Today's Topics:

1. Capstan and Turret Lathe:
2. Capstan and Turret Lathe Working:
3. Capstan and Turret Lathe Advantages:
4. Bar Feeding Mechanism in Capstan and Turret Lathe:
5. Tools used in Capstan and Turret Lathe:
6. Self-opening Die Head:
7. Difference Between Capstan and Turret Lathe Machine:

Capstan and Turret Lathe:

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A **capstan and turret lathe is a production lathe**. It is used to manufacture any number of identical pieces in the minimum time.

These lathes were first developed in the **United States of America** by **Pratt and Whitney** in 1960.

Capstan lathe is one of the types of **semi-automatic lathe**.

In semi-automatic lathes machining operations are done automatically.

Functions other than machining like loading and unloading of a job, the positioning of tools coolant operations are done manually.

The turret head is mounted on the ram fitted with turret slides longitudinally on the saddle.

Turret head has a **hexagonal block having six faces** with a bore for mounting six or more than six tools at a time.

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In the case of a **Capstan Lathe**, **the hexagonal turret is mounted on a short slide or ram** which again fitted with a saddle.

The saddle can be move accordingly throughout the bed ways and can be fixed to the bed if necessary.

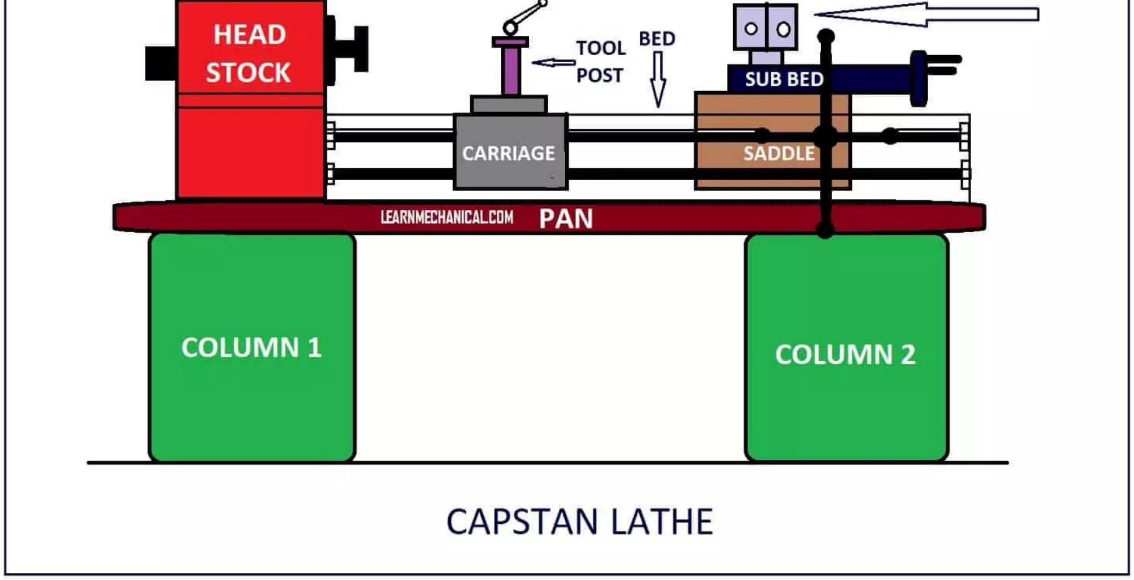
It is specially used for bar type jobs.

But in the case of **Turret Lathe**, the **hexagonal turret directly mounted on the saddle.** The saddle can be move through the bed ways.

Milling Machine
Cutters Manufacturer
- Thread Milling
Cutters

Turret lathe is generally used for chucking type work.

Schematic Diagram of a Capstan Lathe:



SCHEMATIC DIAGRAM OF CAPSTAN LATHE

Schematic Diagram of a Turret Lathe:

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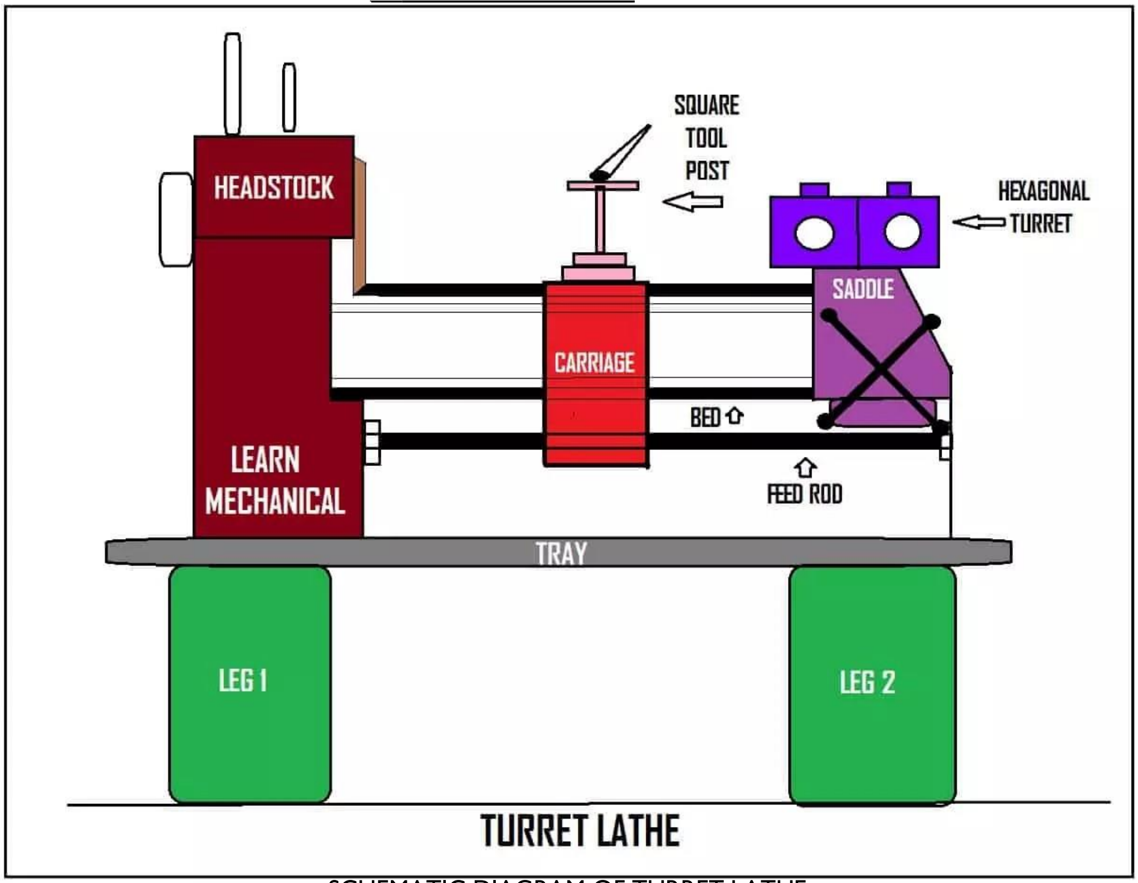

SCHEMATIC DIAGRAM OF TURRET LATHE

Capstan and Turret Lathe Working:

The workpiece is held in collet or chucks which are actuated **hydraulically or pneumatically.**

According to the sequence of operation, the tool is moved with the help of a turret head.

The Parting tool is mounted in an inverted position on the rear end of the turret.

After completing each operation the turret head is moved back to its initial position which indexes the tools automatically.

Capstan and Turret Lathe Advantages:

The advantages of Capstan and Turret Lathe is the following:

The rate of production is higher

Different ranges of speeds are obtained.

A number of tools can be accommodated.

Chucking of larger workpieces can be done.

Operators of less skill are required hence lowers the labor cost.

Higher rigidity so can withstand heavy loads.

Bar Feeding Mechanism in Capstan and Turret Lathe:

In the **bar feeding mechanism**, the bar is pushed after the chuck is released without stopping the **Lathe Machine**

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We use this mechanism for minimizing the setting time.

The bar is passed through the pedestal bushing, bar holding chuck, headstock spindle, and the collet chuck.

The **collet chuck** is screwed on the headstock spindle and holding the feed bar and also helps the bar to rotates as per spindle speed.

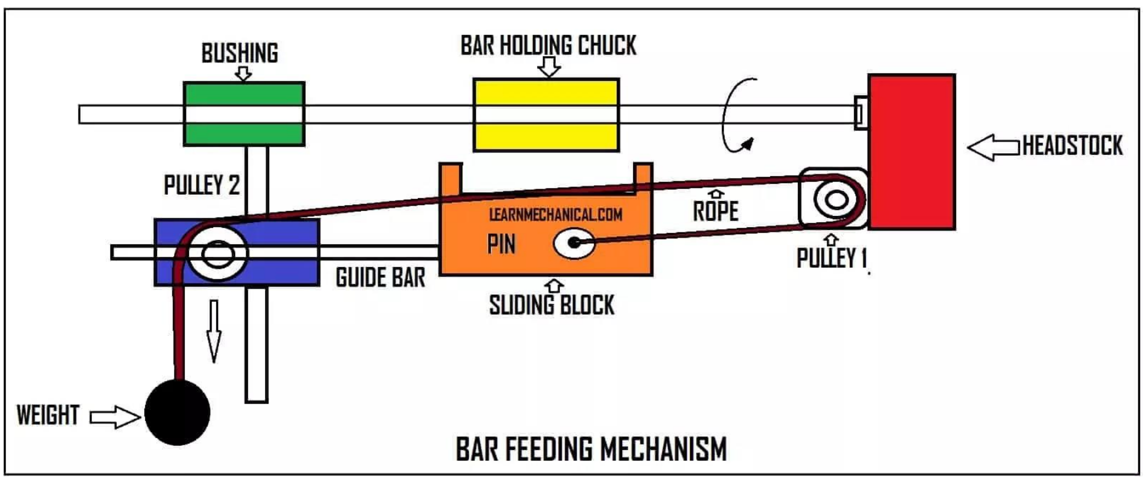
Bar holding chuck rotates within the sliding block with the rotation of the feeding bar.

Also, you can see a rope and a deadweight in this mechanism.

One side of the rope is attached with the sliding block with the help of pin and another side of rope passes through 2 different pulleys and then connecting with a deadweight at its end.

So now when the collet chuck released by the lever the dead weight tends to move in the downward direction, due to this it exerts thrust on the bar holding chuck and feed the bar until it touches the workshop.

As we already have seen that Capstan Lathe is best for bar types jobs that's why we are generally seeing Bar Feeding Mechanism on Capstan Lathe.



BAR FEEDING MECHANISM IN CAPSTAN LATHE

Tools used in Capstan and Turret Lathe:

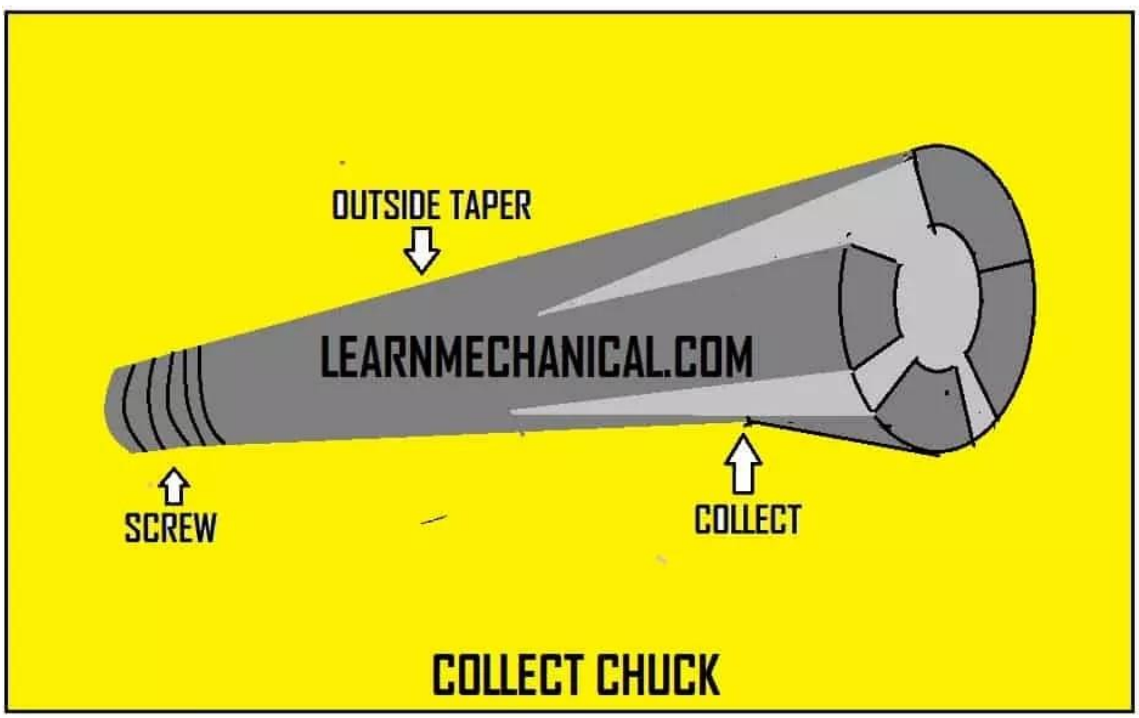
Collect Chuck:

This is **used for griping or you can holding any small bars in Capstan and Turret Lathe** (Mainly when we do Mass production).

The size of collet chucks is different corresponding to the bar sizes.

The jaws of the collet chuck are gripped the workpiece by its springing nature.

It is a thin steel brass bushing having slots on the outer side throughout its length.



How a Collect Chuck looks like

Roller Box Steady Turning tool

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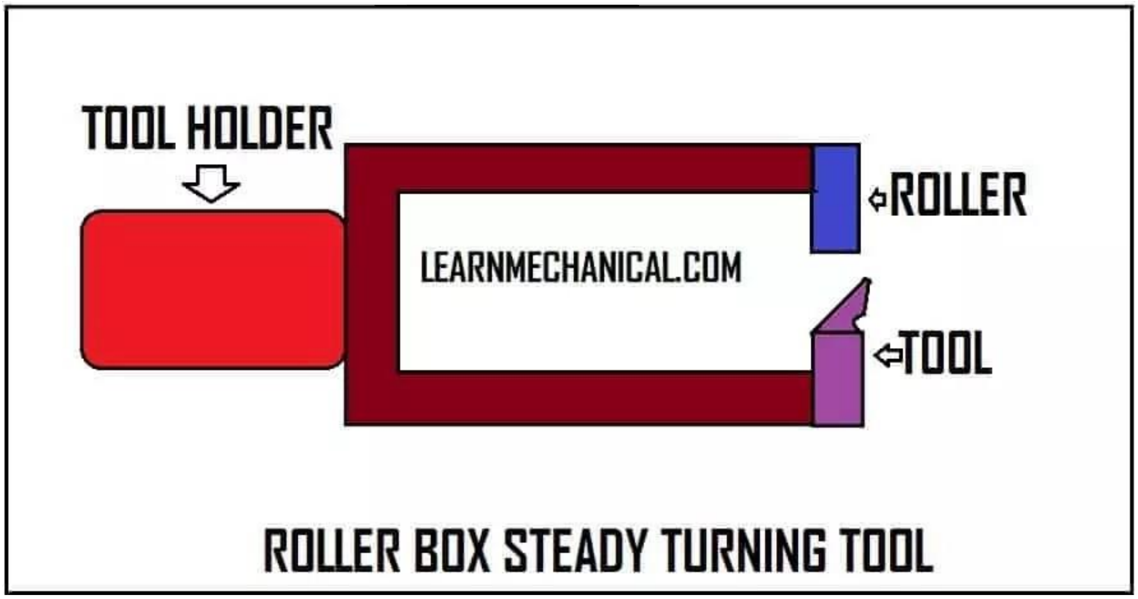
This type of tool is **used on bar work and when a considerable amount of stock is to be removed from the job.**

Roller box consists of the backrest or traveling two roller steadies that can be adjusted as per requirement.

A single point cutting tool is present in front of two rollers and gives rigidity to the workpiece.

Due to this rigid support, depth of cut, turning, etc. can be performed very smoothly.

This is a costly tool only used in mass production.



ROLLER BOX STEADY TURNING TOOL USED IN CAPSTAN AND TURRET LATHE

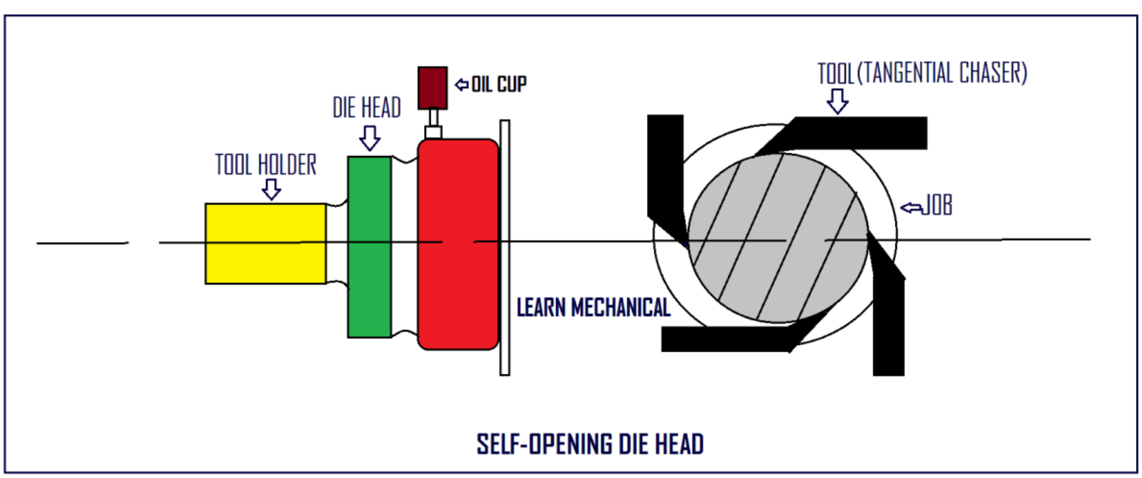
Self-opening Die Head:

This tool is **used especially for cutting external threads.**

The pitch of the cutting edges is determined according to the required thread pitch to be cut.

Chasers may be triangular, tangential, and circular types.

The function of the self-opening die is it opened automatically when the tool travel is stopped after the screw cutting operation.



Difference Between Capstan and Turret Lathe Machine:

Difference Between Capstan and Turret Lathe Machine:

Capstan Lathe	Turret Lathe
In capstan lathe, the turret tool head is mounted over the ram and that is mounted over the saddle.	In turret lathe, the turret tool head is mounted over the saddle like a single unit.
For providing feed to the tool, ram is moved.	For providing feed to the tool, a saddle is moved.
Capstan lathe is a Lightweight machine.	Turret Lathe is a Lightweight machine.
The turret head cannot be moved in the lateral direction of the bed.	The turret head can be moved crosswise i.e. in the lateral direction of bed in some turret lathe.
In capstan lathe, the collet is used to gripping the Job.	In turret lathe, power Jaw chuck is used to gripping the Job.
Capstan lathe is usually horizontal lathes.	Turret lathes are available in horizontal and vertical lathes.
Because of no saddle displacement, Movement of turret tool head over the longitudinal direction of bed is small along with the ram.	Turret tool head moves along with the saddle over the entire bed in the longitudinal direction.

For indexing turret tool head, the handwheel of the ram is reversed and turret tool index automatically.	For indexing turret tool head, a turret is rotated manually after releasing clamping lever.
Capstan lathe working operations are faster because of lighter in construction.	Turret lathe working operations are slower because of heavier in constructions.
Capstan lathe used for shorter workpiece because of limited ram movement.	Turret lathe used for longer workpiece because of saddle movement along the bed.
In Capstan lathe used for machining workpiece up to 60 mm diameter.	In Turret lathe used for machining workpiece up to 120 mm in diameter.
Heavy cuts on the workpiece cannot be given because of non-rigid construction.	Heavy cuts on the workpiece can be given because of the rigid construction of the machine.

Let's see the difference between Capstan and Turret Lathe from the Engine Lathe:

ENGINE LATHE	CAPSTAN AND TURRET LATHE
The direction of rotation is mostly anti-clockwise	It can rotate in both directions.

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Required less power as these machines are design for doing a single operation at a time.	Requied 4-5 times more power because of handaling 2-3 operations at a time.
Less number of spindle speed available in these types of lathe	The vast amount of spindle speeds are available
Setting and machining time is higher.	Setting and machining time for mass production is very less, as its handle sevaral operation at a time.
The skilled operator needed.	Semi-skilled operators can be run the machine
The lead screw present in these types of lathe is long	Lead screw is not present but short threads can be easily cut by chaser.
Any type of taper turning can be done by this machine	Only short length taper can be done with the help of the form tool.

Summary:

What is capstan and turret lathe?

A capstan and turret lathe is a production lathe. It is used to manufacture any number of identical pieces in the minimum time.

These lathes were first developed in the United States of America by Pratt and Whitney in 1960.

What is the working principle of Capstan and Turret lathe?

In these types of a lathe, the workpiece is held in collet or chucks which are actuated hydraulically or pneumatically. All the needed tools are held in the respective holes on the turret head. According to the sequence of operation, the tool is moved with the help of a turret head.

What are the advantages of Capstan and Turret Lathe?

The advantages of Capstan and Turret Lathe is the following:

The rate of production is higher

Different ranges of speeds are obtained.

A number of tools can be accommodated.

Chucking of larger workpieces can be done.

Operators of less skill are required hence lowers the labor cost.

Higher rigidity so can withstand heavy loads.

Conclusion:

As we saw in this article that these machines are the modification of an Engine Lath, also there is no long lead screw in this type of lathe.

Capstan and turret lathes are now used vastly in the Manufacturing tool to produce mass products.

Start

So that is all about **Capstan and Turret Lathe**, feel free to ask your question in the comment box or you can use our Discussion Board to ask your doubts.

And also don’t forget to share our articles on your social handles.

You may be interested to read these articles:

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Shaper Machine: Definition, Working, Types, Operations, Specification, Advantages, Disadvantages, and Application (With PDF)

In Manufacturing Technology

Table of Contents

Hello, readers in today's article, we will learn **how a shaper machine works also we learn about the parts, types, operations, specification, advantages disadvantages, and applications of a shaper machine**.

So let's start with the definition of shaper machine.

Shaper Machine Definition:

The **Shaper** is a reciprocating type of machine tool basically used to produce Horizontal, Vertical or Inclined flat surfaces by means of straight-line reciprocating single-point cutting tools similar to those which is used in lathe operation.

The flat surface produced may be horizontal, vertical or inclined at an angle

Working Principle of Shaper Machine:

A **shaper machine is working on the following principle**:

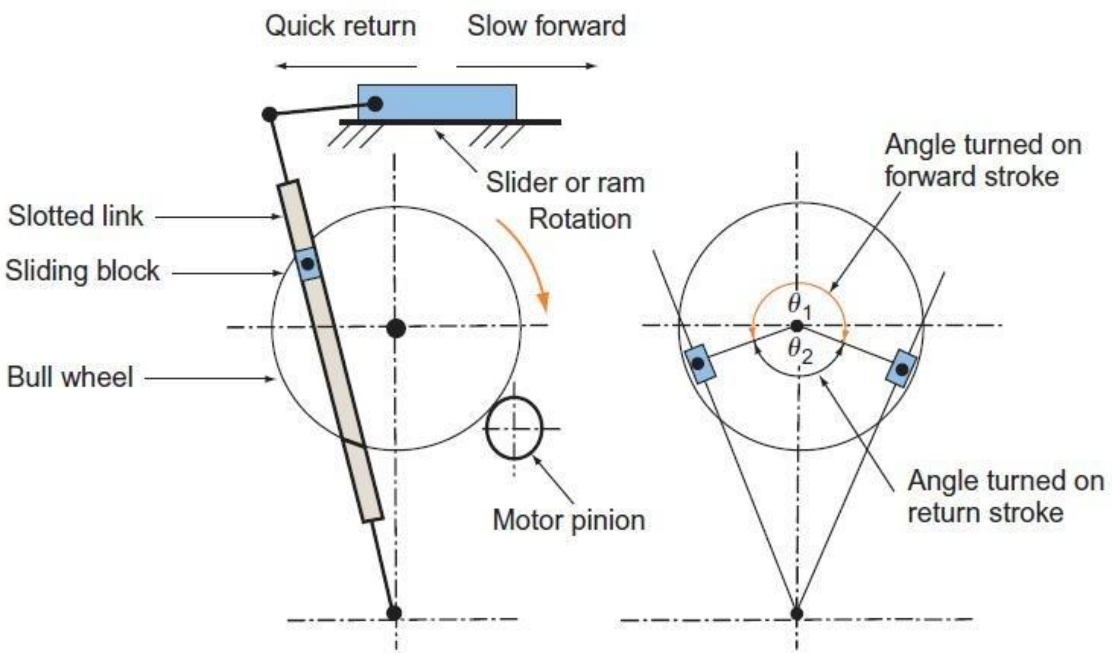
- A shaper machine holds the Single point cutting tool in ram and workpiece is fixed over the table.
- The ram holding the tool reciprocates over the workpiece and metal is cut during the forward stroke called a cutting stroke and
- No metal is cut during its return stroke is called an Idle stroke.
- The feed is given at the end of the cutting stroke.
- Generally, the cutting stroke is carried out at slow speed and the idle stroke is carried at high speed with the help of quick return mechanism.

In the shaper machine, there is another mechanism called **Quick return Motion Mechanism**.

So what happens in quick return motion mechanism is,

In the forward stroke, the Slider moves fast and removing the material from the workpiece.

Whereas in the return stroke, the Slider moves faster than the forward stroke that means Quick return, it takes less time to return, called a return stroke.



Quick return motion mechanism of shaper machine

Quick return mechanism's animation video:

Types of Shaper Machine:

Based on the type of driving mechanism types of shaper machines.

- Crank type (Example: Quick return Motion Mechanism)

- Geared type shaper
- Hydraulic type (I mentioned the **working principle of hydraulic shaper machine** below in this article)

Based on ram travel types of shaper machines.

- Horizontal Shaper
- Vertical Shaper

Based on the table design types of shaper machines.

- Standard or Plain Shaper
- Universal shaper

Standard or Plain Shaper:

In this machine, the table has only two motion: crosswise in the horizontal plane and vertical movement (up and down).

The table is not provided with a swiveling motion.

Universal shaper:

This machine is similar to plain shaper except that the table can be tilted at a various angle, making it possible to inclined flat surfaces.

The table can be swiveled about 360 degrees about a central axis parallel to the cutting stroke direction and also perpendicular to it, that is, around two horizontal axes.

The table also has a movement in the horizontal plane and vertical direction (up and down) as in plain shaper.

A universal Shaper Machine (Source: AliBaba.com)

Based on cutting stroke types of shaper machines.

- Push type shaper machine
- Draw type shaper machine

Operations Performed on Shaper Machine:

There are **4-types of operations performed in a shaper machine**, and those are:

- Horizontal cutting
- Vertical cutting
- Inclined cutting
- Irregular cutting

Horizontal cutting:

Horizontal surfaces are machined by moving the work mounted on the machine table at a cross direction with respect to the ram movement.

The clapper box can be set vertical or slightly inclined towards the uncut surface.

This arrangement enables the tool to lift automatically during the return stroke. The tool will not drag on the machined surface.

Vertical cutting:

A vertical cut is made while machining the end of a workpiece, squaring up a block or machining a shoulder.

