines are having gear boxes for the said purpose. (*iii*) Drill chuck is held at the end of the drill spindle and in turn it holds the drill bit. (*iv*) Adjustable work piece table is supported on the column of the drilling machine. It can be moved both vertically and horizontally. Tables are generally having slots so that the vise or the workpiece can be securely held on it. (*v*) Base table is a heavy casting and it supports the drill press structure. The base supports the column, which in turn, supports the table, head etc. (*vi*) Column is a vertical round or box section which rests on the base and supports the head and the table. The round column may have rack teeth cut on it so that the table can be raised or lowered depending upon the workpiece requirements. This machine consists of following parts

1. Base
2. Pillar
3. Main drive
4. Drill spindle
5. Feed handle
6. Work table



Construction of drilling machine

3.3.2 Types of Drilling Machine

Drilling machines are classified on the basis of their constructional features, or the type of work they can handle. The various types of drilling machines are:

(1) Portable drilling machine
(2) Sensitive drilling machine
    a. Bench mounting
    b. Floor mounting
(3) Upright drilling machine
    a. Round column section
    b. Box column section machine
(4) Radial drilling machine
    a. Plain

b. Semiuniversal
c. Universal

(5) Gang drilling machine
(6) Multiple spindle drilling machine
(7) Automatic drilling machine
(8) Deep hole drilling machine

a. Vertical
b. Horizontal

Few commonly used drilling machines are described as under.

Portable Drilling Machine

A portable drilling machine is a small compact unit and used for drilling holes in worpieces in any position, which cannot be drilled in a standard drilling machine. It may be used for drilling small diameter holes in large castings or weldments at that place itself where they are lying. Portable drilling machines are fitted with small electric motors, which may be driven by both A.C. and D.C. power supply. These drilling machines operate at fairly high speeds and accommodate drills up to 12 mm in diameter.

Sensitive Drilling Machine

It is a small machine used for drilling small holes in light jobs. In this drilling machine, the workpiece is mounted on the table and drill is fed into the work by purely hand control. High rotating speed of the drill and hand feed are the major features of sensitive drilling machine. As the operator senses the drilling action in the workpiece, at any instant, it is called sensitive drilling machine. A sensitive drilling machine consists of a horizontal table, a vertical column, a head supporting the motor and driving mechanism, and a vertical spindle. Drills of diameter from 1.5 to 15.5 mm can be rotated in the spindle of sensitive drilling machine. Depending on the mounting of base of the machine, it may be classified into following types:

1. Bench mounted drilling machine, and
2. Floor mounted drilling machine

Upright Drilling Machine

The upright drilling machine is larger and heavier than a sensitive drilling machine. It is designed for handling medium sized workpieces and is supplied with power feed arrangement. In this machine a large number of spindle speeds and feeds may be available for drilling different types of work. Upright drilling machines are available in various sizes and with various drilling capacities (ranging up to 75 mm diameter drills). The table of the machine also has different types of adjustments. Based on the construction, there are two general types of upright drilling machine:

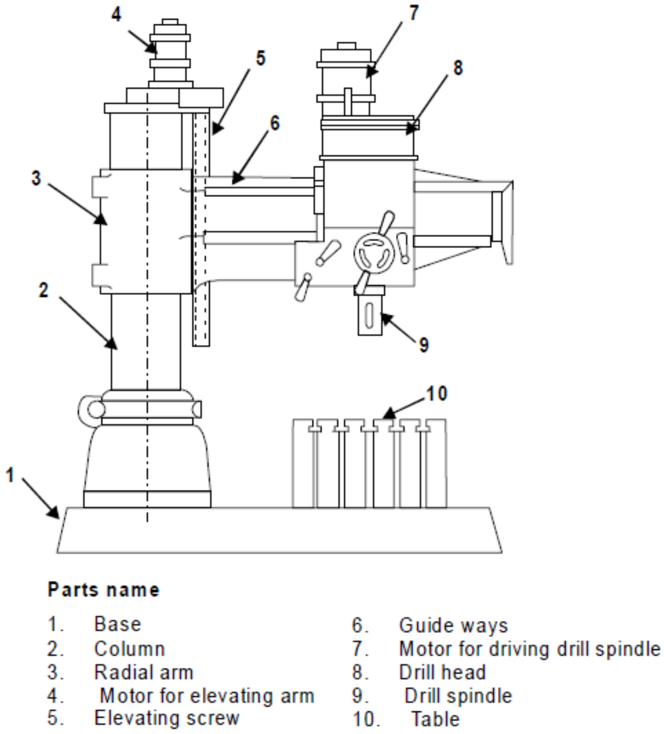
(1) Round column section or pillar drilling machine.
(2) Box column section.

The round column section upright drilling machine consists of a round column whereas the upright drilling machine has box column section. The other constructional features of both are same. Box column machines possess more machine strength and rigidity as compared to those having round section column.

Radial Drilling Machine

Figure illustrates a radial drilling machine. The radial drilling machine consists of a heavy, round vertical column supporting a horizontal arm that carries the drill head. Arm can be raised or lowered on the column and can also be swung around to any position over the work and can be locked in any position. The drill head containing mechanism for rotating and feeding the drill is mounted on a radial arm and can be moved horizontally on the guide-ways and clamped at any desired position. These adjustments of arm and drilling head permit the operator to locate the drill quickly over any point on the work. The table of radial drilling machine may also be rotated through 360 deg. The maximum size of hole that the machine can drill is not more than 50 mm. Powerful drive motors are geared directly into the head of the machine and a wide range of power feeds are available as well as sensitive and geared manual feeds. The radial drilling machine is used primarily for drilling medium to large and heavy workpieces. Depending on the different movements of horizontal arm, table and drill head, the upright drilling machine may be classified into following types-

1. Plain radial drilling machine
2. Semi universal drilling machine, and
3. Universal drilling machine.



Radial drilling machine

In a plain radial drilling machine, provisions are made for following three movements -

1. Vertical movement of the arm on the column,
2. Horizontal movement of the drill head along the arm, and
3. Circular movement of the arm in horizontal plane about the vertical column.

In a semi universal drilling machine, in addition to the above three movements, the drill head can be swung about a horizontal axis perpendicular to the arm. In universal machine, an additional rotatory movement of the arm holding the drill head on a horizontal axis is also provided for enabling it to drill on a job at any angle.

Gang Drilling Machine

In gang drilling machine, a number of single spindle drilling machine columns are placed side by side on a common base and have a common worktable. A series of operation may be performed on the job by shifting the work from one position to the other on the worktable. This type of machine is mainly used for production work.

Multiple-Spindle Drilling Machine

The multiple-spindle drilling machine is used to drill a number of holes in a job simultaneously and to reproduce the same pattern of holes in a number of identical pieces in a mass production work. This machine has several spindles and all the spindles holding drills are fed into the work simultaneously. Feeding motion is usually obtained by raising the worktable.

3.3.3 Operations Performed on Drilling Machine

A drill machine is versatile machine tool. A number of operations can be performed on it. Some of the operations that can be performed on drilling machines are:

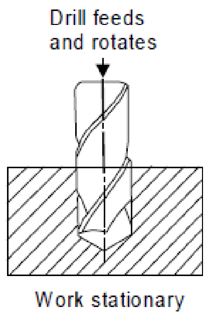
1. Drilling 2. Reaming

3. Boring 4. Counter boring
5. Countersinking 6. Spot facing
7. Tapping 8. Lapping
9. Grinding 10. Trepanning.

The operations that are commonly performed on drilling machines are drilling, reaming, lapping, boring, counter-boring, counter-sinking, spot facing, and tapping. These operations are discussed as under.

Drilling

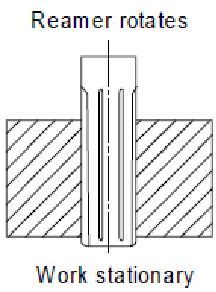
This is the operation of making a circular hole by removing a volume of metal from the job by a rotating cutting tool called drill as shown in Figure. Drilling removes solid metal from the job to produce a circular hole. Before drilling, the hole is located by drawing two lines at right angle and a center punch is used to make an indentation for the drill point at the center to help the drill in getting started. A suitable drill is held in the drill machine and the drill machine is adjusted to operate at the correct cutting speed. The drill machine is started and the drill starts rotating. Cutting fluid is made to flow liberally and the cut is started. The rotating drill is made to feed into the job. The hole, depending upon its length, may be drilled in one or more steps. After the drilling operation is complete, the drill is removed from the hole and the power is turned off.



Drilling operation

Reaming

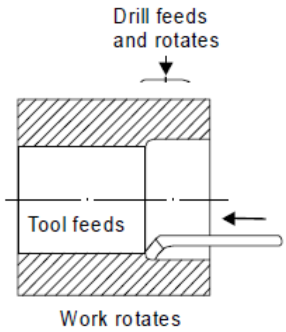
This is the operation of sizing and finishing a hole already made by a drill. Reaming is performed by means of a cutting tool called reamer as shown in Figure. Reaming operation serves to make the hole smooth, straight and accurate in diameter. Reaming operation is performed by means of a multitooth tool called reamer. Reamer possesses several cutting edges on outer periphery and may be classified as solid reamer and adjustable reamer.



Reaming operation

Boring

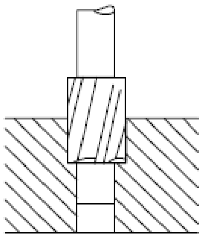
Figure shows the boring operation where enlarging a hole by means of adjustable cutting tools with only one cutting edge is accomplished. A boring tool is employed for this purpose.



Boring operation

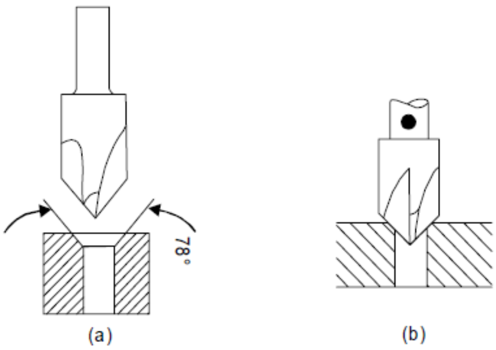
Counter-Boring

Counter boring operation is shown in Figure. It is the operation of enlarging the end of a hole cylindrically, as for the recess for a counter-sunk rivet. The tool used is known as counter-bore.


Counter boring operation

Counter-Sinking

Counter-sinking operation is shown in Figure. This is the operation of making a coneshaped enlargement of the end of a hole, as for the recess for a flat head screw. This is done for providing a seat for counter sunk heads of the screws so that the latter may flush with the main surface of the work.



Counter sinking operation

Lapping

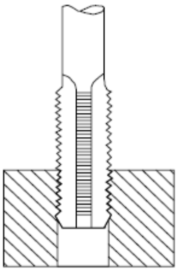
This is the operation of sizing and finishing a hole by removing very small amounts of material by means of an abrasive. The abrasive material is kept in contact with the sides of a hole that is to be lapped, by the use of a lapping tool.

Spot-Facing

This is the operation of removing enough material to provide a flat surface around a hole to accommodate the head of a bolt or a nut. A spot-facing tool is very nearly similar to the counter-bore

Tapping

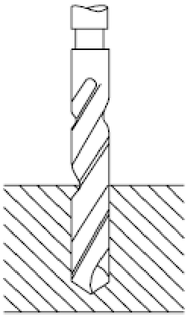
It is the operation of cutting internal threads by using a tool called a tap. A tap is similar to a bolt with accurate threads cut on it. To perform the tapping operation, a tap is screwed into the hole by hand or by machine. The tap removes metal and cuts internal threads, which will fit into external threads of the same size. For all materials except cast iron, a little lubricate oil is applied to improve the action.



