Metal cutting

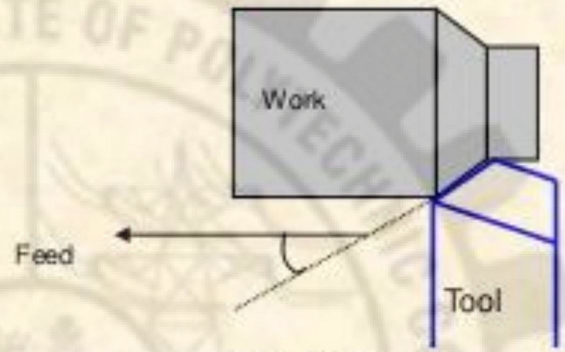
"The process of removing unwanted material in the form of chips, from a block of metal, using cutting tool"

Non Cutting Process – Chip less process

Cutting process – Chip process

Orthogonal and Oblique Cutting

Orthogonal cutting



Oblique cutting

Orthogonal Cutting:

- The cutting edge of the tool remains normal to the direction of tool feed or work feed.
- The direction of the chip flow velocity is normal to the cutting edge of the tool.
- Here only two components of forces are acting: Cutting Force and Thrust Force. So the metal cutting may be considered as a two dimensional cutting.
- Examples are: Parting off operation, Broaching, Sawing, straight milling
- **Shear force acts on smaller area.**

Oblique Cutting:

- The cutting edge of the tool remains inclined at an acute angle to the direction of tool feed or work feed.
- The direction of the chip flow velocity is at an angle with the normal to the cutting edge of the tool. The angle is known as chip flow angle.
- Here three components of forces are acting: Cutting Force, Radial force and Thrust Force or feed force. So the metal cutting may be considered as a three dimensional cutting.
- The cutting edge being oblique, the shear force acts on a larger area and thus tool life is increased.
- Examples are: lathe turning, drilling etc.,
- **Shear force acts on larger area**

SINGLE POINT CUTTING TOOL

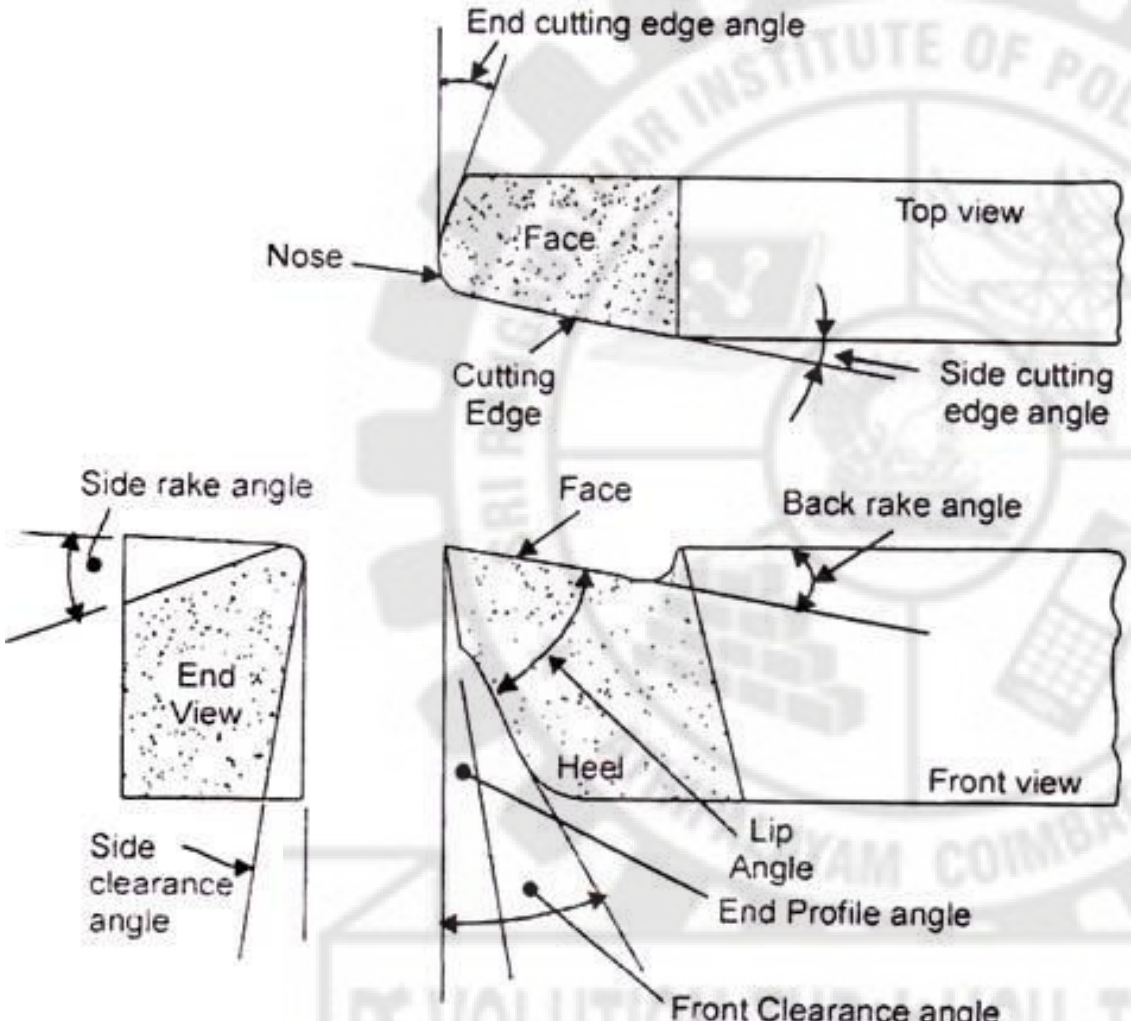
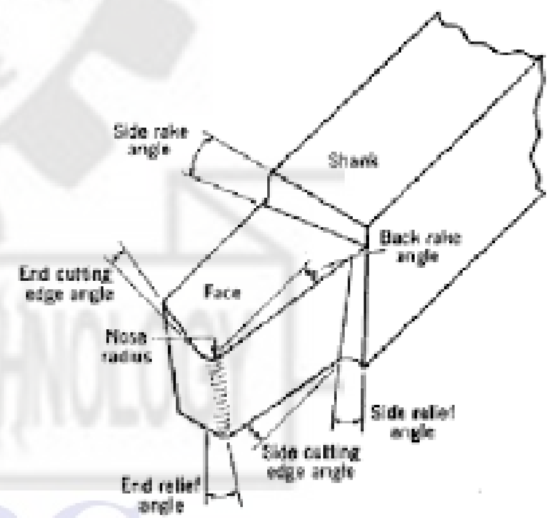
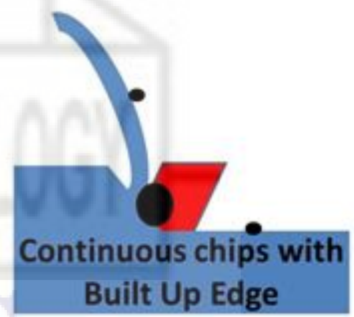


Fig. 14. (*b*) Tool Geometry of a Single point Cutting Tool.

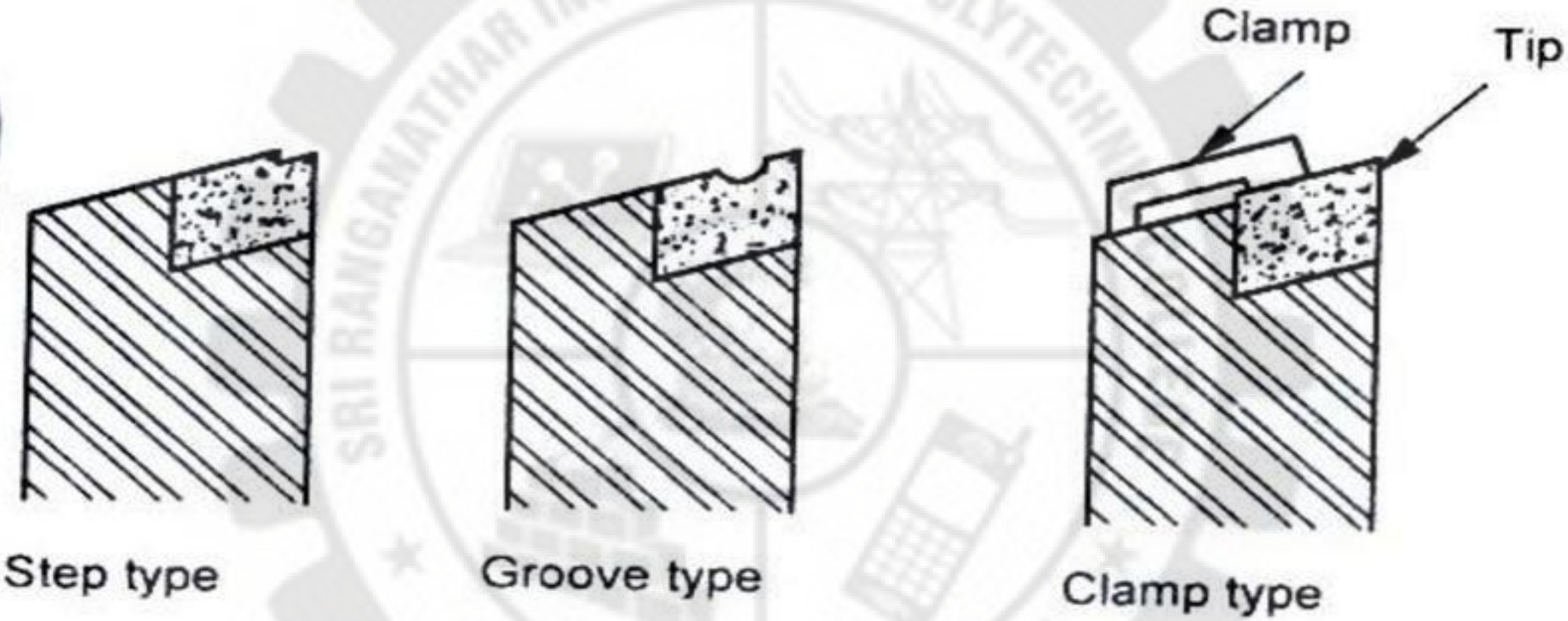


Types of Chips

- Continuous
- Discontinuous
- Continuous chips with Built up edge (BUE)



TYPES OF CHIP BREAKERS



In the step type, a step is ground on the tool face behind the cutting edge. This step will break the chip.

