UNIT - 1
Introduction to Machine Tools & Machines

Syllabus of unit - 1:
Lathe, Shaper, Planer, Milling, Drilling, Slotter, Introduction to Metal Cutting

Introduction

Machine Tools: The equipment that cuts, shears, punches, presses, drills, grinds are called machine tools. Machine tools are generally the power driven metal cutting or metal forming machines used to alter/change the work piece to the required shape and size by:

1. Cutting away the unwanted sections
2. Pressing, drawing, punching or shearing
3. Controlled electrical machinery process

Generation of Machine Tools

1. Machine tools are operated manually or with automatic control. The earlier machines used flywheels to stabilize their motion and had complex system of gears and levers to control the machine and the piece being worked on.

2. Machines continued to be improved and soon after World War II, the numerical controlled (NC) machine was developed. The NC machines used a series of numbers punched on paper tape or punch cards to control their motion.

3. Lately computers have been added and the Computerized Numerical Control (CNC) machines have allowed industry to produce parts quickly and accurately. The same part can be reproduced to the exact accuracy, any number of times if the part programme has been properly prepared. The operating commands that control the machine tool are executed with amazing speed, accuracy, efficiency and reliability.

For becoming the finished product, various operations such as turning, drilling, milling, threading, reaming, grinding etc., have to be performed. A variety of machine tools were used to perform these operations and the choice of a particular machine essentially depends on:

1. Material of the work piece
2. Nature of metal cutting operations
3. Number of parts to be machined
4. Degree of accuracy desired

Any machine tool chosen will have the capability to:

1. Hold and support the work piece and cutting tool
2. Impart suitable reciprocating or rotary movement to the cutting tool or work piece
3. Regulate the cutting speed and feeding movement between the tool and work piece so that the desired cutting actions, accuracy and repeatability can be achieved.

Basic machine tools are the tools that are used for general purpose metal cutting operations within their range and these include engine lathe machine, drilling lathe machine, shapers lathe machine, milling machines, grinder lathe machine and power hacksaws lathe machine, Planer lathe machine, Slotter lathe machine etc.

Cutting tool material

Tools material must be harder than the material which they are to machine that must be strong, tough, rigid, abrasive resistance & not affected by temperature encountered in machining. The various tools materials are:

1) Plain carbon steel
2) Medium alloy steel
2) High speed steel(HSS)
4) cast non ferrous alloy(stellite)
5) Cemented carbides
6) diamond
7) Ceramics
8) cermets
9) Cubic boron nitride (CBN)
10) UCON
11) Silica

Cutting condition

It has an important influence upon metal cutting in machining are as follows:

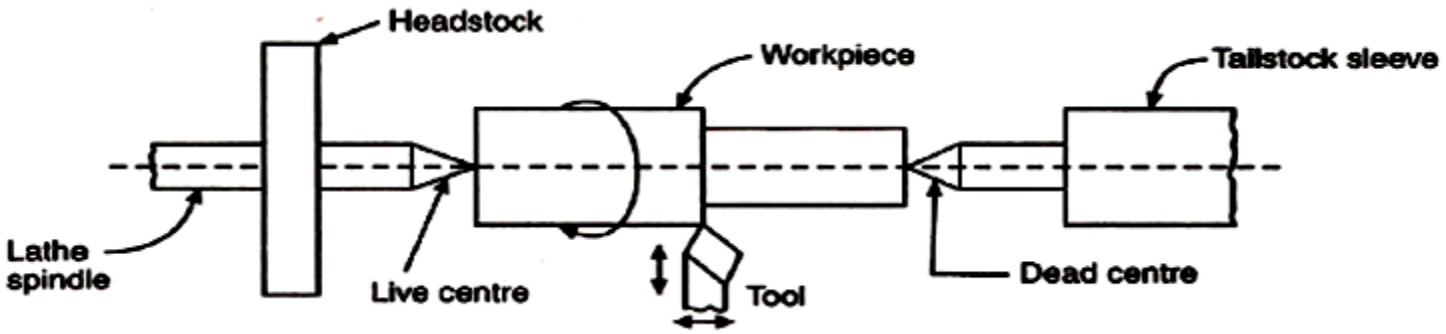
1) Work material
2) cutting tool material
2) Cutting tool shape
4) cutting speed
5) feed
6) depth of cut
7) cutting fluid

Classification of Cutting condition

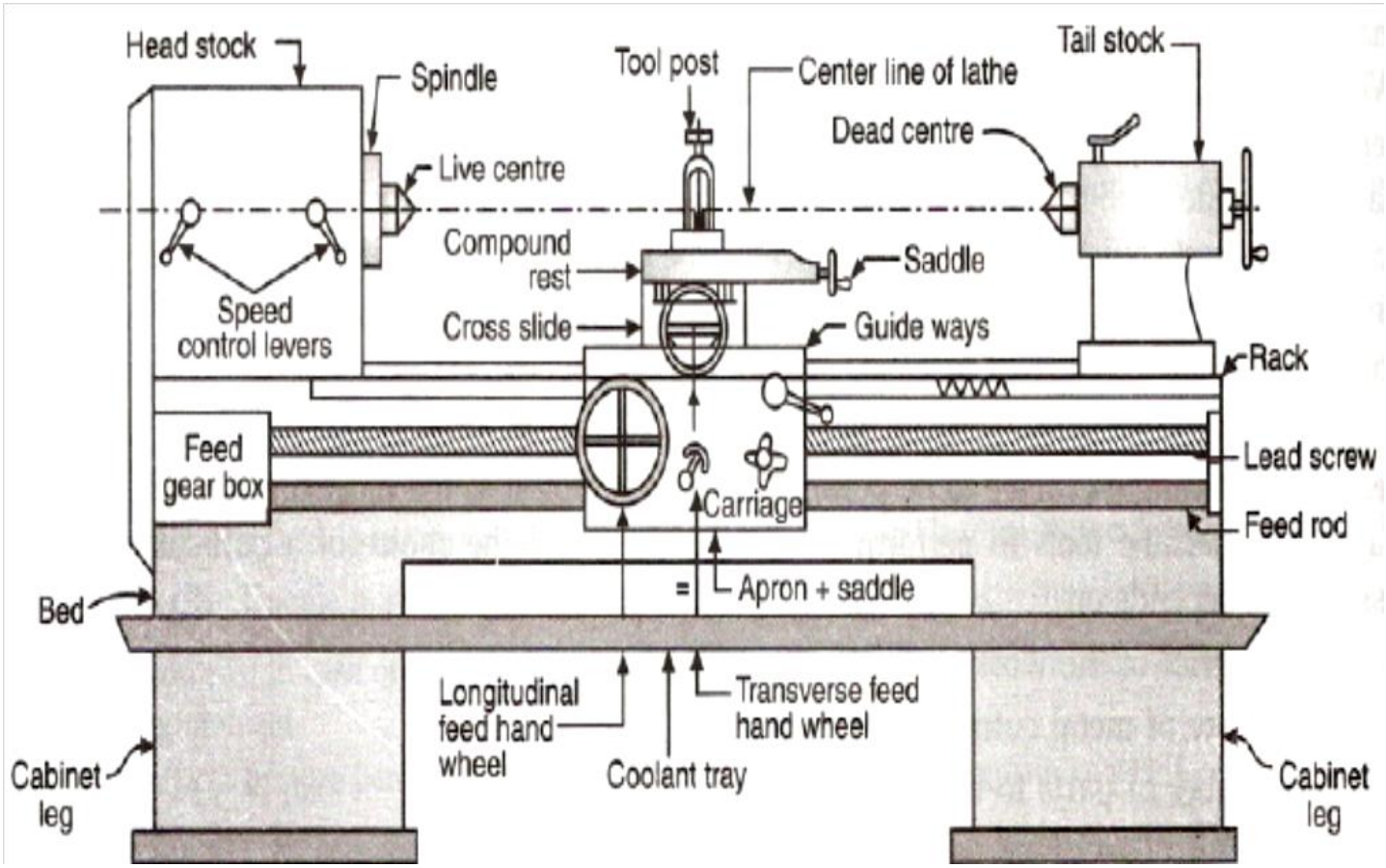
1) Single point cutting tool
2) multi point cutting tool
3) solid tool
4) brazed tool
5) inserted bit tool