Tapping operation

Core drilling

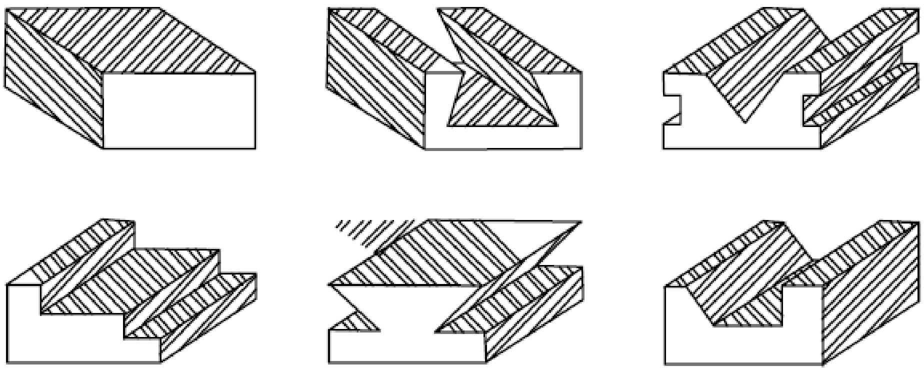
Core drilling operation is shown in Figure. It is a main operation, which is performed on radial drilling machine for producing a circular hole, which is deep in the solid metal by means of revolving tool called drill.



Core drilling operation

3.4 MILLING

A milling machine is a machine tool that removes metal as the work is fed against a rotating multipoint cutter. The milling cutter rotates at high speed and it removes metal at a very fast rate with the help of multiple cutting edges. One or more number of cutters can be mounted simultaneously on the arbor of milling machine. This is the reason that a milling machine finds wide application in production work. Milling machine is used for machining flat surfaces, contoured surfaces, surfaces of revolution, external and internal threads, and helical surfaces of various cross-sections. Typical components produced by a milling are given in Figure. In many applications, due to its higher production rate and accuracy, milling machine has even replaced shapers and slotters.



Job surfaces generated by milling machine

3.4.1 Principle of Milling

In milling machine, the metal is cut by means of a rotating cutter having multiple cutting edges. For cutting operation, the workpiece is fed against the rotary cutter. As the workpiece moves against the cutting edges of milling cutter, metal is removed in form chips of trochoid shape. Machined surface is formed in one or more passes of the work. The work to be machined is held in a vice, a rotary table, a three jaw chuck, an index head, between centers, in a special fixture or bolted to machine table. The rotatory speed of the cutting tool and the feed rate of the workpiece depend upon the type of material being machined.

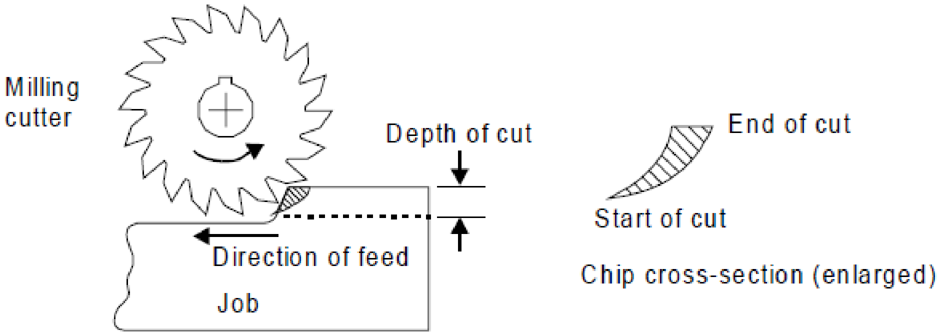
3.4.2 Milling Methods

There are two distinct methods of milling classified as follows:

1. Up-milling or conventional milling, and
2. Down milling or climb milling.

UP-Milling or Conventional Milling Procedure

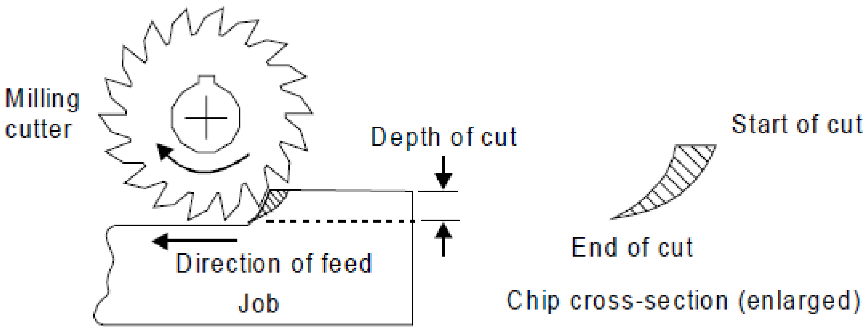
In the up-milling or conventional milling, as shown in Figure, the metal is removed in form of small chips by a cutter rotating against the direction of travel of the workpiece. In this type of milling, the chip thickness is minimum at the start of the cut and maximum at the end of cut. As a result the cutting force also varies from zero to the maximum value per tooth movement of the milling cutter. The major disadvantages of up-milling process are the tendency of cutting force to lift the work from the fixtures and poor surface finish obtained. But being a safer process, it is commonly used method of milling.



Principal of up-milling

Down-Milling or Climb Milling

Down milling is shown in Figure. It is also known as climb milling. In this method, the metal is removed by a cutter rotating in the same direction of feed of the workpiece. The effect of this is that the teeth cut downward instead of upwards. Chip thickness is maximum at the start of the cut and minimum in the end. In this method, it is claimed that there is less friction involved and consequently less heat is generated on the contact surface of the cutter and workpiece. Climb milling can be used advantageously on many kinds of work to increase the number of pieces per sharpening and to produce a better finish. With climb milling, saws cut long thin slots more satisfactorily than with standard milling. Another advantage is that slightly lower power consumption is obtainable by climb milling, since there is no need to drive the table against the cutter.

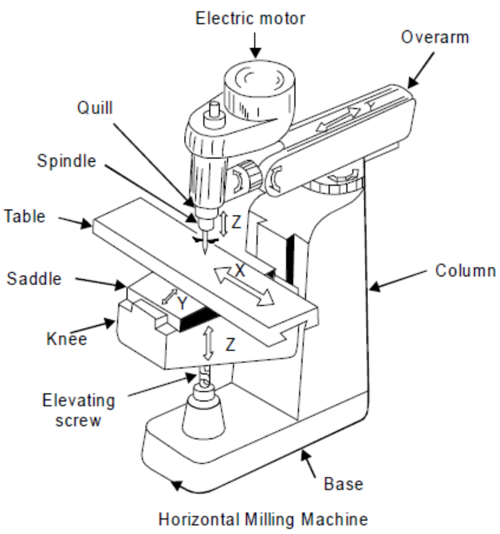


Principal of down-milling

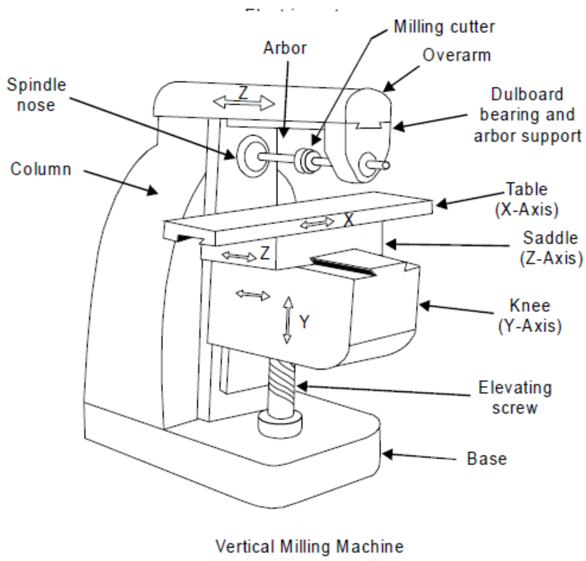
3.4.3 Types of Milling Machines

Milling machine rotates the cutter mounted on the arbor of the machine and at the same time automatically feed the work in the required direction. The milling machine may be classified in several forms, but the choice of any particular machine is determined primarily by the size of the workpiece to be undertaken and operations to be performed. With the above function or requirement in mind, milling machines are made in a variety of types and sizes. According to general design, the distinctive types of milling machines are:

1. Column and knee type milling machines
    - a) Hand milling machine
    - b) Horizontal milling machine
    - c) Universal milling machine
    - d) Vertical milling machine



Horizontal column and knee type milling machine



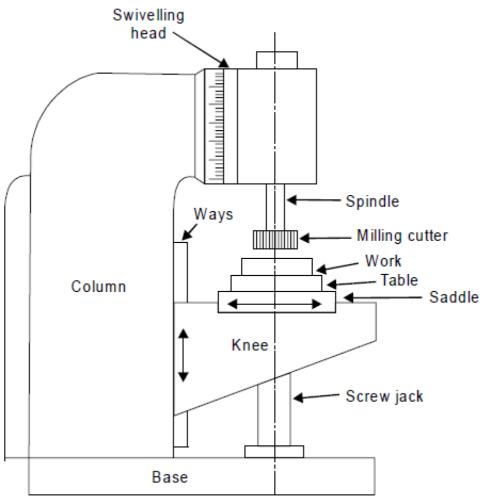
Vertical column and knee type milling machine

2. Planer milling machine
3. Fixed-bed type milling machine
    - a) Simplex milling machine.
    - b) Duplex milling machine.
    - c) Triplex milling machine.
4. Machining center machines
5. Special types of milling machines
    - a) Rotary table milling machine.
    - b) Planetary milling machine.
    - c) Profiling machine.
    - d) Duplicating machine.
    - e) Pantograph milling machine.
    - f) Continuous milling machine.
    - g) Drum milling machine
    - h) Profiling and tracer controlled milling machine

Some important types of milling machines are discussed as under.

Column and Knee Type Milling Machine

Figure shows a simple column and knee type milling machine. It is the most commonly used milling machine used for general shop work. In this type of milling machine the table is mounted on the knee casting which in turn is mounted on the vertical slides of the main column. The knee is vertically adjustable on the column so that the table can be moved up and down to accommodate work of various heights. The column and knee type milling machines are classified on the basis of various methods of supplying power to the table, different movements of the table and different axis of rotation of the main spindle. Column and knee type milling machine comprises of the following important parts-



A column and knee type milling machine

1. Base	2. Column
3. Saddle	4. Table
5. Elevating screw	6. Knee
7. Knee elevating handle	8. Cross feed handle
9. Front brace	10. Arbor support
11. Arbor	12. Overhanging arm
13. Cutter	14. Cone pulley
15. Telescopic feed shaft.	

The principal parts of a column and knee type milling machine are described as under.

- ***Base***

It is a foundation member for all the other parts, which rest upon it. It carries the column at its one end. In some machines, the base is hollow and serves as a reservoir for cutting fluid.

- ***Column***

The column is the main supporting member mounted vertically on the base. It is box shaped, heavily ribbed inside and houses all the driving mechanism for the spindle and table feed. The front vertical face of the column is accurately machined and is provided with dovetail guideway for supporting the knee.

- ***Knee***

The knee is a rigid grey iron casting which slides up and down on the vertical ways of the column face. An elevating screw mounted on the base is used to adjust the height of the knee and it also supports the knee. The knee houses the feed mechanism of the table, and different controls to operate it.

- ***Saddle***

The saddle is placed on the top of the knee and it slides on guideways set exactly at 90° to the column face. The top of the saddle provides guide-ways for the table.

- ***Table***

The table rests on ways on the saddle and travels longitudinally. A lead screw under the table engages a nut on the saddle to move the table horizontally by hand or power. In universal machines, the table may also be swiveled horizontally. For this purpose the table is mounted on a circular base. The top of the table is accurately finished and T -slots are provided for clamping the work and other fixtures on it.

- ***Overhanging arm***

It is mounted on the top of the column, which extends beyond the column face and serves as a bearing support for the other end of the arbor.

- ***Front brace***

It is an extra support, which is fitted between the knee and the over-arm to ensure further rigidity to the arbor and the knee.

- ***Spindle***

It is situated in the upper part of the column and receives power from the motor through belts, gears. and clutches and transmit it to the arbor.

- ***Arbor***

It is like an extension of the machine spindle on which milling cutters are securely mounted and rotated. The arbors are made with taper shanks for proper alignment with the machine spindles having taper holes at their nose. The draw bolt is used for managing for locking the arbor with the spindle and the whole assembly. The arbor assembly consists of the following components.