In groove type, a groove on the tool face behind the cutting edge will break the chip.

In the clamp type, a thin chip breaker is clamped or screwed on the face of the tool.

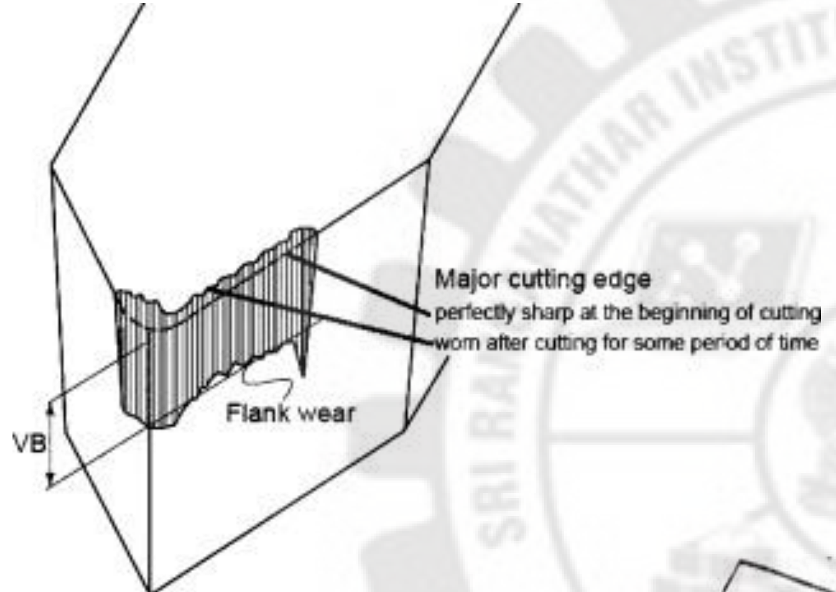


Fig. 9.16. (*a*) Tool Wear Phenomena.

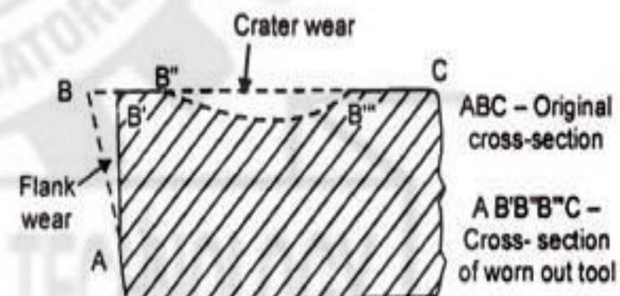


Fig. 9.16. (*b*) Flank and Crater wear.

Factors affecting machinability of metals

1. Material of w/p- hardness, tensile properties, strain hardenability
2. Tool material.
3. Size and shape of the tool.
4. Type of machining operation.
5. Size, shape and velocity of cut.
6. Type and quality of machine used
7. Quality of lubricant used in machining
8. Friction b/w chip & tool
9. Shearing strength of w/p material

Factors affecting tool life

1. Cutting speed
2. Physical properties of w/p
3. Area of cut
4. Ratio of feed to depth of cut
5. Shape and angles of tool
6. Tool material and its heat treatment
7. Nature and quantity of coolants
8. Rigidity of tool and w\p

Characteristics of a Good Cutting Fluid

1. Good cooling capacity
2. Good lubricating qualities
3. Resistance to rancidity
4. Relatively low viscosity
5. Stability (long life)
6. Rust resistance
7. Nontoxic
8. Transparent
9. Non inflammable

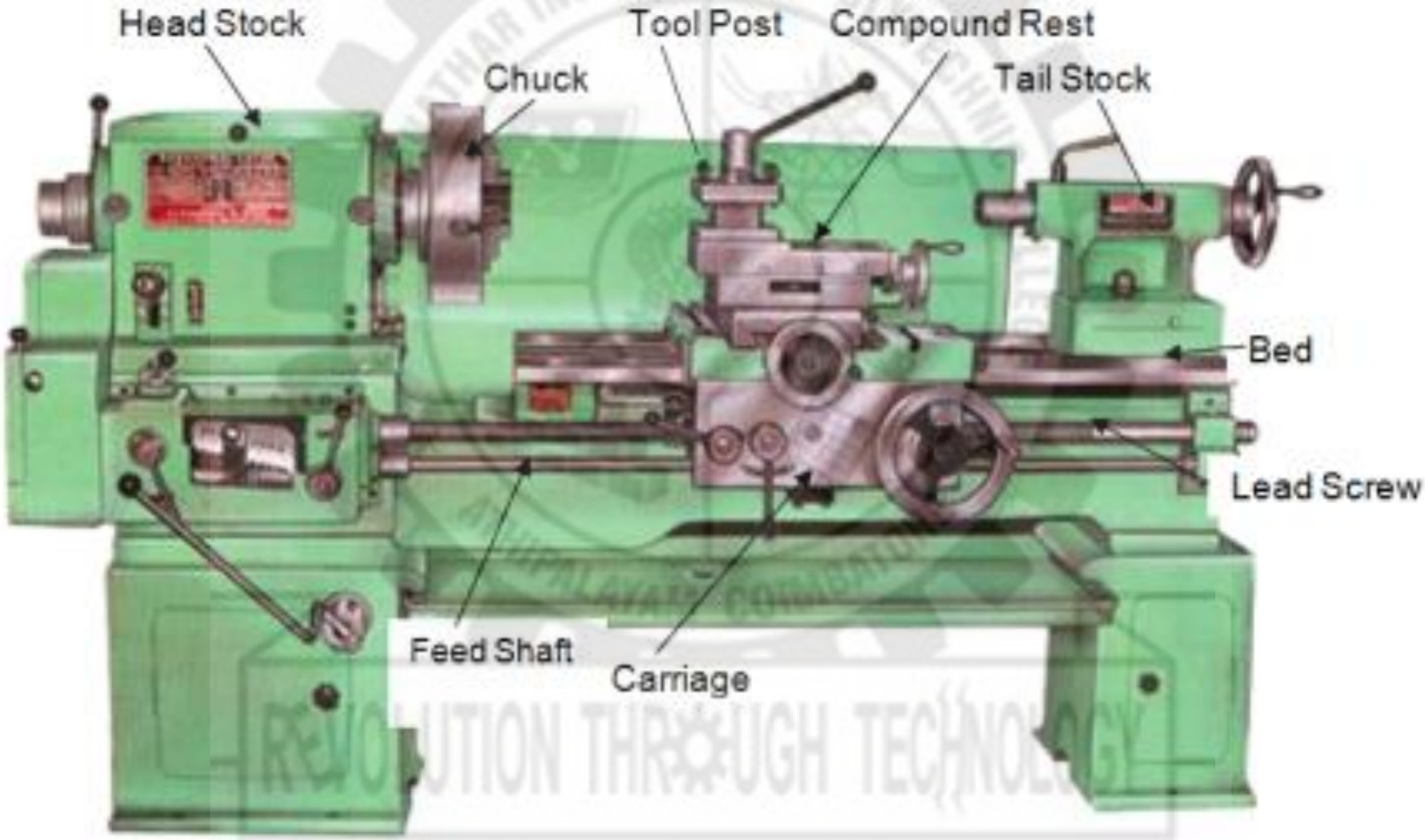
CUTTING FLUIDS

- **Function**:

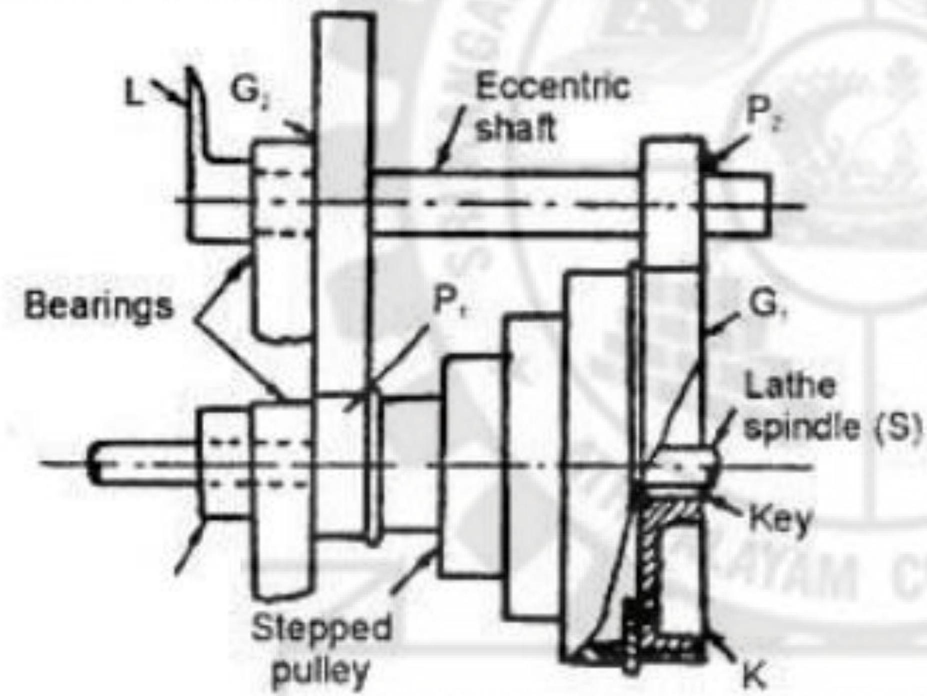
1. Reduce friction & wear, improving tool life & surface finish
2. Reduce forces and energy consumption
3. Cool the cutting zone, reducing workpiece temp and thermal distortion
4. Wash away chips
5. Protect machined surface from environmental corrosion

- **Situation in which cutting fluid is harmful:**

1. Interrupted cutting operations
2. May cause the chip to become curlier, thus concentrating the stresses closer to the tool tip, so concentrate the heat closer to the tool tip which reduces tool life


Head Stock
Tool Post
Compound Rest
Chuck
Tail Stock
Bed
Lead Screw
Feed Shaft
Carriage

BACK GEARED HEADSTOCK - GEAR ARRANGEMENT



- Back gears are mounted eccentric shaft and used to reduce speed.
- There are further two types to obtain variation in speed.
  - Direct speed
  - Indirect speed