The feed is given to the tool by rotating the down feed screw of the vertical slide.

The table is not moved vertically for this purpose.

The apron is swiveled away from the vertical surface being machined.

Inclined cutting:

An angular cut is done at any angle other than a right angle to the horizontal or to the vertical plane.

The work is set on the table and the vertical slide of the tooth head is swiveled to the required angle either towards the left or towards right from the vertical position.

Irregular cutting:

A round nose tool is used for this operation.

For a shallow cut the apron may be set vertical but if the curve is quite sharp, the apron in swiveled towards the right or left away from the surface to be cut.

Parts of a Shaper Machine with Function:

Base:

The Base is designed to take the entire load of the machine tool and it is bolted to the floor of the shop.

This is made of grey cast iron to resist vibration and to take the compressive load.

Column:

The column is a Box like casting made up of cast iron and mounted on a base.

It is provided with accurately machined guideways on the top on which the ram reciprocates.

The guideways are also provided on the front vertical face for the movement of cross rail. The column encloses the ram driving mechanism.

Cross rail:

The cross rail is mounted on the ground vertical guideways of the column.

It consists of two parallel guideways on its top perpendicular to the ram axis is called as a saddle to move the table in crosswise direction by means of a feed screw.

The table can be raised or lowered to accommodate different sizes of the job by rotating elevating screw which causes the cross rail to slide up and down on the vertical face of the column.

Saddle:

It is mounted on the cross rail to hold the table firmly on its top.

The crosswise movement of the saddle causes the table to move crosswise direction by rotating the crossfeed screw.

Table:

It is mounted on the **saddle**.

It can be moved crosswise by rotating crossfeed rod and vertically by rotating the elevating screw.

The table is a box-like casting with accurately machined top and side surfaces. These surfaces having t-slots for clamping the work.

In Universal shaper, the table may be swiveled on a horizontal axis and its upper part may be tilted up or down.

In heavy Shaper, the front face of the table is supported by adjustable table support to give more rigidity.

Ram:

It is a reciprocating member of the shaper which holds the tool and the reciprocates on the guideways on the top of the column by means of quick return motion mechanism.

It houses the screwed shaft for altering the position of the RAM with respect to the work. The RAM is in semi-cylindrical form and heavily ribbed inside to make it more rigid.

Tool Head:

The tool head holds the cutting tool firmly and provides both vertical and angular movement to the tool with the help of down feed screw handle.

The head allows the tool to have an automatic relief during the return stroke.

The vertical slide of a tool head consists of a swivel base which is graduated in degrees. So, the vertical slide can set at any angle with the work surface.

The amount of feed or depth of cut may be adjusted by a micrometer dial on top of the down feed screw.

A tool head again consists of:

- Apron
- Clapper box and clapper block

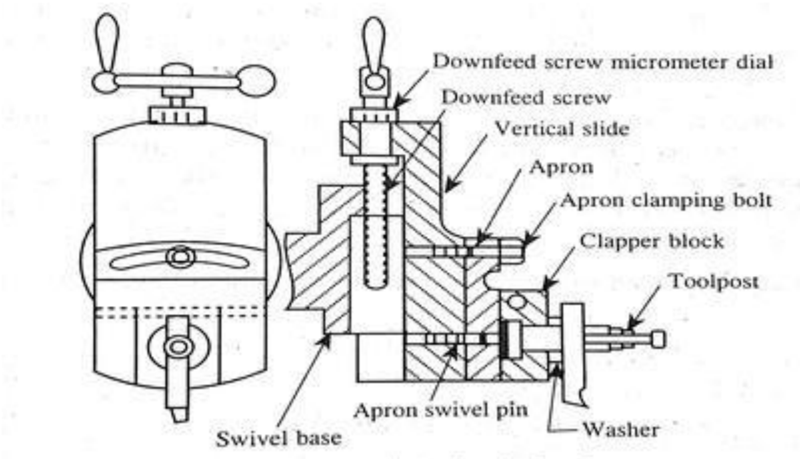
Apron consisting of clapper box and tool post is clamped on the vertical slide by the screw.

The **apron** Can be swiveled upon the apron swivel pin towards left or right.

The **clapper box** houses the **clapper block** by means of a hinge pin.

The **tool post** is mounted on the **clapper block**.

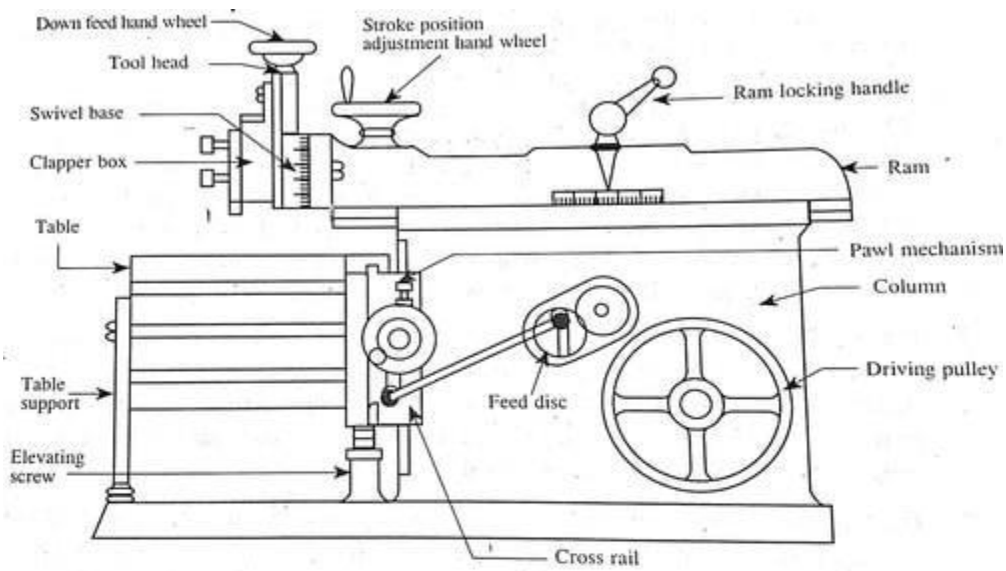
During forwarding cutting stroke the clapper block keeps the rigid support to the tool by fitting securely into clapper box and while returning stroke the tools slide over the work by lifting, the block out of clapper boxes shown in the above figure



. Toolhead of a shaper

Detailed diagram of tool head with parts

The below diagram is shown is a principal part of the Shaper Machine:



Shaper

Specification of Shaper Machine:

The specification of shaper machine depends upon the following:

- The maximum length of stroke ram.
- Types of the drive (Crank, Gear and Hydraulic type)
- Power input of the machine
- Floor space required to establish the machine
- Weight of the machine in tonne.
- Feed
- Cutting to return stroke ratio.
- Angular movement of the table.

Advantages of Shaper Machine:

- The single point tool used which is inexpensive or we can say low tooling cost.
- The cutting stroke having a definite stopping point.
- The work can be held easily in the shaper machine.
- The set up is very quick and easy and also can be readily changed from one job to another job.

Disadvantages of Shaper Machine:

- By nature, it is a slow machine because of its straight-line forward and returns strokes the single point cutting tool requires Several strokes to complete a work. (They are slow)
- The cutting speed is not usually very high speeds of reciprocating motion due to high inertia force developed in the motion of the units and components of the machine.

Applications of Shaper Machine:

- To generate straight and flat surfaces.
- Smooth rough surfaces.
- Make internal splines.
- Make gear teeth.
- To make dovetail slides.
- Make key ways in pullies or gears.
- Machining of die, punches, straight and curved slots.

Hydraulic Shaper Mechanism in Shaper Machine:

In **hydraulic shaper machine**, a constant speed motor drives a hydraulic pump which delivers oil at a constant pressure to the line.

A regulating valve admits oil under pressure to each end on the piston alternately.

At the same time allowing oil from the opposite end of the piston to return to the reservoir.

The piston is pushed by the oil and being connected to ram by piston rod, pushes the ram carrying the tool.

The admission of oil to each end of the piston, alternately, is accomplished with the help of trip dogs and pilot valves.

As the ram moves and complete its stroke (Forward and Return) a trip dog will trip the pilot valve which operates the regulating valve.

The regulating valve will admit the oil to the other side of the piston and the motion of the ram will get reversed.

It is clear that the length of the ram stroke will depend upon the position of trip dogs.

The length of the ram stroke can be changed by unclamping and moving the trip dogs to the desired position.

A hydraulic shaper looks like this:

Hydraulic Shaper Machine (Source: IndiaMart)

Video lecture on Shaping Machine if you wish you can check this video for brief knowledge:

Conclusion:

So today we completed the Shaping machine topic, we discuss definition, parts, working, types, application, advantages, disadvantages, and specifications of a Shaper Machine, hope you understand the whole concept. In case you wanna read this type of article on the lathe machine tool and drilling machine you can check these article for that "Lathe Machine Tool: Definition, Parts, Types and Operations" & "Drilling Machine: Definition, Parts, Types, and Operations"

If you have any queries or doubts about the Shaper machine, you can ask me in the comment section or we have a dedicated Q&A platform for you where you directly post your question: **Click here to post your question**, and also you can **join our facebook group**. I will love to hear from you and glad to help you. Till then enjoy rest your day. Cheers

TABLE DRIVE MECHANISM

A planer driving mechanism provides the longitudinal to and fro motion of the planer worktable. The following methods are employed for the said purpose.

(a) Open and cross belt drive (b) Gear drive (c) Reversible motor drive

(a) Open and cross belt drive:

Two belts, one open and one crossed operate on loose and tight pulleys. Crossed belt is used for forward or cutting stroke and the open belt for return motion. The crossed belt making a greater arc of contact on the pulley is considered better for driving the table on the cutting stroke.

There are two tight pulleys and two loose pulleys. Larger tight pulley - Cutting stroke and smaller tight pulley - quicker return stroke.

Crossed belt drive mechanism permits operation of the gear train in such a manner that the table will travel slowly on the cutting stroke and travel faster on the return stroke. Pulleys keyed to the drive pinion shaft are called tight pulleys and those which turn freely on the shaft are called loose pulleys. During cutting stroke the crossed belt is on the tight pulley, the open belt is on the loose pulley and the position is reverse during the return stroke.

DRIVE MECHANISM

For obtaining continuous forward and return motion of the planer table both the open and crossed belts run continually and are shifted back and forth by the belt shifter which is linked to the reverse lever. Trip dogs are provided, one each at both ends of the planer table. At the end of each stroke, the trip dog meets against the reverse lever, actuates the belt shifter and thus the table movement is reversed

Reversible motor drive:

The reciprocating motion of the planer table is obtained by driving through a worm on to a rack attached to the length of the underside of the table. The reversal of the drive is obtained by reversing the motor itself either by field or phase changing. Commonly used on modern planers as it provides a wider range of table speeds and a better control. Most planers are driven direct by a coupled motor in place of the old method of open and crossed belt drive.

MAJOR COMPONENTS AND THEIR FUNCTIONS:

BED:

- The bed of a planer is a box-like casting having cross ribs. It is very large in size and heavy in weight and it supports the column and all other moving parts of the machine.
- The bed is made slightly longer than twice the length of the table so that the full length of the table may be moved on it.
- The gearing arrangement and hydraulic cylinder for driving the table housed under the bed.

TABLE:

- The planer table is a heavy rectangular casting and is made of good quality cast iron.
- It is driven by hydraulic cylinder or by gear pinion driving and a rack which is fastened under the centre of the table.
- Motor driving pinion is reverse type with variable speed.
- Upper side of the table has T slots to clamp the work piece.

COLUMN:

- The housings also called columns or uprights are rigid box-like vertical structures placed on each side of the bed and are fastened to the sides of the bed.
- It will handle heavy load without deflection.

CROSS RAIL:

- It is mounted on vertical guide ways of column and slides up and down.
- Handled by hand or by power operated screw
- The Crossrail has screws for vertical and crossfeed of the toolheads and a screw for elevating the rail. These screws rotated either by hand or by power.

- This is necessary to generate a flat horizontal surface on a workpiece because the tool follows the pat on the Crossrail during crossfeed.
- The two elevating screws in the two housing are rotated by an equal amount to keep the Crossrail horizontal in any position.
- The front face of the cross rail is accurately machined to provide a guide surface for the tool head saddle.

TOOL HEAD:

- It's generally holds the tool firmly.
- Tool post is connected with the tool head, so that in return stroke tool will be raised and also it saves cutting edge.

Milling

Introduction

- Milling is the process of machining flat, curved, or irregular surfaces by feeding the work piece against a rotating cutter containing a number of cutting edges. The usual Mill consists basically of a motor driven spindle, which mounts and revolves the milling cutter, and a reciprocating adjustable worktable, which mounts and feeds the work piece.
- Milling machines are basically classified as vertical or horizontal. These machines are also classified as knee-type, ram-type, manufacturing or bed type, and planer-type. Most milling machines have self-contained electric drive motors, coolant systems, variable spindle speeds, and power-operated table feeds

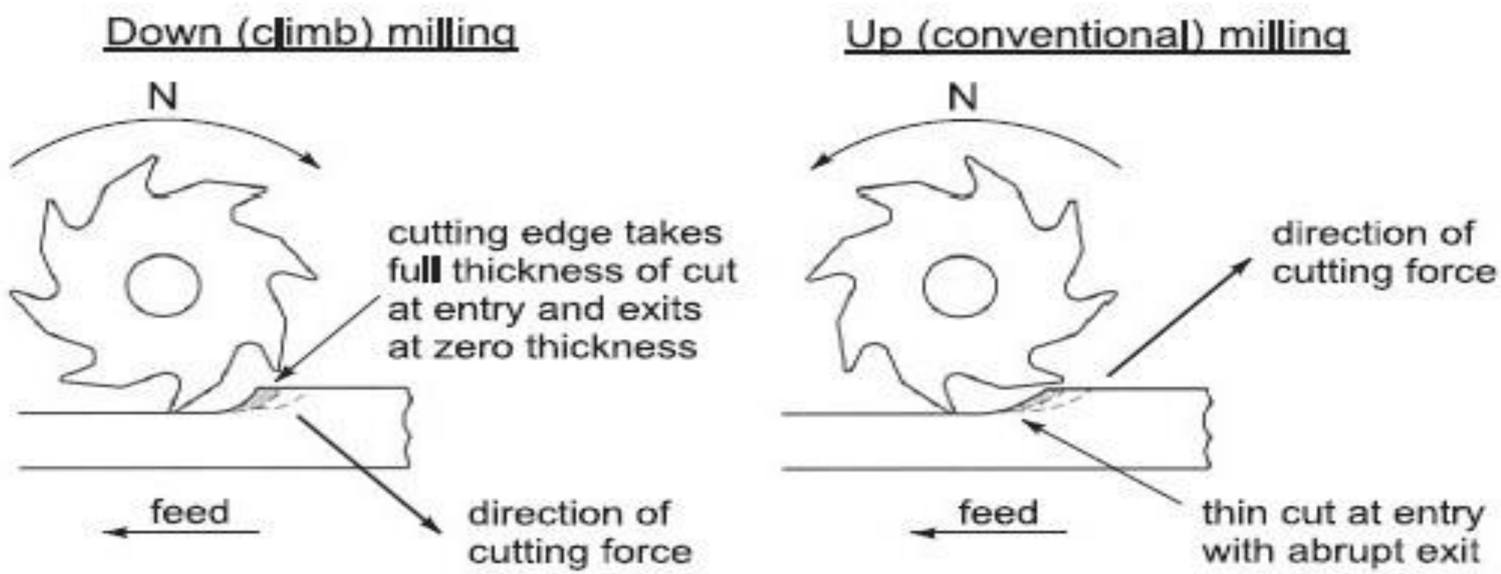
Manufacturing Technology

- Milling is a process of producing flat and complex shapes with the use of multi-tooth cutting tool, which is called a milling cutter and the cutting edges are called teeth.
- The axis of rotation of the cutting tool is perpendicular to the direction of feed, either parallel or perpendicular to the machined surface. The machine tool that traditionally performs this operation is called milling machine.
- Milling is an interrupted cutting operation in which the teeth of the milling cutter enter and exit the work during each revolution. This interrupted cutting action subjects the teeth to a cycle of impact force and thermal shock on every rotation. The tool material and cutter geometry must be designed to withstand these conditions. Cutting fluids are essential for most milling operations.

Manufacturing Technology

Types of milling

- There are two basic types of milling
- *Down* (*climb*) milling, when the cutter rotation is in the same direction as the motion of the work piece being fed.
- *up* (*conventional*) milling, in which the work piece is moving towards the cutter, opposing the cutter direction of rotation



Two types of peripheral milling. Note the change in the cutting force direction.

Comparison of Up and Down Milling

- Down milling, the cutting force is directed into the work table, which allows thinner work parts to be machined. Better surface finish is obtained but the stress load on the teeth is abrupt, which may damage the cutter.
- Up milling, the cutting force tends to lift the work piece. The work conditions for the cutter are more favorable. Because the cutter does not start to cut when it makes contact (cutting at zero cut is impossible), the surface has a natural waviness.

Milling Operations

Milling of Flat Surfaces

Peripheral Milling

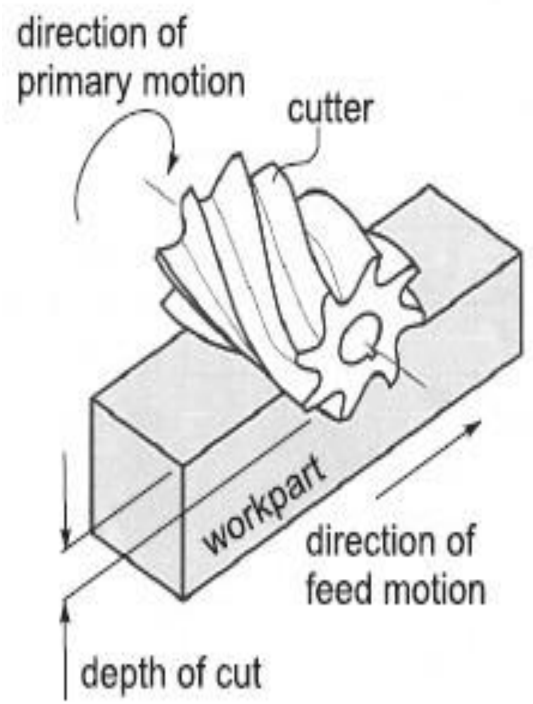
- In *peripheral milling*, also called *plain milling*, the axis of the cutter is parallel to the surface being machined, and the operation is performed by cutting edges on the outside periphery of the cutter. The primary motion is the rotation of the cutter. The feed is imparted to the work piece.
- In peripheral milling the axis of the cutter rotation is parallel to the work surface to be machined.

Types of Peripheral Milling

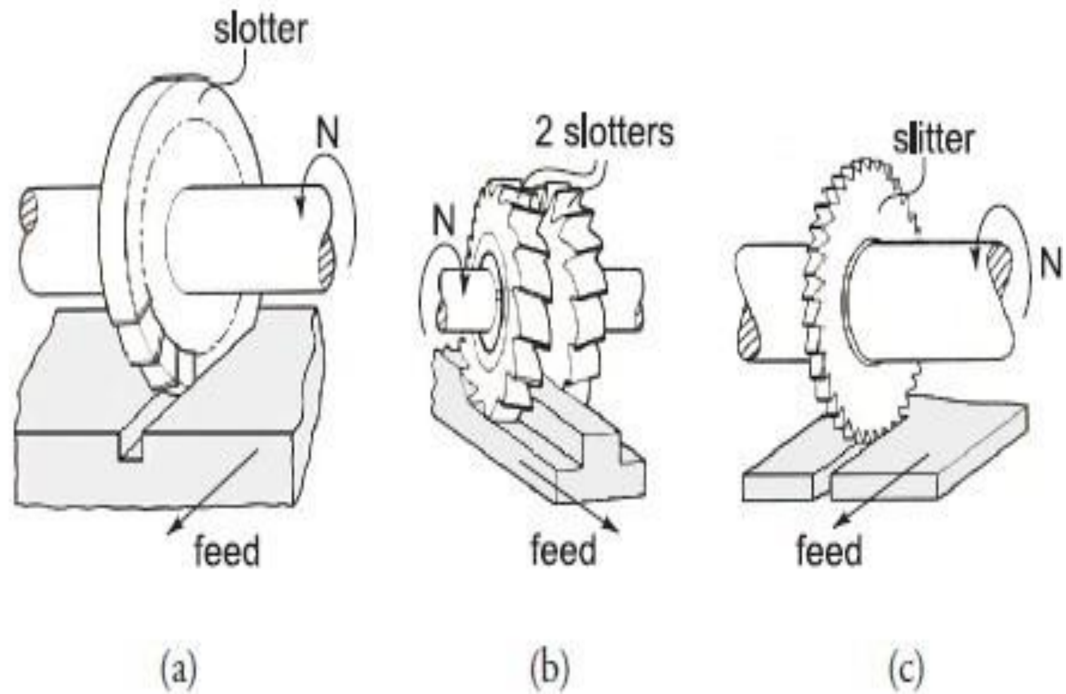
- Slab milling
  - The basic form of peripheral milling in which the cutter width extends beyond the work piece on both sides
- Slotting
  - *Slotting*, also called *slot milling*, in which the width of the cutter, usually called *slotter*, is less than the work piece width.
  - The slotter has teeth on the periphery and over the both end faces. When only the one-side face teeth are engaged, the operations is known as the *side milling*, in which the cutter machines the side of the work piece

- Straddle milling
  - *Straddle milling*, which is the same as side milling where cutting takes place on both sides of the work.
  - In straddle milling, two slotters mounted on an arbor work together;
  - When the slotter is very thin, the operation called *slitting* can be used to mill narrow slots (slits) or to cut a work part in two.
  - The slitting cutter (*slitter*) is narrower than the slotter and has teeth only on the periphery.

Peripheral Milling



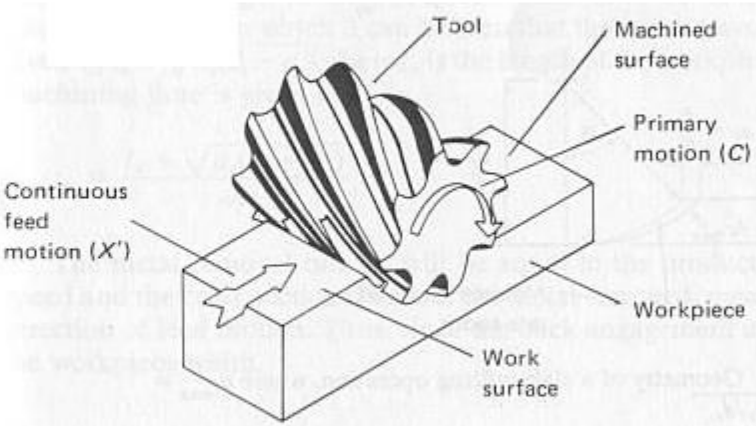
Peripheral slab milling operation.



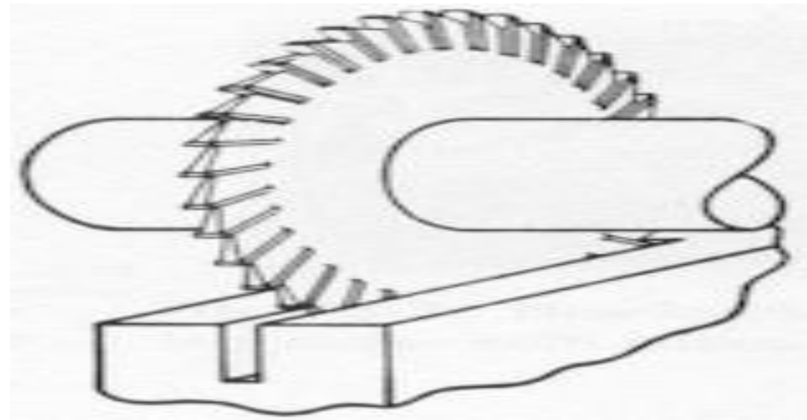
Peripheral milling operations with narrow cutters: (a) slotting, (b) straddle milling, and (c) slitting.

Manufacturing Technology

Peripheral Milling



A



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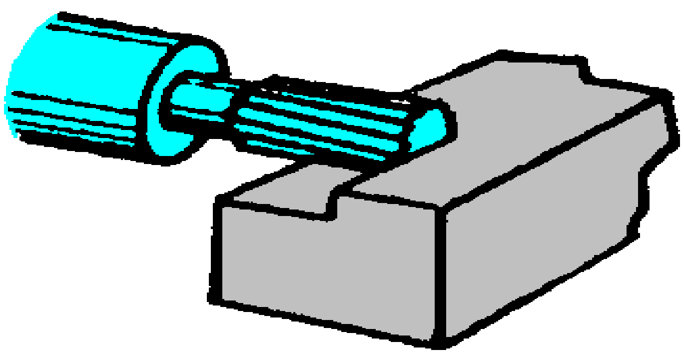

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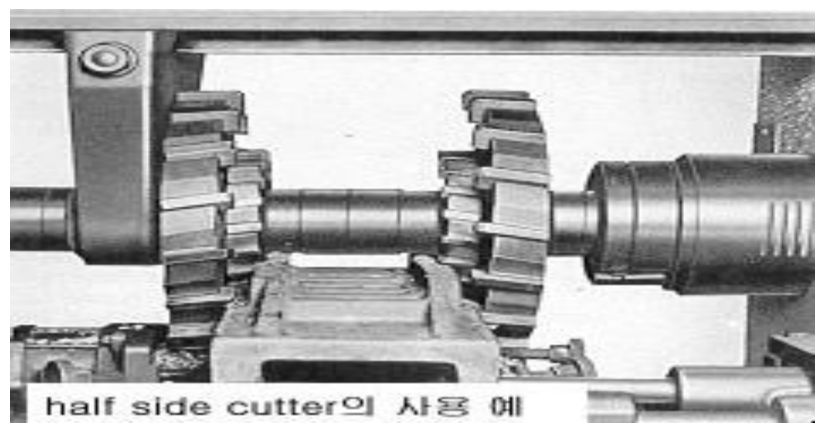

D

A. Slab milling , B. Slot milling , C. Side milling , D. Straddle milling

Advantages of peripheral milling

- More stable holding of the cutter. There is less variation in the arbor torque
- Lower power requirements.
- Better surface finish.

Face milling

- In *face milling*, cutter is perpendicular to the machined surface. The cutter axis is vertical, but in the newer CNC machines it often is horizontal. In face milling, machining is performed by teeth on both the end and periphery of the face-milling cutter.
- Face milling is usually applied for rough machining of large surfaces. Surface finish is worse than in peripheral milling, and feed marks are inevitable. One advantage of the face milling is the high production rate because the cutter diameter is large and as a result the material removal rate is high. Face milling with large diameter cutters requires significant machine power.
- In Face milling the axis of the cutter rotation is perpendicular to the work surface to be machined.