LATHE MACHINE

Working Principle: The lathe is a machine tool which holds the work piece between two rigid and strong supports called centers or in a chuck or face plate which revolves. The cutting tool is rigidly held and supported in a tool post which is fed against the revolving work. The normal cutting operations are performed with the cutting tool fed either parallel or at right angles to the axis of the work. The cutting tool may also be fed at an angle relative to the axis of work for machining tapers and angles.



Construction: The main parts of the lathe are the bed, headstock, quick changing gear box, carriage and tailstock.



1. **Bed**: The bed is a heavy, rugged casting in which are mounted the working parts of the lathe. It carries the headstock and tail stock for supporting the work piece and provides a base for the movement of carriage assembly which carries the tool.

2. **Legs**: The legs carry the entire load of machine and are firmly secured to floor by foundation bolts.

3. **Headstock**: The headstock is clamped on the left hand side of the bed and it serves as housing for the driving pulleys, back gears, headstock spindle, live centre and the feed reverse gear. The headstock spindle is a hollow cylindrical shaft that provides a drive from the motor to work holding devices.

4. **Gear Box**: The quick-change gear-box is placed below the headstock and contains a number of different sized gears.

5. **Carriage**: The carriage is located between the headstock and tailstock and serves the purpose of supporting, guiding and feeding the tool against the job during operation. The main parts of carriage are:

   a). **The saddle** is an H-shaped casting mounted on the top of lathe ways. It provides support to cross-slide, compound rest and tool post.

   b). **The cross slide** is mounted on the top of saddle, and it provides a mounted or automatic cross movement for the cutting tool.

c). **The compound rest** is fitted on the top of cross slide and is used to support the tool post and the cutting tool.

d). **The tool post** is mounted on the compound rest, and it rigidly clamps the cutting tool or tool holder at the proper height relative to the work centre line.

e). **The apron** is fastened to the saddle and it houses the gears, clutches and levers required to move the carriage or cross slide. The engagement of split nut lever and the automatic feed lever at the same time is prevented she carriage along the lathe bed.

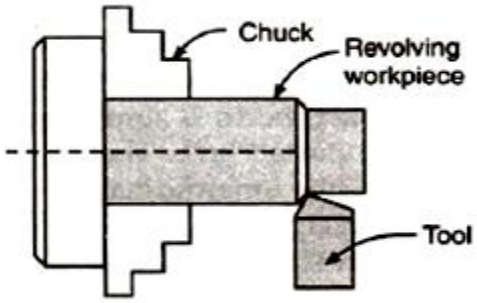
6. **Tailstock**: The tailstock is a movable casting located opposite the headstock on the ways of the bed. The tailstock can slide along the bed to accommodate different lengths of work piece between the centers. A tailstock clamp is provided to lock the tailstock at any desired position. The tailstock spindle has an internal taper to hold the dead centre and the tapered shank tools such as reamers and drills.

LATHE OPERATIONS

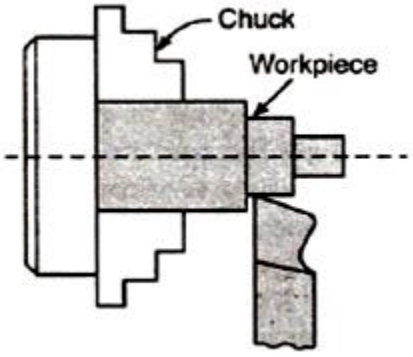
The engine lathe is an accurate and versatile machine on which many operations can be performed. These operations are:

1. Plain Turning and Step Turning
2. Facing
3. Parting
4. Drilling
5. Reaming
6. Boring
7. Knurling
8. Grooving
9. Threading
10. Forming
11. Chamfering
12. Filing and Polishing
13. Taper Turning

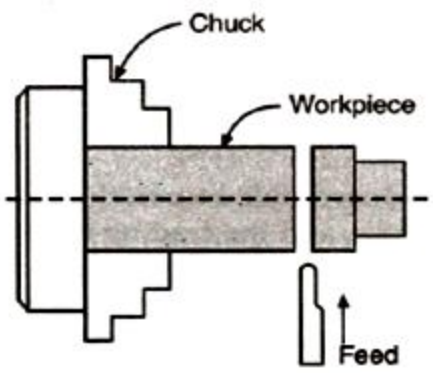
1. **Plain Turning**: Plain turning is the operation of removing excess amount of material from the surface of a cylindrical job.



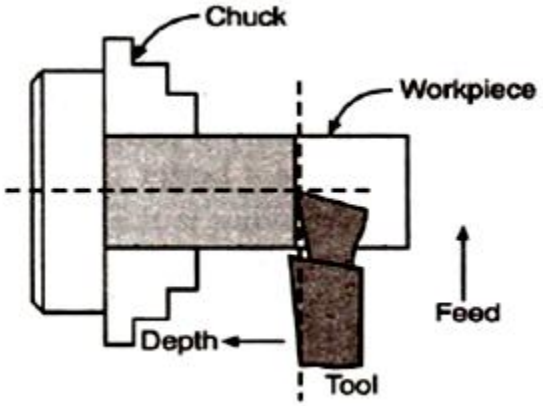
2. **Step Turning**: Step turning produces various steps of different diameters.