- Tumbler gear mechanism

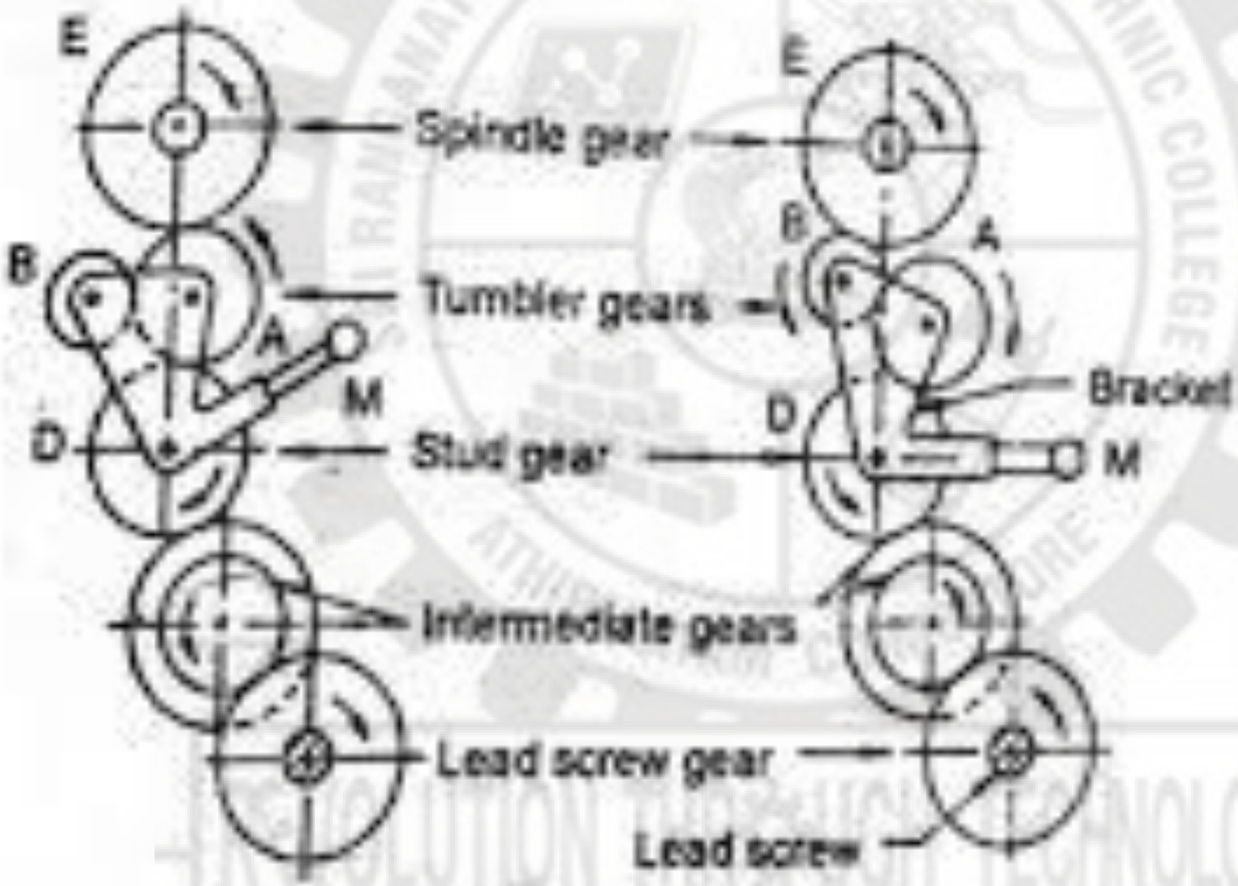
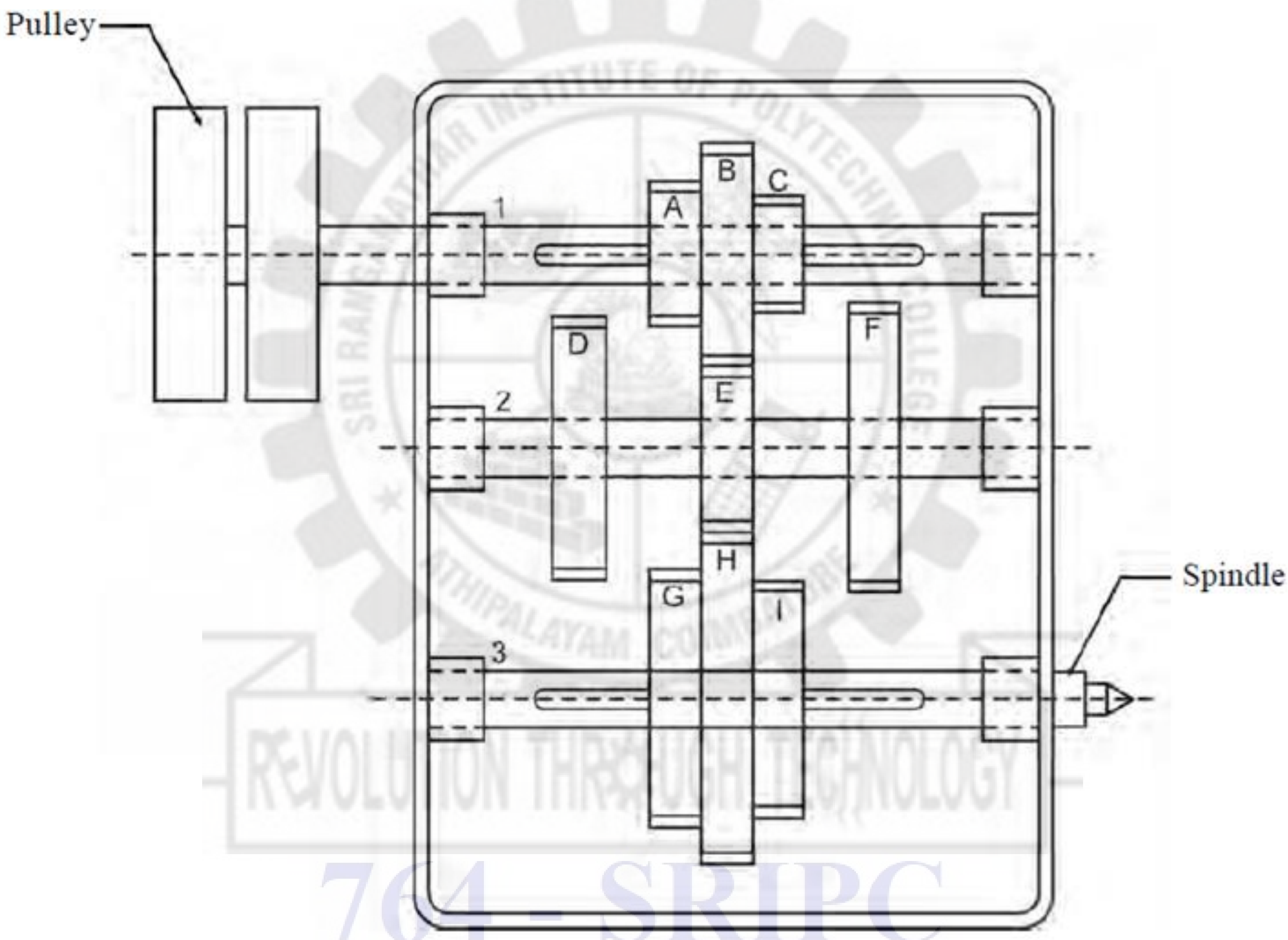
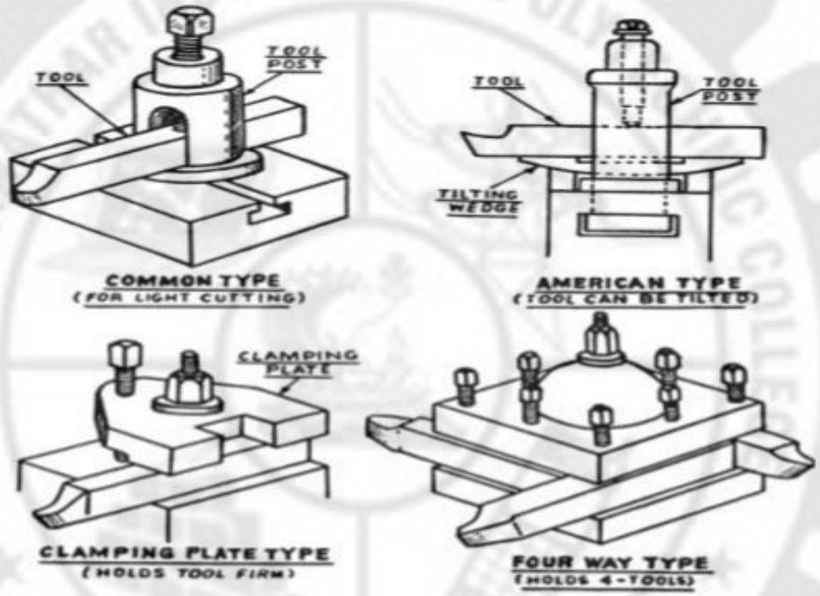


Figure 2.52. Tumbler gear mechanism


Pulley
Spindle
1
2
3
A
B
C
D
E
F
G
H
I



Lathe tool posts

Machining operations:

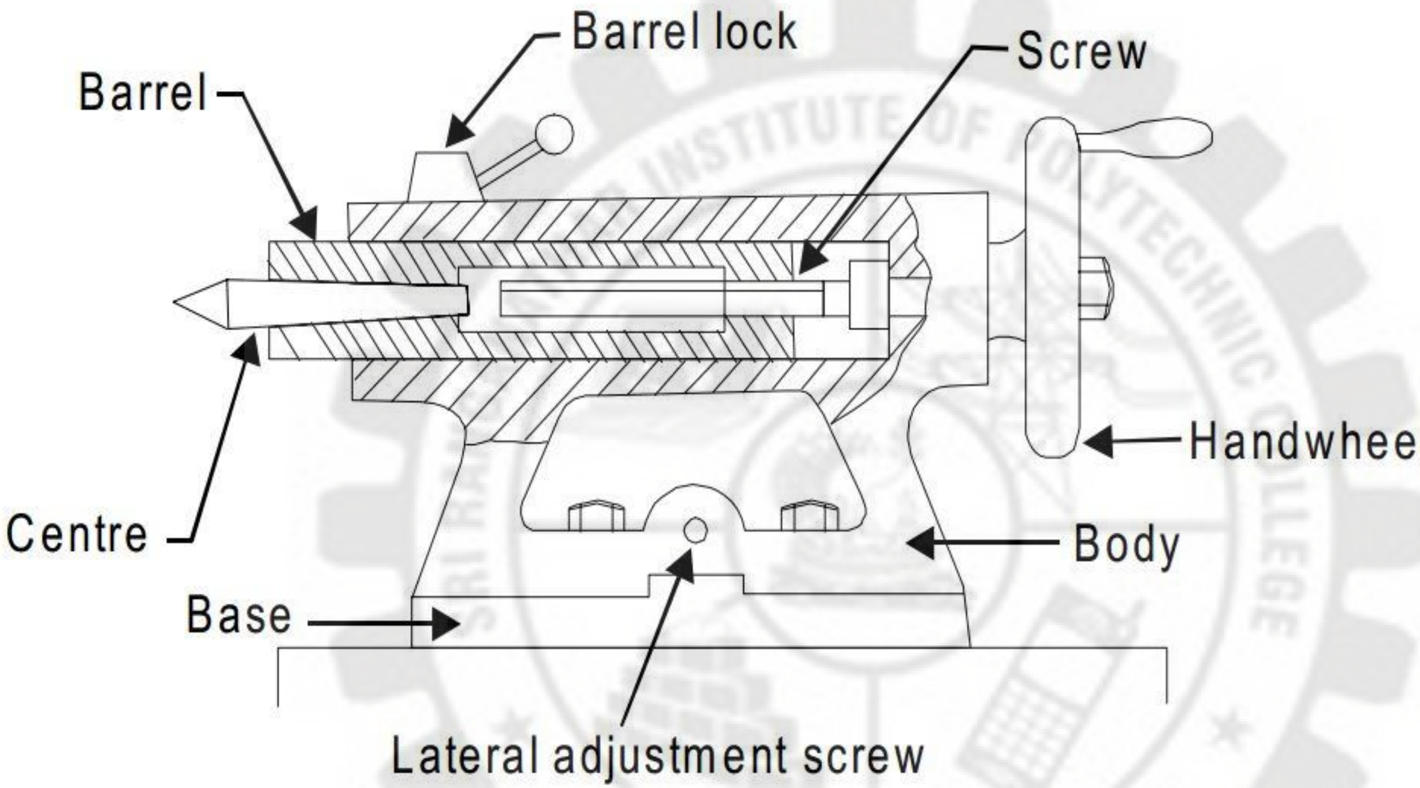
FACING

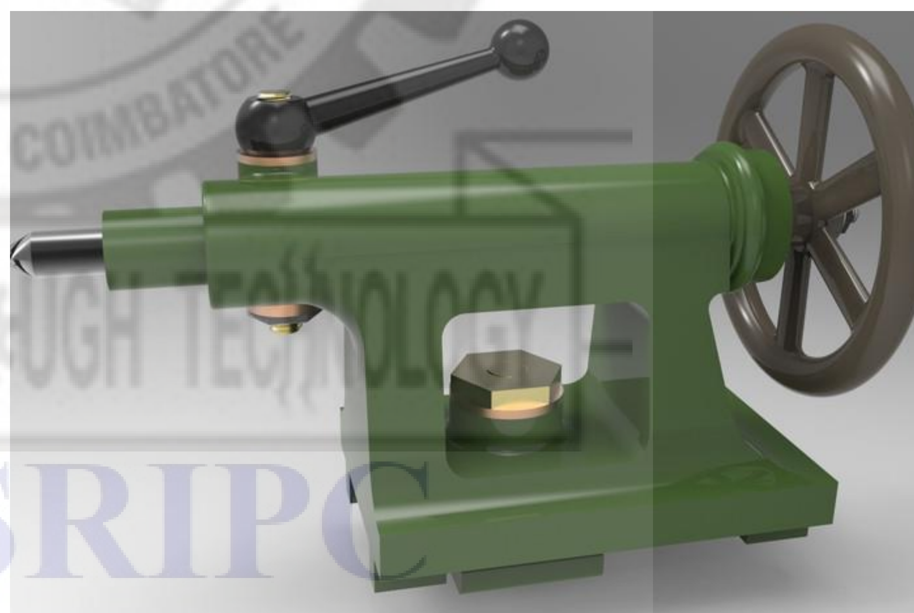
Facing is the machining of the end surfaces and shoulders of a workpiece. In addition to squaring the ends of the work, facing provides a way to cut work to length accurately. Generally, only light cuts are required since the work will have been cut to approximate length or rough machined to the shoulder.

TURNING

Turning is the machining of excess stock from the periphery of the workpiece to reduce the diameter. In most lathe machining operations requiring removal of large amounts of stock, a series of roughing cuts is taken to remove most of the excess stock Then a finishing cut is taken to accurately "size" the workpiece.