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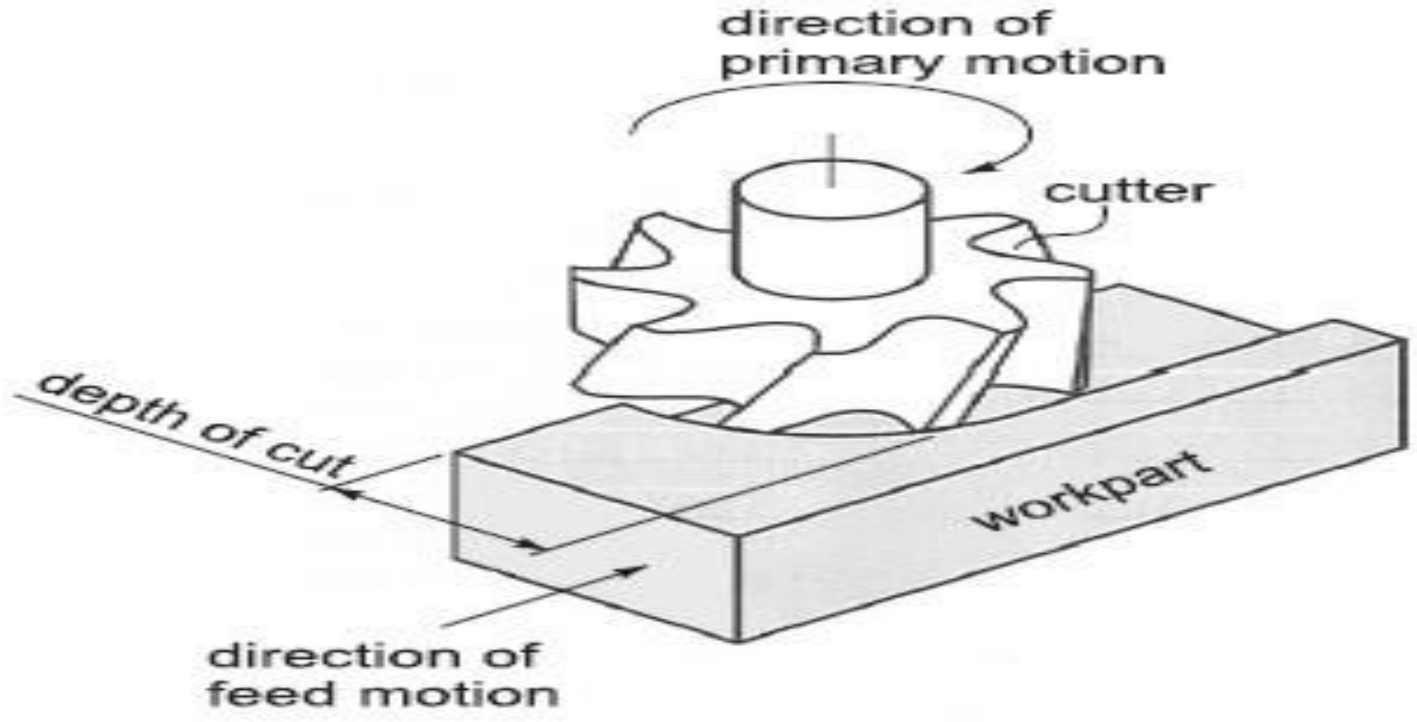
Face milling



Partial face milling operation. The face-milling cutter machines only one side of the workpiece.

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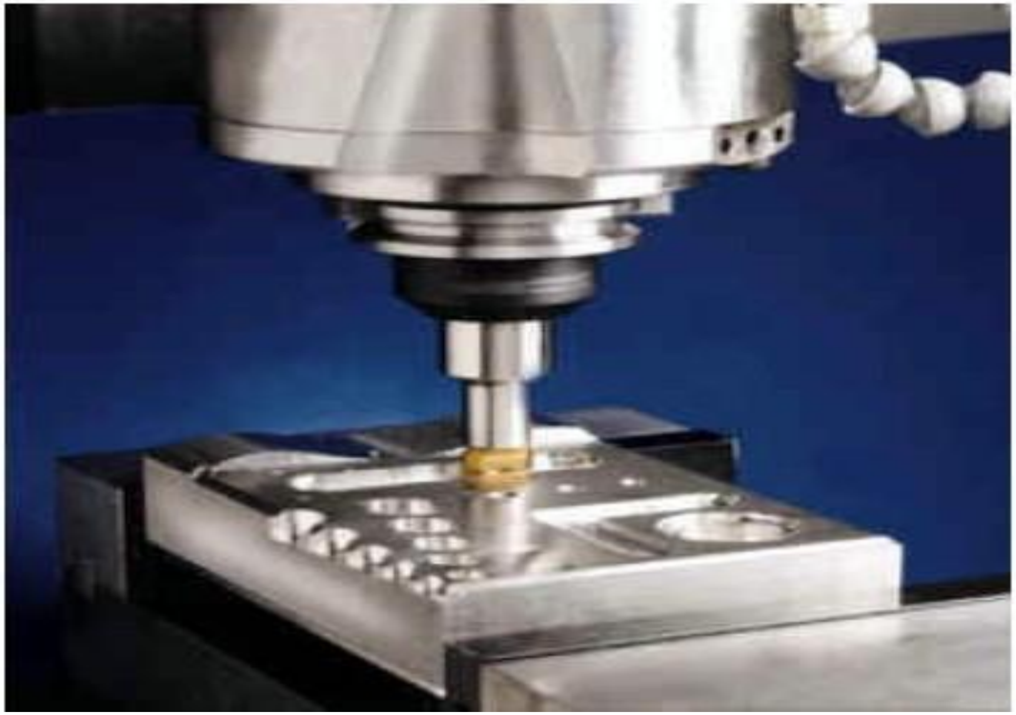
End milling

- In *end milling*, the cutter, called *end mill*, has a diameter less than the work piece width. The end mill has helical cutting edges carried over onto the cylindrical cutter surface are used to produce pockets, closed or end key slots, etc.



End milling operation used to cut a pocket in an aluminum work part.

Milling of Complex Surfaces

- Milling is one of the few machining operations, which are capable of machining complex *two*- and *three-dimensional surfaces*, typical for dies, molds, cams, etc. Complex surfaces can be machined either by means of the cutter path (*profile milling* and *surface contouring*), or the cutter shape (*form milling*).

Form milling

- In form milling, the cutting edges of the peripheral cutter (called *form cutter*) have a special profile that is imparted to the work piece. Cutters with various profiles are available to cut different two-dimensional surfaces. One important application of form milling is gear manufacturing

Types of Form Milling

Profile milling

- In profile milling, the conventional end mill is used to cut the outside or inside periphery of a flat part. The end mill works with its peripheral teeth and is fed along a curvilinear path equidistant from the surface profile.

Surface contouring

- The end mill, which is used in surface contouring has a hemispherical end and is called *ball-end mill*. The ball-end mill is fed back and forth across the work piece along a curvilinear path at close intervals to produce complex three-dimensional surfaces.
- Similar to profile milling, surface contouring require relatively simple cutting tool but advanced, usually computer-controlled feed control system.

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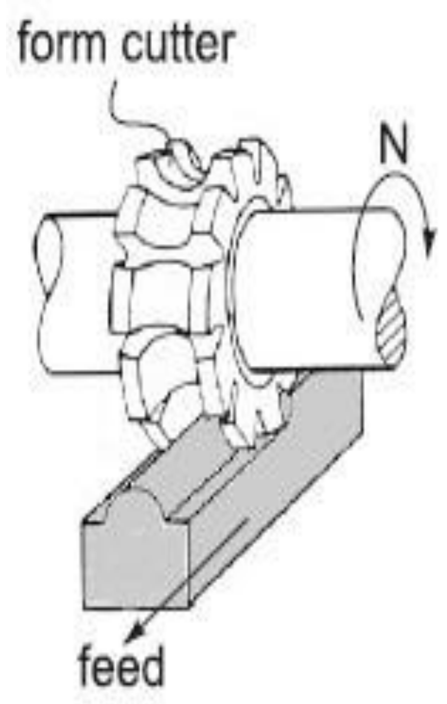
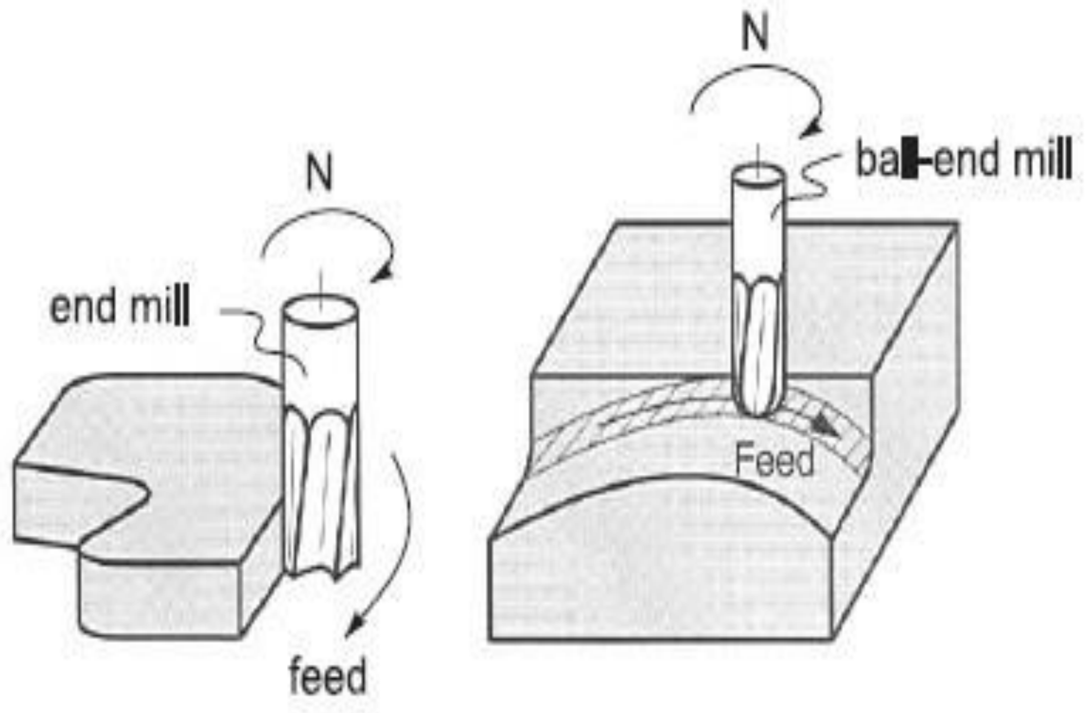
Form Milling



Form milling of two-dimensional surface.



(*Left*) Profile milling of a cam, and (*Right*) Surface contouring of a complex three-dimensional surface.

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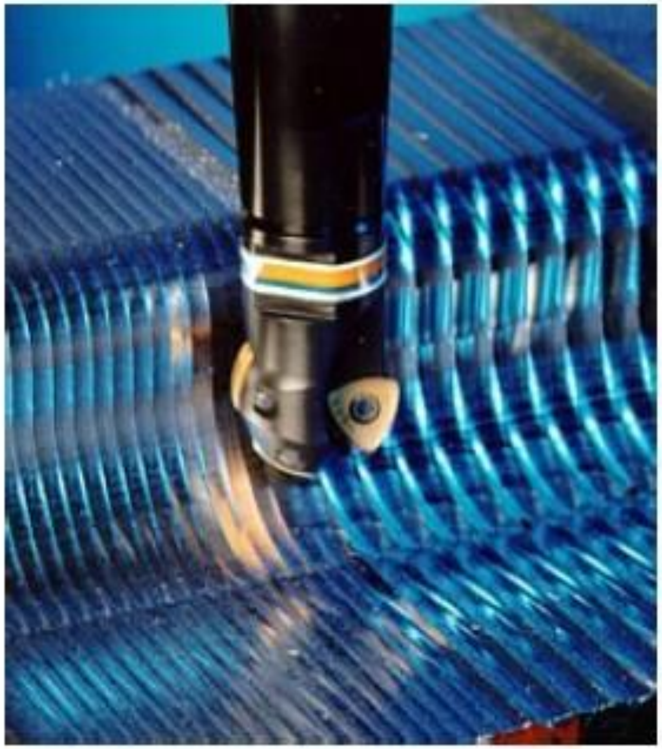
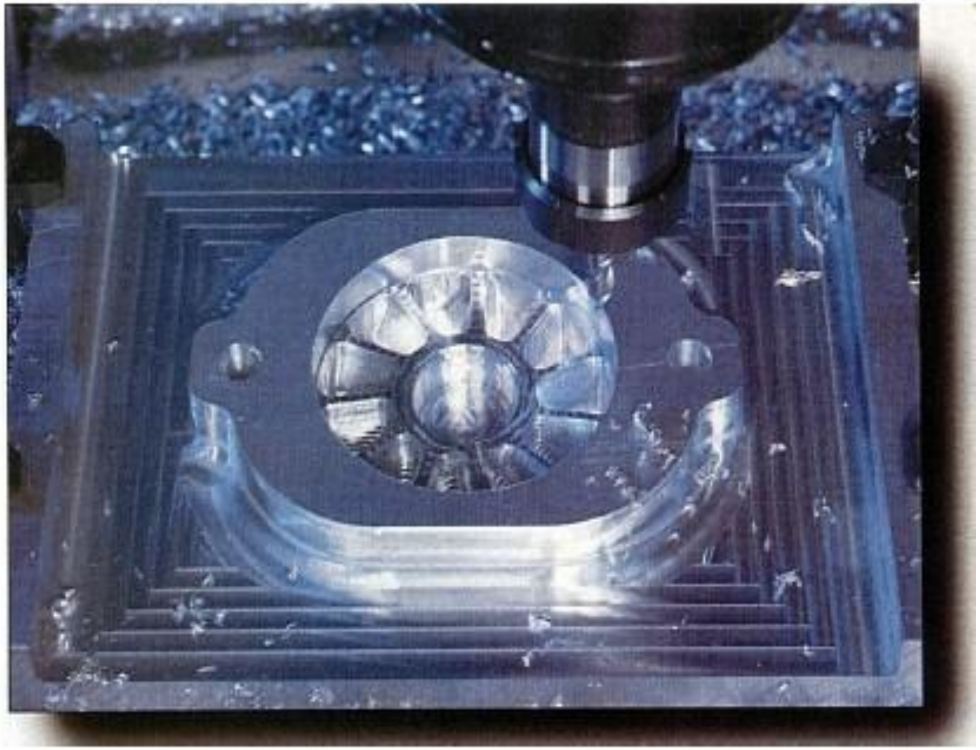
Surface contouring



Close-up view of a hemispherical ball-end mill with indexed carbide inserts used for rough cutting of a three-dimensional surface.



Surface contouring of die cavity. The cutter used is a high-speed steel ball-end mill.

Milling machines

- The conventional milling machines provide a primary rotating motion for the cutter held in the spindle, and a linear feed motion for the work piece, which is fastened onto the worktable.
- Milling machines for machining of complex shapes usually provide both a rotating primary motion and a curvilinear feed motion for the cutter in the spindle with a stationary work piece.

Milling Machine Types

- Various machine designs are available for various milling operations. In this section we discuss only the most popular ones, classified into the following types
  - **Column-and-knee milling machines**
  - **Bed type milling machines**
  - **Machining centers**

Other Classifications

According to nature of purposes of use

- General Purpose Milling Machine
  - Conventional milling machines, e.g Up and down milling machines
- Single Purpose Milling Machine
  - Thread, cam milling machines and slitting machine
- Special Purpose Milling Machine
  - Mass production machines, e.g., duplicating mills, die sinkers, thread milling etc.

According to configuration and motion of the work-holding table / bed

Knee type

- small and medium duty machines the table with the job/work travels over the bed (guides) in horizontal (X) and transverse (Y) directions and the bed with the table and job on it moves vertically (Z) up and down.

Bed type

- Usually of larger size and capacity; the vertical feed is given to the milling head instead of the knee type bed

According to the orientation of the spindle

- Horizontal Milling Machine
  - Horizontal spindle Feed
- Vertical milling machine
  - Vertical Spindle Feed
- Universal milling machine
  - Both Horizontal and Vertical spindle Feed

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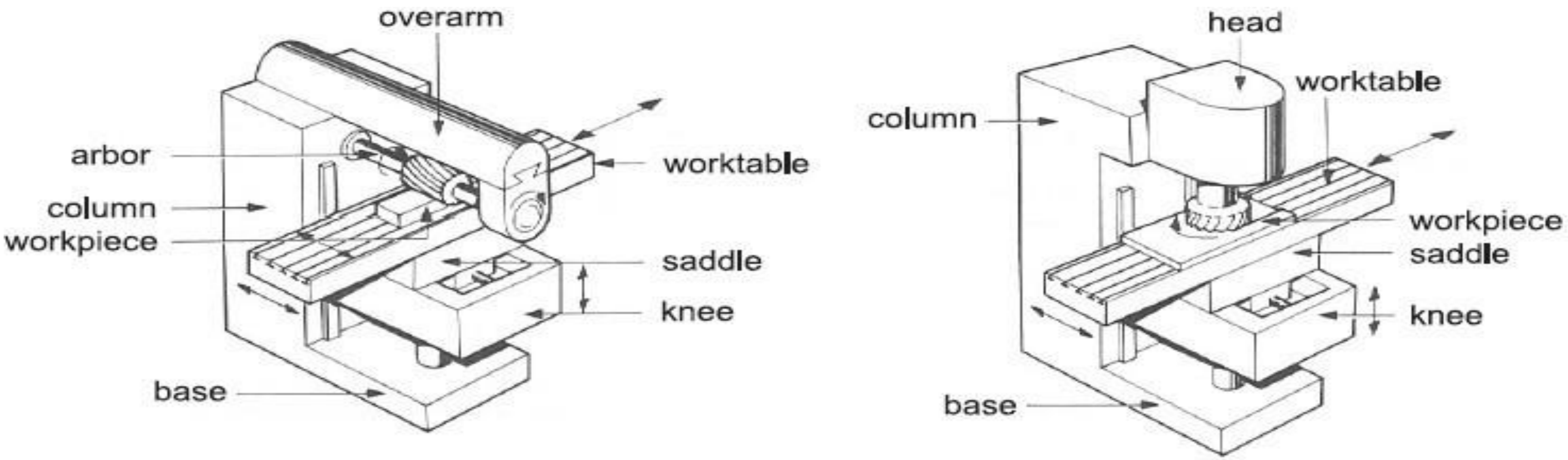
Column-and-knee milling machines

- The *column-and-knee milling machines* are the basic machine tool for milling. The name comes from the fact that this machine has two principal components, a *column* that supports the spindle, and a *knee* that supports the work table.
- There are two different types of column-and-knee milling machines according to position of the spindle axis
  - Horizontal &Vertical.



Two basic types of column-and-knee milling machines, (*Left*) horizontal, and (*Right*) vertical.

Bed type machines

- In bed type milling machines, the worktable is mounted directly on the bed that replaces the knee. This ensures greater rigidity, thus permitting heavier cutting conditions and higher productivity. This machines are designed for mass production.
- Single-spindle bed machines are called *simplex mills* and are available in either horizontal or vertical models. *Duplex mills* have two spindle heads, and *triplex mills* add a third spindle mounted vertically over the bed to further increase machining capability.

Portal planer mill for heavy machining of large workparts.

Machining centers

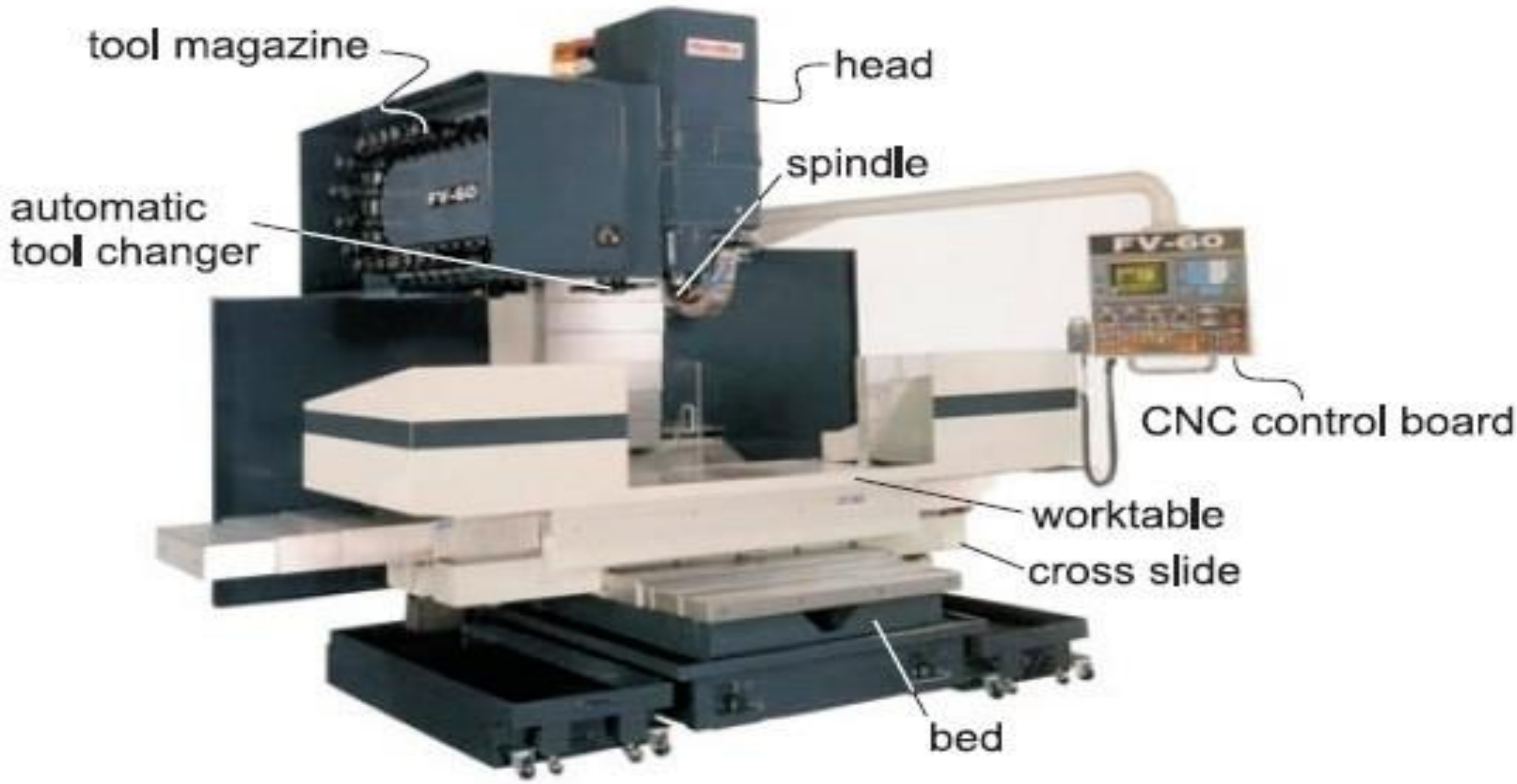
- A machining center is a highly automated machine tool capable of performing multiple machining operations under CNC control.

The features that make a machining center unique include the following

- Tool storage unit called *tool magazine* that can hold up to 120 different cutting tools.
- A*utomatic tool changer*, which is used to exchange cutting tools between the tool magazine and machining center spindle when required. The tool changer is controlled by the CNC program.
- *Automatic work part positioning*. Many of machining centers are equipped with a rotary worktable, which precisely position the part at some angle relative to the spindle. It permits the cutter to perform machining on four sides of the part.

Manufacturing Technology

Machining center



Universal machining center.

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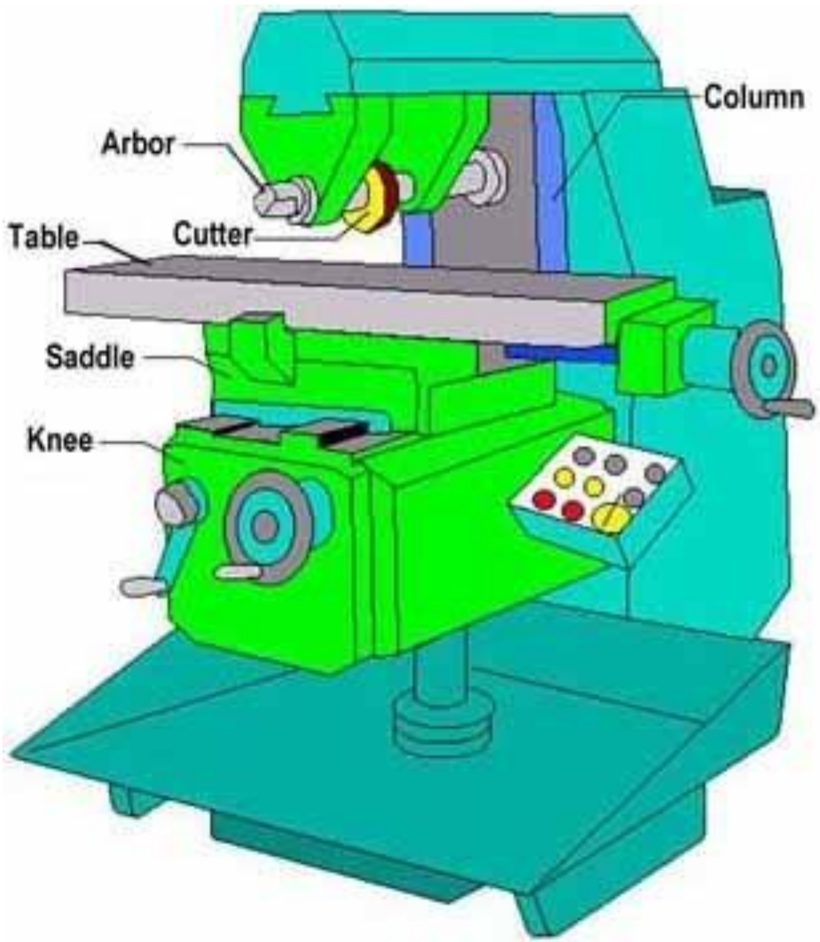
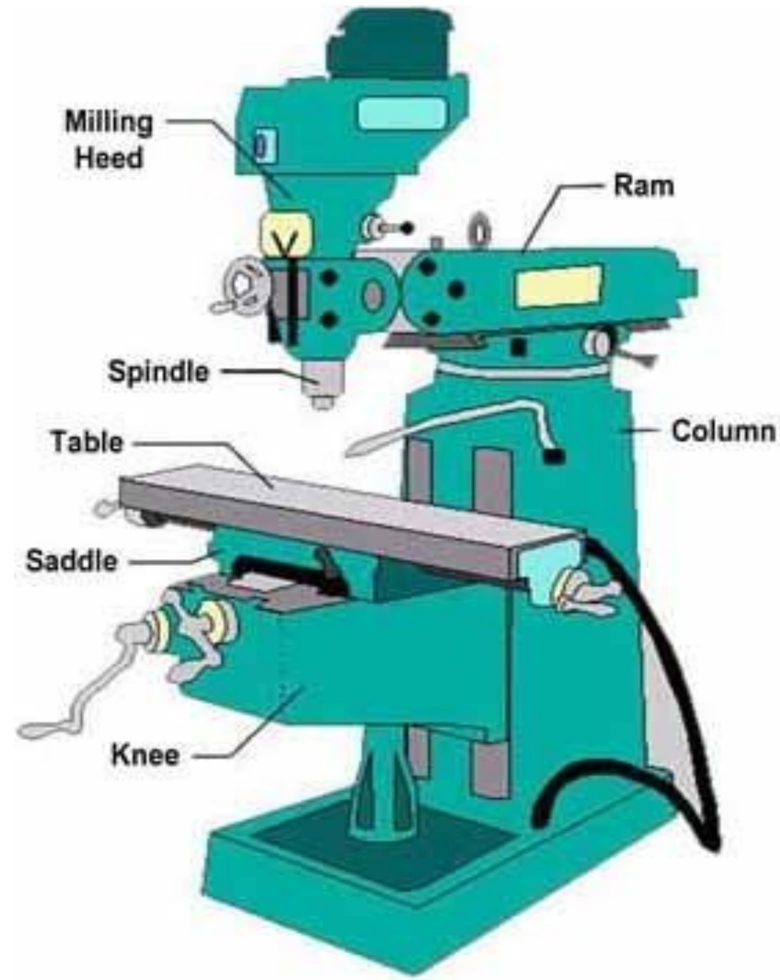
- Milling Machine Specifications