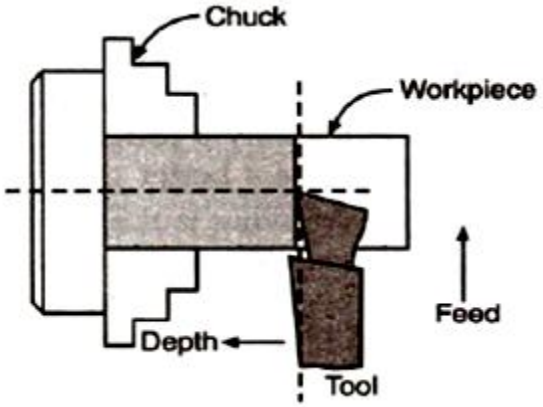
3. **Facing:** The facing is a machining operation by which the end surface of the work piece is made flat by removing metal from it.



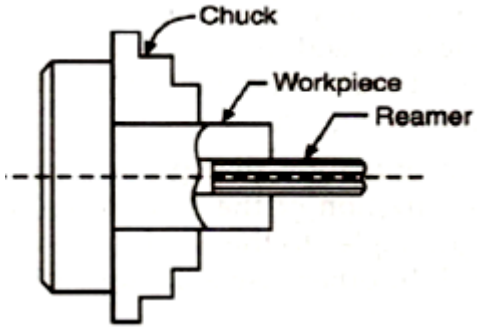
4. **Parting**: The parting or cutting off is the operation of cutting away a desired length of the work piece, *i.e.,* dividing the work piece in two or more parts.



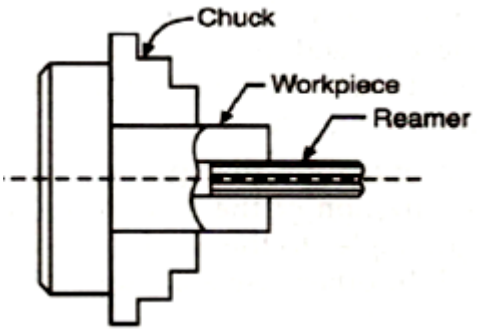
5. **Drilling**: Drilling is the operation of producing a cylindrical hole in the work piece.



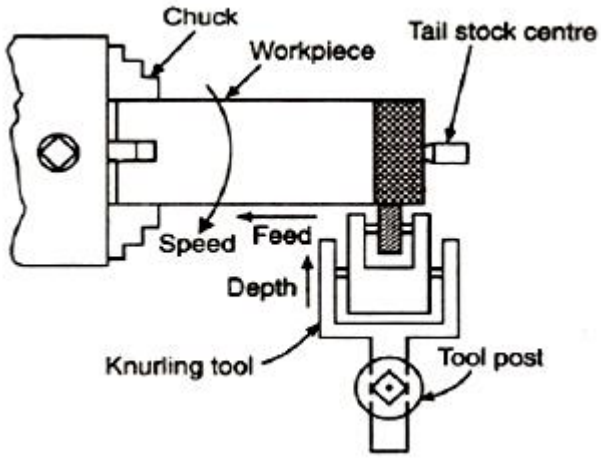
6. **Reaming**: The holes that are produced by drilling are rarely straight and cylindrical in form. The reaming operation finishes and sizes the hole already drilled into the work piece.



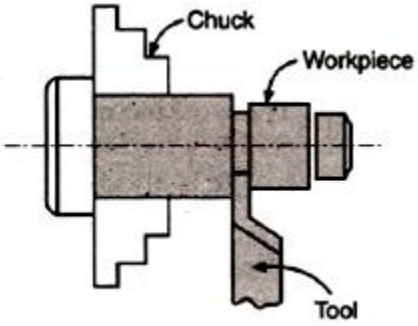
7. **Boring**: The boring operation is the process of enlarging a hole already produced by drilling.



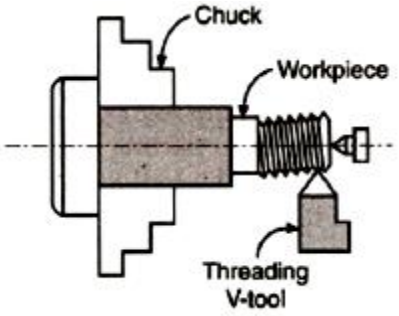
8. **Knurling**: The knurling is a process of embossing (impressing) a diamond-shaped or straight-line pattern into the surface of work piece. Knurling is essentially a roughening of the surface and is done to provide a better gripping surface.



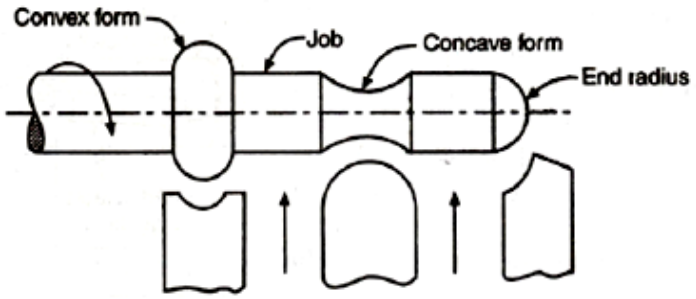
9. **Grooving**: Grooving is the act of making grooves of reduced diameter in the work piece.



10. **Threading**: Threading is the act of cutting of the required form of threads on the internal or external cylindrical surfaces.



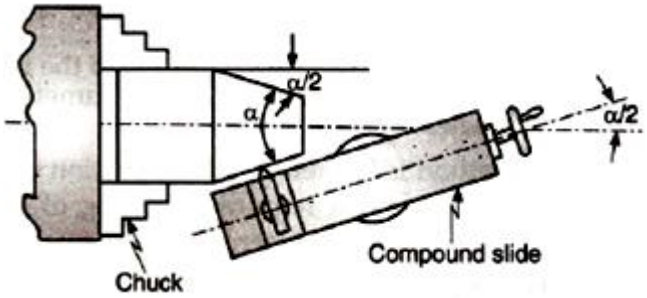
11. **Forming**: The forming is an operation that produces a convex, concave or any irregular profile on the work piece.



12. **Chamfering**: Chamfering removes the burrs and sharp edges, and thus makes the handling safe. Chamfering can be done by a form tool having angle equal to chamfer which is generally kept at 45°.

13. **Filing and Polishing:** The filing is the finishing operation that removes burrs, sharp corners and feed marks from the work piece. After filing, the surface quality is the work piece is improved by the polishing operation with the help of emery cloth of fine grades.

14. **Taper Turning**: The taper turning is an operation of producing a conical surface by gradual reduction in the diameter of a cylindrical work piece.