PARTING


Barrel lock
Screw
Barrel
Handwheel
Centre
Body
Base
Lateral adjustment screw



AIR OPERATED CHUCK

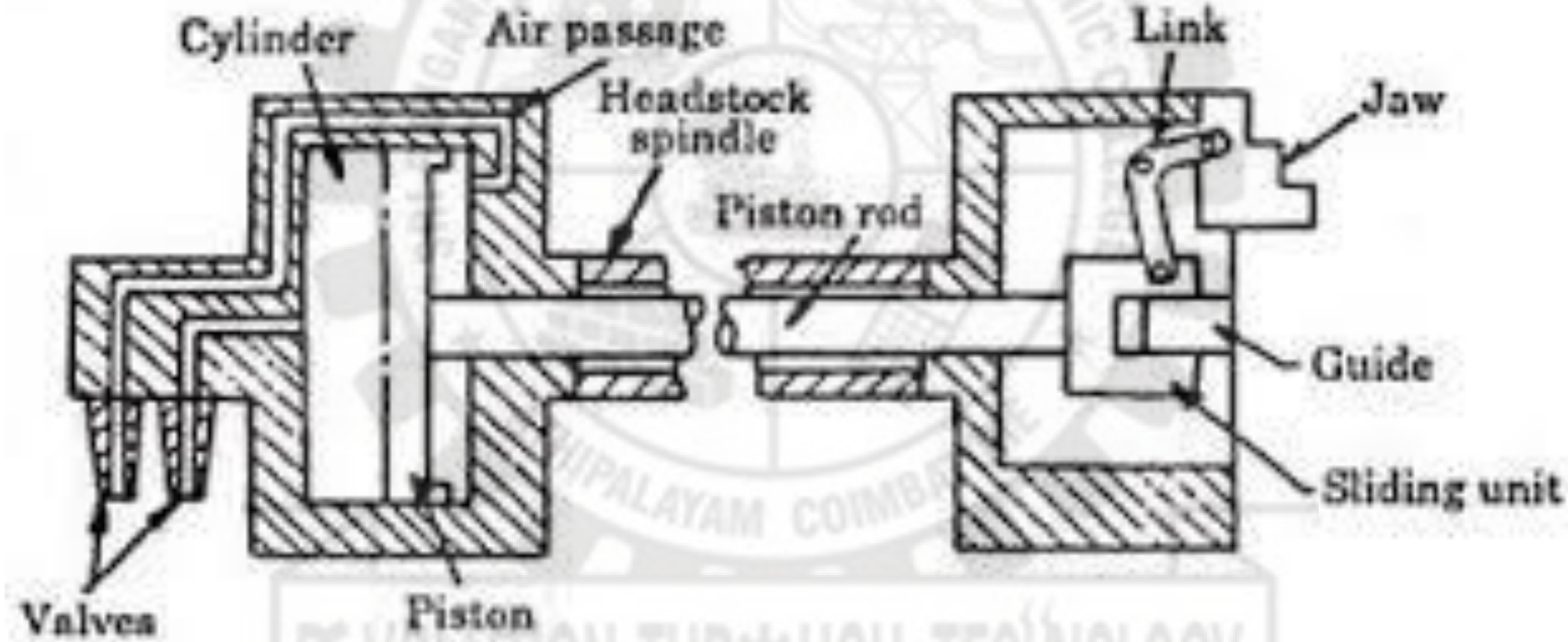
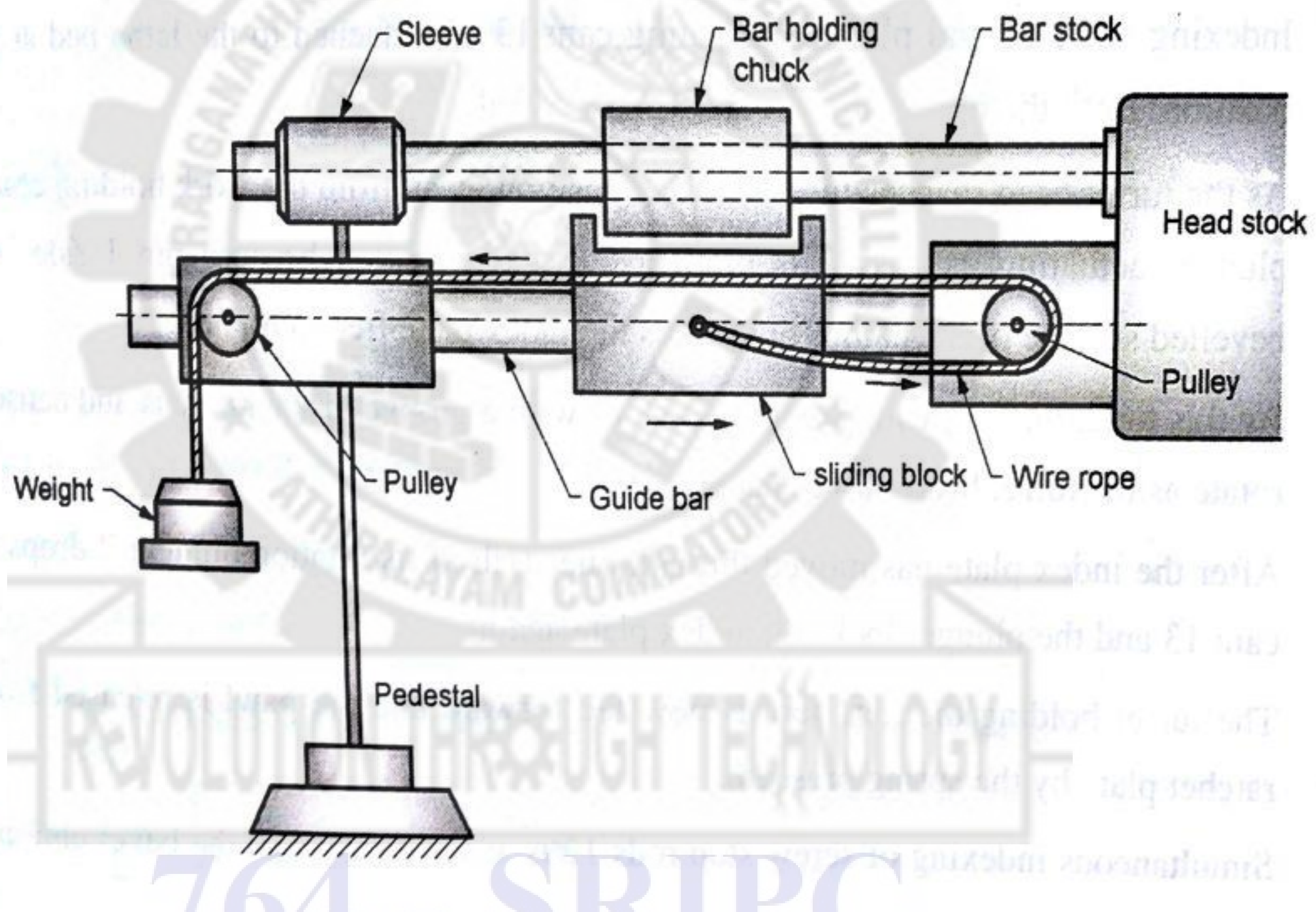
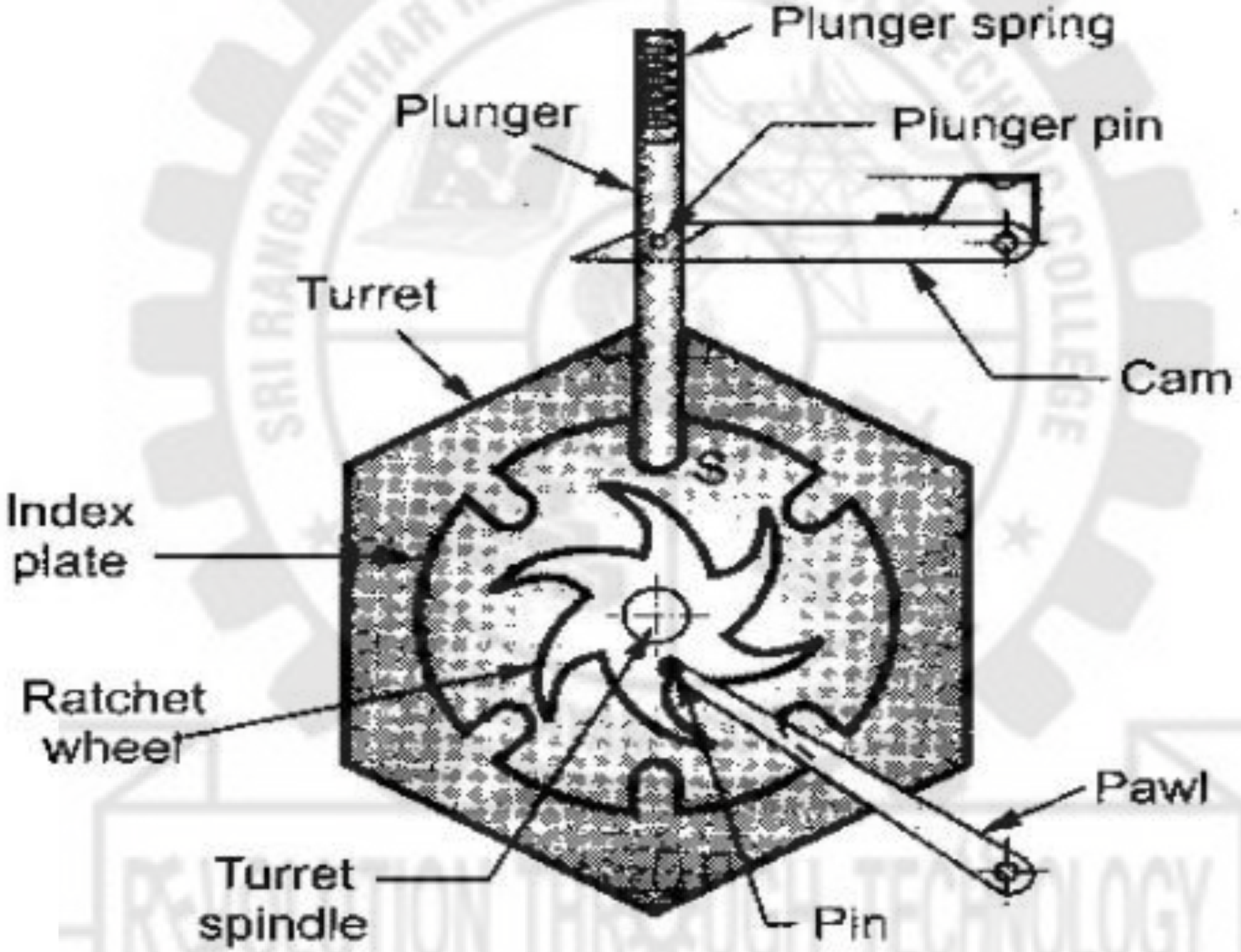


Fig. 12.43

Bar Feed Mechanism





Turret head indexing mechanism

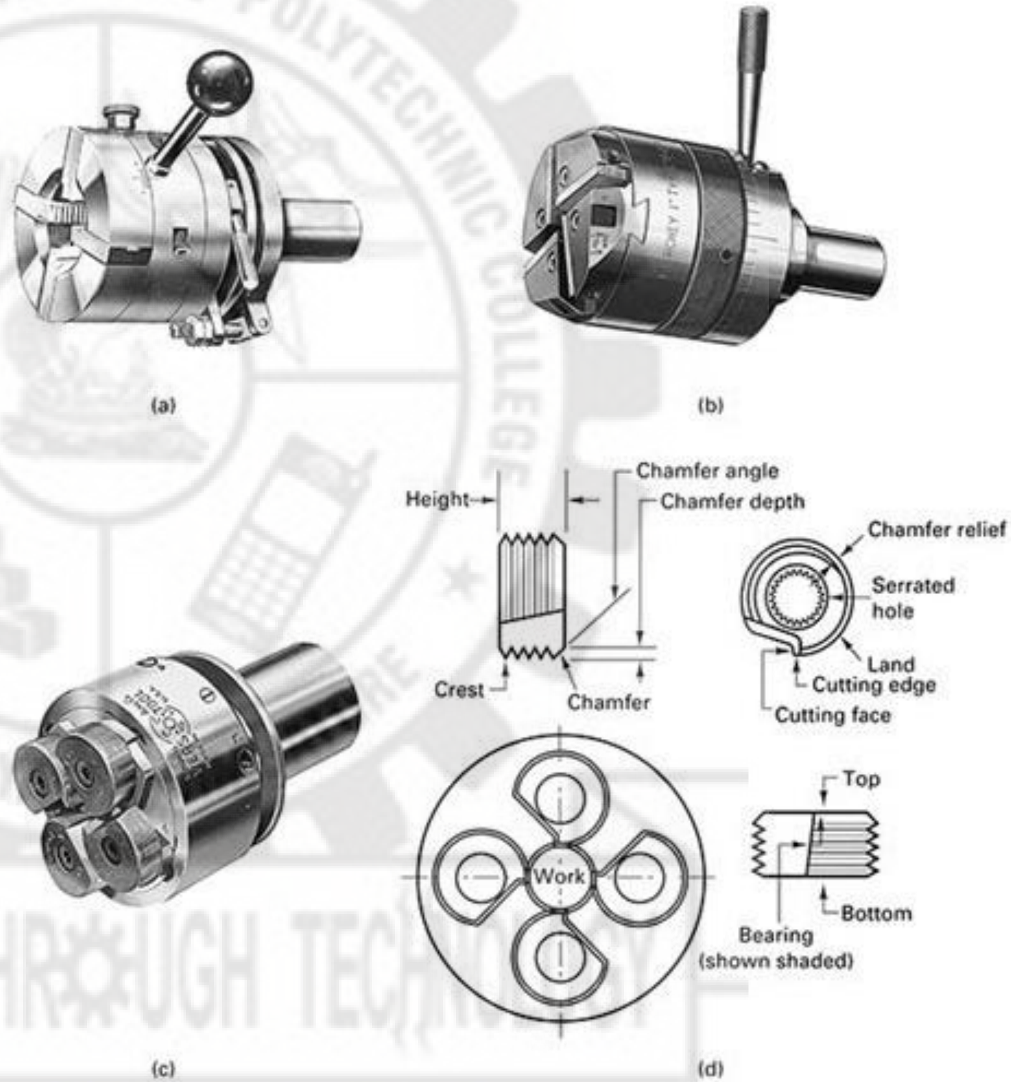


FIGURE 2.13 Self-opening die heads, with (a) radial cutter, (b) tangential cutters, (c) circular cutters, and (d) terminology of circular chasers and their relation to the work.