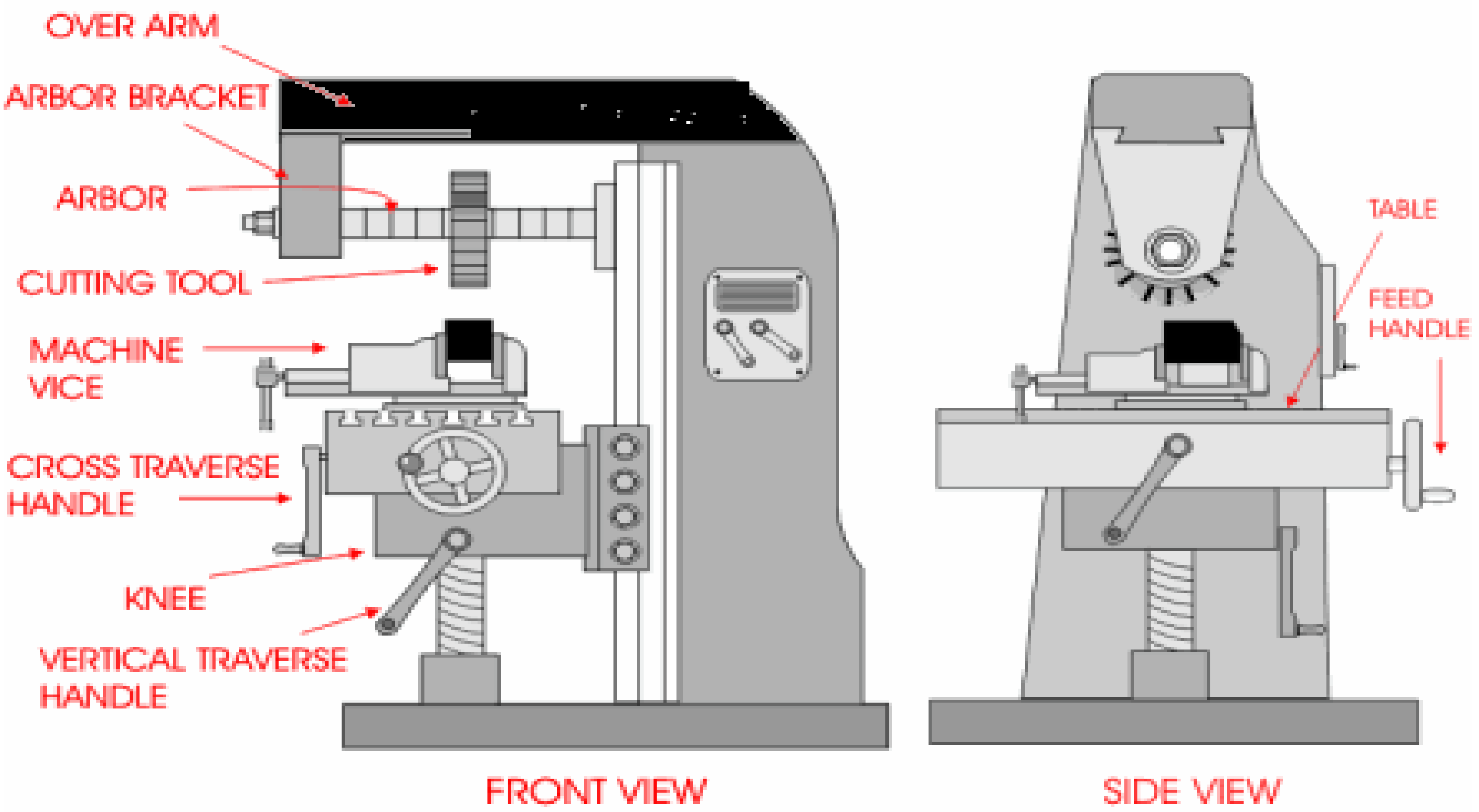
Horizontal Milling Machine



Vertical Milling Machine

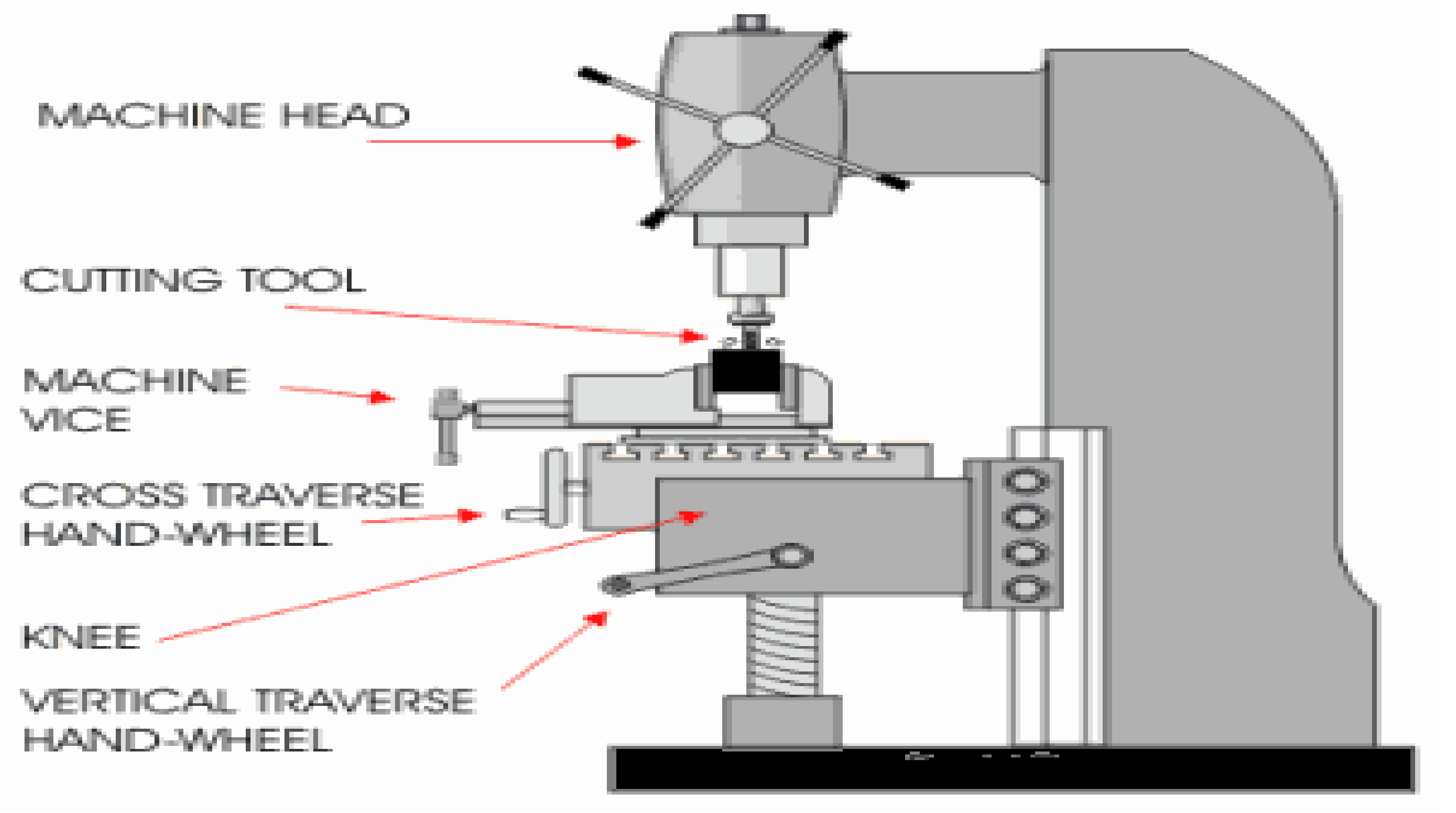
Manufacturing Technology

- Milling Machine Specifications



Manufacturing Technology

- Milling Machine Specifications



Milling cutters

Classification of milling cutters according to their design

- *HSS cutters:* Many cutters like end mills, slitting cutters, slab cutters, angular cutters, form cutters, etc., are made from high-speed steel (HSS).
- *Brazed cutters*: Very limited number of cutters (mainly face mills) are made with brazed carbide inserts. This design is largely replaced by mechanically attached cutters.
- *Mechanically attached cutters:* The vast majority of cutters are in this category. Carbide inserts are either clamped or pin locked to the body of the milling cutter.

Milling Cutter Nomenclature

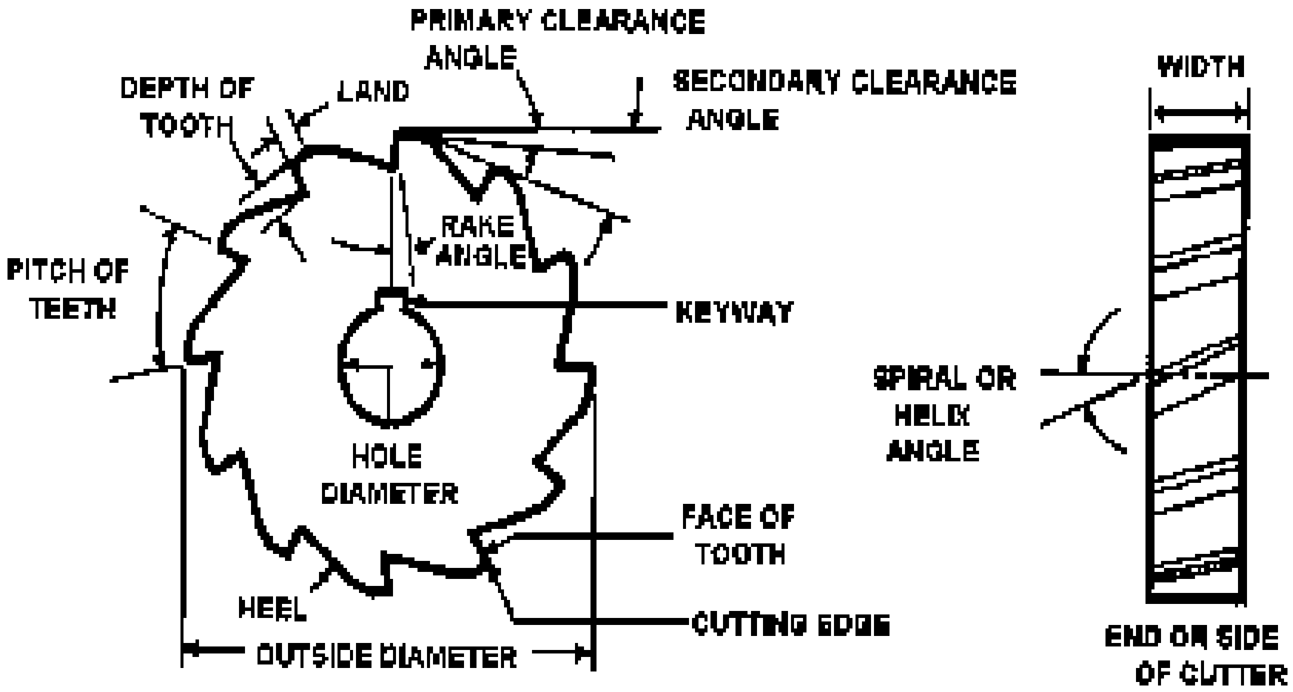


Figure 8-3. Milling cutter nomenclature.

Milling Cutter Nomenclature

- The pitch refers to the angular distance between like or adjacent teeth.
- The pitch is determined by the number of teeth. The tooth face is the forward facing surface of the tooth that forms the cutting edge.
- The cutting edge is the angle on each tooth that performs the cutting.
- The land is the narrow surface behind the cutting edge on each tooth.
- The rake angle is the angle formed between the face of the tooth and the centerline of the cutter. The rake angle defines the cutting edge and provides a path for chips that are cut from the workpiece.
- The primary clearance angle is the angle of the land of each tooth measured from a line tangent to the centerline of the cutter at the cutting edge. This angle prevents each tooth from rubbing against the workpiece after it makes its cut.

Milling Cutter Nomenclature

- This angle defines the land of each tooth and provides additional clearance for passage of cutting oil and chips.
- The hole diameter determines the size of the arbor necessary to mount the milling cutter.
- Plain milling cutters that are more than 3/4 inch in width are usually made with spiral or helical teeth. A plain spiral-tooth milling cutter produces a better and smoother finish and requires less power to operate. A plain helical-tooth milling cutter is especially desirable when milling an uneven surface or one with holes in it.

Classification of milling cutters associated with the various milling operations

Profile sharpened cutters

- surfaces are not related with the tool shape
  - Slab or plain milling cutter : straight or helical fluted
  - Side milling cutters – single side or both sided type
  - Slotting cutter
  - Slitting or parting tools
  - End milling cutters – with straight or taper shank
  - Face milling cutters

Form relieved cutters

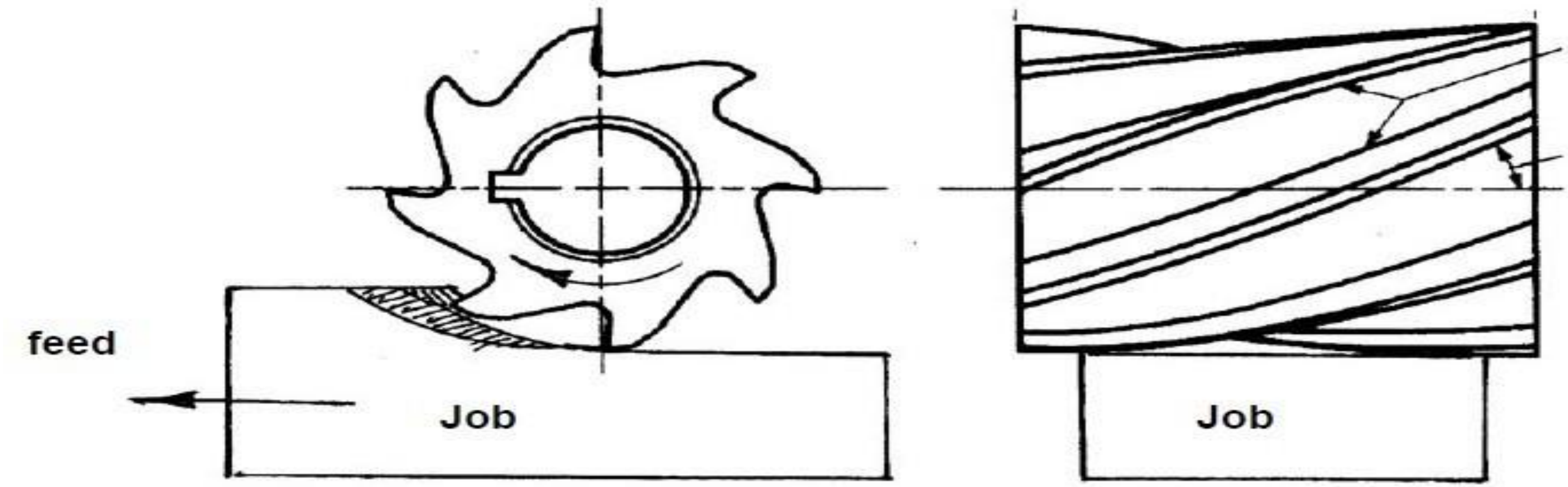
- Where the job profile becomes the replica of the tool-form
  - Form cutters
  - Gear (teeth) milling cutters
  - Spline shaft cutters
  - Tool form cutters
  - T-slot cutters
  - Thread milling cutter

Profile sharpened cutters

- The profile sharpened cutters are inherently used for making flat surfaces or surface bounded by a number of flat surfaces only.

Slab or Plain milling cutters

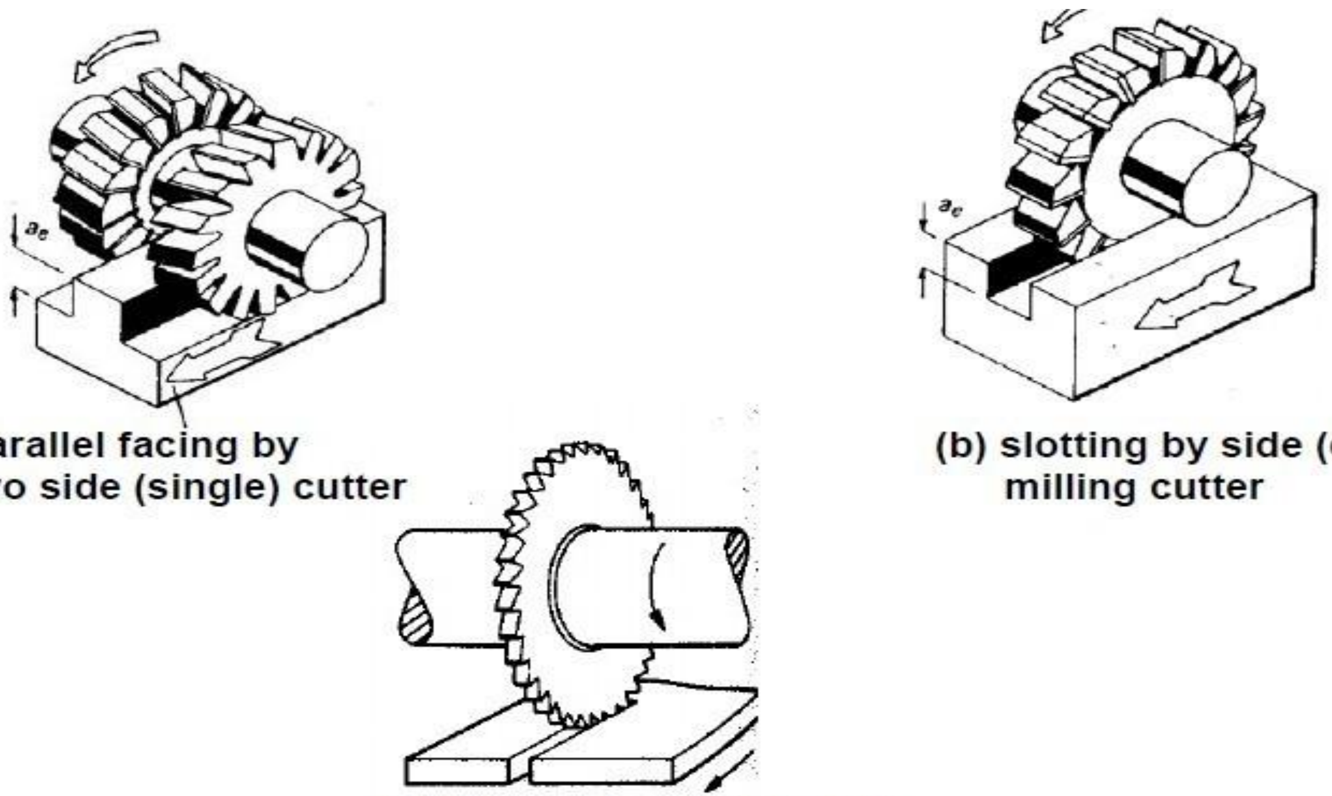
- Plain milling cutters are hollow straight HSS cylinder of 40 to 80 mm outer diameter having 4 to 16 straight or helical equi-spaced flutes or cutting edges and are used in horizontal arbour to machine flat surface



Machining flat surface by slab milling Cutter

Side and slot milling cutters

- These arbour mounted disc type cutters have a large number of cutting teeth at equal spacing on the periphery.



(a) parallel facing by two side (single) cutter

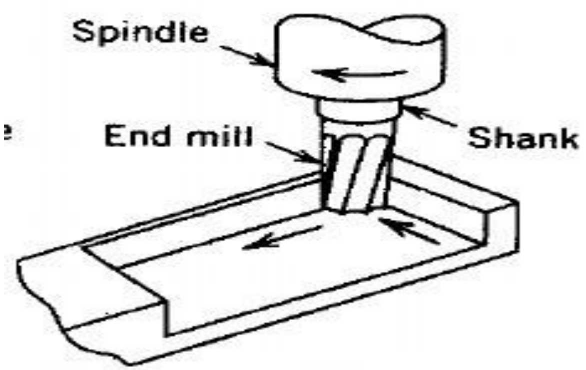
(b) slotting by side (double sided) milling cutter

(c) Parting by slitting saw

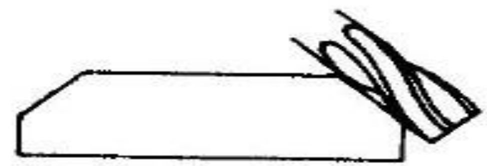
Side milling cutters

End milling cutters

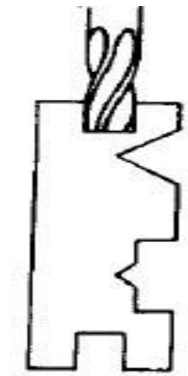
- The end milling cutter, also called an end mill, has teeth on the end as well as the periphery



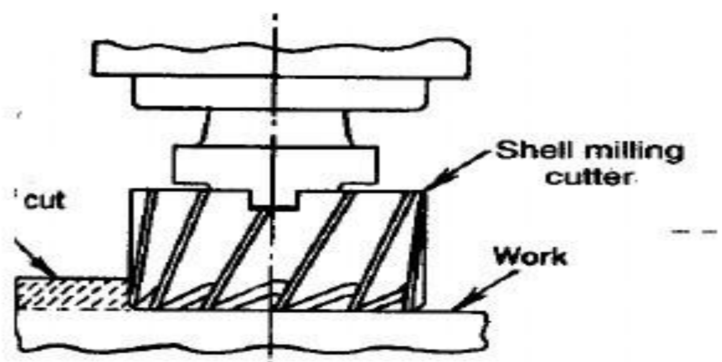
(a) face milling



(b) angular milling

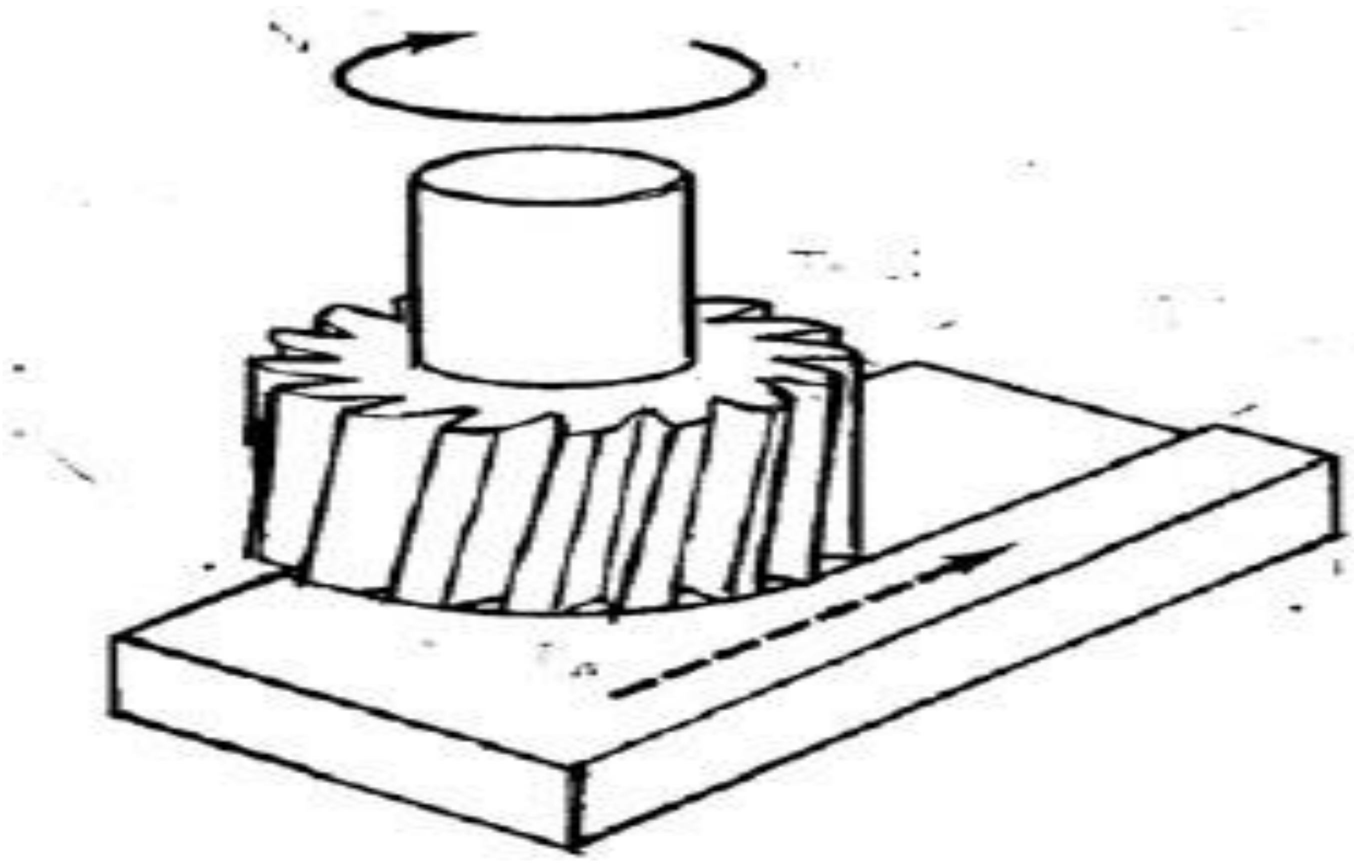


(c) slotting



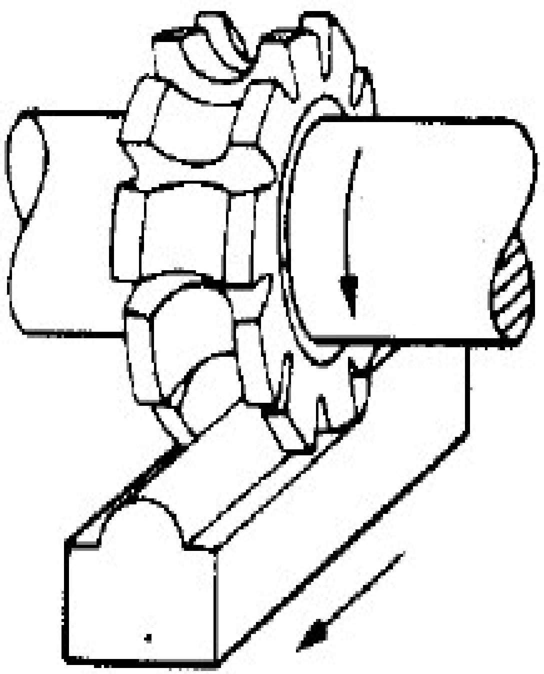
(d) shell milling

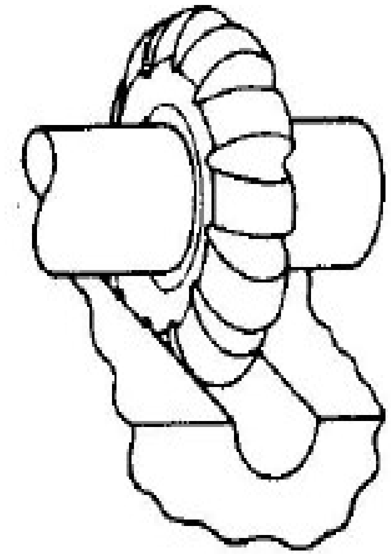
Face milling cutter

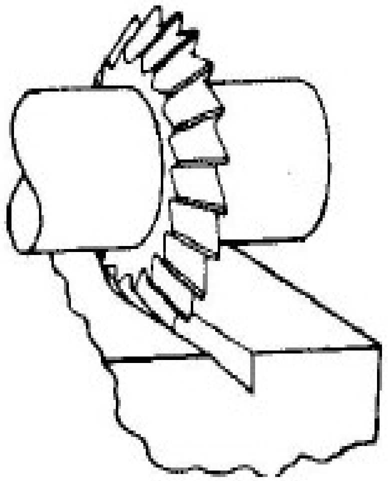


Form relieved cutters

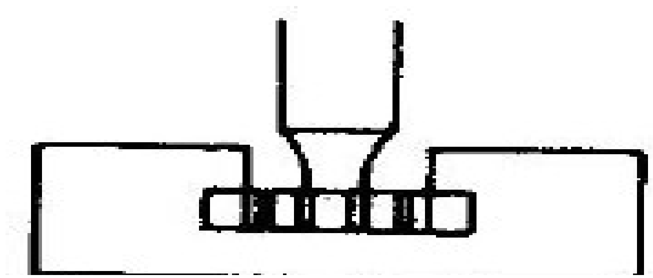
- Form of the tool is exactly replica of the job-profile to be made
- Clearance or flank surfaces of the teeth are spiral shaped instead of flat
- Used for making 2-D and 3-D contour surfaces