1. Arbor	2. Spindle
3. Spacing collars	4. Bearing bush
5. Cutter	6. Draw bolt
7. Lock nut	8. Key block
9. Set screw	

Planer Type Milling Machine

It is a heavy duty milling machine. It resembles a planer and like a planning machine it has a cross rail capable of being raised or lowered carrying the cutters, their heads, and the saddles, all supported by rigid uprights. There may be a number of independent spindles carrying cutters on the rail as two heads on the uprights. The use of the machine is limited to production work only and is considered ultimate in metal re-moving capacity.

Special Type Milling Machines

Milling machines of non-conventional design have been developed to suit special purposes. The features that they have in common are the spindle for rotating the cutter and provision for moving the tool or the work in different directions.

3.4.4 Size of Milling Machine

The size of the column and knee type milling machine is specified by

(1) The dimensions of the working surface of the table, and
(2) Its maximum length of longitudinal, cross and vertical travel of the table.

In addition to above, number of spindle speeds, number of feeds, spindle nose taper, power available, floor space required and net weight of machine will also be required for additional specification.

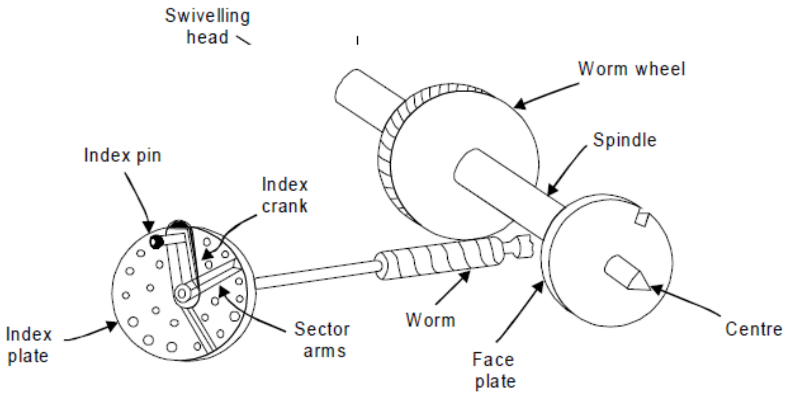
3.4.5 Depth of Cut

The depth of cut in milling is defined as the thickness of the material removed in one pass of the work under the cutter. Thus it is the perpendicular distance measured between the original and final surface of the workpiece, and is expressed in mm.

3.4.6 Indexing and Dividing Heads

Indexing is the operation of dividing the periphery of a piece of work into any number of equal parts. In cutting spur gear equal spacing of teeth on the gear blank is performed by indexing. Indexing is accomplished by using a special attachment known as dividing head or index head as shown in Fig. 24.8. The dividing heads are of three types:

(1) Plain or simple dividing head,
(2) Universal dividing head and
(3) Optical dividing head.



Dividing head

Plain or Simple Dividing Head

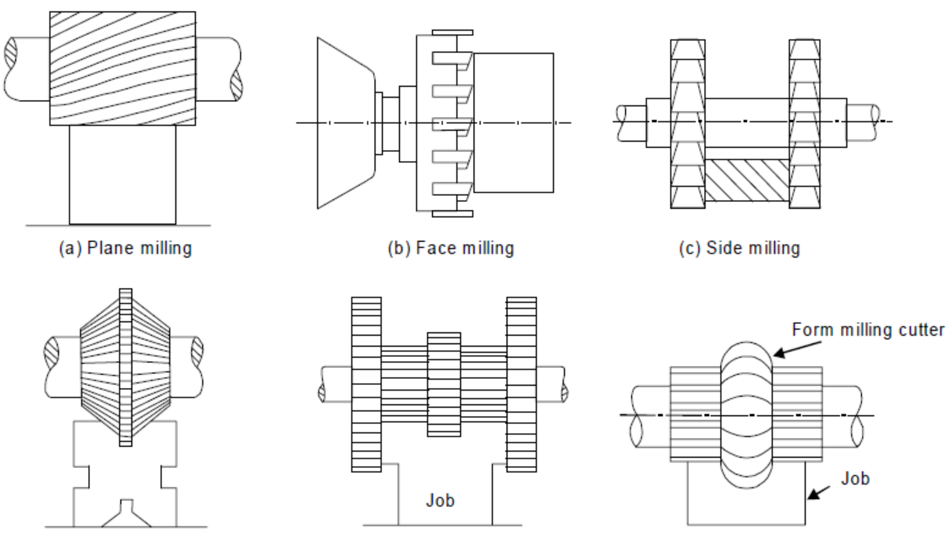
The plain dividing head comprises a cylindrical spindle housed on a frame, and a base bolted to the machine table. The index crank is connected to the tail end of the spindle directly, and the crank and the spindle rotate as one unit. The index plate is mounted on the spindle and rotates with it. The spindle may be rotated through the desired angle and then clamped by inserting the clamping lever pin into anyone of the equally spaced holes or slots cut on the periphery of the index plate. This type of dividing head is used for handling large number of workpieces, which require a very small number of divisions on the periphery.

1. Swiveling block 2. Live centre

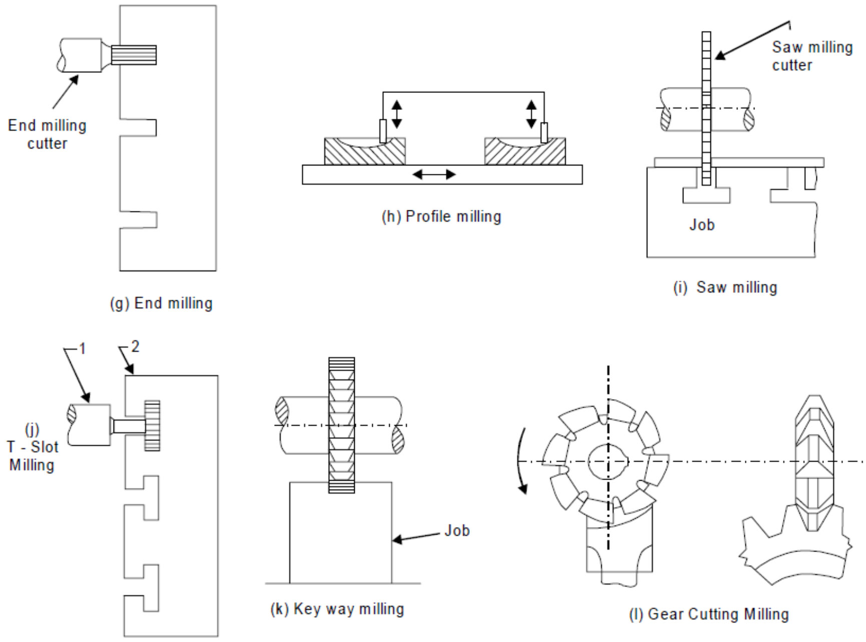
3. Index crank 4. Index plate.

3.4.7 Operations Performed on Milling Machine

Unlike a lathe, a milling cutter does not give a continuous cut, but begins with a sliding motion between the cutter and the work. Then follows a crushing movement, and then a cutting operation by which the chip is removed. Many different kinds of operations can be performed on a milling machine but a few of the more common operations will now be explained. These are:



(a) Plane milling (b) Face milling (c) Side milling
(d) Angular milling (e) Gang milling (f) Form Milling



3.5 ABRASIVE MACHINING

Abrasive machining is a material removal process that involves the use of abrasive cutting tools. There are three principle types of abrasive cutting tools according to the degree to which abrasive grains are constrained,

- ***Bonded abrasive tools***: abrasive grains are closely packed into different shapes, the most common is the *abrasive wheel*. Grains are held together by bonding material. Abrasive machining process that use bonded abrasives include *grinding*, *honing*, *superfinishing;*
- ***Coated abrasive tools***: abrasive grains are glued onto a flexible cloth, paper or resin backing. Coated abrasives are available in sheets, rolls, endless belts. Processes include *abrasive belt grinding*, *abrasive wire cutting*;
- ***Free abrasives***: abrasive grains are not bonded or glued. Instead, they are introduced either in oil-based fluids (*lapping*, *ultrasonic machining*), or in water (*abrasive water jet cutting*) or air (*abrasive jet machining*), or contained in a semisoft binder (*buffing*).

Abrasive machining can be likened to the other machining operations with multipoint cutting tools. Each abrasive grain acts like a small single cutting tool with undefined geometry but usually with high negative rake angle. Abrasive machining involves a number of operations, used to achieve ultimate dimensional precision and surface finish.

3.5.1 Grinding

Grinding is a material removal process in which abrasive particles arc contained in a bonded grinding wheel that operates at very high surface speeds. The grinding wheel is usually disk shaped and is precisely balanced for high rotational speeds.

Grinding wheel

A *grinding wheel* consists of abrasive particles and bonding material. The bonding material holds the particles in place and establishes the shape and structure of the wheel.

The way the abrasive grains, bonding material, and the air gaps are structured, determines the parameters of the grinding wheel, which are

- *abrasive material*,
- *grain size*,
- *bonding material*,
- *wheel grade*, and
- *wheel structure*.

To achieve the desired performance in a given application, each parameter must be carefully selected.

Abrasive materials

The *abrasive materials* of greatest commercial importance today are listed in the table:

Abrasive material	Work material	Color
Aluminum oxide		
97-99% Al_2O_3	hardened steels, HSS	white
87-96% Al_2O_3	steels, cast iron	pink to brown
Silicon carbide		
96-99% SiC	HSS, cemented carbides	green
<96% SiC	aluminum, brass, brittle materials	black
Cubic boron nitride (CBN)	tool steels, aerospace alloys	
Synthetic diamond	ceramics, cemented carbides	

Grain size

- The *grain size* of the abrasive particle is an important parameter in determining surface finish and material removal rate. Small grit sizes produce better finishes while larger grain sizes permit larger material removal rates.
- The abrasive grains are classified in a screen mesh procedure, as explained in *Section 3.2*. In this procedure smaller grit sizes have larger numbers and vice versa.
- Grain sizes used in grinding wheels typically range between 6 and 600. Grit size 6 is very coarse and size 600 is very fine. Finer grit sizes up to 1000 are used in some finishing operations

Bonding Materials

The *bonding material* holds the abrasive grains and establishes the shape and structural integrity of the grinding wheel. Desirable properties of the bond material include strength, toughness, hardness, and temperature resistance.

Bonding materials commonly used in grinding wheels include the following:

- *vitrified bond*: vitrified bonding material consists chiefly of ceramic materials. Most grinding wheels in common use are vitrified bonded wheels. They are strong and rigid, resistant to elevated temperatures, and relatively unaffected by cutting fluids;
- *rubber bond*: rubber is the most flexible of the bonding materials. It is used as a bonding material in cutoff wheels;
- *resinoid bond*: this bond is made of various thermosetting resin materials. They have very high strength and are used for rough grinding and cutoff operations;
- *shellac bond*: shellac-bonded grinding wheels are relatively strong but not rigid. They are often used in applications requiring a good finish;
- *metallic bond*: metal bonds, usually bronze, are the common bond material for diamond and CBN grinding wheels. Diamond and CBN abrasive grains are bond material to only the outside periphery of the wheel, thus conserving the costly abrasive materials.

Wheel grade

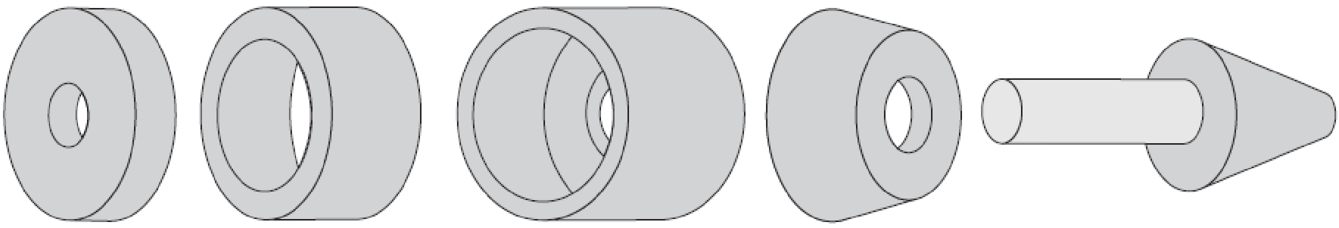
Wheel grades indicates the wheel bond strength. It is measured on a scale ranging from *soft* to *hard*. Soft wheels loose grains easily and are used for low material removal rates and grinding of hard materials. Harder grades are preferred for high productivity and grinding of relatively soft materials.