1. Drilling; Producing a hole through material.

FLAT DRILL

STRAIGHT FLUTE DRILL

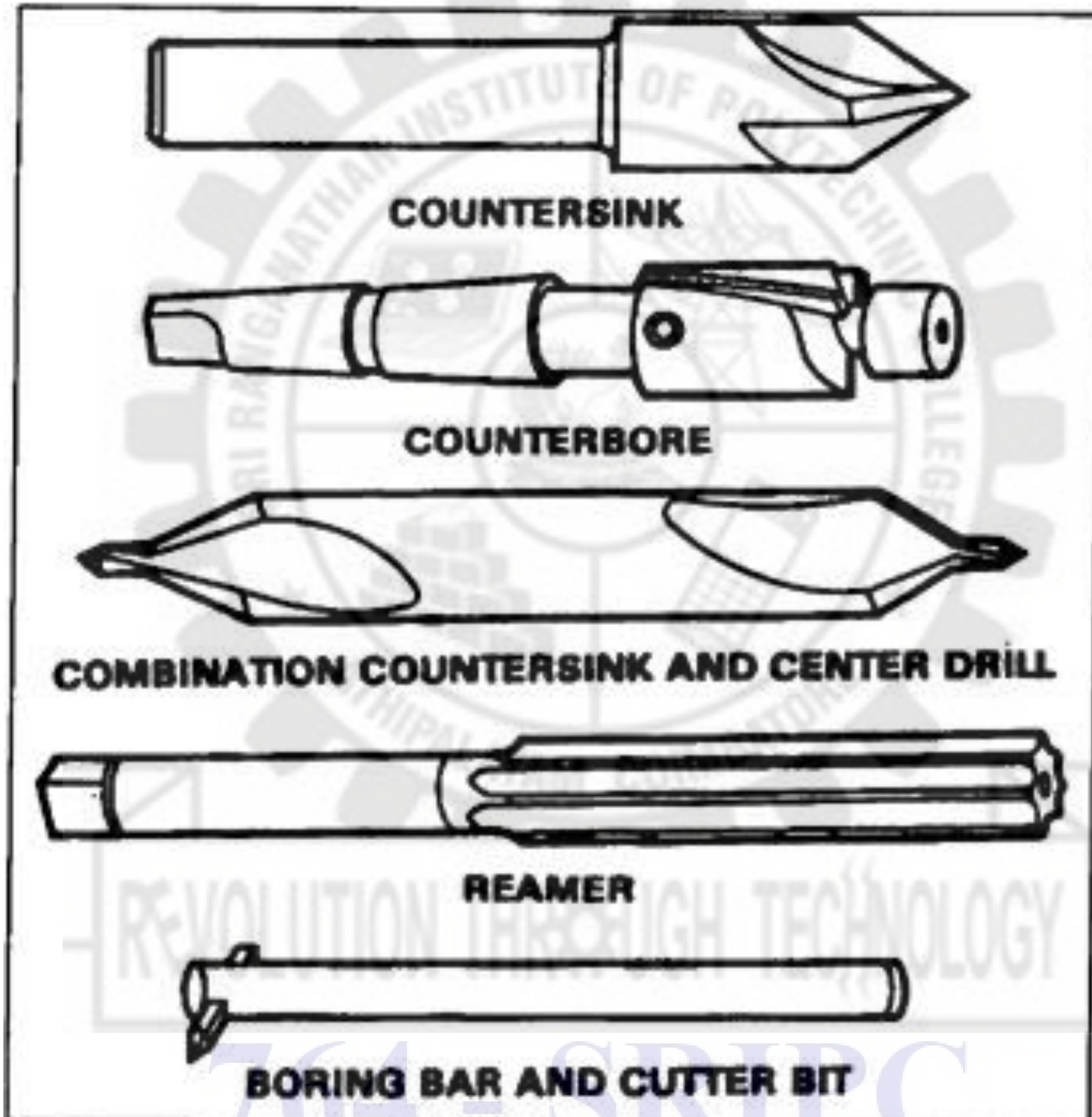
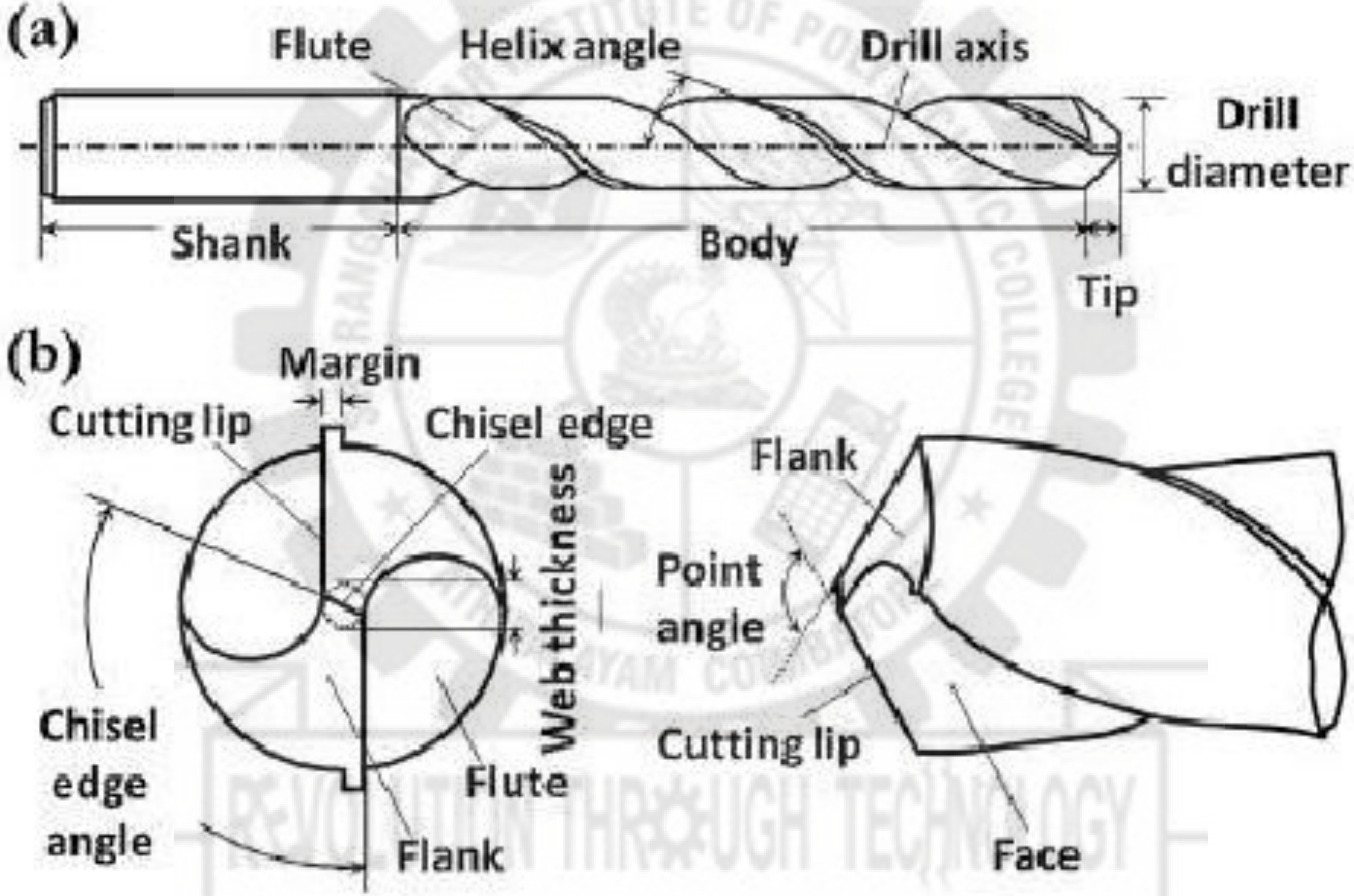


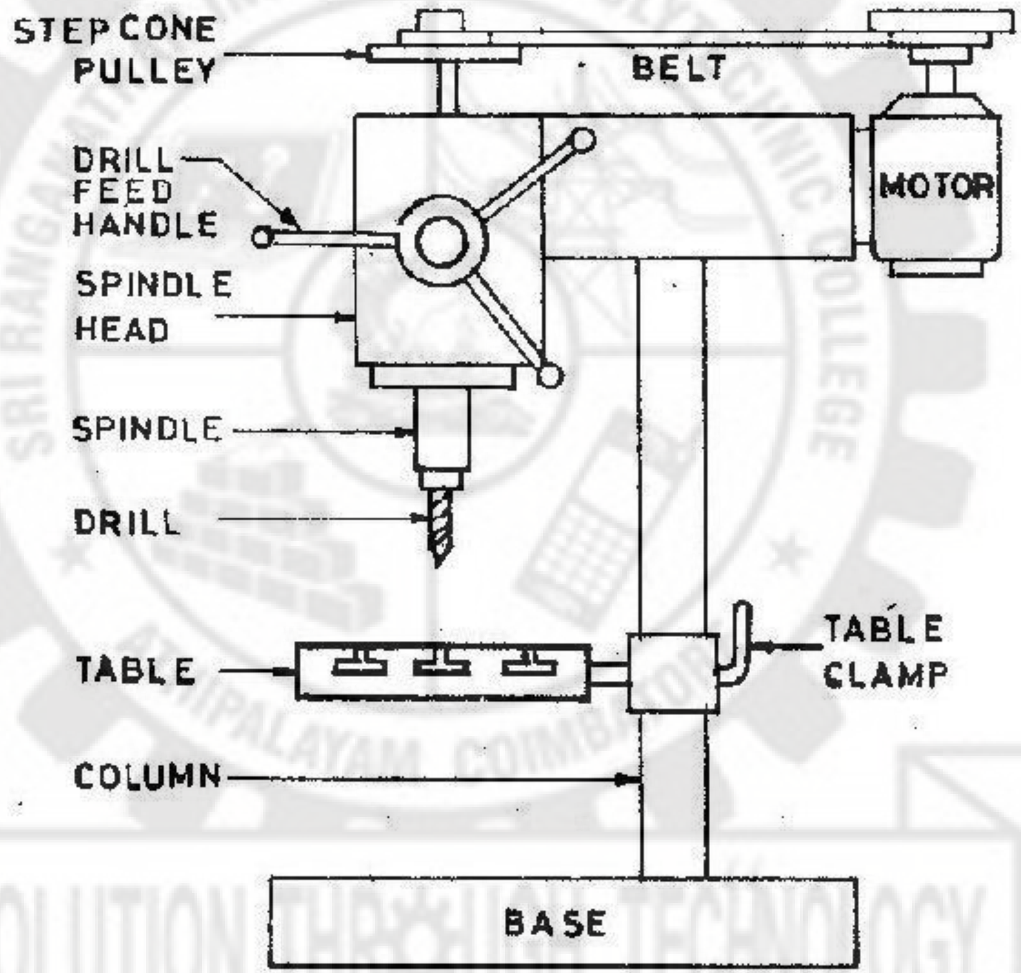
Figure 4-21. Other types of cutters.