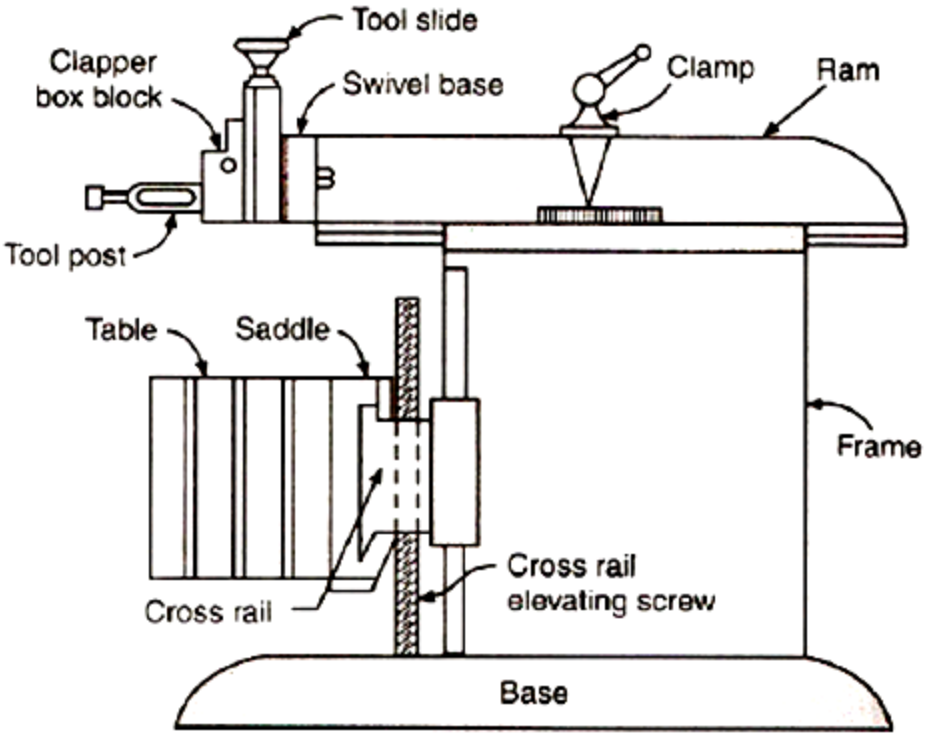
SAHAPER MACHINE

Introduction: The shaper is a machine tool used primarily for:

1. Producing a flat or plane surface which may be in a horizontal, a vertical or an angular plane.
2. Making slots, grooves and keyways
3. Producing contour of concave/convex or a combination of these

Working Principle: The job is rigidly fixed on the machine table. The single point cutting tool held properly in the tool post is mounted on a reciprocating ram. The reciprocating motion of the ram is obtained by a quick return motion mechanism. As the ram reciprocates, the tool cuts the material during its forward stroke. During return, there is no cutting action and this stroke is called the idle stroke. The forward and return strokes constitute one operating cycle of the shaper.

Construction: The main parts of the Shaper machine is Base, Body (Pillar, Frame, Column), Cross rail, Ram and tool head (Tool Post, Tool Slide, Clamper Box Block).



Base: The base is a heavy cast iron casting which is fixed to the shop floor. It supports the body frame and the entire load of the machine. The base absorbs and withstands vibrations and other forces which are likely to be induced during the shaping operations.

Body (Pillar, Frame, Column): It is mounted on the base and houses the drive mechanism compressing the main drives, the gear box and the quick return mechanism for the ram movement. The top of the body provides guide ways for the ram and its front provides the guide ways for the cross rail.

Cross rail: The cross rail is mounted on the front of the body frame and can be moved up and down. The vertical movement of the cross rail permits jobs of different heights to be accommodated below the tool. Sliding along the cross rail is a saddle which carries the work table.

Ram and tool head: The ram is driven back and forth in its slides by the slotted link mechanism. The back and forth movement of ram is called stroke and it can be adjusted according to the length of the work piece to be-machined.

PLANER MACHINE

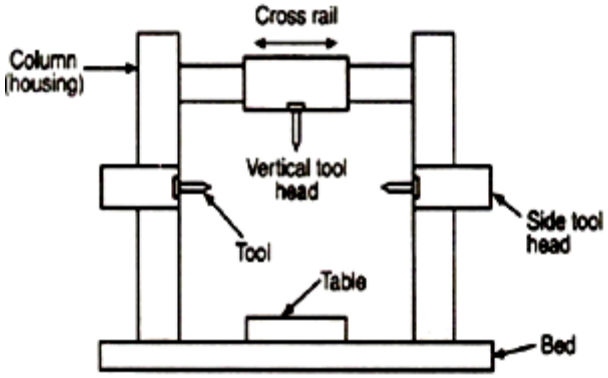
Introduction: The planer is a machine tool designed to produce plane and flat surface on a work piece which is too large or too heavy. The work piece is securely fixed on a table called platen, and it reciprocates horizontally against a single edged cutting tool. The surface machined may be horizontal, vertical or at an angle.

Operations of planer machine: The planer is used for:

1. Planing flat horizontal, vertical and curved surfaces.
2. Planing at an angle and machining dovetails.
3. Planing slots and grooves.

The planer are available in different types for doing different types and sizes of job; the most common being the standard and double housing planer.

Construction: The main parts of the double Housing Planer machine is Bed and table, Housings, Cross rail, , Tool heads, Driving and feed mechanism.



Bed and table: The bed is a long heavy base and table made of cast iron. Its top surface is flat and machined accurately. The flat top surface has slots in which the work piece can be securely clamped. The work piece needs rigid fixing so that it does not shift out of its position. The standard clamping devices used on planer machine are: Heavy duty vice, T-holders and clamps, angle plate, planer jack, step blocks and stop. The table movement may be actuated by a variable speed drive through a rack and pinion arrangement, or a hydraulic system.

Housings: The housings are the rigid and upright column like castings. These are located near the centre on each side of the base.

Cross rail: The cross rail is a horizontal member supported on the machined ways of the upright columns. Guide ways are provided on vertical face of each column and that enables up and vertical movement of the cross rail. The vertical movement of the cross rail allows to accommodate work piece of different heights. Since the cross rail is supported at both the ends, this type of planer machine is rigid in construction.

Tool heads: Generally two tool heads are mounted in the horizontal cross rail and one on each of the vertical housing. Tool heads may be swiveled so that angular cuts can be made.

Driving and feed mechanism: The tool heads may be fed either by hand or by power in crosswise or vertical direction. The motor drive is usually at one side of the planer near the centre and drive mechanism is located under the table.

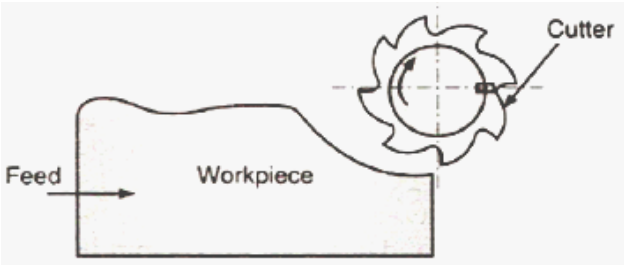
The size of the planer is specified by the maximum length of the stroke, and also by the size of the largest rectangular solid that can be machined on it.