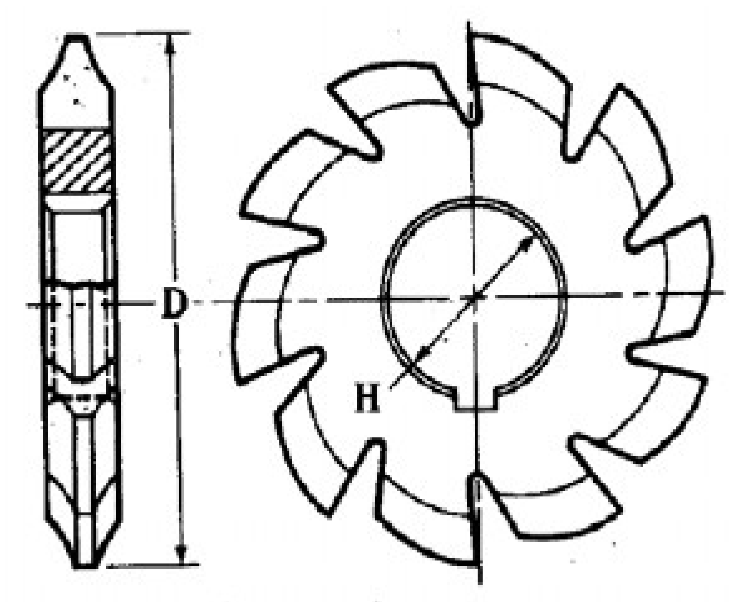


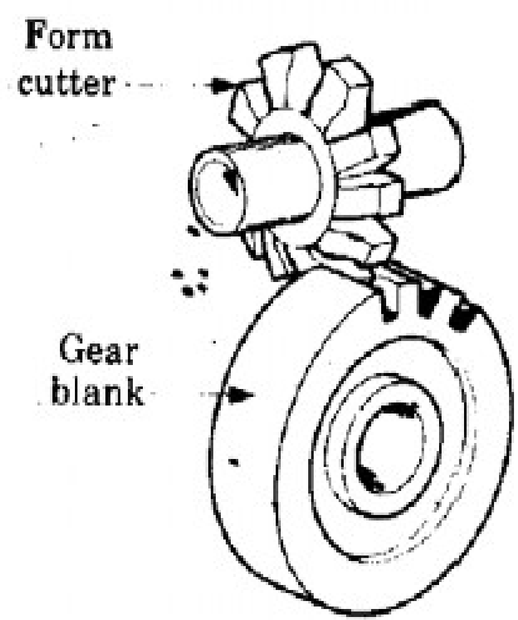


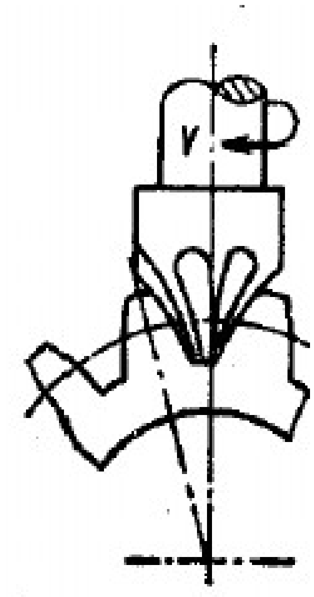


T-slot & Gear milling cutters

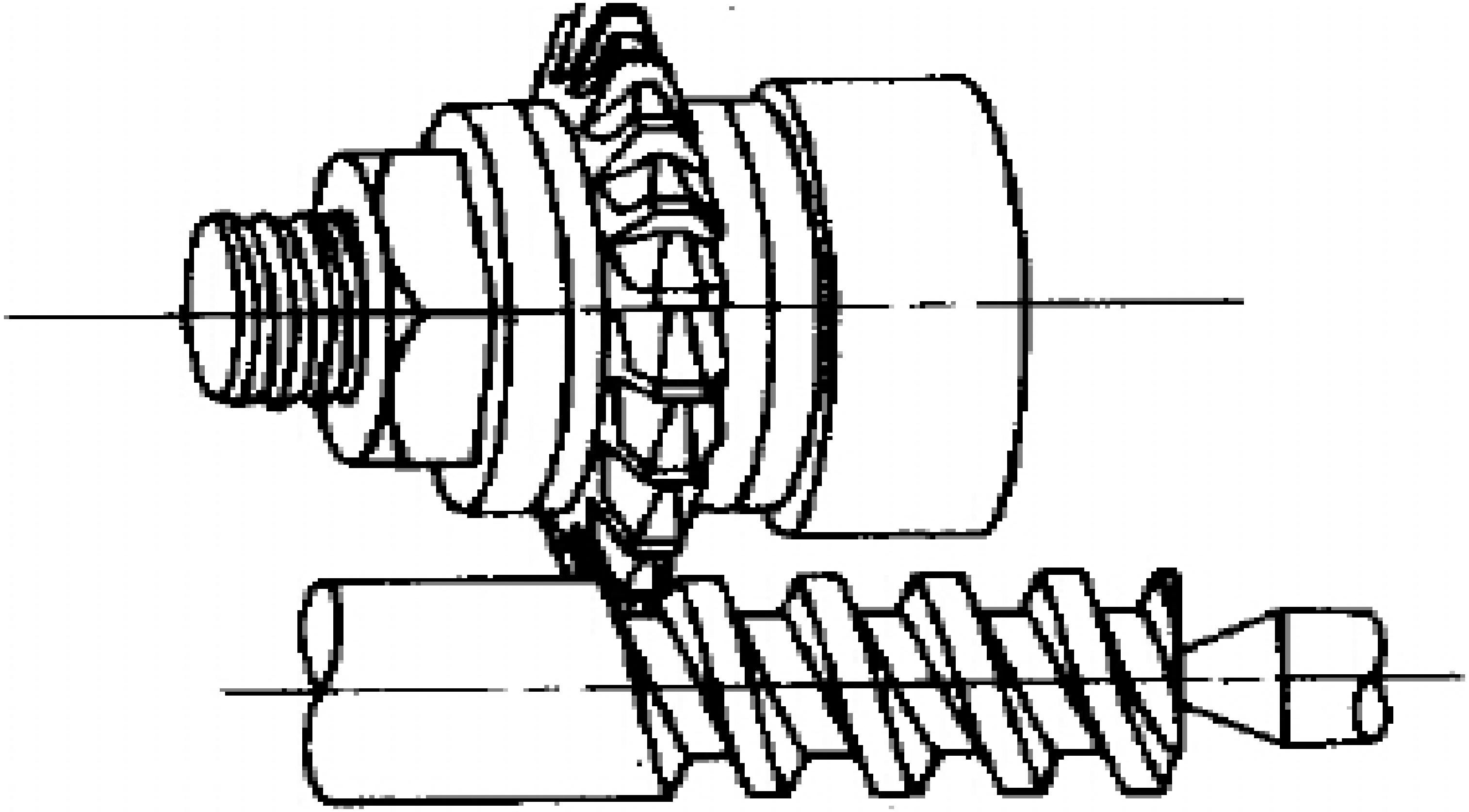








Thread milling cutter

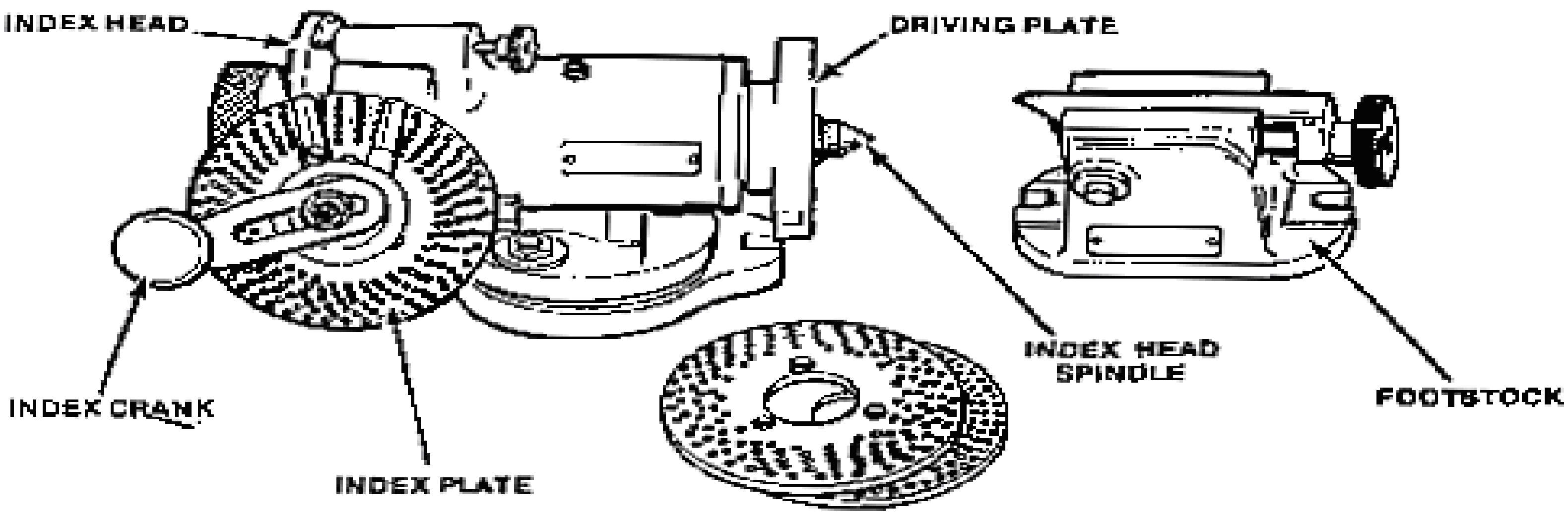


Indexing

- Indexing is the process of evenly dividing the circumference of a circular work piece into equally spaced divisions, such as in cutting gear teeth, cutting splines, milling grooves in reamers and taps, and spacing holes on a circle.
- The index head of the indexing fixture is used for this purpose.

Index Head

- The index head of the indexing fixture (Figure) contains an indexing mechanism which is used to control the rotation of the index head spindle to space or divide a work piece accurately. A simple indexing mechanism consists of a 40-tooth worm wheel fastened to the index head spindle, a single-cut worm, a crank for turning the worm shaft, and an index plate and sector. Since there are 40 teeth in the worm wheel, one turn of the index crank causes the worm, and consequently, the index head spindle to make 1/40 of a turn; so 40 turns of the index crank revolve the spindle one full turn.

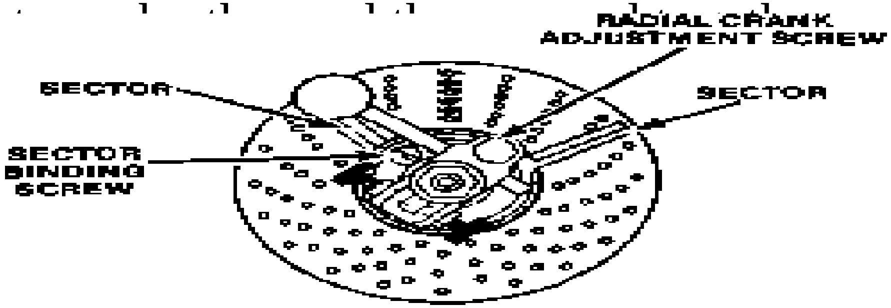


Index Plate

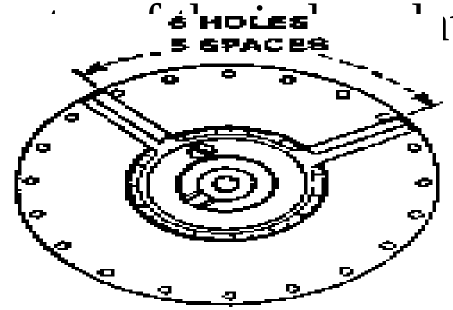
- The indexing plate (Figure) is a round plate with a series of six or more circles of equally spaced holes; the index pin on the crank can be inserted in any hole in any circle. With the interchangeable plates regularly furnished with most index heads, the spacing necessary for most gears, bolt heads, milling cutters, splines, and so forth can be obtained.

Sector

- The sector (Figure) indicates the next hole in which the pin is to be inserted and makes it unnecessary to count holes when moving the index crank after each cut. It consists of two radial, beveled arms which can be set at any angle [illegible] ate.



INDEX PLATE WITH CRANK AND SECTOR



OPERATION OF SECTOR

Index Plate Types

- **Brown and Sharpe type consists of 3 plates of 6 circles each drilled as follows:**
  - **Plate I - 15, 16, 17, 18, 19, 20 holes**
  - **Plate 2 - 21, 23, 27, 29, 31, 33 holes**
  - **Plate 3 - 37, 39, 41, 43, 47, 49 holes**
- **Cincinnati type consists of one plate drilled on both sides with circles divided as follows:**
  - **First side - 24, 25, 28, 30, 34, 37, 38, 39, 41, 42, 43 holes**
  - **Second side - 46, 47, 49, 51, 53, 54, 57, 58, 59, 62, 66 holes**

Indexing Methods

Simple Indexing or Plain Indexing

- In simple or plain indexing, an index plate selected for the particular application, is fitted on the worm shaft and locked through a locking pin'
- To index the work through any required angle, the index crank pin is withdrawn from the hole of the index plate than the work is indexed through the required angle by turning the index crank through a calculated number of whole revolutions and holes on one of the hole circles, after which the index pin is relocated in the required hole
- If the number of turns that the crank must be rotated for each indexing can be found from the formula
  - $N = 40 / Z$
  - Where
  - Z **-** No of divisions or indexings needed on the work
  - 40 – No of teeth on the worm wheel attached to the indexing plate, since 40 turns of the index crank will turn the spindle to one full turn

- Suppose it is desired to mill a gear with eight equally spaced teeth. l/8th of 40 or 5 turns (Since 40 turns of the index crank will turn the spindle one full turn) of the crank after each cut, will space the gear for 8 teeth. If it is desired to space equally for 10 teeth, 1/10 of 40 or 4 turns would produce the correct spacing.
- The same principle applies whether or not the divisions required divide equally into 40. For example, if it is desired to index for 16 divisions, 16 divided into 40 equals 2 8/16 turns. i.e for each indexing we need two complete rotations of the crank plus 8 more holes on the 16 hole circle of plate 1(**Plate I - 15, 16, 17, 18, 19, 20 holes)**

Direct Indexing

- In direct indexing, the index plate is directly mounted on the dividing head spindle (no worm shaft or wheel)
- While indexing, the index crank pin is withdrawn from the hole of the index plate than the pin is engaged directly after the work and the indexing plate are rotated to the desire number of holes
- In this method fractions of a complete turn of the spindle are limited to those available with the index plate
- Direct indexing is accomplished by an additional index plate fastened to the index head spindle. A stationary plunger in the index head fits the holes in this index plate. By moving this plate by hand to index directly, the spindle and the work piece rotate an equal distance. Direct index plates usually have 24 holes and offer a quick means of milling squares, hexagons, taps, and so forth. Any number of divisions which is a factor of 24 can be indexed quickly and conveniently by the direct indexing method.

Differential Indexing

- Sometimes, a number of divisions is required which cannot be obtained by simple indexing with the index plates regularly supplied. To obtain these divisions, a differential index head is used. The index crank is connected to the worm shaft by a train of gears instead of a direct coupling as with simple indexing. The selection of these gears involves calculations similar to those used in calculating change gear ratio for lathe thread cutting.
- Gear Ratio I = 40/K (K – Z)

  Where

  - K – a number very nearly equal to Z
  - For example if the value of Z is 53, the value of K is 50

Indexing in Degrees

- Work pieces can be indexed in degrees as well as fractions of a turn with the usual index head. There are 360 degrees in a complete circle and one turn of the index crank revolves the spindle 1/40 or 9 degrees. Therefore, 1/9 turn of the crank rotates the spindle 1 degree. Work pieces can therefore be indexed in degrees by using a circle of holes divisible by 9. For example, moving the crank 2 spaces on an 18-hole circle, 3 spaces on a 27-hole circle, or 4 spaces on a 36-hole circle will rotate the spindle 1 degree.
- Smaller crank movements further subdivide the circle: moving 1 space on an 18-hole circle turns the spindle 1/2 degree (30 minutes), 1 space on a 27-hole circle turns the spindle 1/3 degree (20 minutes), and so forth.

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Indexing Head:

The index head of the indexing fixture contains an indexing mechanism which is used to control the rotation of the index head spindle to space or divide a workpiece accurately. A simple indexing mechanism consists of 4o teeth worm wheel fastened to the index head spindle, a single cut worm, a crank for turning the worm shaft and index plate and sector. Since there are 40 teeth in worm wheel, one turn of the index crank causes the worm and consequently, the index head spindle to make 1/40 of turn , so that 40 turns of the index crank revolve the spindle one full turn.

Index Plate:

The indexing plate is a round plate with a series of six or more circles of equally spaced holes, the index pin on the crank can be inserted in any desired hole in any circle. With interchangeable plate regularly furnished with most index heads, the spacing is necessary for most gears, bolt heads, milling cutters, splines etc.

Index Plate Types
Brown and Sharpe type
Consists of 3 plates of 6 circles each drilled as follows:

Plate I - 15, 16, 17, 18, 19, 20 holes
Plate 2 - 21, 23, 27, 29, 31, 33 holes
Plate 3 - 37, 39, 41, 43, 47, 49 holes

Cincinnati type
Consists of one plate drilled on both sides with circles
Divided as follows:
First side - 24, 25, 28, 30, 34, 37, 38, 39, 41, 42, 43 holes
Second side - 46, 47, 49, 51, 53, 54, 57, 58, 59, 62, 66 holes

Sector:

The sector indicates the next hole in which the pin is to be inserted and makes it unnecessary to count holes when moving the index crank after each cut. It consists of two radial, beveled arms which can be set at any angle.

Simple Indexing Head:

Simple indexing is also called as 9 indexing. It is more accurate and has a large range of indexing than rapid indexing. For indexing, the dividing head spindle is turned by the index crank. The worm shaft carrying the crank has a single-threaded worm which meshes with worm gear having 40 teeth, 40 turns of the crank are necessary to rotate the index head spindle through one revolution. Therefore, one complete turn of the index crank will cause the worm wheel to make 1/40 of a revolution. To facilitate indexing to the fraction of a turn, an Index plate is used to cover practically all numbers. The Index plate with a circle of holes manufactured by the brown and sharp company is:

Plate No 1- 15, 16, 17,18,19,20

Plate No 2- 21, 23, 27,29,31,33

Plate No 3- 37, 39, 41,43,47,49

[Index crank movement *OR* Number of crank rotation = 40/N]
Where N = number of divisions required on the work.

Angular Indexing Head:

The angular indexing is the Process of dividing the periphery of work in angular measurements. There are 360 degrees in a circle, and then the index crank is rotated by 40 number of revolution and the spindle rotates through 1 complete Revolution or by 360 degrees, one complete turn off the crank will cause the spindle and the work to rotate through 360/40=9 degrees. When a result is a whole number, the index crank is rotated through the full calculated number. If the result is a fraction and a whole number, the part of the revolution of the crank after turning the whole number is calculated by multiplying is suitable for numbers to the numerator and denominator of the fraction, defecation to make the denominator of the fraction is equal to the number of holes in the index plate circle and the now numerator number for holes to be moved by the index Crank.

[Index crank movement *OR* Number of crank rotation = Indexing angle required/9]
Where N = number of divisions required on the work.

Compound Indexing Head:

In Compound indexing, there are two separate movements of the index crank in two different hole circles of one index plate to get the crank movement. In Compound indexing, there are two separate movements of the index crank in two different hole circles of one index plate to get the crank movement. The index plate is held stationary by Lock pin head which engages with one of the whole circle of the index place from the back. For indexing , the crankpin is rotated by the required number of the spaces in one of the holes of the circle of the index plate and then the pin is engaged with the plate. The second index movement is done by removing the real lock pin and the rotating the plate together with the index crank forward or backward through the calculated number of spaces of another hole circle, and the lock pin is engaged.

STEP 1 : Convert that division into two fractions like example 77= 11 * 7

STEP 2 : Select the hole circle number based on the number of division like example

11 * 7

(11 * 3) (7 * 3)

(33) (21)

STEP 3 : Solve equation and find hole circle number and hole no. by Trial and error method

X/21 (+/-) Y/33 = 40 / 77

Differential Indexing Head:

Sometimes, a number of divisions is required which cannot be obtained by simple indexing with the index plates regularly supplied. To obtain these divisions, a differential index head is used. The index crank is connected to the worm shaft by a train of gears instead of a direct coupling as with simple indexing. The selection of these gears involves calculations similar to those used in calculating change gear ratio for lathe thread cutting.

STEP 1 : Select the nearest value such a way that it is divisible by 40

STEP 2 **: 40/N’ + 1/N (a.b/c.d) = 40/N’**

N = Given divisible number in the question

N’ = Nearest divisible no. that will be divisible by 40

INTRODUCTION TO GRINDING PROCESS

- It is the only economical method of cutting hard material like hardened steel.
- It produces very smooth surface , suitable for bearing surface.
- Surface pressure is minimum in grinding. It is suitable for light work,which will spring away from the cutting tool in the other machining processes.

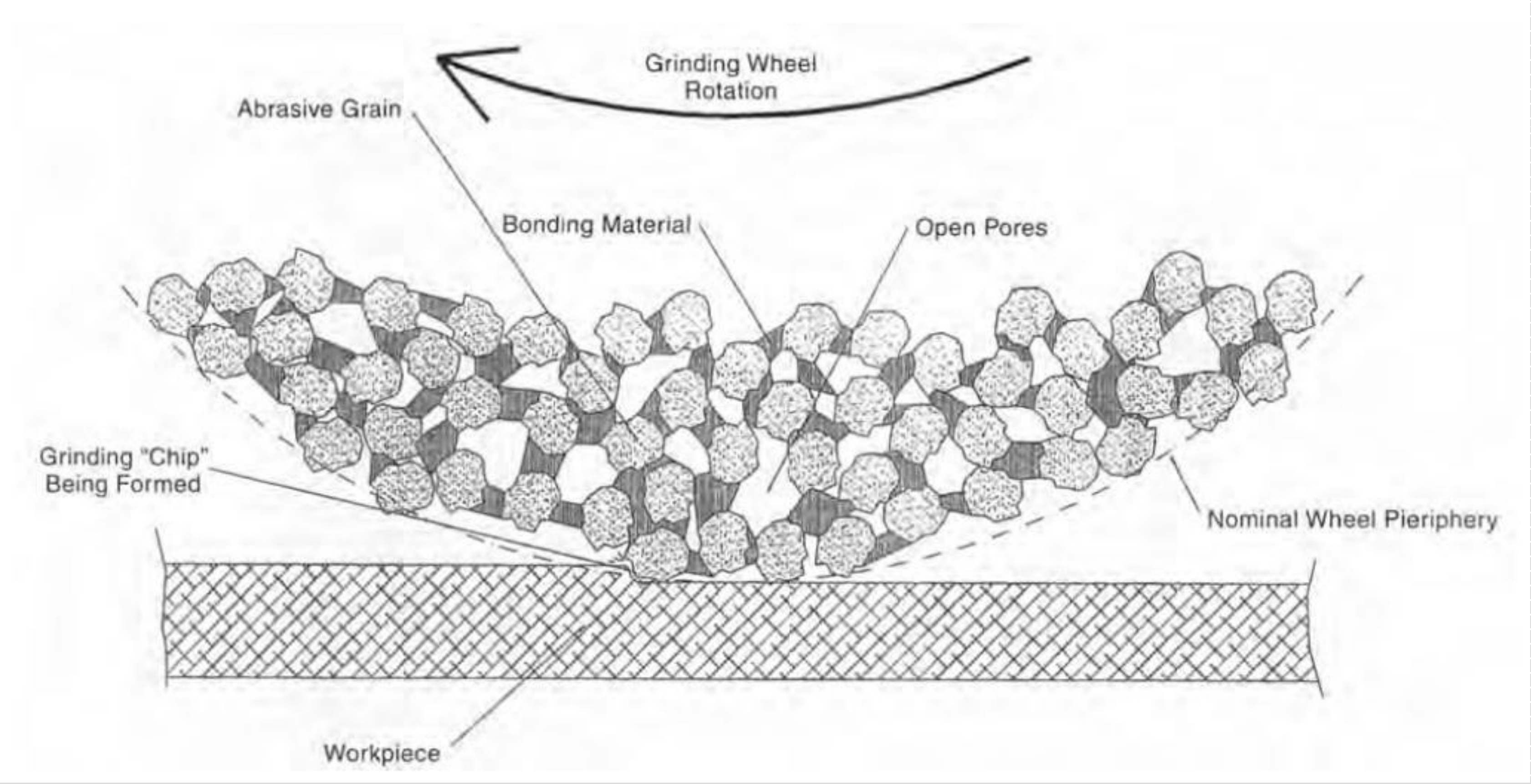
Grinding operation

Types of grinding operation

1. Ruff or precision Grinding
   a) Snagging
   b) Off-hand
2. Precision Grinding
   a) Surface grinding
   b) Cylindrical grinding
   c) Center less grinding
   d) Form and profile grinding
   e) Plunge cut grinding

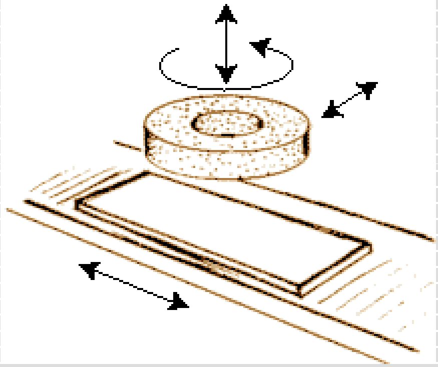
Grinding Process

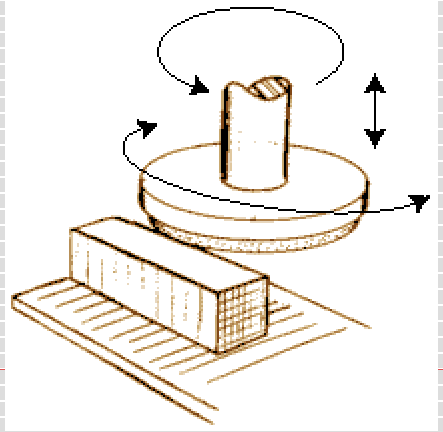
Grinding is an abrasive machining process that uses a grinding wheel as the cutting tool.