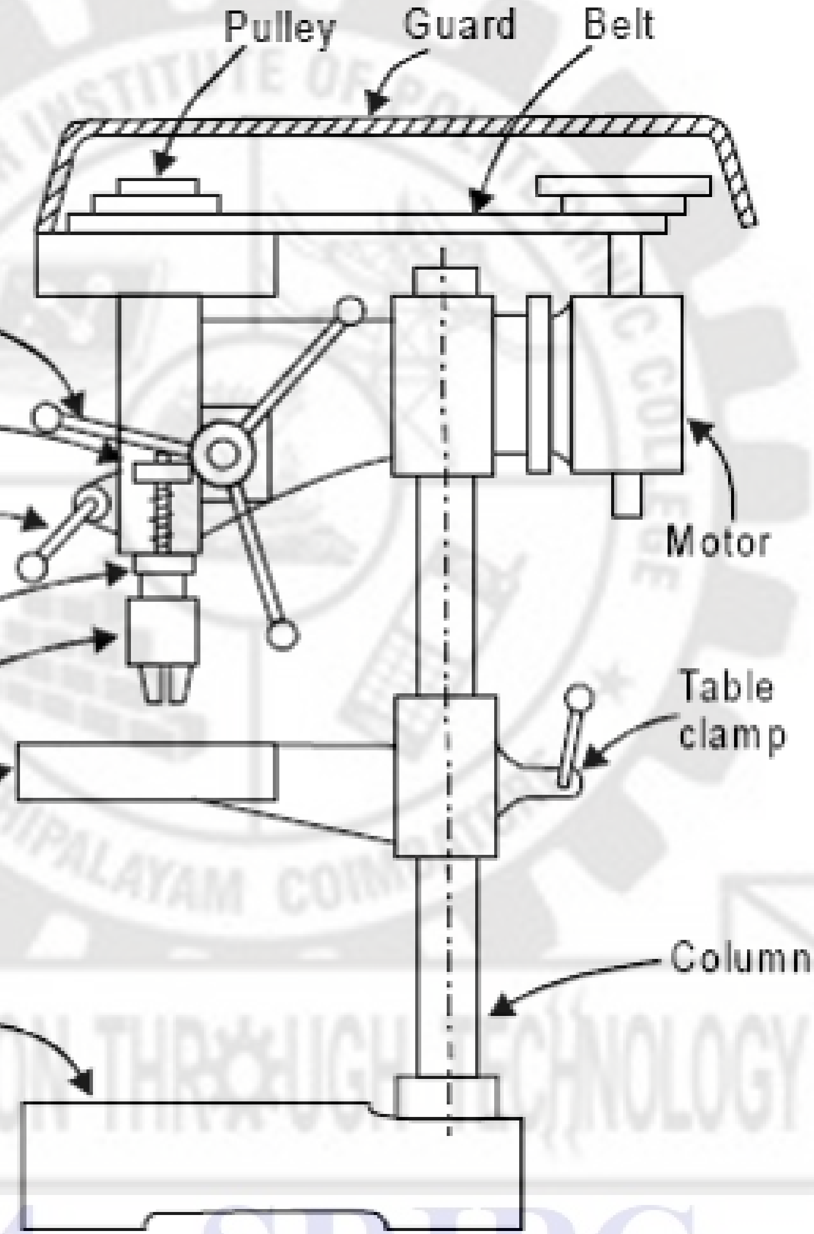
Drill Bit Types

Twist Bit | Brad Point Bit | Auger Bit | Plug Cutter | Glass / Tile Bit

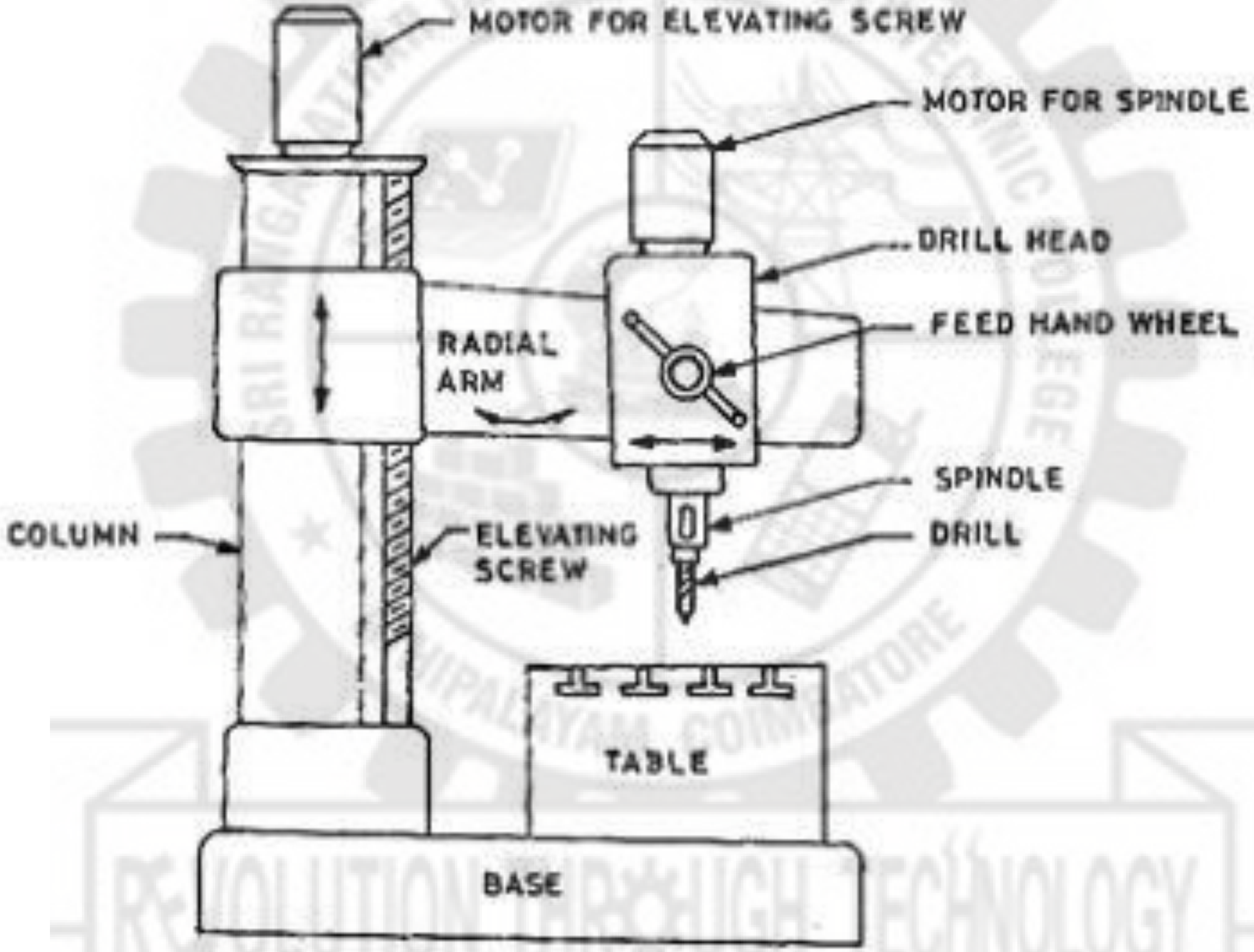

(a)
Flute
Helix angle
Drill axis
Drill
diameter
Shank
Body
Tip
(b)
Margin
Cutting lip
Chisel edge
Web thickness
Chisel
edge
angle
Flute
Flank
Flank
Point
angle
Cutting lip
Face