MILLING MACHINE

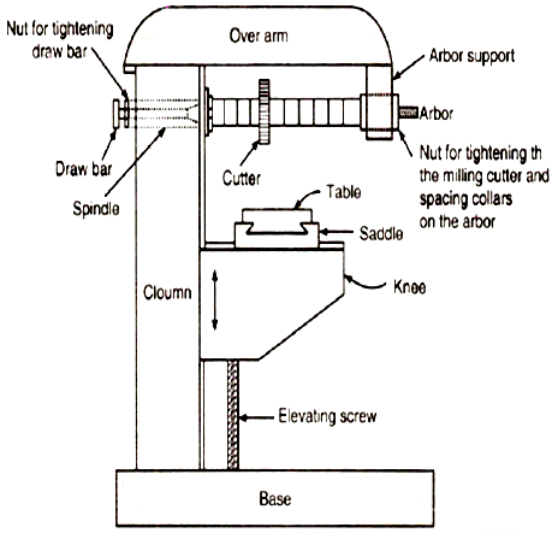
Introduction: Milling is the cutting operation that removes metal by feeding the work against a rotating, cutter having single or multiple cutting edges. Flat or curved surfaces of many shapes can be machined by milling with good finish and accuracy. A milling machine may also be used for drilling, slotting, making a circular profile and gear cutting by having suitable attachments.

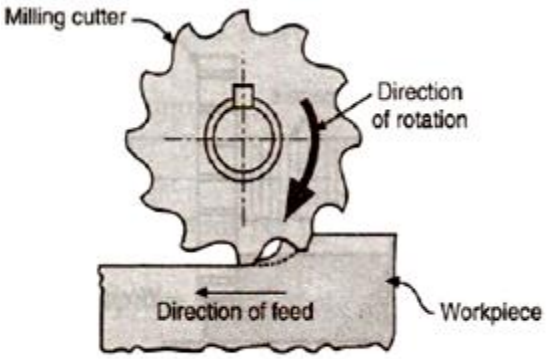
Working Principle:
The work piece is holding on the worktable of the machine. The table movement controls the feed of work piece against the rotating cutter. The cutter is mounted on a spindle or arbor and revolves at high speed. Except for rotation the cutter has no other motion. As the work piece advances, the cutter teeth remove the metal from the surface of work piece and the desired shape is produced.

.



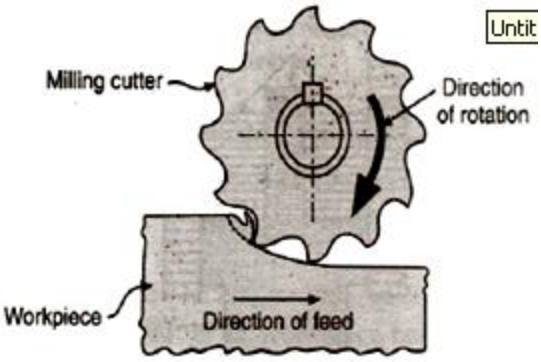
Horizontal Milling Machine Construction: The main part of machine is base, Column, Knee, Saddle, Table, Overarm, Arbor Support and Elevating Screw.





(b) Down milling

Untit



(a) Up milling

1. **Base**: It gives support and rigidity to the machine and also acts as a reservoir for the cutting fluids.

2. **Column**: The column is the main supporting frame mounted vertically on the base. The column is box shaped, heavily ribbed inside and houses all the driving mechanisms for the spindle and table feed.

3. **Knee**: The knee is a rigid casting mounted on the front face of the column. The knee moves vertically along the guide ways and this movement enables to adjust the distance between the cutter and the job mounted on the table. The adjustment is obtained manually or automatically by operating the elevating screw provided below the knee.

4. **Saddle**: The saddle rests on the knee and constitutes the intermediate part between the knee and the table. The saddle moves transversely, i.e., crosswise (in or out) on guide ways provided on the knee.

5. **Table**: The table rests on guide ways in the saddle and provides support to the work. The table is made of cast iron, its top surface is accurately machined and carriers T-slots which accommodate the clamping bolt for fixing the work. The worktable and hence the job fitted on it is given motions in three directions:

   a). Vertical (up and down) movement provided by raising or lowering the knee.
   b). Cross (in or out) or transverse motion provided by moving the saddle in relation to knee.
   c). Longitudinal (back and forth) motion provided by hand wheel fitted on the side of feed screw.

   In addition to the above motions, the table of a universal milling machine can be swiveled 45° to either side of the centre line and thus fed at an angle to the spindle.

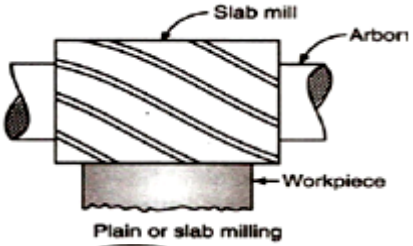
6. **Overar**m: The Overarm is mounted at the top of the column and is guided in perfect alignment by the machined surfaces. The Overarm is the support for the arbor.

7. **Arbor support**: The arbor support is fitted to the Overarm and can be clamped at any location on the Overarm. Its function is to align and support various arbors. The arbor is a machined shaft that holds and drives the cutters.

8. **Elevating screw**: The upward and downward movement to the knee and the table is given by the elevating screw that is operated by hand or an automatic feed.

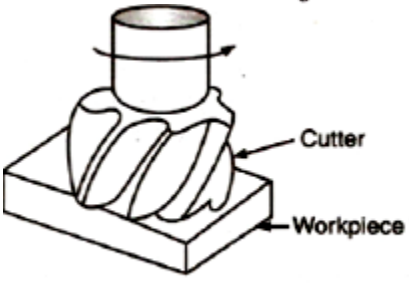
<u>Operations performed on a milling machine are</u>:

1. **Plain or slab milling**: Machining of a flat surface which is parallel to the axis of the rotating cutter.



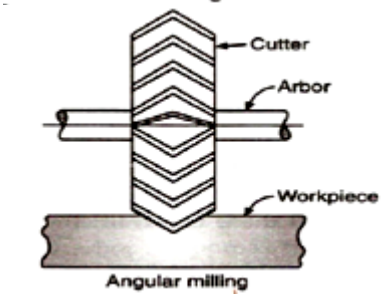
Plain or slab milling

2. **Face milling**: Machining of a flat surface which is at right angles to the axis of the rotating cutter.



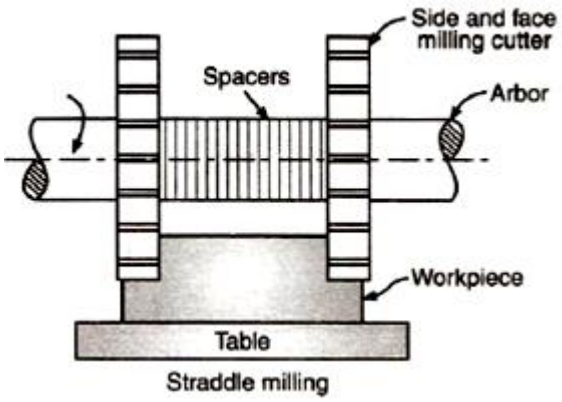
Face milling

3. **Angular milling**: Machining of a flat surface at an angle, other than a right angle, to the axis of revolving cutter.