Structure

The *wheel structure* indicates spacing of the abrasive grains in the wheel. It is measured on a scale that ranges from *open* to *dense*. Open structure means more pores and fewer grains per unit wheel volume, and vice versa. Open structure is recommended for work materials that tend to produce continuous chips, while denser structure is used for better surface finish and dimensional precision.

Grinding wheel specification

Grinding wheels are marked with a standardized system of letters and numbers, which specifies the parameters of the grinding wheel. Grinding wheels are available in a variety of shapes and sizes the most popular shown in the figure:

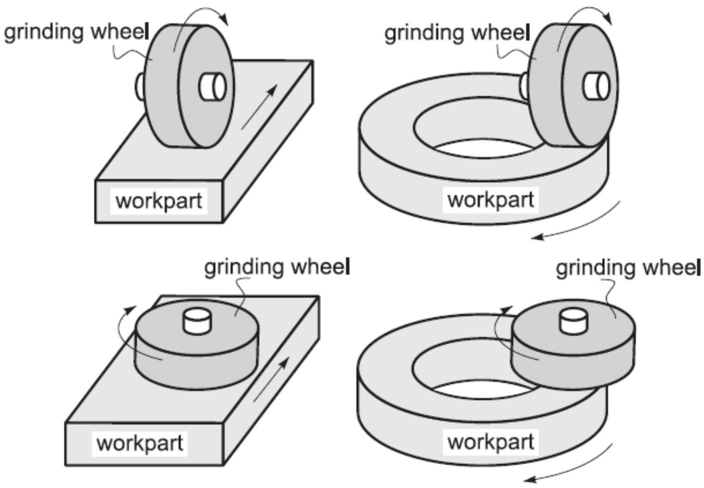


Some common types of grinding wheels; (*From left to right*) straight, cylinder, straight cup, flaring cup, mounted.

Surface grinding

Surface grinding is an abrasive machining process in which the grinding wheel removes material from the plain flat surfaces of the workpiece.

In surface grinding, the spindle position is either *horizontal* or *vertical*, and the relative motion of the workpiece is achieved either by *reciprocating* the workpiece past the wheel or by *rotating* it. The possible combinations of spindle orientations and workpiece motions yield four types of surface grinding processes illustrated in the figure:

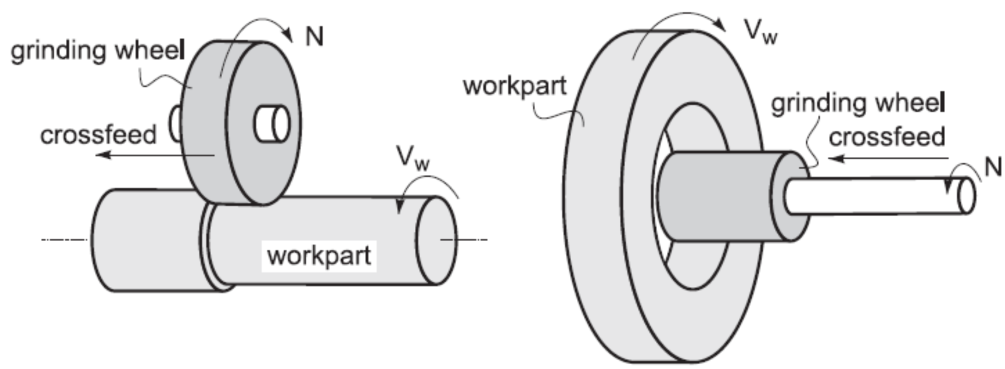


Four types of surface grinding with horizontal or vertical spindles, and with reciprocating linear motion or rotating motion of the workpiece.

Cylindrical grinding

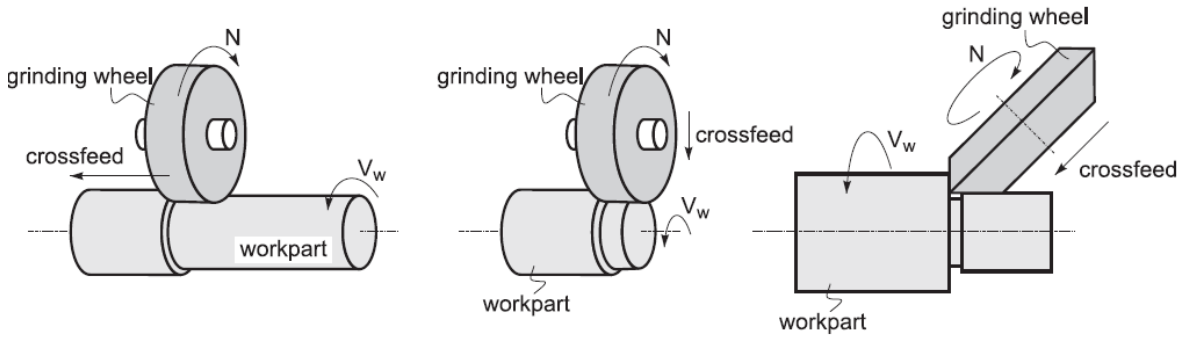
In this operation, the external or internal cylindrical surface of a workpiece are ground. In *external cylindrical grinding* (also *center-type grinding*) the workpiece rotates and reciprocates along its axis, although for large and long workparts the grinding wheel reciprocates.

In *internal cylindrical grinding*, a small wheel grinds the inside diameter of the part. The workpiece is held in a rotating chuck in the headstock and the wheel rotates at very high rotational speed. In this operation, the workpiece rotates and the grinding wheel reciprocates.



Two types of surface grinding, (*Left*) external, and (*Right*) internal.

Three types of feed motion are possible according to the direction of feed motion, t*raverse feed grinding* (also *through feed grinding*, *cross-feeding*) in which the relative feed motion is parallel to the spindle axis of rotation, *plunge grinding* in which the grinding wheel is fed radially into the workpiece, and a *combination of traverse and plunge grinding* in which the grinding wheel is fed at 45^o to grind simultaneously the cylindrical part of the workpiece and the adjacent face. This methods provides a precise perpendicular mutual position of both surfaces.



Three types of cylindrical grinding: (*From left to right*) traverse feed grinding, plunge grinding, a combination of both previous types.

3.5.2 Grinding Machines

Grinding Machines are also regarded as machine tools. A distinguishing feature of grinding machines is the rotating abrasive tool. Grinding machine is employed to obtain high accuracy along with very high class of surface finish on the workpiece. However, advent of new generation of grinding wheels and grinding machines, characterised by their rigidity, power and speed enables one to go for high efficiency deep grinding (often called as abrasive milling) of not only hardened material but also ductile materials.

Conventional grinding machines can be broadly classified as:

a. Surface grinding machine
b. Cylindrical grinding machine
c. Internal grinding machine
d. Tool and cutter grinding machine

Surface grinding machine:

This machine may be similar to a milling machine used mainly to grind flat surface. However, some types of surface grinders are also capable of producing contour surface with formed grinding wheel.

Basically there are four different types of surface grinding machines characterised by the movement of their tables and the orientation of grinding wheel spindles as follows:

- Horizontal spindle and reciprocating table

- Vertical spindle and reciprocating table
- Horizontal spindle and rotary table
- Vertical spindle and rotary table

Horizontal spindle reciprocating table grinder

Figure illustrates this machine with various motions required for grinding action. A disc type grinding wheel performs the grinding action with its peripheral surface. Both traverse and plunge grinding can be carried out in this machine as shown in Figure.

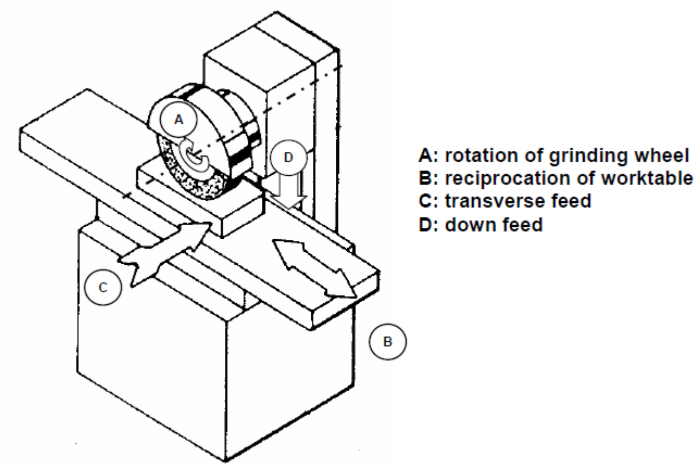


***Fig.29.1**: Horizontal spindle reciprocating table surface grinder*

Vertical spindle reciprocating table grinder

This grinding machine with all working motions is shown in Figure. The grinding operation is similar to that of face milling on a vertical milling machine. In this machine a cup shaped wheel grinds the workpiece over its full width using end face of the wheel as shown in Figure. This brings more grits in action at the same time and consequently a higher material removal rate may be attained than for grinding with a peripheral wheel.

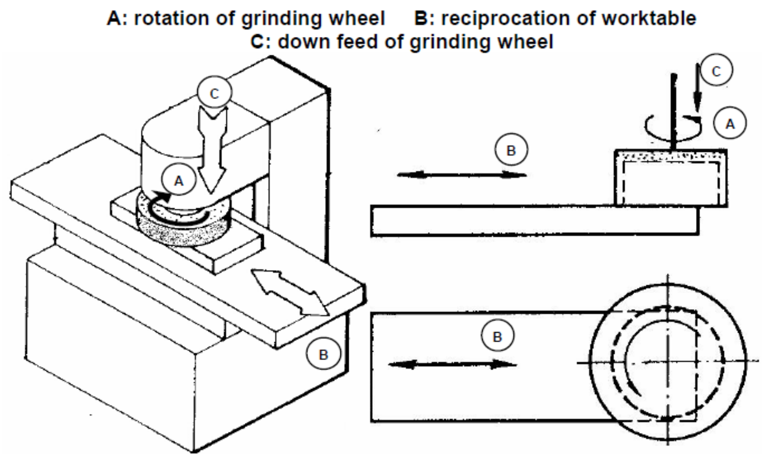


***Fig. 29.3** Vertical spindle reciprocating table surface grinder*

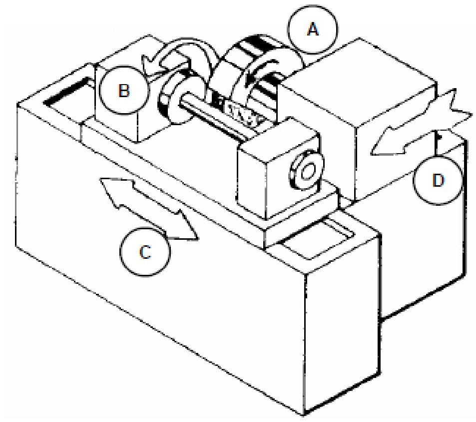
***Fig. 29.4** Surface grinding in Vertical spindle reciprocating table surface grinder*

Cylindrical grinding machine

This machine is used to produce external cylindrical surface. The surfaces may be straight, tapered, steps or profiled. Broadly there are three different types of cylindrical grinding machine as follows:

1. Plain centre type cylindrical grinder
2. Universal cylindrical surface grinder
3. Centreless cylindrical surface grinder

Figure illustrates schematically this machine and various motions required for grinding action. The machine is similar to a centre lathe in many respects. The workpiece is held between head stock and tailstock centres. A disc type grinding wheel performs the grinding action with its peripheral surface. Both traverse and plunge grinding can be carried out in this machine as shown in Figure.