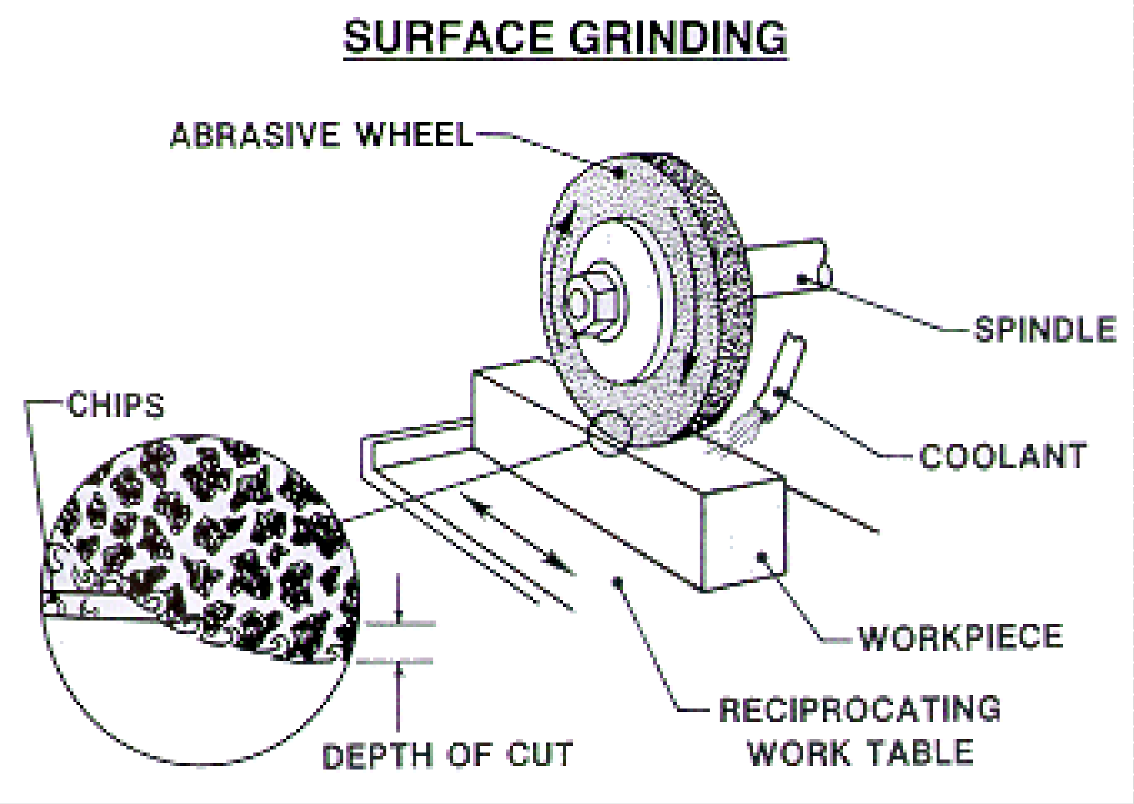


Surface Grinding

Surface grinding uses a rotating abrasive wheel to remove material, creating a flat surface.



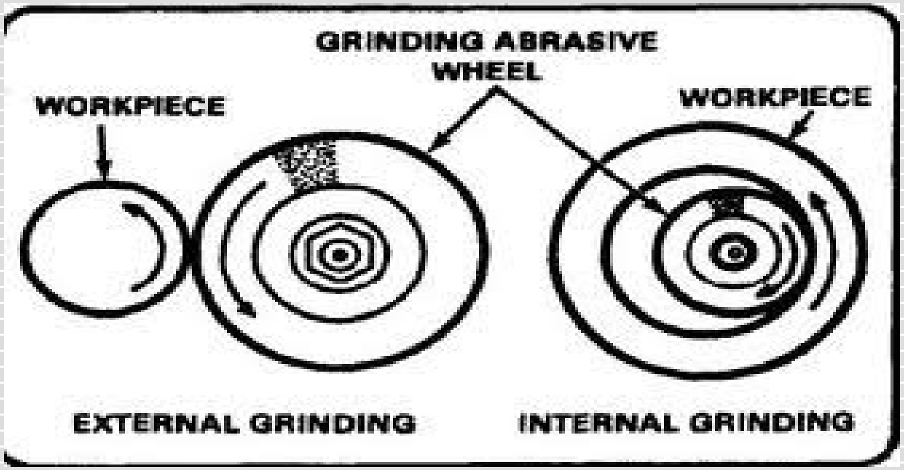




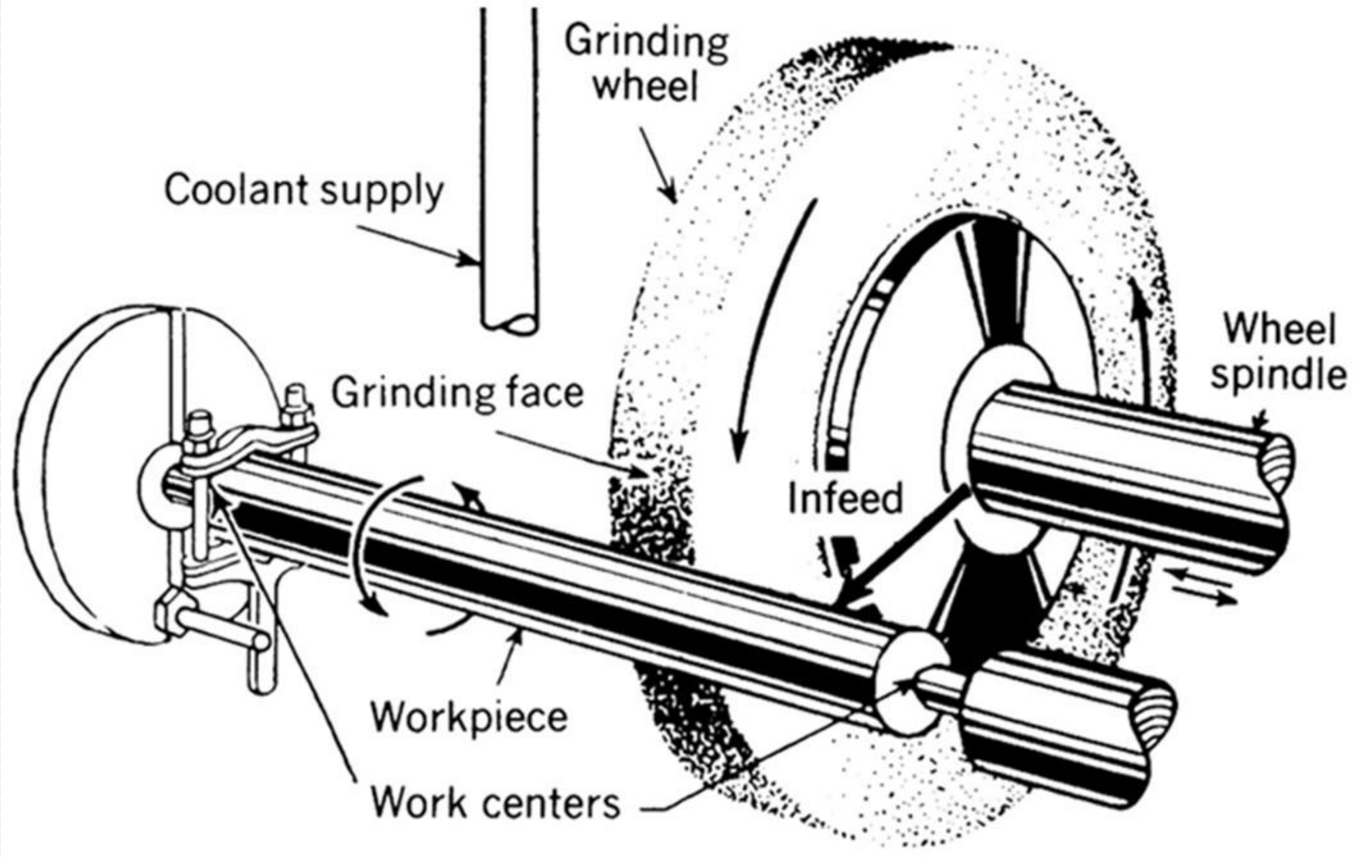
Cylindrical Grinding

Cylindrical grinding (also called center-type grinding) is used to grind the cylindrical surfaces and shoulders of the workpiece.

1. External cylindrical grinding
2. Internal cylindrical grinding

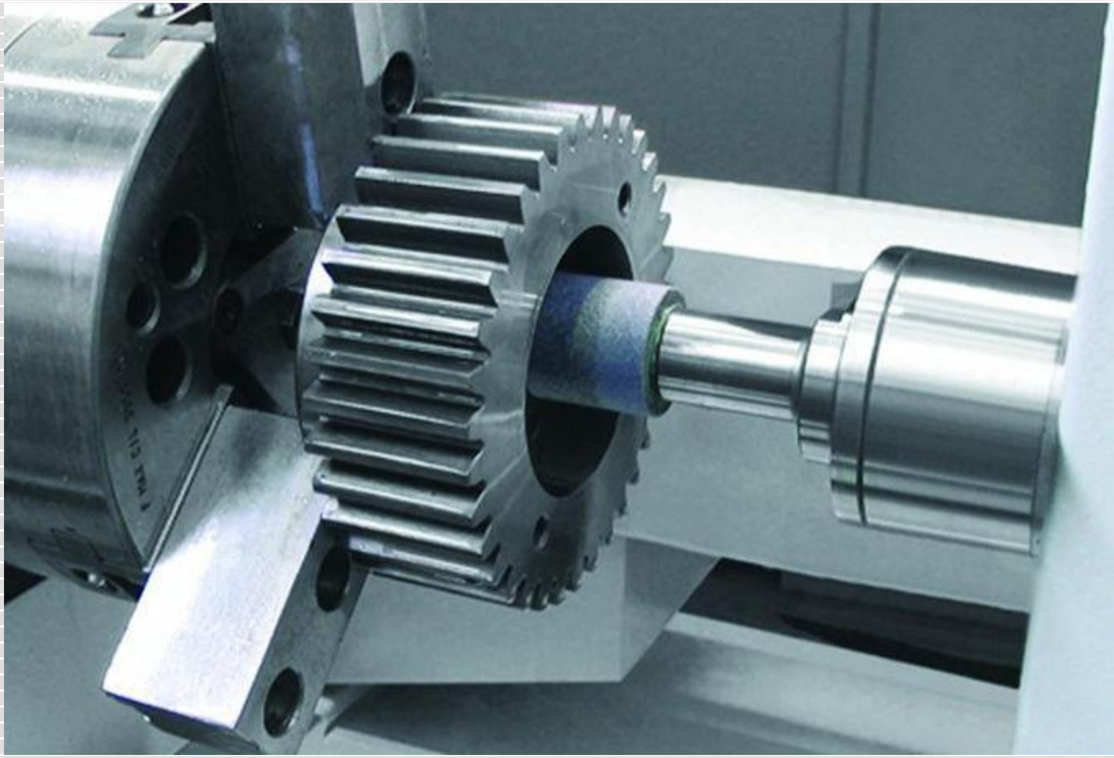


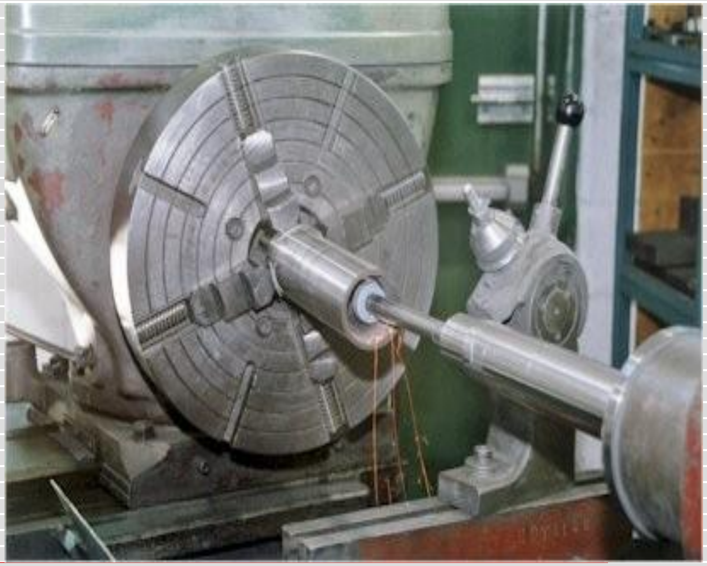
External cylindrical grinding



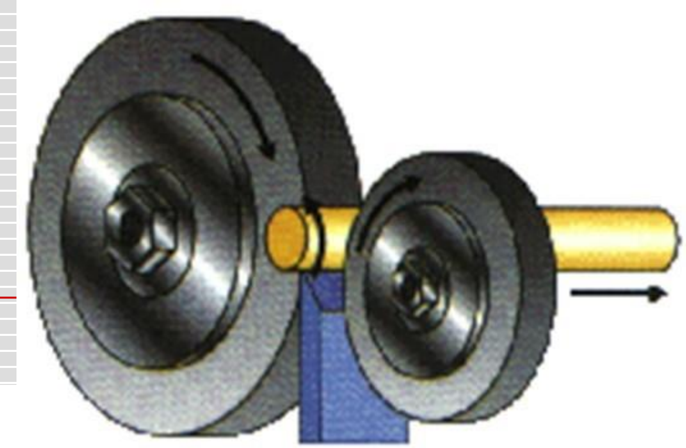
Internal cylindrical grinding

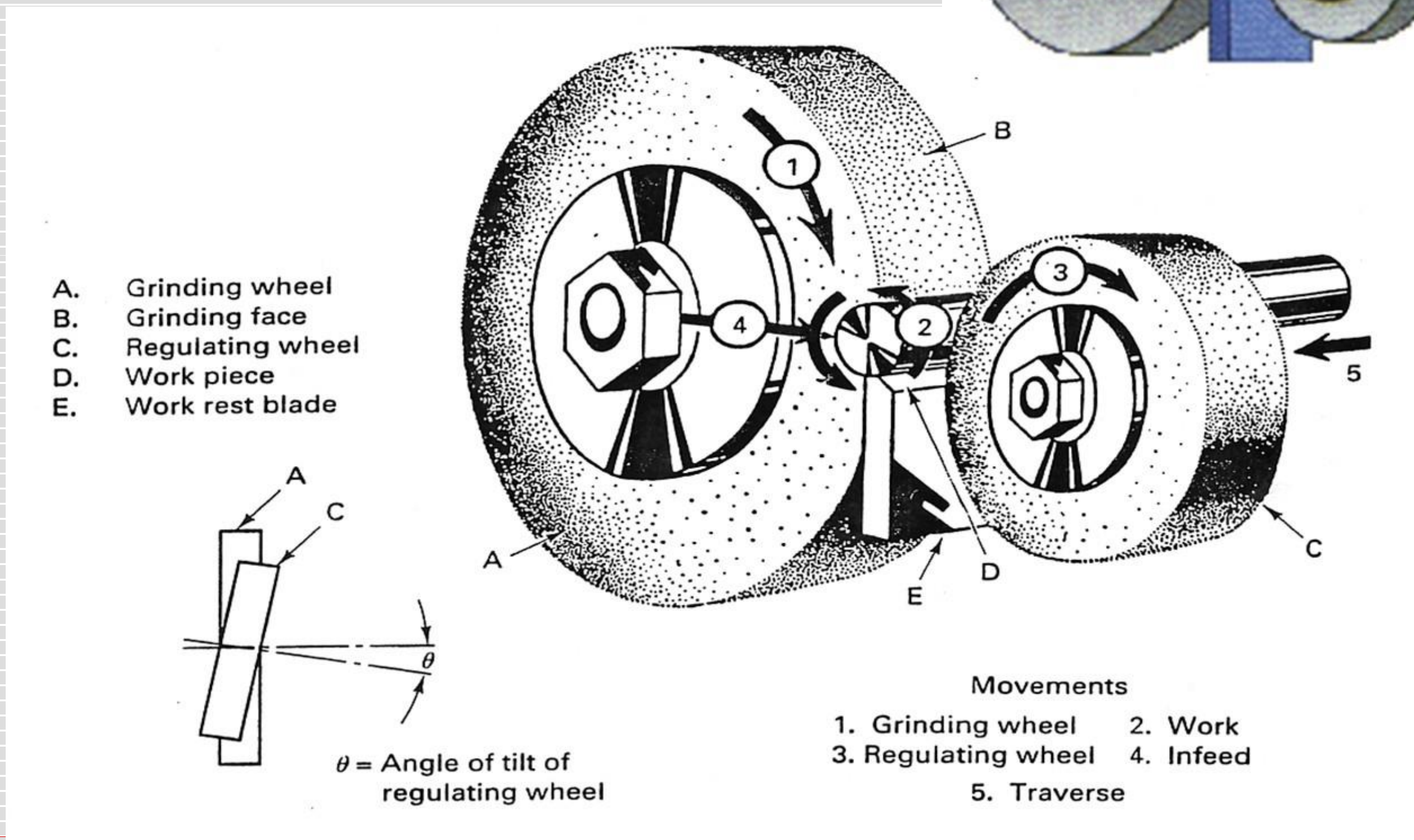
Internal grinding is used to grind the internal diameter of the workpiece. Tapered holes can be ground with the use of internal grinders that can swivel on the horizontal.





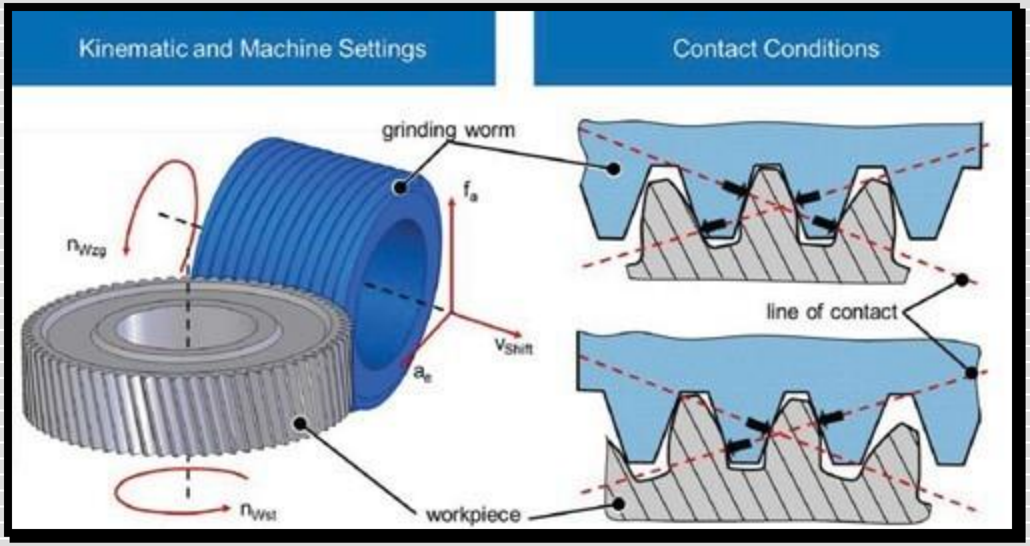
Centerless grinding





Form and profile grinding

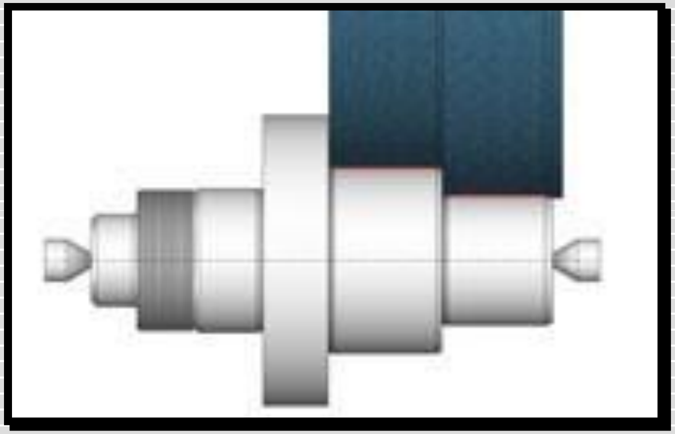
Form grinding is a specialized type of cylindrical grinding where the grinding wheel has the exact shape of the final product. The grinding wheel does not traverse the workpiece.



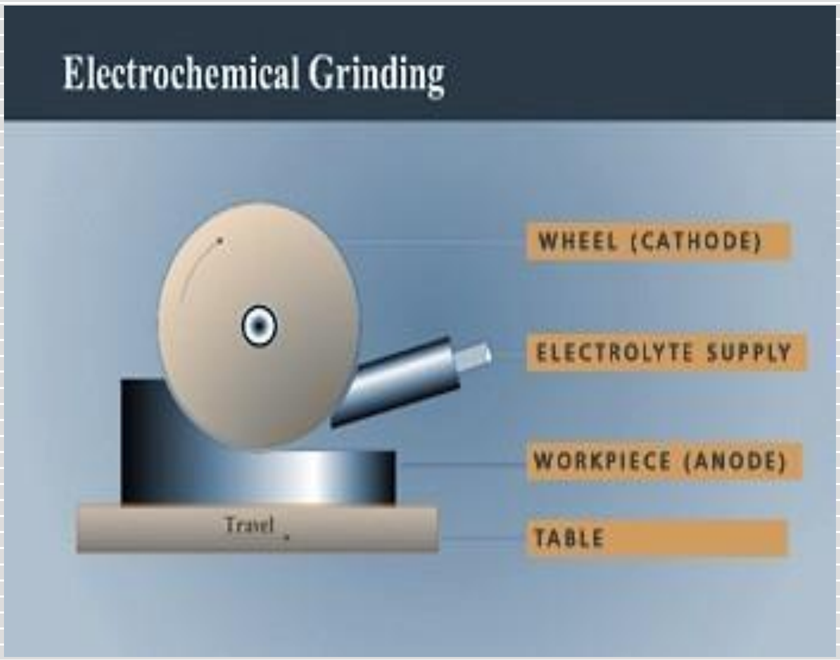
Plunge cut grinding

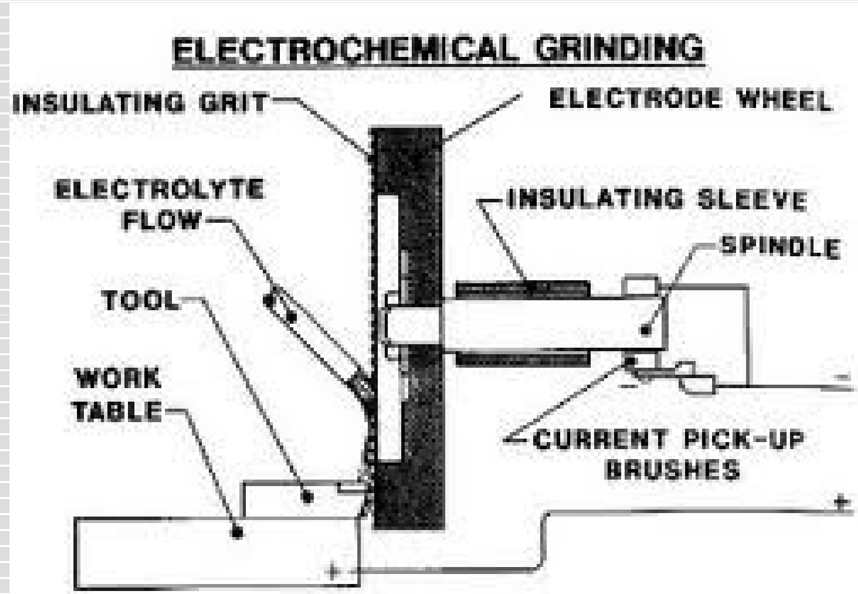
Infeed (Plunge) Grinding is used to grind workpieces which have projections or shoulders, multiple diameters or other irregular shapes which preclude the use of through feed grinding.

For example :- Grinding of crank shaft.



Electrochemical grinding





Electrochemical grinding

- The wheels and workpiece are electrically conductive.
- Wheels used last for many grindings - typically 90% of the metal is removed by electrolysis and 10% from the abrasive grinding wheel.
- Capable of producing smooth edges without the burrs caused by mechanical grinding.
- Does not produce appreciable heat that would distort workpiece.
- Decomposes the workpiece and deposits them into the electrolyte solution. The most common electrolytes are sodium chloride and sodium nitrate at concentrations of 2 lbs. per gallon

SIGNIFICANCE OF GRINDING OPERATIONS:

- Grinding is a material removal and surface generation process used for shape and finish components made up of metals and other materials.
- The surface obtained through grinding is 10 times better than any other machining like turning or milling.

MANUFACTURING OF GRINDING WHEELS:

A **grinding wheel** is a wheel composed of an abrasive compound and used for various grinding (abrasive cutting) and abrasive machining operations. Such wheels are used in grinding machines.

The wheels are generally made from a composite material consisting of coarse-particle aggregate pressed and bonded together by a cementing matrix (called the *bond* in grinding wheel terminology) to form a solid, circular shape. Various profiles and cross sections are available depending on the intended usage for the wheel. They may also be made from a solid steel or aluminum disc with particles bonded to the surface. Today most grinding wheels are artificial composites made with artificial aggregates, but the history of grinding wheels began with natural composite stones, such as those used for millstones.

The manufacture of these wheels is a precise and tightly controlled process, due not only to the inherent safety risks of a spinning disc, but also the composition and uniformity required to prevent that disc from exploding due to the high stresses produced on rotation.

Grinding wheels are consumables, although the life span can vary widely depending on the use case, from less than a day to many years. As the wheel cuts, it periodically releases individual grains of abrasive, typically because they grow dull and the increased drag pulls them out of the bond. Fresh grains are exposed in this wear process, which begin the next cycle. The rate of wear in this process is usually very predictable for a given application, and is necessary for good performance.

Selection of Grinding Wheels:

The proper selection of grinding wheels is very important for getting good results (i.e. obtaining better finish and at the same time having more life of the wheel). In order to meet all these requirements, the various elements that influence the process must be considered.

Selection mainly depends upon the following factors:

(a) Constant factors.

(b) Variable factors.

Constant factors include:

(i) Work material. It should be remembered that for grinding a soft material, hard wheel should be used and vice versa,

(ii) Amount and rate of stock removal,

(iii) Area of contact between work and wheel.

(iv) Condition of grinding machine. A softer grade of wheel is used on robust and heavy machine,

(v) Finish and accuracy required on the job.

Variable factors include:

(i) Wheel speed,

(ii) Work speed,

(iii) Condition of grinding machine (state of the wheel spindle bearing),

iv) Skill of operator (personal factors).