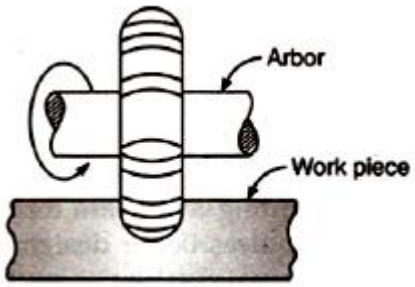
Angular milling

4. **Straddle milling**: Simultaneous machining of two parallel vertical faces of the work-pieces by a pair of side milling cutters.



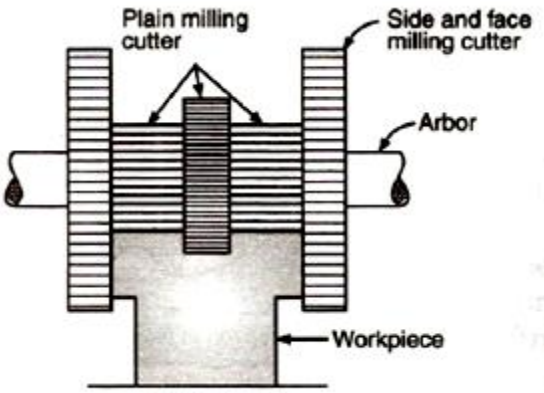
Straddle milling

5. **Form milling**: Machining of surfaces which are of irregular shape. The teeth of the form milling cutter have a shape which corresponds to the profile of the surface to be produced.



Form milling b

6. **Gang milling**: Simultaneous machining of a number of flat horizontal and vertical surfaces of a work piece by using a combination of more than two cutters mounted on a common arbor.



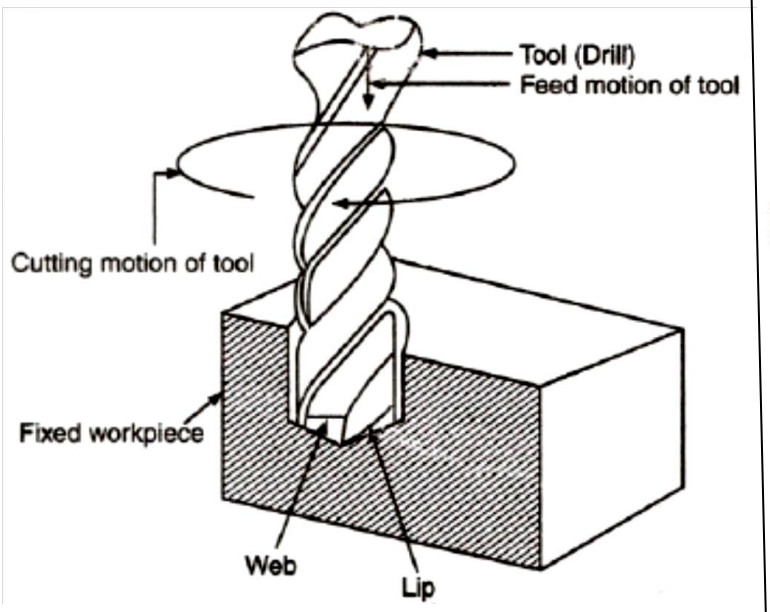
Gang milling

DRILLING MACHINE

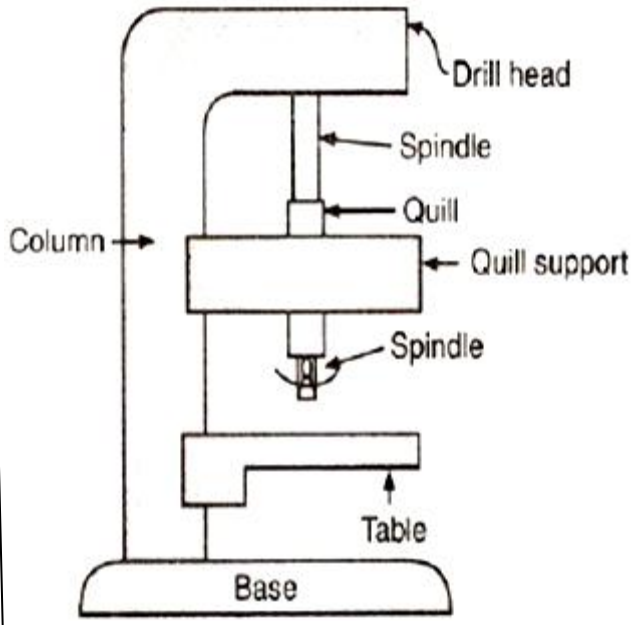
Introduction: The drilling machine or drill press is one of the most common and useful machine employed in industry for producing forming and finishing holes in a work piece. The unit essentially consists of:

1. A spindle which turns the tool (called drill) which can be advanced in the work piece either automatically or by hand.
2. A work table which holds the work piece rigidly in position.

Working principle: The rotating edge of the drill exerts a large force on the work piece and the hole is generated. The removal of metal in a drilling operation is by shearing and extrusion.



Working Principle of Drill machine



Sensitive Drill Machine/Drill Press

Types of Drilling Machines: A wide variety of drilling machines are available ranging from the simple portable to highly complex automatic and numerically controlled machines are as follows:

1. **Portable drilling machine**: It is a small light weight, compact and self contained unit that can drill holes upto 12.5 rnrn diameter. The machine is driven by a small electric motor operating at high speed. The machine is capable of drilling holes in the work pieces in any position.

2. **Sensitive drill machine/press**: This is a light weight, high speed machine designed for drilling small holes in light jobs. Generally the machine has the capacity to rotate drills of 1.5 to 15.5 rnrn at high speed of 20,000 rev/min.

Construction: The machine has only a hand feed mechanism for feeding the tool into the work piece. This enables the operator to feel how the drill is cutting and accordingly he can control the down feed pressure. Sensitive drill presses are manufactured in bench or floor models, *i.e.*, the base of machine may be mounted on a bench or floor.

The main operating parts of a sensitive machine/drill press are Base, Column, Table, and Drill Head.

1. **Base**: The base is a heavy casting that supports the machine structure; it provides rigid mounting for the column and stability for the machine. The base is usually provided with holes and slots which help to Bolt the base to a table or bench and allow the work-holding device or the work piece to be fastened to the base.

2. **Column**: The column is a vertical post that Column holds the worktable and the head containing the driving mechanism. The column may be of round or box section.

3. **Table**: The table, either rectangular or round. Drill machine/press in shape supports the work piece and is carried by the vertical column. The surface of the table is 90-degree to the column and it can be raised, lowered

and swiveled around it. The table can be clamp/hold the required the work piece. Slots are provided in most tables to allow the jigs, fixtures or large work pieces to be securely fixed directly to the table.