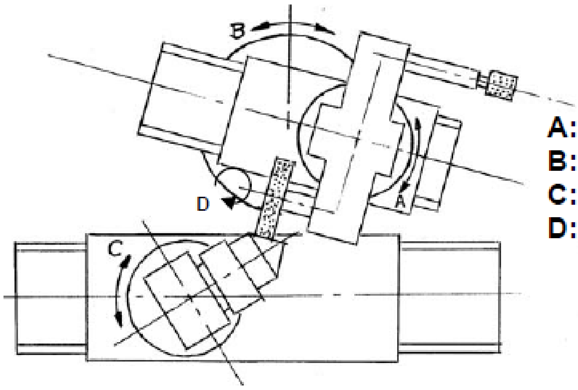


A: rotation of grinding wheel
B: work table rotation
C: reciprocation of worktable
D: infeed

Plain centre type cylindrical grinder

Universal cylindrical surface grinder

Universal cylindrical grinder is similar to a plain cylindrical one except that it is more versatile. In addition to small worktable swivel, this machine provides large swivel of head stock, wheel head slide and wheel head mount on the wheel head slide. This allows grinding of any taper on the workpiece. Universal grinder is also equipped with an additional head for internal grinding. Schematic illustration of important features of this machine is shown in Figure.



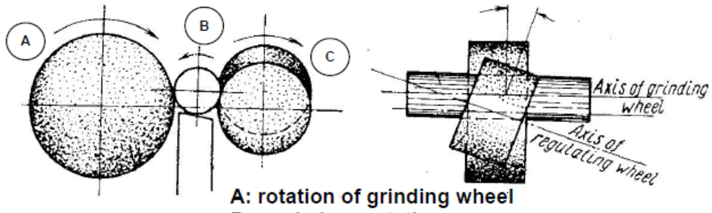
A: swivelling wheel head
B: swivelling wheel head slide
C: swivelling head stock
D: rotation of grinding wheel

important features of universal cylindrical grinding machine

External centreless grinder

This grinding machine is a production machine in which out side diameter of the workpiece is ground. The workpiece is not held between centres but by a work support blade. It is rotated by means of a regulating wheel and ground by the grinding wheel.

In through-feed centreless grinding, the regulating wheel revolving at a much lower surface speed than grinding wheel controls the rotation and longitudinal motion of the workpiece. The regulating wheel is kept slightly inclined to the axis of the grinding wheel and the workpiece is fed longitudinally as shown in Figure.



A: rotation of grinding wheel
B: workpiece rotation
C: reciprocation of worktable

Centreless through feed grinding

Internal grinding machine

This machine is used to produce internal cylindrical surface. The surface may be straight, tapered, grooved or profiled.

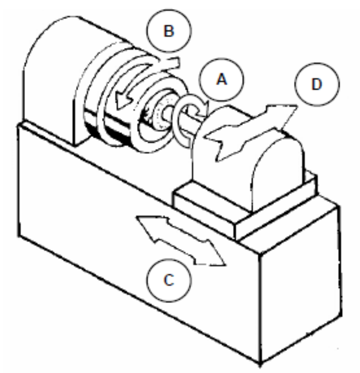
Broadly there are three different types of internal grinding machine as follows:

1. Chucking type internal grinder
2. Planetary internal grinder
3. Centreless internal grinder

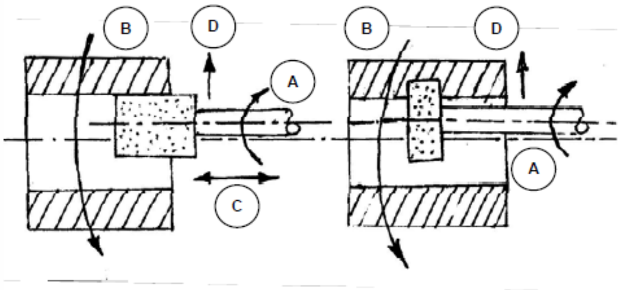
Chucking type internal grinder

Figure illustrates schematically this machine and various motions required for grinding action. The workpiece is usually mounted in a chuck. A magnetic face plate can also be used. A small grinding wheel performs the necessary grinding with its peripheral surface. Both transverse and plunge grinding can be carried out in this machine as shown in Figure.

A: rotation of grinding wheel **B**: workpiece rotation
C: reciprocation of worktable **D**: infeed



Internal centreless grinder

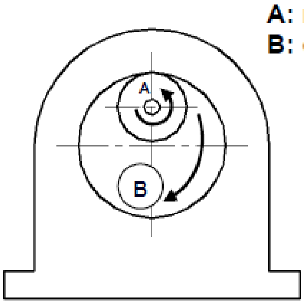


Internal (a) traverse grinding and (b) plunge grinding

Planetary internal grinder

Planetary internal grinder is used where the workpiece is of irregular shape and can not be rotated conveniently as shown in Figure. In this machine the workpiece does not rotate. Instead, the grinding wheel orbits the axis of the hole in the workpiece.

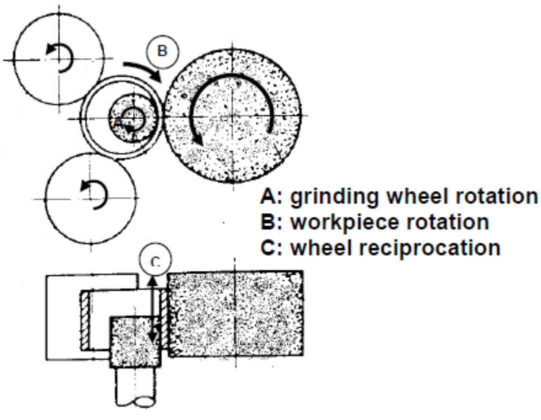
A: rotation of grinding wheel
B: orbiting motion of grinding



Internal grinding in planetary grinder

Centreless internal grinder

This machine is used for grinding cylindrical and tapered holes in cylindrical parts (e.g. cylindrical liners, various bushings etc). The workpiece is rotated between supporting roll, pressure roll and regulating wheel and is ground by the grinding wheel as illustrated in Figure.



Internal centreless grinding

3.6 SHAPER

Shaper is a reciprocating type of machine tool in which the ram moves the cutting tool backwards and forwards in a straight line. It is intended primarily to produce flat surfaces. These surfaces may be horizontal, vertical, or inclined. In general, the shaper can produce any surface composed of straight-line elements

3.6.1 Working Principle of Shaper

A single point cutting tool is held in the tool holder, which is mounted on the ram. The workpiece is rigidly held in a vice or clamped directly on the table. The table may be supported at the outer end. The ram reciprocates and thus cutting tool held in tool holder moves forward and backward over the workpiece. In a standard shaper, cutting of material takes place during the forward stroke of the ram. The backward stroke remains idle and no cutting takes place during this stroke. The feed is given to the workpiece and depth of cut is adjusted by moving the tool downward towards the workpiece. The time taken during the idle stroke is less as compared to forward cutting stroke and this is obtained by quick return mechanism.

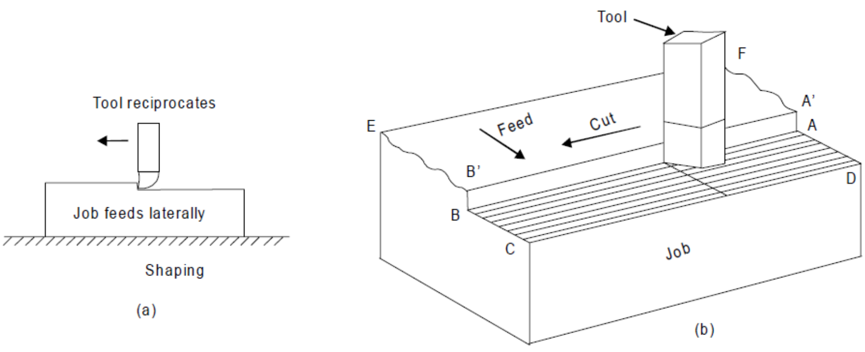


Fig. (a, b) Working principal of shaping machine

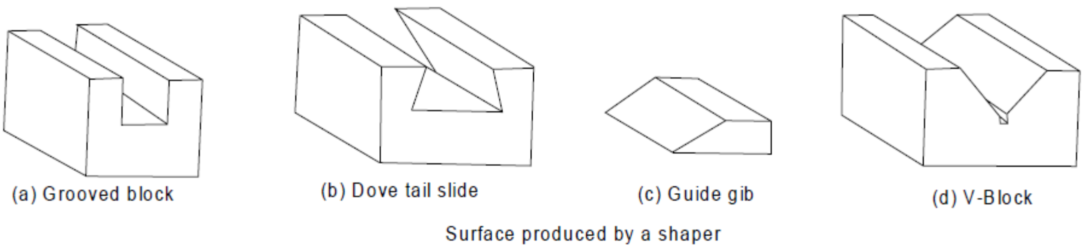


Fig. Job surfaces generated by shaper

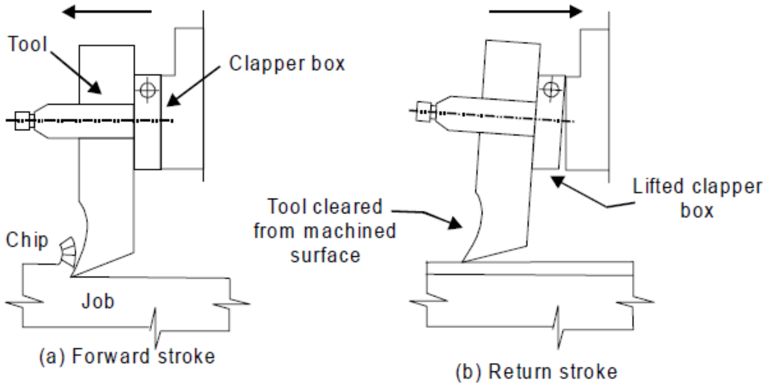


Fig. Cutting action and functioning of clapper box

3.6.2 Types of Shapers

Shapers are classified under the following headings:

(1) According to the type of mechanism used for giving reciprocating motion to the ram
   a) Crank type
   b) Geared type
   c) Hydraulic type

(2) According to the type of design of the table:
   a) Standard shaper
   b) Universal shaper

(3) According to the position and travel of ram:
   a) Horizontal type
   b) Vertical type
   c) Traveling head type

(4) According to the type of cutting stroke:
   a) Push type
   b) Draw type.

Crank Shaper-This is the most common type of shaper. It employs a crank mechanism to change circular motion of a large gear called “bull gear” incorporated in the machine to reciprocating motion of the ram. The bull gear receives power either from an individual motor or from an overhead line shaft if it is a belt-driven shaper.

Geared Shaper-Geared shaper uses rack and pinion arrangement to obtain reciprocating motion of the ram. Presently this type of shaper is not very widely used.

Hydraulic Shaper-In hydraulic shaper, reciprocating motion of the ram is obtained by hydraulic power. For generation of hydraulic power, oil under high pressure is pumped into the operating cylinder fitted with piston. The piston end is connected to the ram through piston rod. The high pressure oil causes the piston to reciprocate and this reciprocating motion is transferred to the ram of shaper. The important advantage of this type of shaper is that the cutting speed and force of the ram drive are constant from the very beginning to the end of the cut.

Standard Shaper-In standard shaper, the table has only two movements, horizontal and vertical, to give the feed.

Universal Shaper-A universal shaper is mostly used in tool room work. In this type of shaper, in addition to the horizontal and vertical movements, the table can be swiveled about an axis parallel to the ram ways, and the upper portion of the table can be tilted about a second horizontal axis perpendicular to the first axis.

Horizontal Shaper-In this type of shaper, the ram holding the tool reciprocates in a horizontal axis.

Vertical Shaper-In vertical shaper, the ram reciprocates in a vertical axis. These shapers are mainly used for machining keyways, slots or grooves, and internal surfaces.

Travelling Head Shaper-In this type of shaper, the ram while it reciprocates, also moves crosswise to give the required feed.

Push Type Shaper-This is the most general type of shaper used in common practice, in which the metal is removed when the ram moves away from the column, i.e. pushes the work.

Draw Type Shaper-In this type of shaper, the cutting of metal takes place when the ram moves towards the column of the machine, i.e. draws the work towards the machine. The tool is set in a reversed direction to that of a standard shaper.