From above it is obvious that several factors are to be considered for the proper selection of the right wheel. The different wheels are constituted by different combinations of abrasive materials, grain size, type of bond, hardness of bond, structure etc. Thus the difficulty in choosing right wheel for any particular job can be gauged from the fact that more than 10,000 different combinations are obtainable in one wheel.

Work Material:

It will influence the following elements:

(a) Abrasive material,

(b) Grain size of grit number (mesh number),

(c) Grade (strength of bond),

(d) Structure.

(a) Abrasive:

This choice of right abrasive is to some extent determined by the type of material only to be ground, which will decide whether the abrasive is Silicon Carbide (SiC) or Aluminium Oxide (Al_2O_3) as these are most commonly used abrasives in different varieties. SiC is the best suited abrasive for brittle and hard materials like grey cast iron castings, chilled iron, tungsten carbide, hard steels, stone, porcelain and other ceramic substances.

SiC is also recommended for low tensile strength material such as non-ferrous metals, bronze, brass, copper, aluminium and plastic materials, $A1_20_3$ is better for tough materials having high tensile strength like mild steel, alloy steel, high speed annealed malleable iron, tough bronze, wrought iron, etc.

(b) Grain Size:

For softer materials, it is a general practice to use coarse grain size and for harder materials, fine grains. Coarser grain is used for high rate of stock removal. Fine grain is used if the work size or the work surface finish is important. Grain size is determined by the mesh number by which it is retained when passed through a series of meshes in a vibrating sieve.

(c) Grade:

The hard materials and materials having high strength offer more resistance to wheel while grinding operation is performed. Thus if hard grade of wheel is used then wheel will get blunt soon and the grinding will not be good. Therefore, for better results on such materials, the abrasive particles should break and fall quickly so that new sharp faces of the particles do the work and they never get blunt.

For softer materials, high or harder grade, i.e. good bond is used. The grading is done by capital alphabets, the first alphabets being used for softer grade and last ones for harder grade.

(d) Structure:

This represents the void between the abrasives and is influenced by the work material. In the case of harder materials the chips are of small size and also the rate of metal removal is low. Thus a small reservoir is needed to remove the chips from the hard material, and the dense structure is desirable for it.

For softer materials, the open structure is prescribed as the rate of metal removal is high and size of chips is also big. The structure is denoted by numbers from 1 to 15.

Amount and Rate of Stock Removal:

It does not influence the abrasive material but the

(a) Grain size,

(b) Grade,

(c) Structure.

For fast removal of metal, coarse gain size is required and vice versa. As regards grade, soft grade is used for fast removal of metal, of course at the cost of wheel life. With softer grade, the abrasive particles fall off quickly and wheel keeps on sharpening, thus removing more quantity of material. Also in order that metal may be removed at faster rate, more space is required for chip removal and hence open structure is desirable for fast removal of metal and vice versa.

Area of Contact:

It mainly influences grade and to some extent grain size also. When the area of contact in grinding operation is large, total grinding pressure is distributed over a larger area and the pressure per unit area is less and hence a softer wheel is needed for it. Thus for internal grinding where arc of contact is more, softer wheel is used and for external grinding, harder wheel.

Condition of Grinding Machine:

Heavy rigid machines demand the softer grade of wheel than the light machines. If condition of grinding machine is such as to cause vibration, harder grade is used compared to one where complete freedom from vibrations is there.

Finish and Accuracy Required:

For high degree of accuracy and fine finish requirement, small sized grain wheels should be used.

Variable Factors:

i. Wheel Speed and Work Speed:

These are the most predominant factors and about 70% of the complaints can be improved by proper selection of work and wheel speed e.g. if one gets burnt surface then speed of the wheel may be reduced. If there is excess wheel wear, it indicates that either wheel is running too slow or the work too fast.

Wheel speed affects the grade to a considerable extent and for higher wheel speed, soft wheel (soft grade) should be used. Wheel speed depends upon type of grinding operation e.g. external or internal grinding or parting off operation. Work speed depends upon type of work, type of grinding and finish required. It also affects the grade, and for higher work speed it is desirable to use harder wheel and vice versa.

ii. Condition of Grinding:

(By condition of grinding we mean whether the grinding is done in wet conditions or dry conditions.) In dry conditions with hard wheel the heat generation is more and thus soft wheel is required and vice versa.

iii. Skill of Operator:

An unskilled worker can't handle soft wheels and he is likely to break them. Thus unskilled worker should be allowed to work only in those conditions which require a hard wheel.

Selection of Grinding Wheels for Thread Grinding and Tool Sharpening:

The factors influencing the type of abrasive for thread grinding wheels are the material of workpiece, its hardness, pitch and profile of the threads. Al_2O_3 wheel is preferred for most of the applications. For grinding titanium, SiC wheel is used and for grinding carbide and ceramic materials, diamond wheel is used. Finer grit size is used for finer pitch.

If fine grit it used then harder wheel is employed. For high precision thread grinding, and where lead errors in pre-cut threads are to the corrected, vitrified bond wheels are used which are more rigid also. Resinoid bond wheels are very flexible and can remove stock rapidly. However, these can't correct the lead errors in pre-cut threads because of their flexibility.

For tool sharpening, Al_2O_3 wheels are used for H.S.S; silicon carbide wheels are used for carbide-tipped tools. The operation of lapping and fine finish is done by diamond wheel. CBN wheel is well suited for grinding a variety of difficult to machine tool steels. Other considerations are same as for general grinding applications.

Selection of Grinding Wheel According to I.S. Specifications:

Various elements are put in systematic manner as follows:

Compulsory Elements:

Following have to be mentioned in all the wheels:

(1) Abrasive,

(2) Grain size,

(3) Grade,

(4) Type of Bond.

Optional Elements are:

(1) Prefix,

(2) Structure,

(3) Suffix.

Abrasive:

These are denoted by:

A—for Al_2O_3, C—for SiC

WA—for white Al_2O_3, GC—for green grit SiC.

The last two are sometimes put under prefix also.

Grain Size:

It is denoted by grit number.

The various numbers for different types of grain size are given below:

Coarse grain: 8, 10, 12, 14, 16, 24

Medium grain: 30, 36, 46, 54, 60

Fine grain: 80, 100, 120, 150,180

Very fine grain: 220, 240, 280, 320, 400,500,600.

For all types of grinding higher limit is upto 180. The grit number above 200 is recommended for lapping operation etc.

Grade:

The following classification is employed for grade:

A—E: Very soft,

G—K: Soft, L—

O: Medium, P—

S: Hard, T—Z:

Very hard. **Type**

of Bond:

The following notations are followed:

V—Vitrified,

B—Resinoid, BF—

Resinoid reinforced R—

Rubber,

RF—Rubber reinforced

E—Shellac,

S—Silicate, Mg—

Magnesia **Prefix:**

It denotes manufacturer symbol for exact nature of abrasive e.g. GC. Here G is prefix and C stands for silicon carbide.

This varies from manufacturer to manufacturer and they have their own code numbers. Sometimes mixture of two varieties may also be used in abrasives.

Structure:

It is denoted by number from 1 to 15. 1—

8: Dense structure

9—15: Open structure.

Suffix:

It is manufacturer's own identification mark (trade secret) and depends upon the process and type of manufacturer.

GRINDING MACHINE

Introduction

- A **grinding machine,** often shortened to **grinder,** is any of various power tools or machine tools used for grinding, which is a type of machining using an abrasive wheel as the cutting tool. Each grain of abrasive on the wheel's surface cuts a small chip from the work piece via shear deformation.

- Grinding is used to finish work pieces that must show high surface quality (e.g., low surface roughness) and high accuracy of shape and dimension. As the accuracy in dimensions in grinding is on the order of 0.000025 mm, in most applications it tends to be a finishing operation and removes comparatively little metal, about to 0.50 mm depth. However, there are some roughing applications in which grinding removes high volumes of metal quite rapidly. Thus, grinding is a diverse field.

- The grinding machine consists of a bed with a fixture to guide and hold the work piece, and a power-driven grinding wheel spinning at the required speed. The speed is determined by the wheel’s diameter and manufacturer’s rating. The user can control the grinding head to travel across a fixed work piece, or the work piece can be moved while the grind head stays in a fixed position.

- Fine control of the grinding head or tables position is possible using a vernier calibrated hand wheel, or using the features of numerical controls.

- Grinding machines remove material from the work piece by abrasion, which can generate substantial amounts of heat. To cool the work piece so that it does not overheat and go outside its tolerance, grinding machines incorporate a coolant. The coolant also benefits the machinist as the heat generated may cause burns. In high-precision grinding machines (most cylindrical and surface grinders), the final grinding stages are usually set up so that they remove about 200 nm (less than 1/10000 in) per pass - this generates so little heat that even with no coolant, the temperature rise is negligible. '

Types of Grinding Machine

- Belt grinder
- Bench grinder
- Cylindrical grinder
- Surface grinder
- Tool and cutter grinder
- Jig grinder
- Gear grinder

Belt grinder

- Belt grinder, which is usually used as a machining method to process metals and other materials, with the aid of coated abrasives. Sanding is the machining of wood; grinding is the common name for machining metals. Belt grinding is a versatile process suitable for all kind of applications like finishing, deburring, and stock removal.

Bench grinder

- Bench grinder, which usually has two wheels of different grain sizes for roughing and finishing operations and is secured to a workbench or floor stand. Its uses include shaping tool bits or various tools that need to be made or repaired. Bench grinders are manually operated.

Cylindrical grinder

- Cylindrical grinder, which includes both the types that use centers and the **centerless** types. A cylindrical grinder may have multiple grinding wheels. The work piece is rotated and fed past the wheel(s) to form a cylinder. It is used to make precision rods, tubes, bearing races, bushings, and many other parts.

Surface grinder

- Surface grinder which includes the **wash grinder.** A surface grinder has a "head" which is lowered, and the work piece is moved back and forth past the grinding wheel on a table that has a permanent magnet for use with magnetic stock. Surface grinders can be manually operated or have CNC controls. Rotary surface grinders or commonly known as "Blanchard" style grinders, the grinding head rotates and the table usually magnetic but can be vacuum or fixture, rotates in the opposite direction, this type machine removes large amounts of material and grinds flat surfaces with noted spiral grind marks. Used to make and sharpen; burn-outs, metal stamping die sets, flat shear blades, fixture bases or any flat and parallel surfaces.

Tool and cutter grinder

- Tool and cutter grinder and the D-bit grinder. These usually can perform the minor function of the drill bit grinder, or other specialist tool room grinding operations.

Jig grinder

- Jig grinder, which as the name implies, has a variety of uses when finishing jigs, dies, and fixtures. Its primary function is in the realm of grinding holes and pins. It can also be used for complex surface grinding to finish work started on a mill.

Gear grinder

- Gear grinder, which is usually employed as the final machining process when manufacturing a high-precision gear. The primary function of these machines is to remove the remaining few thousandths of an inch of material left by other manufacturing methods (such as gashing or hobbing).

Examples of Bonded Abrasives

Fig: A variety of bonded abrasive used in abrasive machining processes

Common Grinding Wheels

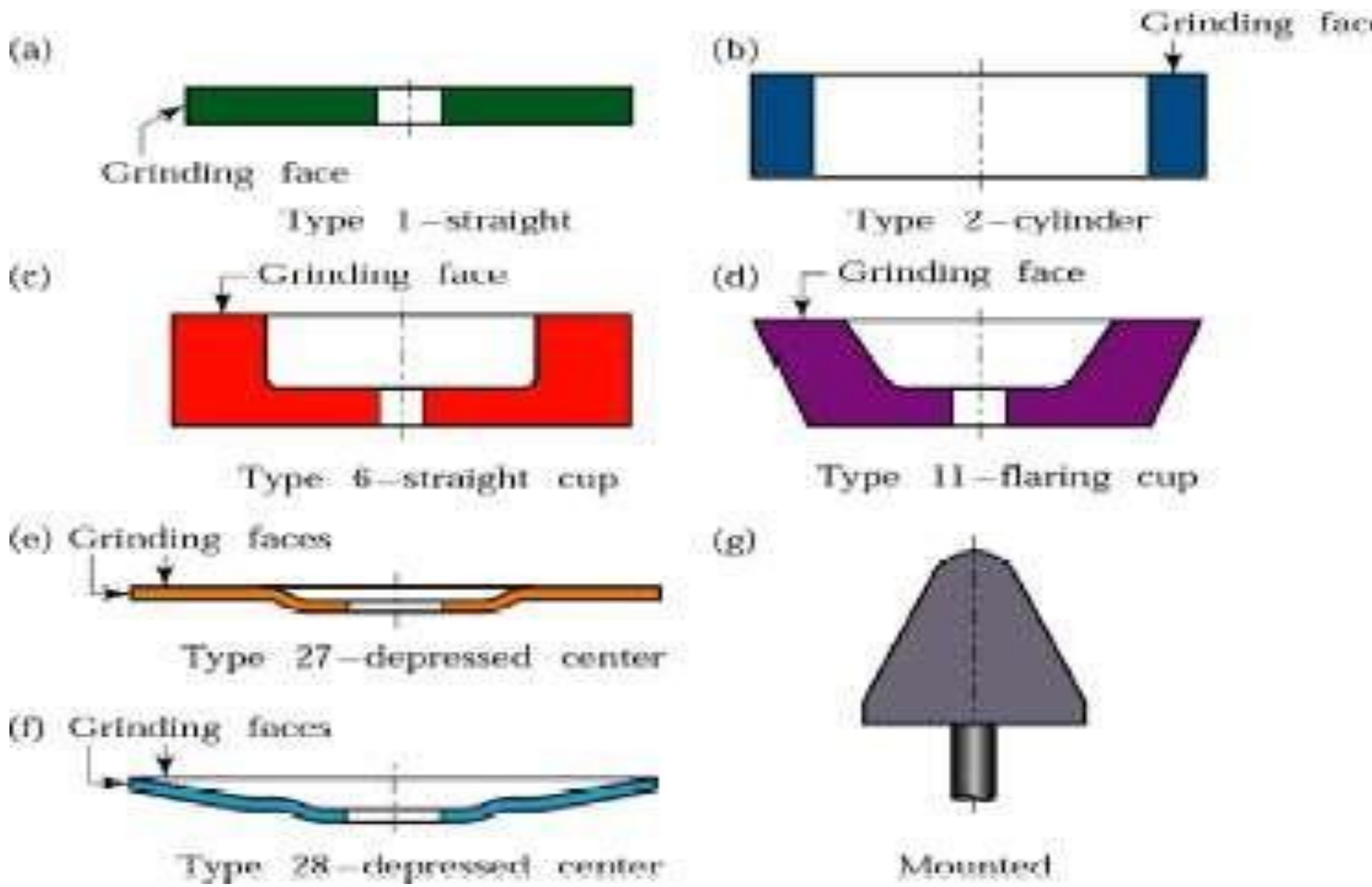


Fig: Common Type of Grinding Wheels made with conventional abrasives. Note that each wheel has a specific grinding face; grinding on other surfaces is improper and unsafe

GRINDING WHEEL SPECIFICATONS

PRESENTATION BY:-

YASHRAJ V. PATIL

DEFINITION:-

- A grinding wheel is a multitooth cutter made up of many hard particles known as abrasives which have been crushed to leave sharped edges for machining.
- Every grinding wheel has two constituents:

i. abrasive used for cutting.

ii. bond that holds abrasive grains.

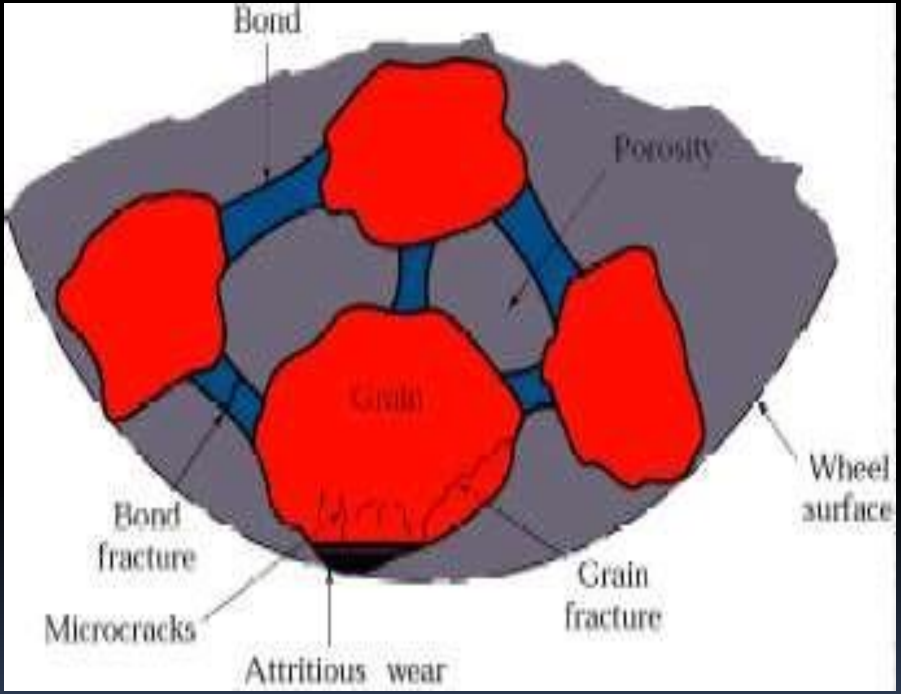
BASIC FUNCTIONS OF A GRINDING WHEEL:-

- Removal of stock
- Generation of cylindrical, flat and curved surfaces
- Production of highly finished surfaces
- Cutting off operations
- Production of sharp edges and points.

CONSTRUCTION OF GRINDING WHEEL:-

Grinding wheel consists of-

i. Abrasives
ii. Bond
iii. Grit/grain size
iv. Grade
v. Structure of wheels



ABRASIVES:-

- An abrasive is a hard and tough substance, having sharp edges. It cuts or wears away materials softer than itself.
- Important properties of abrasives are penetration hardness, fracture resistance and wear resistance.

TYPES OF ABRASIVES:-

- Natural abrasives- they are obtained from nature. Natural abrasives are sand stone, emergy/corundum, diamond and garnet.
- Artificial/synthetic abrasives- they are manufactured to have well defined and controlled properties of hardness, roughness and type of structure. Artificial o synthetic abrasives are silicon carbide(SiC), aluminium OXIDE(Al_2O_3)

BOND : -

- The bond is an adhesive substance which cements or holds the abrasive grains together to form a grinding wheel.
- Depending upon the application, bond imparts the qualities of hardness or softness to the grinding wheel.
- The choice or selection of the bond depends upon the accuracy, the required surface finish and the nature of grinding operation.

SR. NO.	NAME OF BOND	CHARACTERISTICS	DESIGNATION
1.	Vitrified bond	Good strength and high porosity	V
2.	Silicate bond	Waterproof, used for large diameter wheels. Grinding of fine edge tools, etc.	S
3.	Shellac bond	Thin wheels, high elasticity, not suitable for heavy duty application.	E
4.	Resinoid bond	Rough grinding, high speed grinding.	B
5.	Rubber bond	Thin wheels, fine finishing and polishing e.g. ball bearing races.	R
6.	Oxychloride bond	Disc grinders, less brittle.	O

GRIT/GRAIN SIZE:-

- Size of grain grit is determined by sorting or grading the material by passing through screens with the no. of meshes per linear inch.
- The grain size influences stock removal rate and the generated surface finish.
- The selection of grain size is determined by-
  i. Nature of grinding operation
  ii. Material to be grinded
  iii. Material removal rate
  iv. Surface finish required

SR. NO.	SIZE	TYPE	APPLICATIONS
1.	10,12,14,16,20,24	Coarse	Rapid material removal
2.	30,36,46,54,60	Medium	Stock removal and finish both
3.	80,100,120,150,180	Fine	Less stock removal, high surface finish
4.	220,240,280,320,400,500, 600	Very fine	Very high surface finish, grinding hard materials

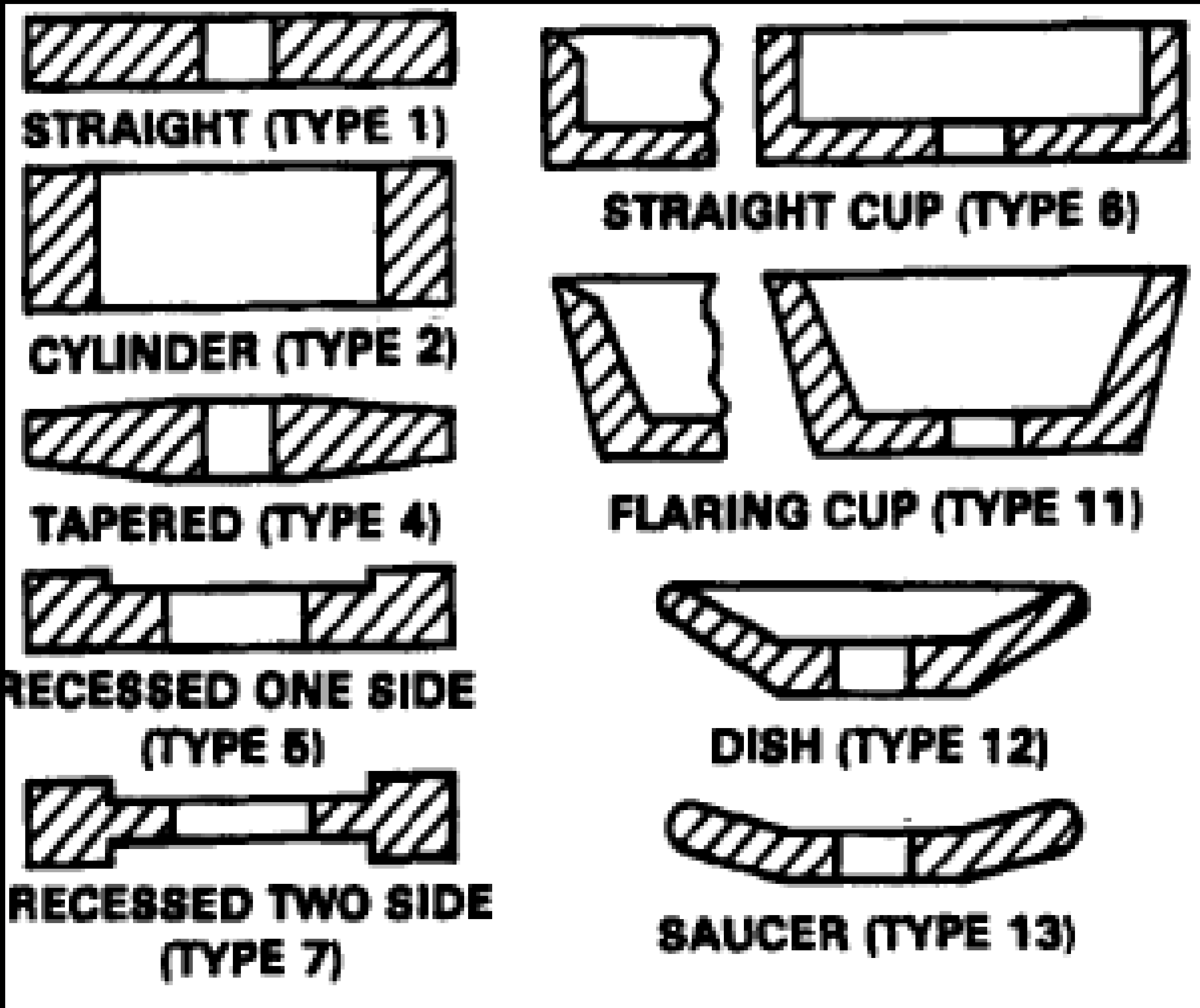
GRADE OF THE WHEEL:-

- Structure of the grinding wheel represents to the grain spacing or the manner in which the abrasive grains are distributed throughout the wheel.
- The entire volume is occupied by abrasive grains, bonding material and pores.
- The primary purpose of structure is to provide chip clearance and it may be open medium or dense.

SR. NO.	TYPE	DESIGNATION	APPLICATION
1.	Dense	1,2,3,4	Cutting and snagging, hard and brittle materials
2.	Medium	5,6,7,8	90% grinding wheels
3.	Open	9,10,11,12,13,14	Soft, tough, ductile materials e.g. ball bearings, brass, bronze

WHEEL SHAPES AND SIZES:-

- The shape of grinding wheel should be such that it permits proper contact between the wheel and all of the permits proper contact between the wheel and all of the surface must be ground.
- They are classified in the following groups:
  1. Straight side grinding wheel
  2. Cylindrical wheels
  3. Cup wheels
  4. Dish wheels


STRAIGHT (TYPE 1)
CYLINDER (TYPE 2)
TAPERED (TYPE 4)
RECESSED ONE SIDE (TYPE 5)
RECESSED TWO SIDE (TYPE 7)
STRAIGHT CUP (TYPE 6)
FLARING CUP (TYPE 11)
DISH (TYPE 12)
SAUCER (TYPE 13)

(WHEEL DESIGNING):

- It consists of 6 symbols representing following properties of grinding wheel:
  i. Manufacturer's symbol
  ii. Type of abrasive
  iii. Grain size
  iv. Grade
  v. Structure
  vi. Type of bond
  vii. Manufacture symbol (optional) for reference

Example of a wheel specification:

51 A 36 L 5 V 40

51 → Manufacturer's symbol indicating type of abrasive

A → Abrasive (aluminium oxide)

36 → Grain size(medium)

L → Grade(medium)

5 → Structure(dense)

V → Bond(vitrified)

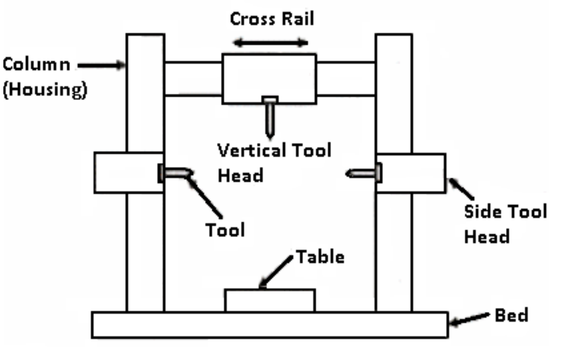
40 → Manufacture symbol (suffix) optional

WHEEL IDENTIFICATION:

Prefix	Abrasive	Grain size	Grade	Structure	Bond	Suffix
45	C	54	H	6	S	23
(Optional)	A → Al2O3	Coarse → 10,12,14,16, 20,24	Soft → H,I,J,K	Dense → 1,2,3,4	Vitrified(V)	(optional)
By	Aluminium oxide	Medium → 30,36,46,54,60	Medium → L,M,N,O	Medium → 5,6,7,8	Silicate(S)	By
Manufacturer	S → SiC	Fine → 80,100,120,150,180	Hard → P,Q,R,S	Open → 9,10,11,12,13,14	Shellac(E)	Manufacturer
	Silicon	Very fine → 220,240,280,320, 400,500,600	Very hard → T,U,V,W		Rubber(R)	
	Carbide				Resinoide(R)	
					Oxychloride (O)	

Planer Machine

The **planer machine** is similar to a shaper machine. It intended to produce plane and flat surfaces by a single-point cutting tool. **A planer machine is very large** and massive compared to a shaper machine. It is capable of a machining heavy workpiece, which cannot be fit on a shaper table.



PLANER MACHINE

The fundamental difference between a shaper and a planer is that

 In a planer, the work which is supported on the table reciprocates over the stationary cutting tool. And the feed is supplied by the lateral movement of the tool.
 In a shaper, the tool which is mounted upon the ram reciprocates. And the feed is given by the crosswise movement of the table.