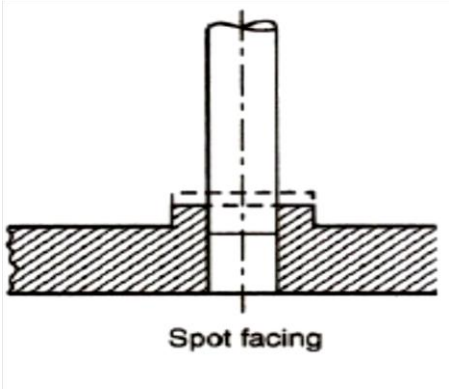
4. **Drilling Head**: The drilling head, mounted close to the top of the column, houses the driving arrangement and variable speed pulleys. These units transmit rotary motion at different speeds to the drill spindle. The hand feed lever is used to control the vertical movement of the spindle sleeve and the cutting tool.

The system is called the sensitive drilling machine/press as the operator is able to sense the progress of drill with hand-faced.

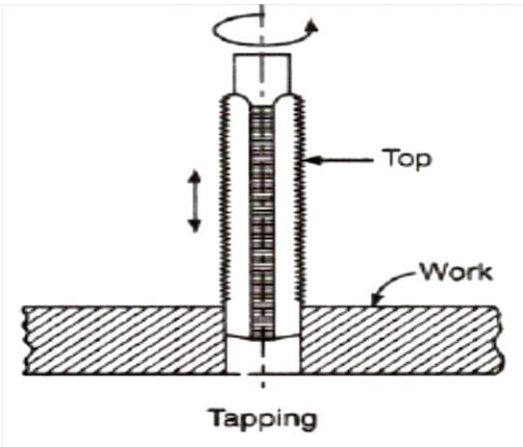
Operations performed by drilling machine/press as follows:

1. **Drilling**: Drilling is the operation of producing a hole by removing metal from a solid mass by the rotating edge of a cutting tool known as drill.

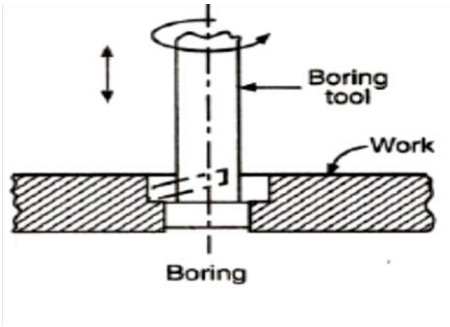
2. **Spot facing**: Spot facing is the operation of smoothing and squaring the surface around and at the end of a hole so as to provide a smooth seat for a nut or for the head of a cap screw. Spot facing is generally done on castings and forgings.



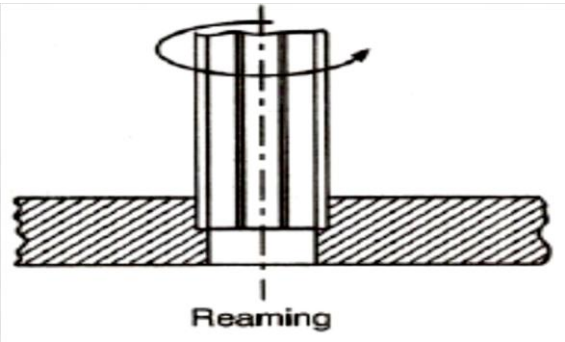
3. **Tapping**: Tapping is the operation for making internal threads in a hole by means of a tool called tap. The tap is essentially a bolt with threads cut on it.



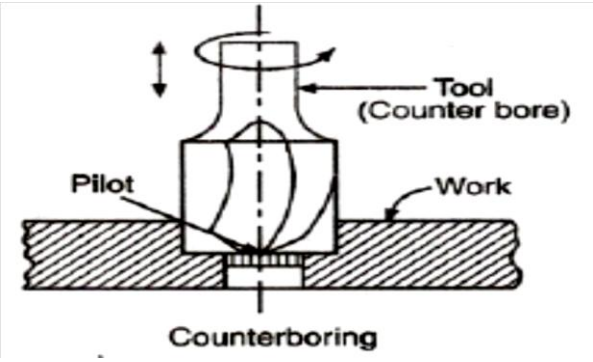
4. **Boring**: Boring is the operation of truing and enlarging a previously drilled hole by means of a single point cutting tool. Boring is done on drilling machine to perform the following tasks on a hole already drilled:



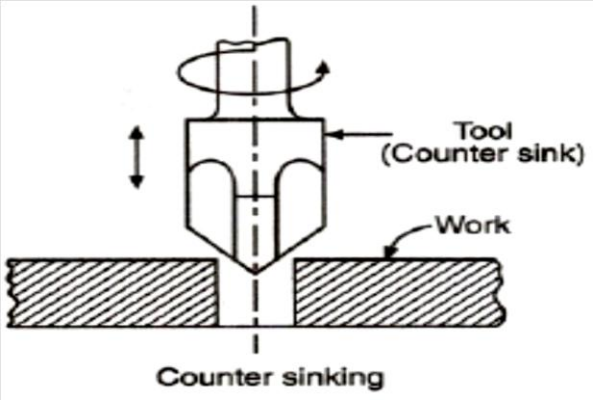
5. **Reaming**: The holes that are produced by drilling are rarely straight and cylindrical in form. To produce accurate and smooth holes, the drilled holes are reamed by a tool called reamer. The reamer is a cutting tool having several cutting edges in straight or helix shape.



6. **Counter boring**: Counter boring is the operation of enlarging one end of an existing hole concentric with the original hole with square bottom. It is done to accommodate the heads of bolts, studs and pins. The cutting edges of the counter-bore (tool used for counter boring) may have straight or spiral teeth.



7. **Counter sinking** is the operation of making a cone shaped enlargement at the end of a hole to provide recess for a flat head screw or a countersunk rivet. The counter-sunks (tools used for counter sinking) carry included angles of 60°, 82° or 90° and the cutting edges of the tool are formed at the conical surface.