3.6.3 Principal Parts of Shaper

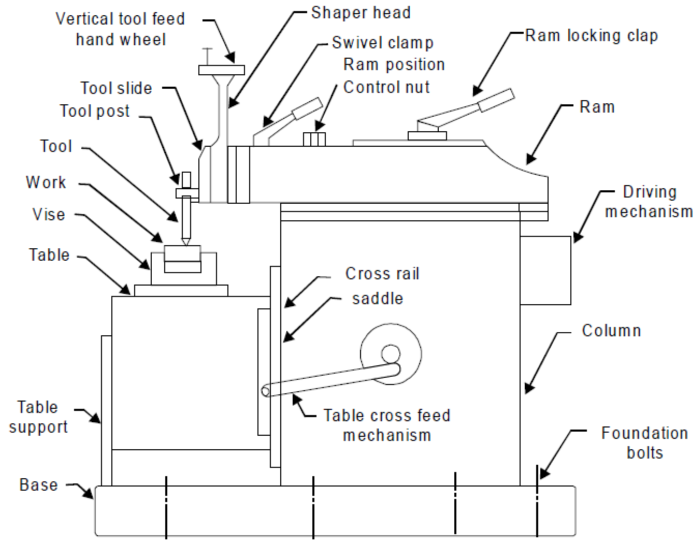


Fig. Parts of a standard shaper

Base - It is rigid and heavy cast iron body to resist vibration and takes up high compressive load. It supports all other parts of the machine, which are mounted over it. The base may be rigidly bolted to the floor of the shop or on the bench according to the size of the machine.

Column - The column is a box shaped casting mounted upon the base. It houses the ram-driving mechanism. Two accurately machined guide ways are provided on the top of the column on which the ram reciprocates.

Cross rail - Cross rail of shaper has two parallel guide ways on its top in the vertical plane that is perpendicular to the rai1 axis. It is mounted on the front vertical guide ways of the column. It consists mechanism for raising and lowering the table to accommodate different sizes of jobs by rotating an elevating screw which causes the cross rail to slide up and down on the vertical face of the column. A horizontal cross feed screw is fitted within the cross rail and parallel to the top guide ways of the cross rail. This screw actuates the table to move in a crosswise direction.

Saddle - The saddle is located on the cross rail and holds the table on its top. Crosswise movement of the saddle by rotation the cross feed screw by hand or power causes the table to move sideways.

Table -The table is a box like casting having T -slots both on the top and sides for clamping the work. It is bolted to the saddle and receives crosswise and vertical movements from the saddle and cross rail.

Ram - It is the reciprocating part of the shaper, which reciprocates on the guideways provided above the column. Ram is connected to the reciprocating mechanism contained within the column.

Tool head - The tool head of a shaper performs the following functions-

(1) It holds the tool rigidly,
(2) It provides vertical and angular feed movement of the tool, and
(3) It allows the tool to have an automatic relief during its return stroke.

The various parts of tool head of shaper are apron clamping bolt, clapper box, tool post, down feed, screw micrometer dial, down feed screw, vertical slide, apron washer, apron swivel pin, and swivel base. By rotating the down feed screw handle, the vertical slide carrying the tool gives down feed or angular feed movement while machining vertical or angular surface. The amount of feed or depth of cut may be adjusted by a micrometer dial on the top of the down feed screw. Apron consisting of clapper box, clapper block and tool post is clamped upon the vertical slide by a screw. The two vertical walls on the apron called clapper box houses the clapper block, which is connected to it by means of a hinge pin. The tool post is mounted upon the clapper block. On the forward cutting stroke the clapper block fits securely to the clapper box to make a rigid tool support. On the return stroke a slight frictional drag of the tool on the work lifts the block out of the clapper box a sufficient amount preventing the tool cutting edge from dragging and consequent wear. The work surface is also prevented from any damage due to dragging.

3.6.3 Specification of a Shaper

The size of a shaper is specified by the maximum length of stroke or cut it can make. Usually the size of shaper ranges from 175 to 900 mm. Besides the length of stroke, other particulars, such as the type of drive (belt drive or individual motor drive), floor space required, weight of the machine, cutting to return stroke ratio, number and amount of feed, power input etc. are also sometimes required for complete specification of a shaper.

3.6.4 Shaper Mechanism

In a shaper, rotary motion of the drive is converted into reciprocating motion of the ram by the mechanism housed within the column or the machine. In a standard shaper metal is removed in the forward cutting stroke, while the return stroke goes idle and no metal is removed during this period as shown in Figure. The shaper mechanism is so designed that it moves the ram holding the tool at a comparatively slower speed during forward cutting stroke, whereas during the return stroke it allow the ram to move at a faster speed to reduce the idle return time. This mechanism is known as quick return mechanism. The reciprocating movement of the ram and the quick return mechanism of the machine are generally obtained by anyone of the following methods:

(1) Crank and slotted link mechanism
(2) Whitworth quick return mechanism, and
(3) Hydraulic shaper mechanism

Crank and Slotted Link Mechanism

In crank and slotted link mechanism, the pinion receives its motion from an individual motor or overhead line shaft and transmits the motion or power to the bull gear. Bull gear is a large gear mounted within the column. Speed of the bull gear may be changed by different combination of gearing or by simply shifting the belt on the step cone pulley. A radial slide is bolted to the centre of the bull gear.

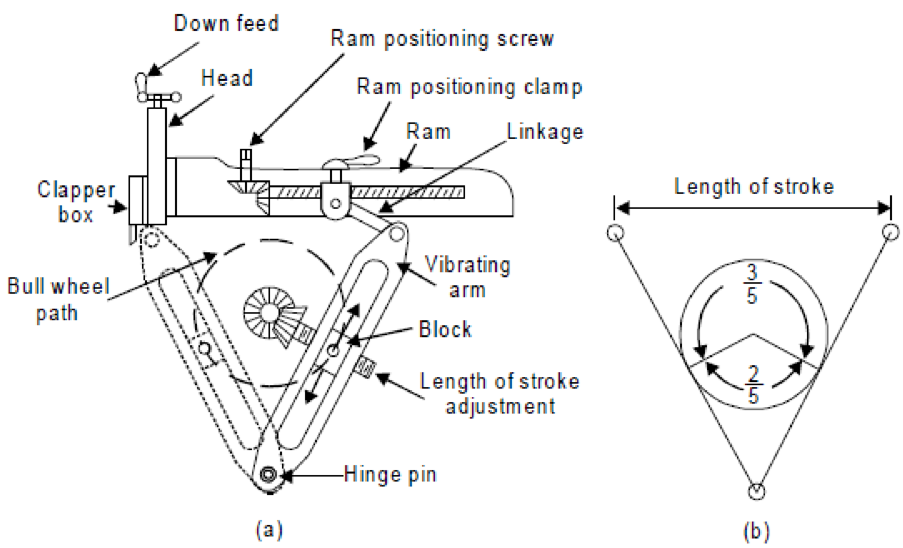


Fig Crank and slotted link mechanism

This radial slide carries a sliding block into which the crank pin is fitted. Rotation of the bull gear will cause the bush pin to revolve at a uniform speed. Sliding block, which is mounted upon the crank pin is fitted within the slotted link. This slotted link is also known as the rocker arm. It is pivoted at its bottom end attached to the frame of the column.

The upper end of the rocker arm is forked and connected to the ram block by a pin. With the rotation of bull gear, crank pin will rotate on the crank pin circle, and simultaneously move up and down the slot in the slotted link giving it a rocking movement, which is communicated to the ram. Thus the rotary motion of the bull gear is converted to reciprocating motion of the ram.

3.6.5 Shaper Operations

A shaper is a machine tool primarily designed to generate a flat surface by a single point cutting tool. Besides this, it may also be used to perform many other operations. The different operations, which a shaper can perform, are as follows:

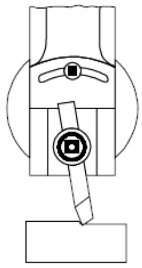


Fig Machining horizontal vertical surface on shaper

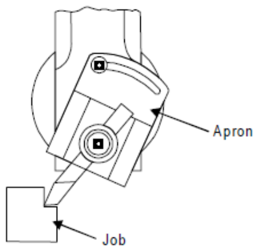
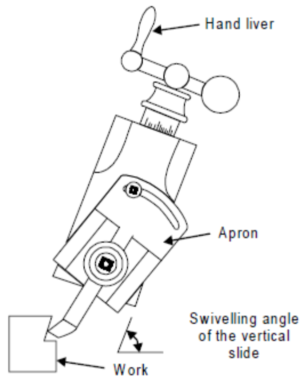
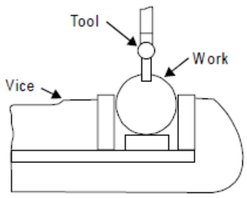


Fig. Machining vertical surface on shaper



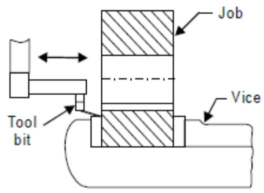
Cutting slots and keyways.

Fig. Machining angular surface on shaper



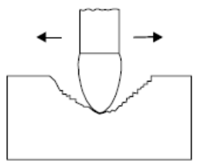
Slot cutting

Fig. Slot cutting on shaper



Keyway cutting

Fig. Keyway cutting on shaper



Irregular machining

Fig. Machining irregular surface on shaper

3.7 PLANER

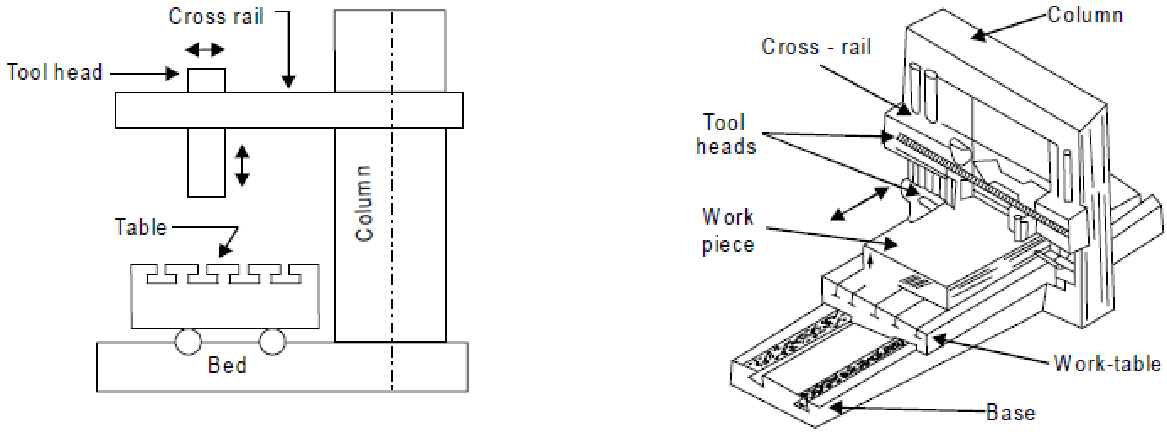
Like a shaper, planer is used primarily to produce horizontal, vertical or inclined flat surfaces by a single point cutting tool. But it is used for machining large and heavy workpieces that cannot be accommodated on the table of a shaper. In addition to machining large work, the planer is frequently used to machine multiple small parts held in line on the platen. Planer is mainly of two kinds namely open housing planer and double housing planer. The principle parts of the open housing planer are shown in Figure(a).

The principle parts of the double housing planer are shown in Fig ure(b). The bigger job is fixed with help of the grooves on the base of the planer and is accurately guided as it travels back and forth. Cutting tools are held in tool heads of double housing planer and the work piece is clamped onto the worktable as shown in Figure(b).

The worktable rides on the gin tool heads that can travel from side to side i.e., in a direction at right angle to the direction of motion of the worktable. Tool heads are mounted on a horizontal cross rail that can be moved up and down. Cutting is achieved by applying the linear primary motion to the workpiece (motion X) and feeding the tool at right angles to this motion (motion Y and Z).

The primary motion of the worktable is normally accomplished by a rack and pinion drive using a variable speed motor. As with the shaper, the tool posts are mounted on clapper boxes to prevent interference between the tools and work-piece on the return stroke and the feed motion is intermittent.

The size of a standard planer is specified by the size of the largest solid that can reciprocate under the tool. In addition to this, some other parameters such as table size (length and width), type of drive, number of speeds and feeds available, power input, weight of the machine, floor space required etc. may be required to specify a planer completely



(a) Open Side Planer (b) Double Housing Planer

Fig. Principle parts of double housing planer

3.7.1 Working Principal of Planer

Figure depicts the working principle of a planer. In a planer, the work which is supported on the table reciprocates past the stationary cutting tool and the feed is imparted by the lateral movement of the tool.