Types of Planer Machine

Following are the different **types of planer machine**:
1. Standard or Double housing type planer machine
2. open side type planer machine
3. Pit planer machine
4. Edge or plate planer
5. Divided table planer

Different classes of work necessitate designing the different types of planer machine to suit various requirements of our present-day industry.

Read Also: Slotter Machine: Types, Parts and Operations [Complete Guide]

Parts of Planer Machine

Following are the important parts of the planer machine:

- Bed
- Table or Platen
- Housing or Column
- Cross rail
- Tool head
- Driving and Feed Mechanism

Bed

- The bed of a planer is a box-like casting having cross ribs. It is very large in size and heavy in weight and it supports the column and all other moving parts of the machine.
- The bed is made slightly longer than twice the length of the table so that the full length of the table may be moved on it.
- It is provided with precision ways over the entire length on its top surface and the table slides on it.
- In a standard machine, two V-type of guideways are provided.
- Three or more guideways may be provided on a very large wide machine for supporting the table.
- Some of these guideways may be the flat type to lend support to the table.
- The guideways should be horizontal, true and parallel to each other.
- The ways are properly lubricated and in modern machines oil under pressure is pumped into the different parts of the guideways to ensure a continuous and adequate supply of lubricants.
- The hollow space within the box-like the structure of the bed houses the driving mechanism for the table.

Table

- The table supports the work and reciprocates along with the ways of the bed.
- The planer table is a heavy rectangular casting and is made of good quality cast iron.
- The top face of the planer table is accurately finished in order to locate the work correctly.
- T-slots are provided on the entire length of the table so that the work and work holding devices may be bolted upon it.
- Accurate holes are drilled on the top surface of the planer table at regular intervals for supporting the poppets and stop pins.
- At each end of the table, a hollow space is left which acts as a trough for collecting chips. Long works can also rest upon the troughs.
- A groove is cut on the side of the table for clamping planer reversing dogs at different positions.
- In a standard planer, the table is made up of one single casting but in a divided table planer there are two separate tables mounted upon the bedways.

The tables may be reciprocated individually or together. All planets have some form of safety device to prevent the heavily loaded table from running away in case of electrical or mechanical failure which otherwise would have caused severe damage to the machine.
 Hydraulic bumpers are sometimes fitted at the end of the bed to stop the table from overrunning giving cushioning effect.
 In some machines, if the table overruns, a large cutting tool bolted to the underside of the table will take a deep cut on a replaceable block attached to the bed, absorbing the kinetic energy of the moving table.

Housing

 The housings also called columns or uprights are rigid box-like vertical structures placed on each side of the bed and are fastened to the sides of the bed.
 They are heavily ribbed to take up severe forces due to cutting.
 The front face of each housing is accurately machined to provide precision ways on which the cross rail may be made to slide up and down for accommodating different heights of work.
 Two side-toolheads also slide upon it. The housing encloses the Crossrail elevating screw, vertical and crossfeed screws for tool heads, counterbalancing weight for the Crossrail, etc. These screws operated either by hand or power.

Cross rail

 The Crossrail is a rigid box-like casting connecting the two housings. This construction ensures the rigidity of the machine.
 The Crossrail may be raised or lowered on the face of the housing and can be clamped at any desired position by manual, hydraulic or electrical clamping devices.
 The Crossrail when clamped should remain absolutely parallel to the top surface of the table, i.e. it must be horizontal irrespective of its position.
 This is necessary to generate a flat horizontal surface on a workpiece because the tool follows the pat on the Crossrail during crossfeed.
 The two elevating screws in the two housing are rotated by an equal amount to keep the Crossrail horizontal in any position.
 The front face of the cross rail is accurately machined to provide a guide surface for the tool head saddle.
 Usually, two toolheads, are mounted upon the Crossrail which are called railhead.
 The Crossrail has screws for vertical and crossfeed of the toolheads and a screw for elevating the rail. These screws rotated either by hand or by power.

Read Also: Horizontal Boring Machine [Types, Tools and Operations]

Tool-head

The tool head of a planer is similar to that of a shaper both in construction and operation. The important parts of a tool head are:
1. Saddle
2. Swivel base
3. Vertical Slide

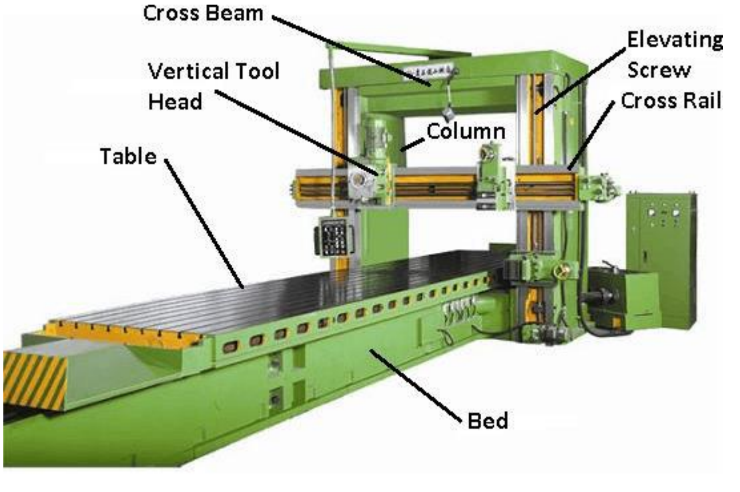
4. Apron
5. Clapper box
6. Clapper block
7. Toolpost
8. Down feed screw
9. Apron clamping bolt,
10. Apron swivelling pin
11. Mechanism for cross and down-feed of the tool.

Different Types of Planer Machine

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

1. Standard or Double Housing Planer Machine

The **standard or double housing planer** is the most widely used types of planer machine in workshops. **A double housing planer** has a long heavy base on which a table reciprocates on accurate guideways.



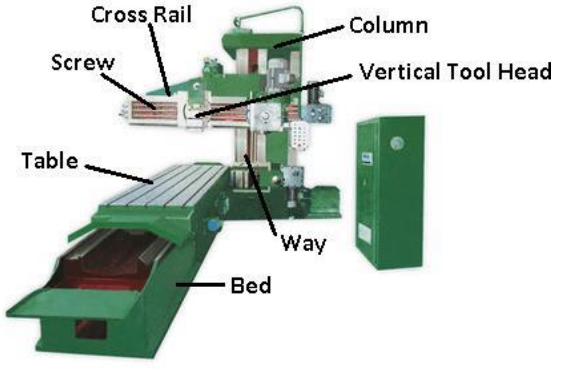
DOUBLE HOUSING PLANER

The length of the bed is little over twice the length of the table.
 Two massive vertical housings or uprights are mounted near the middle of the base, one on each side of the bed. To ensure the rigidity of the structure, these two housings are connected at the top by a cast-iron member.
 The vertical faces of the two housing are accurately machined so that horizontal Crossrail carrying two tool heads may slide upon it.
 The tool heads which hold the tools are mounted upon the Crossrail.
These tools may be feed either by the power in Crossrail or vertical direction. In addition to these tool heads, there are two other tool heads which are mounted upon the vertical face of the housing.

They can also be moved either in a vertical or horizontal direction to apply feed. The planer table may be **driven** either by **mechanical or hydraulic devices.**

Openside Planer Machine

An openside planer has a housing only on one side of the base. And the Crossrail is suspended from the housing as a cantilever. This feature of the machine allows the large and wide workpiece to be clamped on the table and reciprocated over the cutting tool.

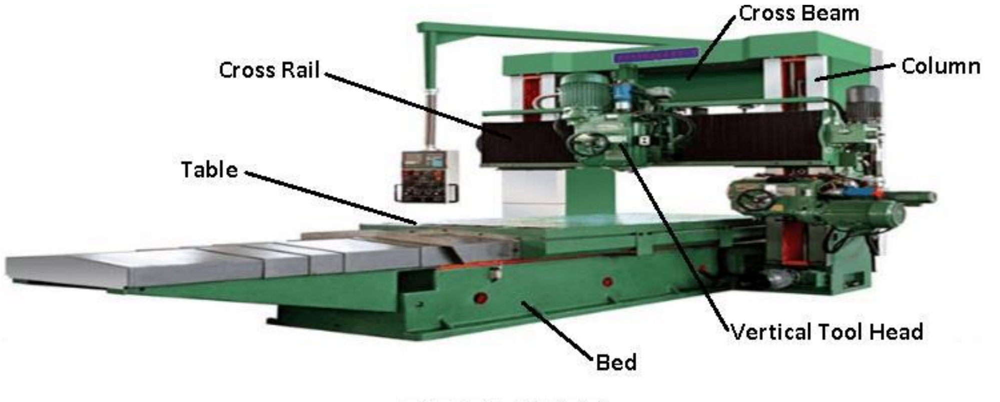


OPEN SIDE PLANER

One side of the planer being opened, large and wide jobs may project out of the table and reciprocate without being interfered by the housing.
In a double housing planer, the maximum width of the job which can be machined is limited by the distance between the two housing. As the single housing has to take up the entire load, it is made extra-massive to resist the forces.
Only three tool heads are mounted on this machine. The constructional and driving features of the machine are the same as that of a double housing planer.

3. Pit Planer Machine

A pit type planer is massive in construction. It differs from an ordinary planer. In this the table is stationary and the column carrying the Crossrail reciprocates on massive horizontal rails mounted on both sides of the table.



PIT PLANER

This types of planer machine are suitable for machining a very large work which cannot be supported on a standard planer. This machine design saves much of floor space.

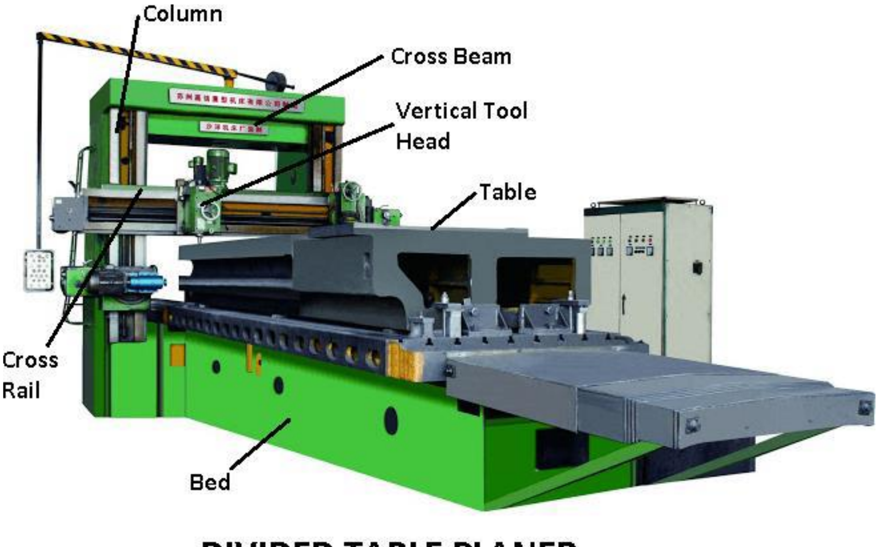
The length of the bed required in a pit type planer is little over the length of the table. Whereas in a standard planer the length of the bed is near twice the length of the table. The uprights and the Crossrail are made sufficiently rigid to take up the forces while cutting.

4. Edge or Plate Planer

The design of a plate or edge planer is totally unlike that of an ordinary planer. It is specially intended for squaring and bevelling the edges of steel plates. Also used for different pressure vessels and ship-building works.

One end of a long plate which remains stationary is clamped with the machine frame by a large number so air operated clamps. The cutting tool is attached to a carriage which is supported on two horizontal ways of the planer on its front end.
The operator can stand on a platform extending from the carriage. The carriage holding the tool reciprocates over the edge of the plate. The feed and depth of cut are adjusted by the tool holder which can be operated from the platform.

5. Divided Table Planer



DIVIDED TABLE PLANER

This type of planer has two tables on the bed which may be reciprocated separately or together.
This type of design saves much of idle time while setting the work. The setting up of a large number of identical workpieces on the planing machine table takes quite a long time. It may require as much time for setting up as may necessary for machining.
To have continuous production on the table is used for setting up the work. While the other reciprocates over the cutting tool finishing the work. When the work on the second table is finished, it is stopped and finished jobs are removed.

Fresh jobs are now set up on this table while the first table holding the jobs now reciprocates over the tool. When a heavy and large job has to be machined, both the table are clamped together and are given reciprocating movement under the tool.

Slotter Machine

The **slotter machine** falls under the category of the reciprocating type of machine tool similar to a shaper to a shaper or a planner. It operates almost on the same principle as that of a shaper.
The major difference between a slotter machine and a shaper machine is that in a slotter the ram holding the tool reciprocates in the vertical axis. whereas in a shaper the ram holding the tool reciprocates in a horizontal axis. A vertical shaper and slotter machines are almost similar to each other as regards their construction, operation, and use.

The only difference being, in the case of a **vertical shaper,** the ram holding the tool may also reciprocate at an angle to the horizontal table in addition to the vertical stroke. The ram can be swivelled not more than 5° to the vertical.

The slotter machine is used for

 Cutting grooves, keyways and slots of various shapes.
 Used for making regular and irregular surfaces both internal and external.
 For handling large and awkward workpiece.
 For cutting internal or external gears and many other operations which cannot be easily machined in any other machine tool described before.

The **slotter machine** was developed by **Brunel** in the year 1800 much earlier than a shaper was invented.

Types of Slotter Machine

There are mainly two **types of slotter machine.**
1. Puncher slotter.
2. Precision slotter.

1. Puncher Slotter

The puncher slotter machine is a heavy, rigid machine designed for removal of a large amount of metal from large forgings or castings. The length of stroke of a puncher slotter is sufficiently large. It may be as long as 1800 to 2000mm.

The puncher slotter ram is usually driven by a spiral pinion meshing with the rack teeth cut on the underside of the ram. The pinion is driven by a variable speed reversible electric motor similar to that of a planer. The feed is also controlled by electrical gears.

2. Precision Slotter

The precision slotter machine is a lighter machine and is operated at high speeds. The machine is designed to take light cuts giving the accurate finish.

Using special jigs, the machine can handle a number of works on a production basis. The precision slotter machines are also used for general purpose work and are usually fitted with Whitworth quick return mechanism.

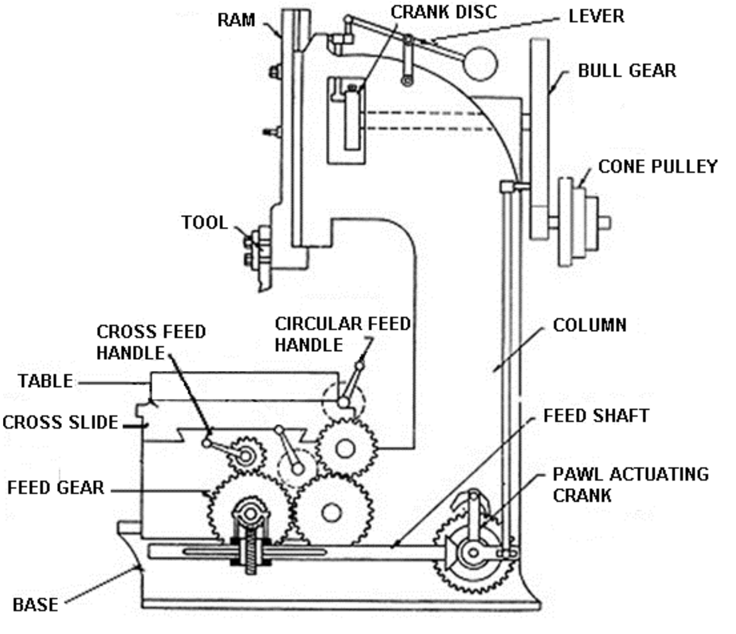
Slotter Size

The size of a slotter machine like that of a shaper is specified by the maximum length of stroke of the ram, expressed in mm. The size of a general-purpose or precision slotter usually ranges from 80 to 900mm.
To specify a slotter correctly the diameter of the table in mm. Amount of cross and longitudinal travel of the table expressed in mm. The number of speeds and feeds available, h.p. of the motor, floor space required etc. should also be stated.

Parts of Slotter Machine

The different parts of a slotter machine are,

1. Base.
2. Column.
3. Saddle.
4. Crosslide.
5. Rotating table.
6. Ram and tool head assembly.
7. Ram drive mechanism.
8. Feed mechanism.



SLOTTER MACHINE

1. Base or Bed

 The base is rigidly built to take up all the cutting forces and the entire load of the machine.
 The top of the bed is accurately finished to provide guideways on which the saddle is mounted.
 The guideways are perpendicular to the column face.

2. Column

 The column is the vertical member which is cast integrally with the base and houses driving mechanism of the ram and feeding mechanism.
 The front vertical face of the column is accurately finished for providing ways in which the ram reciprocates.

3. Saddle

 The saddle is mounted upon the guideways and may be moved toward or away from the column either power or manual control to supply longitudinal feed to the work.
 The top face of the saddle is accurately finished to provide guideways for the cross-slide. These guideways are perpendicular to the guideways on the base.

4. Cross-slide

 The cross-slide is mounted upon the guideways of the saddle and maybe moved parallel to the face of the column.
 The movement of the slide may be controlled either by hand or power to supply crossfeed.

5. Rotary Table

 The rotary table is a circular table which is mounted on the top of the cross-slide.
 The table may be rotated by rotating a worm which meshes with a worm gear connected to the underside of the table.
 The rotation of the table may be effected either by hand or power. In some
 In some machines, the table is graduated in degrees that enable the table to be rotated for indexing or diving the periphery of a job in the equal number of parts.
 T-slots are cut on the top face of the table for holding the work by different clamping devices. The rotary table enables a circular or contoured surface to be generated on the workpiece.

6. Ram and Toolhead Assembly

 The ram is the reciprocating member of the machine mounted on the guideways of the column. It supports the tool at its bottom end on a tool head.
 A slot is cut on the body of the ram for changing the position of the stroke.
 In some machines, special type for tool holders is provided to relieve the tool during its return stroke.

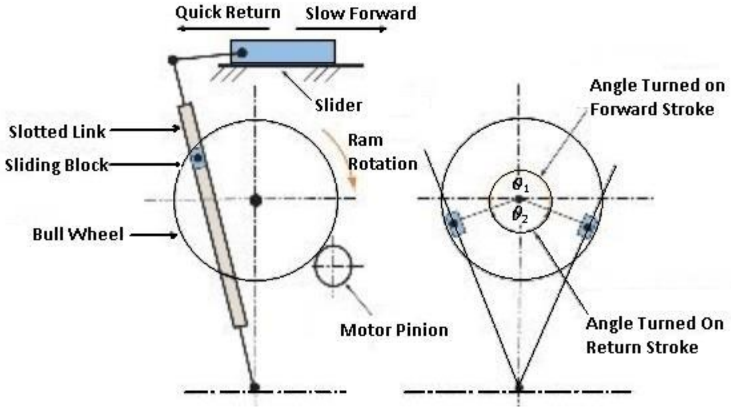
Ram Drive Mechanism

A slotter removes metal during downward cutting stroke only whereas during upward return stroke no metal is removed. The reduce the idle return time quick return mechanism is incorporated in the machine. The usual types of ram drive mechanism are,

1. Whitworth quick return mechanism.
2. Variable speed reversible motor drive mechanism.
3. Hydraulic drive mechanism.

Whitworth Quick Return Mechanism

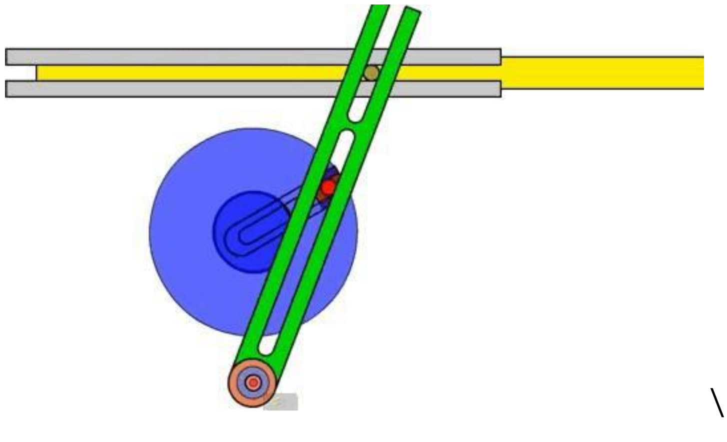
A simple Whitworth quick return mechanism as shown in fig.
The bull gear is mounted on a fixed hub at the rear end of the machine and it is rotated by a driving pinion from the motor. The driving plate is connected to the main shaft through the fixed hub. The main shaft is placed eccentrically with respect to the bull gear centre.



The bull gear holds the crankpin with sliding block and slides in a driving plate. So that when the bull gear rotates, imparts rotary motion to the driving plate and shaft causing the disc to rotate at the end of the main shaft.
The disc is connected to the lower end of the connecting rod eccentrically by means of a pin in a radial T-slots on the face of the disc, which converts the rotary motion of the disc into reciprocating motion of the ram connected to the top end of the connecting rod.

The Principle of a Quick Return Mechanism

The principle of quick return mechanism can be explained simply by a line diagram. A and B are the fixed centres of the bull gear and the driving plate. The crack pin and the slide block rotate in a circular path at a constant speed in a driving plate about B. This causes the disc to rotate through the main shaft.



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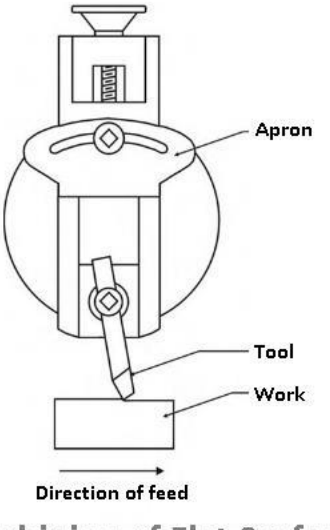
The pin 3 on the disc rotates in a circular path about the fixed point B. The length of the ram is equal to twice the narrow of eccentricity and it is equal to 2x3B (3B= throw of eccentricity). When the slide block is at C, the ram is at the maximum upward position of the stroke and when it is at D, the ram is at the maximum downward position.
If the bull gear rotates in an anticlockwise direction and the slide block rotates through an angle CAD, the ram performs downward cutting stroke, whereas when the block rotates through an angle DAC the ram perform return stroke.
As the block rotates at a constant speed the rotation of slide block through an angle CAD during cutting stroke takes longer time than the rotation through an angle DAC during the return stroke. Thus the quick return motion is obtained.

Slotter Machine Operations

1. Machining cylindrical surface.
2. Flat surface Machining.
3. Machining irregular surface and cam machining.
4. Machining slots, keyways and grooves.

1. Flat Surfaces Machining

The external and internal flat surfaces may be generated on a workpiece easily in a slotter machine. The work to be machined is supported on parallel strips so that the tool will have clearance with the table when it is at the extreme downward position of the stroke.

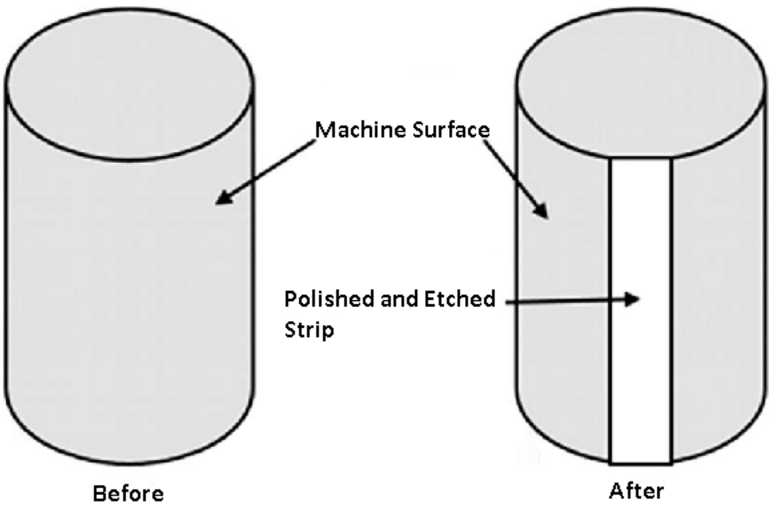


Machining of Flat Surface

The work is then clamped properly on the table and the position and the length of the stroke is adjusted. A clearance of 20 to 25mm is left before the beginning of cutting stroke, so that the feeding movement may take place during this idle part of the stroke.
The table is clamped to prevent any longitudinal or rotary travel and the cut is started from one end of the work. The crossfeed is supplied at the beginning of each cutting stroke and the work is completed by using a roughing and a finishing tool. While machining an internal surface, a hole is drilled into the workpiece through which the slotter tool may pass during the first cutting stroke.
A second surface parallel to the first machined surface can be completed without disturbing the setting by simply rotating the table through 180° and adjusting the position of the saddle. A surface perpendicular to the first machined surface may be completed by rotating the table by 90° and adjusting the position of the saddle and cross slide.

2. Machining Circular Surfaces

The external and internal surface of a cylinder can also be machined in a slotter machine. The work is placed centrally on the rotary table and packing pieces and clamps are used to hold the work securely on the table.



Machining of Cylindrical Surface

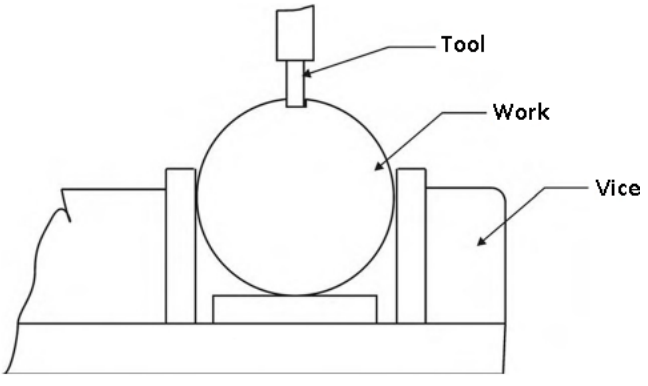
The tool is set radially on the work and necessary adjustments of the machine and the tool are made. The saddle is clamped in its position and the machine is started. While machining, the feeding is done by the rotary table feed screw which rotates the able through a small arc at the beginning of each cutting stroke.

3. Machining Irregular Surfaces or Cams

The work is set on the table and necessary adjustments of the tool and the machine are made as detailed in other operation. By combining cross, longitudinal and rotary feed movements of the table any contoured surface can be machined on a workpiece.

4. Machining Grooves or Keyways

Internal and external grooves are cut very conveniently machine. A slotter is specially intended for cutting internal grooves which are difficult to produce in other machines.



Machining of Keyways

External or internal gear teeth can also be machined in a slotter by cutting equally spaced grooves on the periphery of the work. The indexing or dividing the periphery of the work is done by the graduations on the rotary table.

Difference between shaper and slotter machine

1. In shaper machines, the direction of cutting stroke is horizontal with slower than the return stroke. But in slotter machines, the direction of cutting stroke is vertical with slower than the return stroke.
2. In shaper, Ram holding the tool reciprocates in a horizontal axis whereas, in slotter, the ram holding the tool reciprocates in a vertical axis.
3. Shaper machine is used to produce horizontal, vertical or inclined flat surfaces. Whereas in slotter machine is used for cutting keyways, grooves and slots of various shapes, for making regular and irregular surfaces both external and internal, for cutting internal gears, for handling large and for awkward jobs