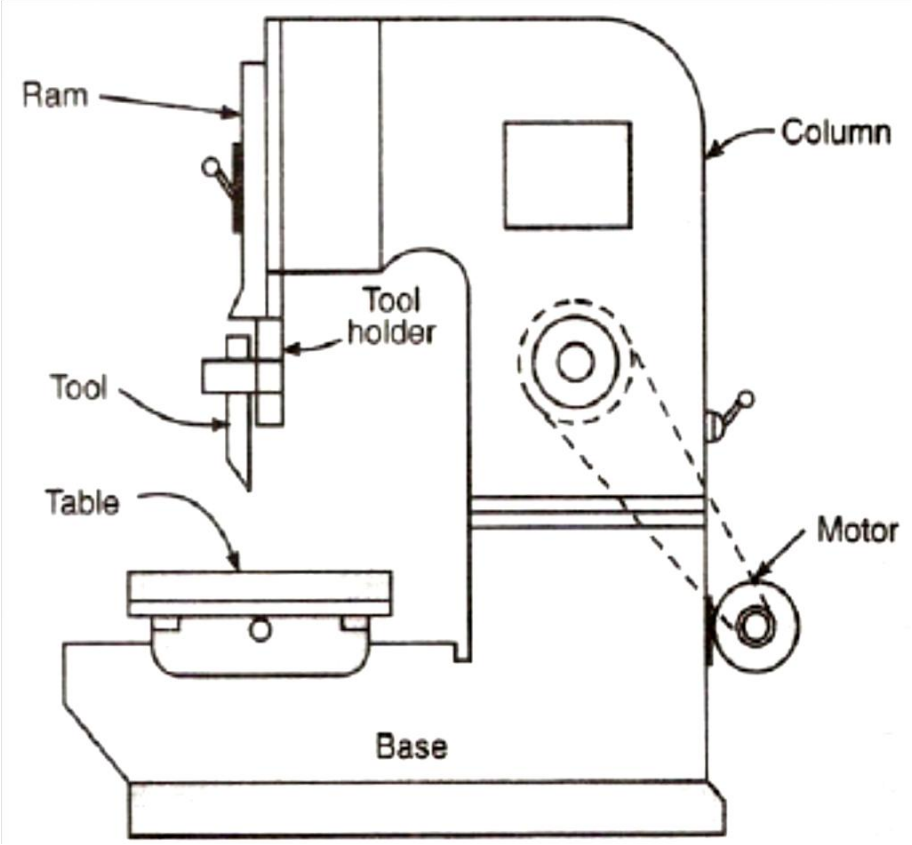


SLOTTING MACHINE

Introduction: The slotting machine is a reciprocating machine tool in which, the ram holding the tool reciprocates in a vertical axis and the cutting action of the tool is only during the downward stroke.

Construction: The slotter can be considered as a vertical shaper and its main parts are**:**

1. Base, column and table
2. Ram and tool head assembly
3. Saddle and cross slide
4. Ram drive mechanism and feed mechanism.



The base of the slotting machine is rigidly built to take up all the cutting forces. The front face of the vertical column has guide ways for Tool the reciprocating ram. The ram supports the tool head to which the tool is attached. The work piece is mounted on the table which can be given longitudinal, cross and rotary feed motion.

The slotting machine is used for cutting grooves, keys and slotes of various shapes making regular and irregular surfaces both internal and external cutting internal and external gears and profiles The slotter machine can be used on any type of work where vertical tool movement is considered essential and advantageous.

The different types of slotting machines are:

1. **Punch slotter**: a heavy duty rigid machine designed for removing large amount of metal from large forgings or castings

2. **Tool room slotter**: a heavy machine which is designed to operate at high speeds. This machine takes light cuts and gives accurate finishing.

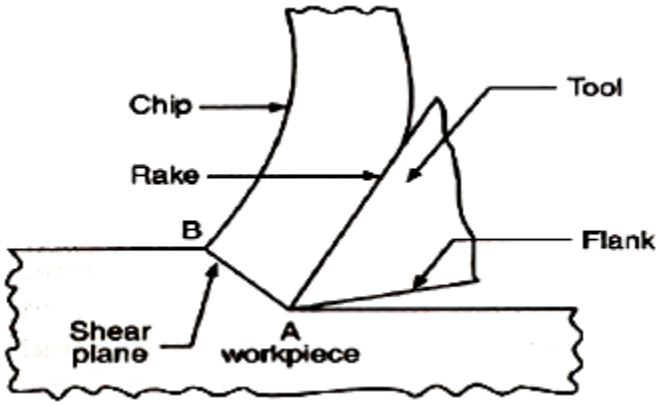
3. **Production slotter**: a heavy duty slotter consisting of heavy cast base and heavy frame, and is generally made in two parts.

INTRODUCTION TO METAL CUTTING:

Metal cutting is the process of producing a job by removing a layer of unwanted material from a given work piece. Fig. shows the schematics of a typical metal cutting process in which a wedge shaped, sharp edged tool is set to a certain depth of cut and moves relative to the work piece.

Under the action of force, pressure is exerted on the work piece metal causing its compression near the tip of the tool. The metal undergoes shear type deformation and a piece or layer of metal gets repeated in the form of a chip.

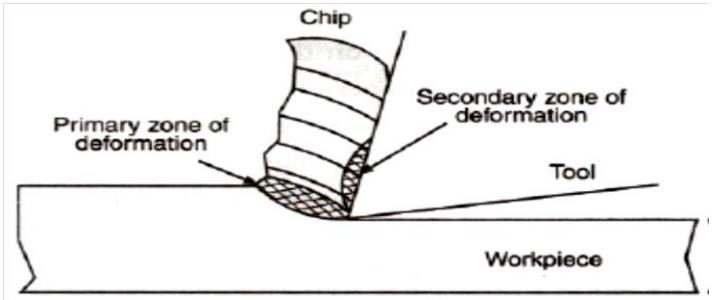
If the tool is continued to move relative to work piece, there is continuous shearing of the metal ahead of the tool. The shear occurs along a plane called the shear plane.



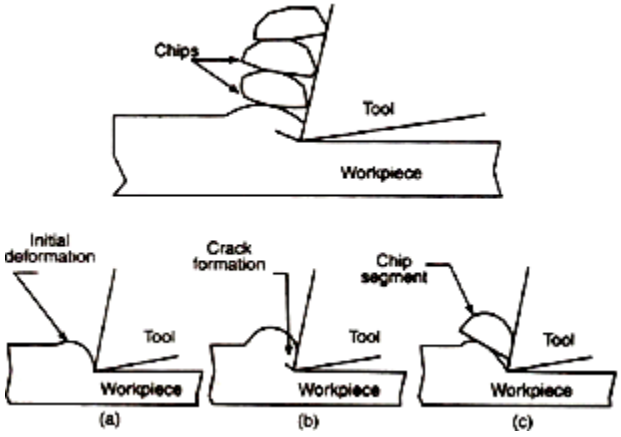
All machining processes involve the formation of chips; this occurs by deforming the work material on the surface of job with the help of a cutting tool. Depending upon the tool geometry, cutting conditions and work material, chips are produced in different shapes and sizes. The type of chip formed provides information about the deformation suffered by the work material and the surface quality produced during cutting.

<u>Types of Chips</u>:

1) **Continuous chips**: While machining ductile materials, large plastic deformation of the work material occurs ahead of the cutting edge of the tool. The metal of the work piece is compressed and slides over the tool face in the form of a long continuous chip.



2) **Discontinuous (segmented) chips**: A discontinuous chip is a segmented chip produced in the form of small pieces. The discontinuous chips are produced when cutting brittle materials like cast iron, bronze and brass. The working on ductile materials under poor cutting condition may also sometimes lead to the formation of discontinuous chips.



3) **Continuous chips with built-up-edge**: The term built-up-edge refers to the small metal particles that stick to the cutting tool and the machined surfaces as result of high temperature, high pressure and high frictional

resistance during machining. The building up and breaking down of the built-up-edge is periodic; its size first increases, then decreases and again increases-the cycle gets repeated rapidly.