The tool is clamped in the tool holder and work on the table. Like shaper, the planner is equipped with clapper box to raise the tool in idle stroke. The different mechanisms used to give reciprocating motion to the table are following-

1. Reversible motor drive
2. Open and cross belt drive
3. Hydraulic drive

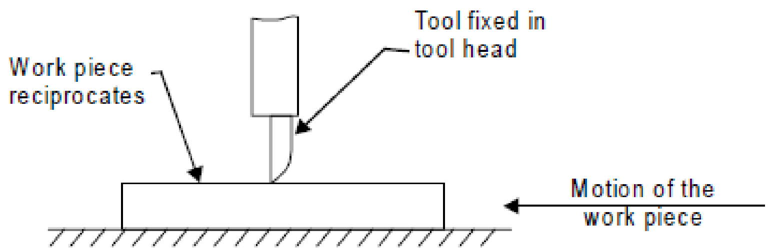


Fig. Working principle of a planer

3.7.2 Difference Between Shaper and Planer

S.No.	Shaper	Planer
1	The work is held stationary and the cutting tool on the ram is moved back and forth across the work	In a planer, the tool is stationary and the workpiece travels back and forth under the tool.
2	It is used for shaping much smaller jobs	A planer is meant for much larger jobs than can be undertaken on a shaper. Jobs as large as 6 metre wide and twice as long can be machined on a planer
3	A shaper is a light machine	It is a heavy duty machine.
4	Shaper can employ light cuts and finer feed	Planer can employ heavier cuts and coarse feed,
5	A shaper uses one cutting tool at a time	Several tools can cut simultaneously on a planer
6	The shaper is driven using quick-return link mechanism	The drive on the planer table is either by gears or by hydraulic means
7	It is less rigid and less robust	Because of better rigidity of planer, as compared to that of a shaper, planer can give more accuracy on machined surfaces.

3.7.3 Types of Planers

Planers may be classified in a number of ways, but according to general construction, these are the following types:

1. Double housing planer
2. Open side planer
3. Pit planer
4. Edge or plate type planer
5. Divided table planer

3.8 SLOTTER

The slotter or slotting machine is also a reciprocating type of machine tool similar to a shaper or a planer. It may be considered as a vertical shaper. The chief difference between a shaper and a slotter is the direction of the cutting action. The machine operates in a manner similar to the shaper, however, the tool moves vertically rather than in a horizontal direction. The job is held stationary. The slotter has a vertical ram and a hand or power operated rotary table.

3.8.1 PRINCIPLE PARTS OF A SLOTTER

The main parts of a slotter are discussed as under:

Bed or Base - It is made up of cast iron. It supports column, tables, ram, driving mechanism etc. The top of the bed carries horizontal ways along which the worktable can traverse.

Table - It holds the work piece and is adjustable in longitudinal and cross-wise directions. The table can be rotated about its centre.

Hand wheels - They are provided for rotating the table and for longitudinal and cross traverse.

Column is the vertical member - They are made up of cast iron and it houses the driving mechanism. The vertical front face of the column is accurately finished for providing ways along which the ram moves up and down.

Ram - It is provided to reciprocate vertically up and down. At its bottom, it carries the cutting tool. It is similar to the ram of a shaper; but it is more massive and moves vertically, at right angle to the worktable, instead of having the horizontal motion of a shaper.

Cross-slide - It can be moved parallel to the face of the column. The circular work-table is mounted on the top of the cross-slide.

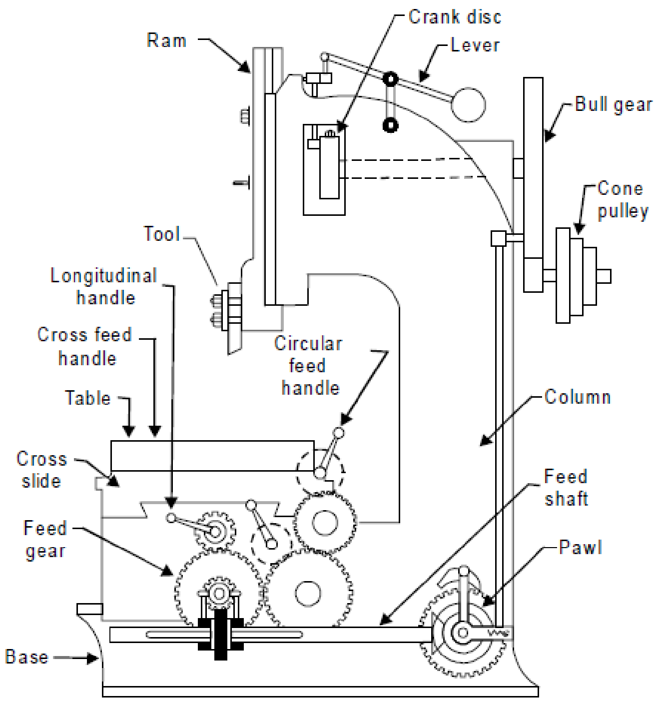


Fig. Slotter and its various parts

3.8.2 Operations Performed on a Slotting Machine

A slotter is a very economical machine tool when used for certain classes of work given as under.

a. It is used for machining vertical surfaces
b. It is used angular or inclined surfaces
c. It is used It is used to cut slots, splines keyways for both internal and external jobs such as machining internal and external gears,
d. It is used for works as machining concave, circular, semi-circular and convex surfaces
e. It is used for shaping internal and external forms or profiles
f. It is used for machining of shapes which are difficult to produce on shaper
g. It is used for internal machining of blind holes
h. It is used for machining dies and punches, and Since a slotter works slowly. It has less use in mass production work. It can be substituted by the broaching machine.

3.9 BASIC PRINCIPLES OF BROACHINING

Broaching is a machining process for removal of a layer of material of desired width and depth usually in one stroke by a slender rod or bar type cutter having a series of cutting edges with gradually increased protrusion as indicated in Figure. In shaping, attaining full depth requires a number of strokes to remove the material in thin layers step – by – step by gradually infeeding the single point tool. Whereas, broaching enables remove the whole material in one stroke only by the gradually rising teeth of the cutter called broach. The amount of tooth rise between the successive teeth of the broach is equivalent to the infeed given in shaping.

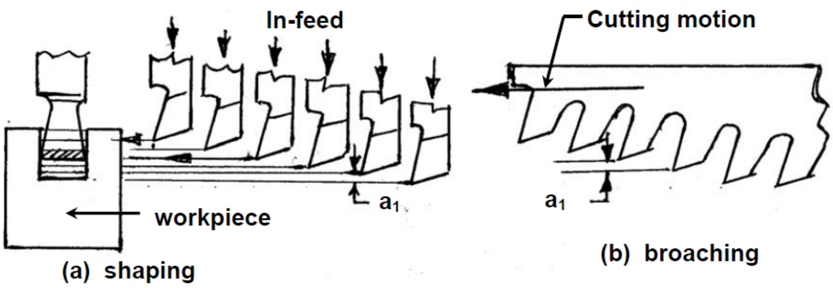


Fig. *Basic principle of broaching.*

Machining by broaching is preferably used for making straight through holes of various forms and sizes of section, internal and external through straight or helical slots or grooves, external surfaces of different shapes, teeth of external and internal splines and small spur gears etc. Figure schematically shows how a through hole is enlarged and finished by broaching.

3.9.1 Broaches

A broach is a multiple-edge cutting tool that has successively higher cutting edges along the length of the tool.

Types of Broaches:

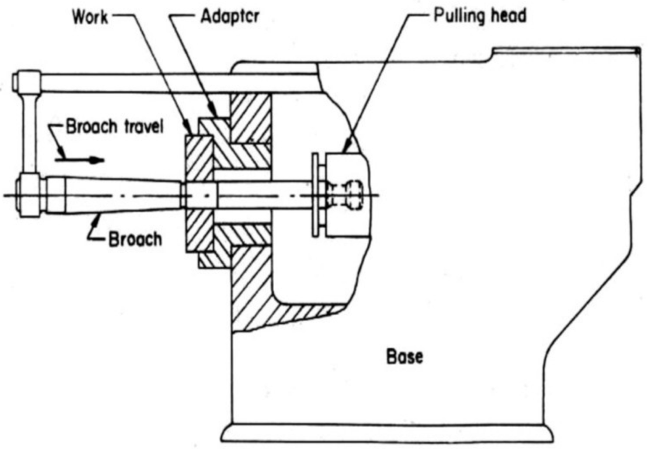
Broaches may be classified in various ways, according to:

Type of operation: internal or external.

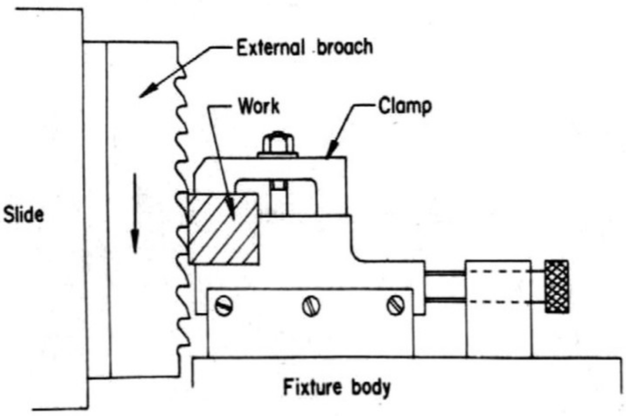
Method of operation: push or pull.

Type of construction: solid, built-up, inserted tooth, progressive cut, rotor cut, double jump, or overlapping tooth.'

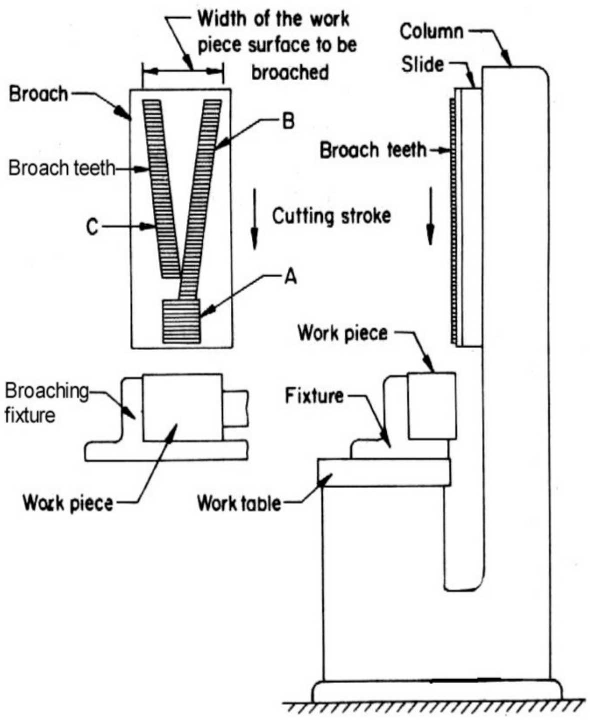
Function: surface, keyway, round hole, splint, spiral, burnishing, etc.



HORIZONTAL BROACHING MACHINE

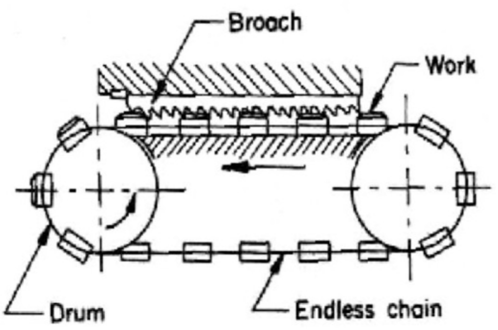


SURFACE BROACHING



VERTICAL BROACHING MACHINE

CONTINUES BROACHING



3.9.2 Advantages of Broaching

- Rate of production is very high. With properly applied broaches, fixtures, and machines, more pieces can be turned per hour by broaching than by any other means,
- Little skill is required to perform a broaching operation. In most cases the operator merely loads and unloads the workpiece.
- High accuracy and a high class of surface finish is possible. A tolerance of ± 0.0075 mm and a surface finish of about 0.8 microns (1 micron = 0.001mm) can be easily obtained in broaching.
- Both roughing and finishing cuts are completed in one pass of the tool.
- The process can be used for either internal or external surface finishing.
- Any form that can be reproduced on a broaching can be machined.
- Cutting fluid may be readily applied where it is most effective because a broach tends to draw the fluid into the cut.

3.9.3 Dis-Advantages of Broaching

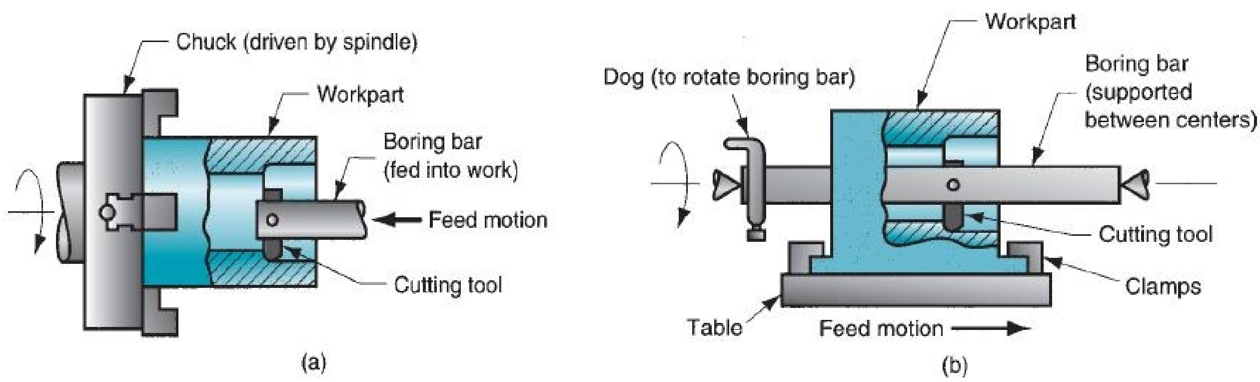
- High tool cost. A broach usually does only one job and is expensive to make and sharpen.
- Very large workpieces cannot be broached.
- The surfaces to be broached cannot have an obstruction.
- Broaching cannot be used for the removal of a large amount of stock.
- Parts to be broached must be capable of being rigidly supported and must be able to withstand the forces that set up during V Cutting.

3.10 BORING

Boring is similar to turning. It uses a single-point tool against a rotating workpart. The difference is that boring is performed on the inside diameter of an existing hole rather than the outside diameter of an existing cylinder.

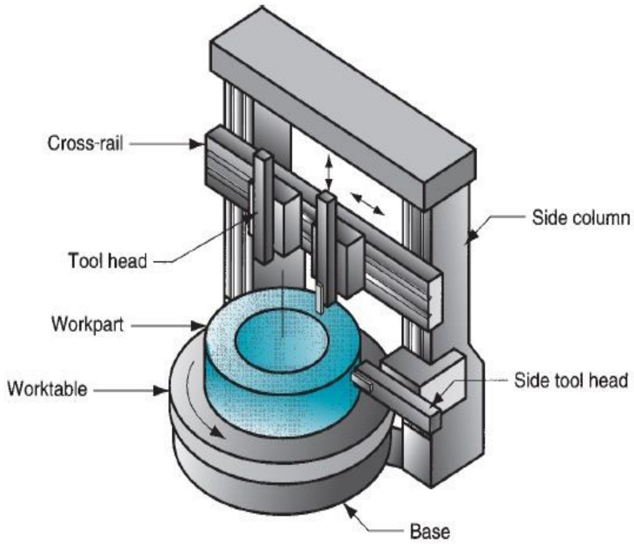
3.10.1 Horizontal Boring

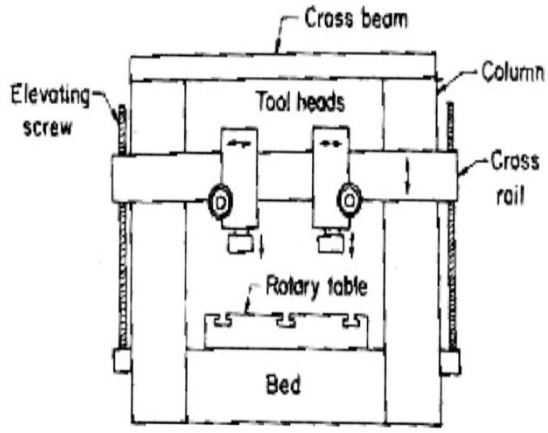
- In a horizontal boring operation, the setup can be arranged in either of two ways. The first setup is one in which the work is fixtured to a rotating spindle, and the tool is attached to a cantilevered boring bar that feeds into the work shown in figure.
- The boring bar in this setup must be very stiff to avoid deflection and vibration during cutting. To achieve high stiffness.
- The second possible setup is one in which the tool is mounted to a boring bar, and the boring bar is supported and rotated between centers. The work is fastened to a feeding mechanism that feeds it past the tool. This setup is shown in figure.



3.10.2 Vertical Boring Machine

- A vertical boring machine is used for large heavy workparts with large diameters,usually the workpart diameter is greater than its length. As in Figure the part is clamped to a worktable that rotates relative to the machine base. Work tables up to 40 ft in diameter are available.
- The tools are mounted on tool heads that can be fed horizontally and vertically relative to theworktable
- One or two heads aremounted ona horizontal cross-rail assembled to the machine tool housing above the worktable
- The cutting tools mounted above the work can be used for facing and boring. In addition to the tools on the cross-rail, one or two additional tool heads can be mounted on the side columns of the housing to enable turning on the outside diameter of the work.





VERTICAL BORING MACHINE

3.11 AUTOMATION OF MANUFACTURING PROCESS

Automation

Automation generally is defined as the process of enabling machines to follow a predetermined sequence of operations with little or no human intervention and using specialized equipment and devices that perform and control manufacturing processes and operations.

Automation is an evolutionary rather than a revolutionary concept. In manufacturing plants, for example, it has been implemented especially in the following basic areas of activity:

- Manufacturing processes: Machining, forging, cold extrusion, casting, powder metallurgy, and grinding operations.
- Material handling and movement: Materials and parts in various stages of completion (works in progress) are moved throughout a plant by computer controlled equipment, with little or no human guidance.
- Inspection: Parts are inspected automatically for dimensional accuracy, surface finish, quality, and various specific characteristics during their manufacture (in-process inspection).
- Assembly: Individually manufactured parts and components are assembled automatically into subassemblies and then assemblies to complete a product.
- Packaging: Products are packaged automatically for shipment. Industrial Revolution in the 1750s (also referred to as the First Industrial Revolution, the Second Industrial

Revolution having begun in the mid 1950s, with advances in many areas) that automation began to be introduced in the production of goods. Machine tools (such as turret lathes, automatic screw machines, and automatic glass bottle-making equipment) began to be developed in the late 1890s. Mass-production techniques and transfer machines were developed in the 1920s. These machines had fixed automatic mechanisms and were designed to produce specific products, best represented by the automobile industry, which produced passenger cars at a high production rate and low cost.

The major breakthrough in automation began with numerical control (NC) of machine tools in the early 1950s. Since this historic development, rapid progress has been made in automating almost all aspects of manufacturing, from the introduction of computers into automation, to computerized numerical control (CNC) and adaptive control (AC), to industrial robots, to computer-aided design, engineering, and manufacturing (CAD/CAE/CAM) and computer-integrated manufacturing (CIM) systems.

Manufacturing involves various levels of automation, depending on the processes used, the products to be made, and production volumes. Manufacturing systems, in order of increasing automation, include the following classifications °]ob shops: These facilities use general-purpose machines and machining centers with high levels of labor involvement.

- Stand-alone NC production: This method uses numerically controlled machines but with significant operator-machine interaction.
- Manufacturing cells: These cells use a cluster of machines with integrated computer control and flexible material handling, often with industrial robots.
- Flexible manufacturing systems: These systems use computer control of all aspects of manufacturing, the simultaneous incorporation of a number of manufacturing cells, and automated material-handling systems.
- Flexible manufacturing lines: These lines organize computer-controlled machinery in production lines instead of cells. Part transfer is through hard automation and product flow is more limited than in flexible manufacturing systems, but the throughput is larger for higher production quantities.
- Flow lines and transfer lines: These lines consist of organized groupings of machinery with automated material handling between machines. The manufacturing line is designed with limited or no flexibility, since the goal is to produce a single part.

3.11.1 Numerical Control

Numerical control (NC) is a method of controlling the movements of machine components by directly inserting coded instructions in the form of numbers and letters into the system. The system automatically interprets these data and converts them to output signals, which, in turn, control various machine components-for example, turning spindles on and off, changing tools, moving the workpiece or the tools along specific paths, and turning cutting fluids on and off.

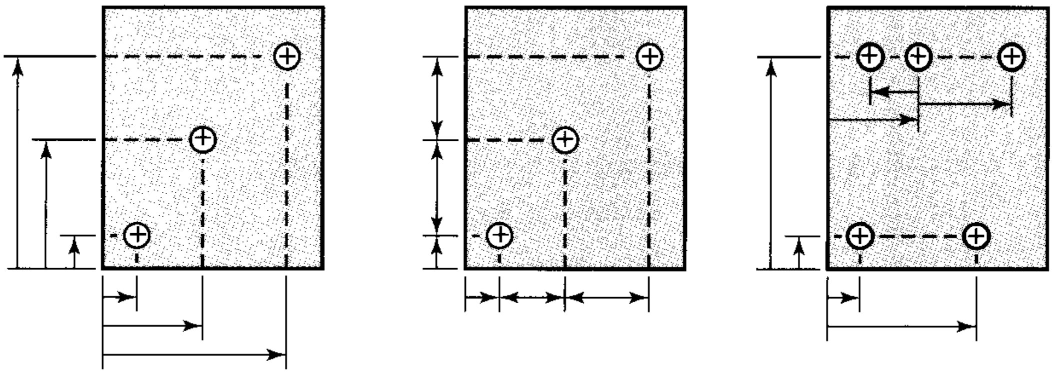
The importance of numerical control can be illustrated by the following example: Assume that several holes are to be drilled on a part in the positions shown in Figure. In the traditional manual method of machining this part, the operator positions the drill bit with respect to the workpiece, using reference points given by any of the three methods shown in the figure.

The operator then proceeds to drill the holes. Assume now that 100 parts, all having exactly the same shape and dimensional accuracy, are to be drilled. Obviously, this operation is going to be tedious and time consuming, because the operator has to go through the same motions repeatedly.

Moreover, the probability is high that, for a variety of reasons, some of the parts machined will be different from others. Now assume further that, during this production run, the order of processing these parts is changed and, in addition, 10 of the parts now require holes in different positions. The machinist now has to reposition the worktable, an operation that is time consuming and subject to error.

Such operations can be performed easily by numerical-control machines, which are capable of producing parts repeatedly and accurately and of handling different parts simply by loading different part programs. In numerical-control operations, data concerning all aspects of the machining operation (such as tool locations, speeds, feeds, and cutting fluids) are stored on hard disks. On the basis of input information, relays and other devices (known as hardwired controls) can be actuated to obtain a desired machine setup. Complex operations, such as turning a part having various contours or die sinking in a milling machine, are now carried out easily.

NC machines are used extensively in small- and medium-quantity production (typically 500 or fewer parts) of a wide variety of parts, both in small shops and in large manufacturing facilities.



(a) Absolute (b) Incremental (c) Mixed

3.11.2 Computer Numerical Control

In the next step in the development of numerical control, the control hardware (mounted on the NC machine) was converted to local computer control by software. Two types of computerized systems were developed-direct numerical control and computer numerical control:

In direct numerical control (DNC), several machines are controlled directly step by step-by a central mainframe computer. In this system, the operator has access to the central computer through a remote terminal. With DNC, the status of all machines in a manufacturing facility can be monitored and assessed from a central computer.

However, DNC has a crucial disadvantage: If the computer shuts down, all of the machines be- I (onboard computer). The machine operator can program Qi onboard computers, modify the programs directly, prepare u? programs for different parts, and store the programs. CNC systems are used widely today because of the availability of (a) small computers with large memory, (b) low-cost programmable controllers and microprocessors, and (c) programediting capabilities.