BENCH DRILLING MACHINE



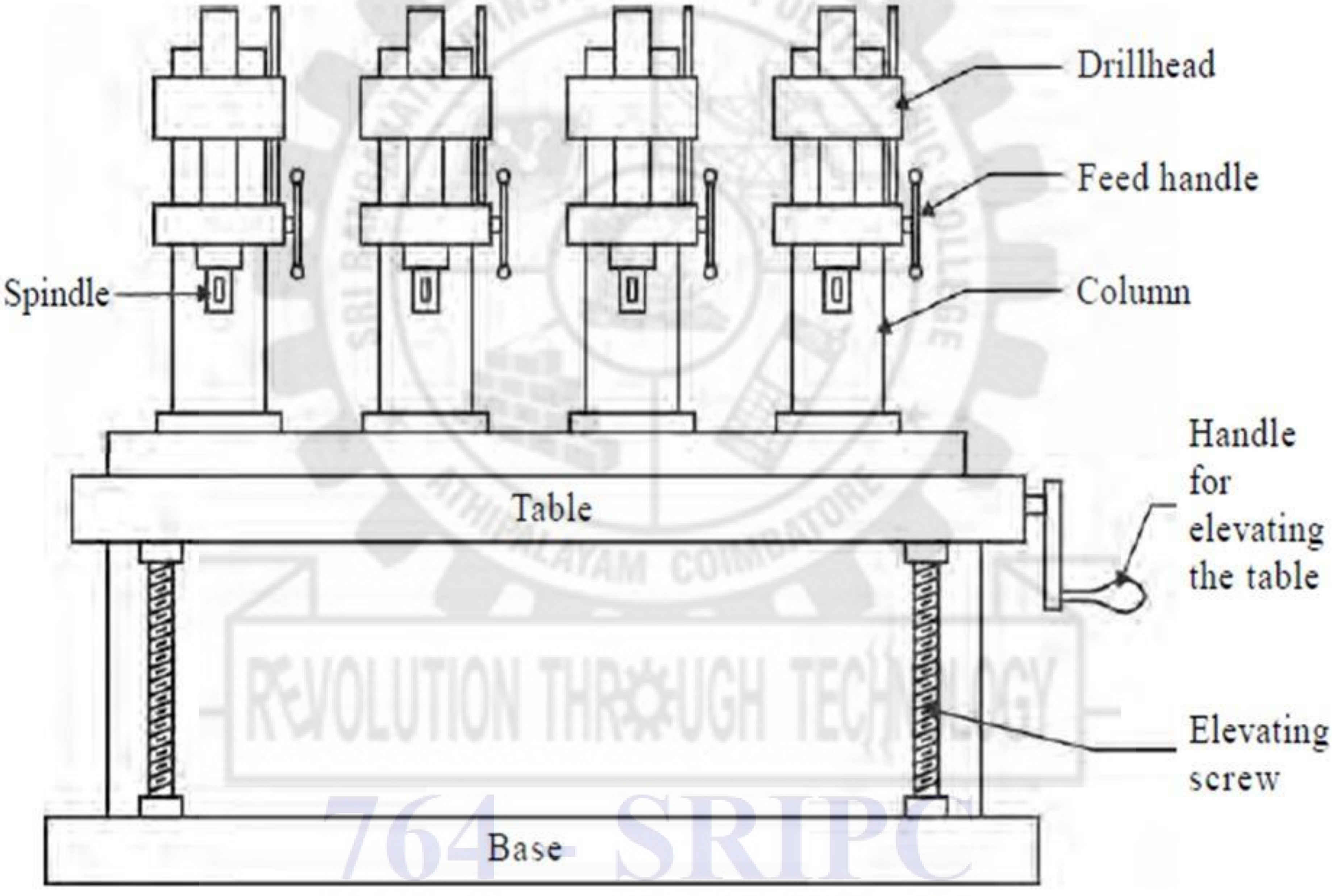


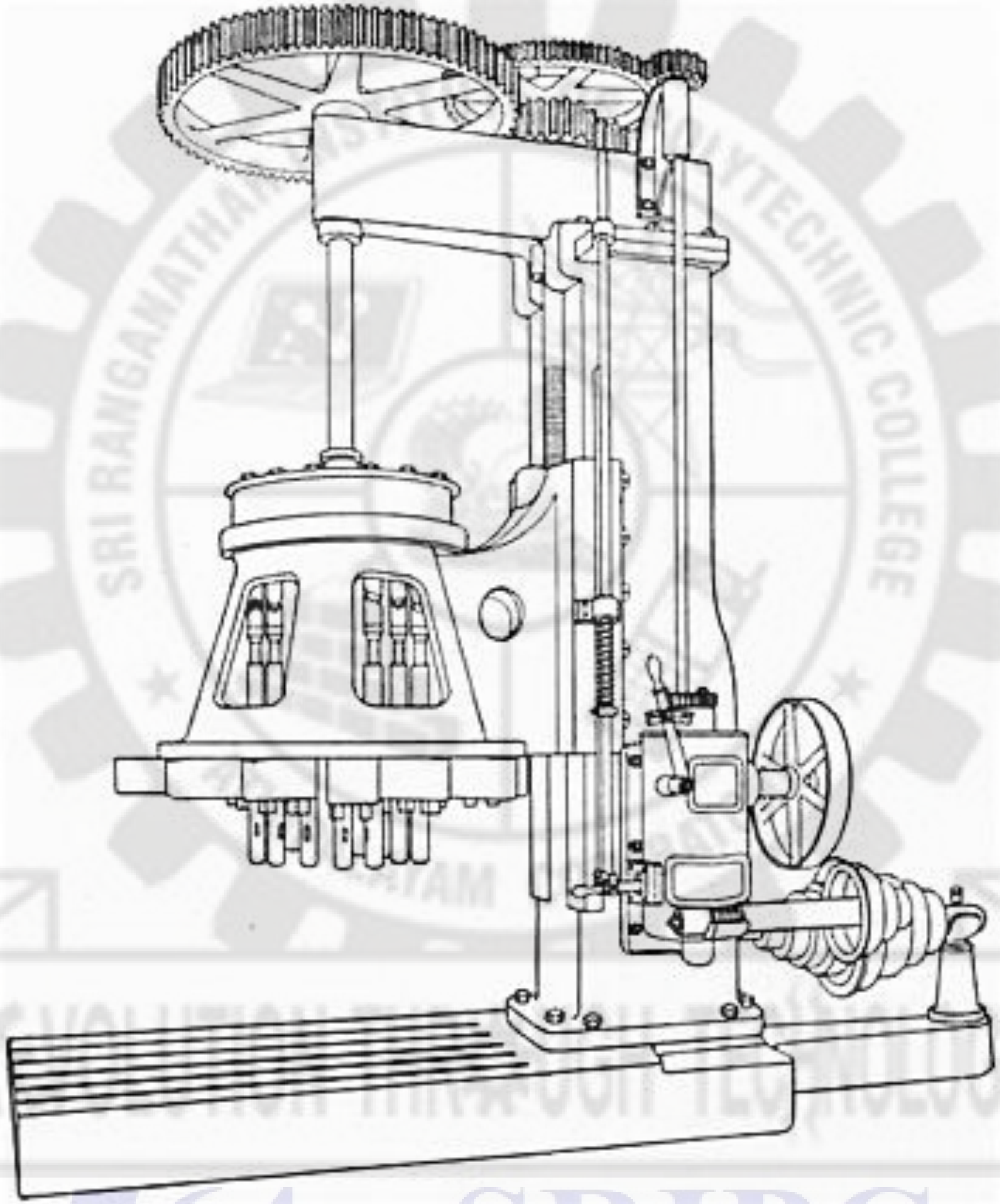
UPRIGHT DRILLING MACHINE



RADIAL DRILLING MACHINE

5) Gang drilling machine

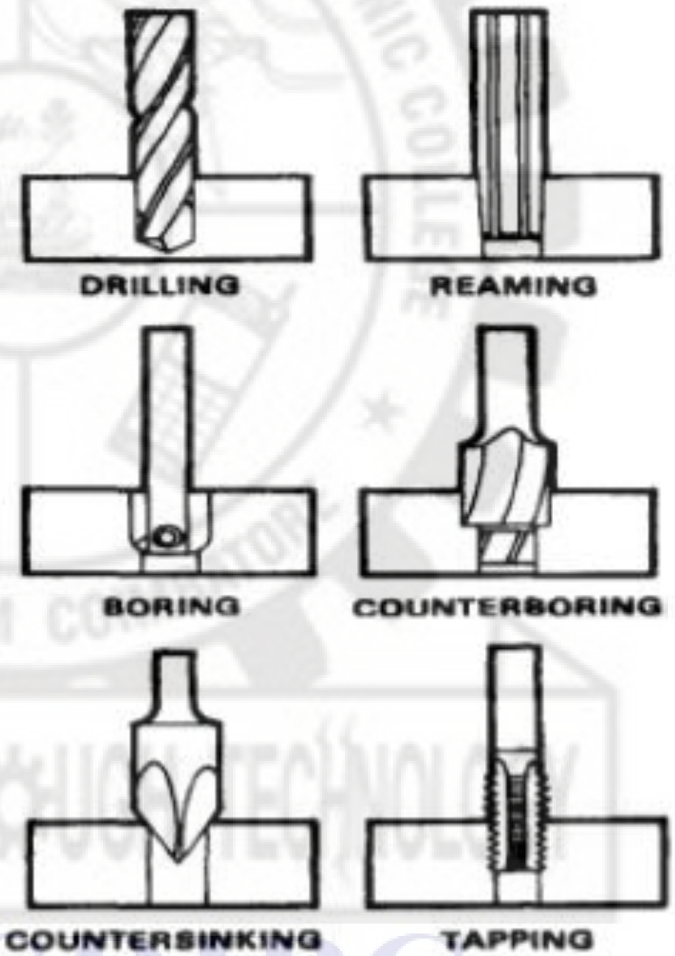


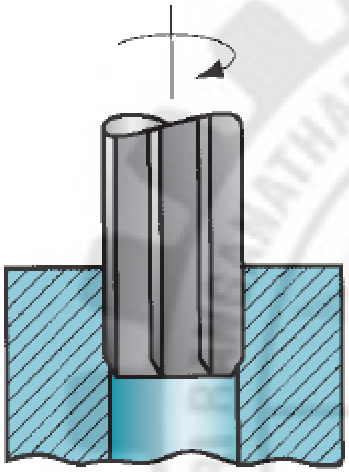


MULTI SPINDLE DRILLING MACHINE

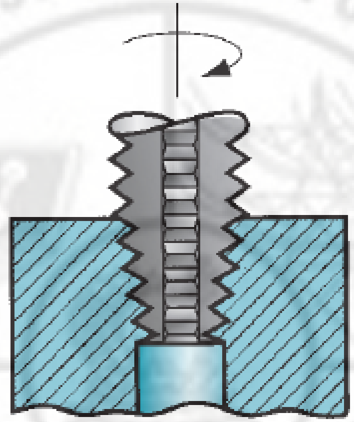
Drilling Machine Operations

- Drilling
- Reaming
- Boring
- Counter Boring
- Counter Sinking
- Tapping
- Spot Facing

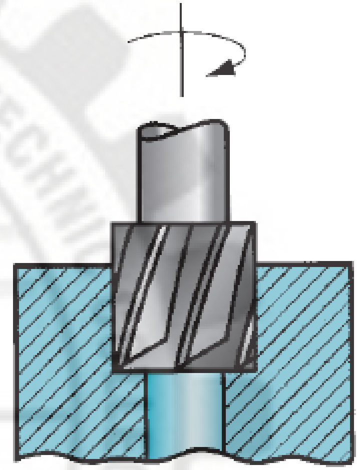




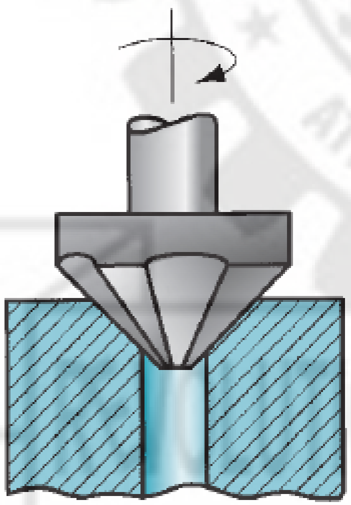
1. Reaming



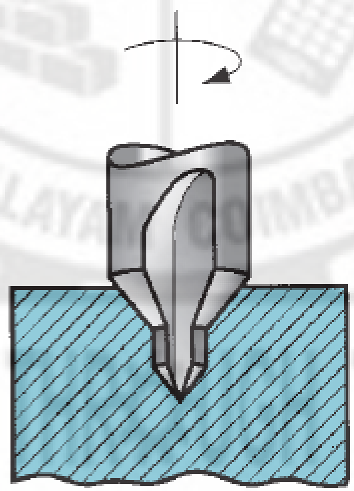
2. Tapping



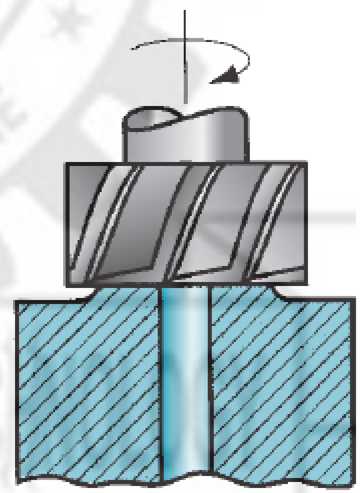
3. Counterboring



4. Countersinking



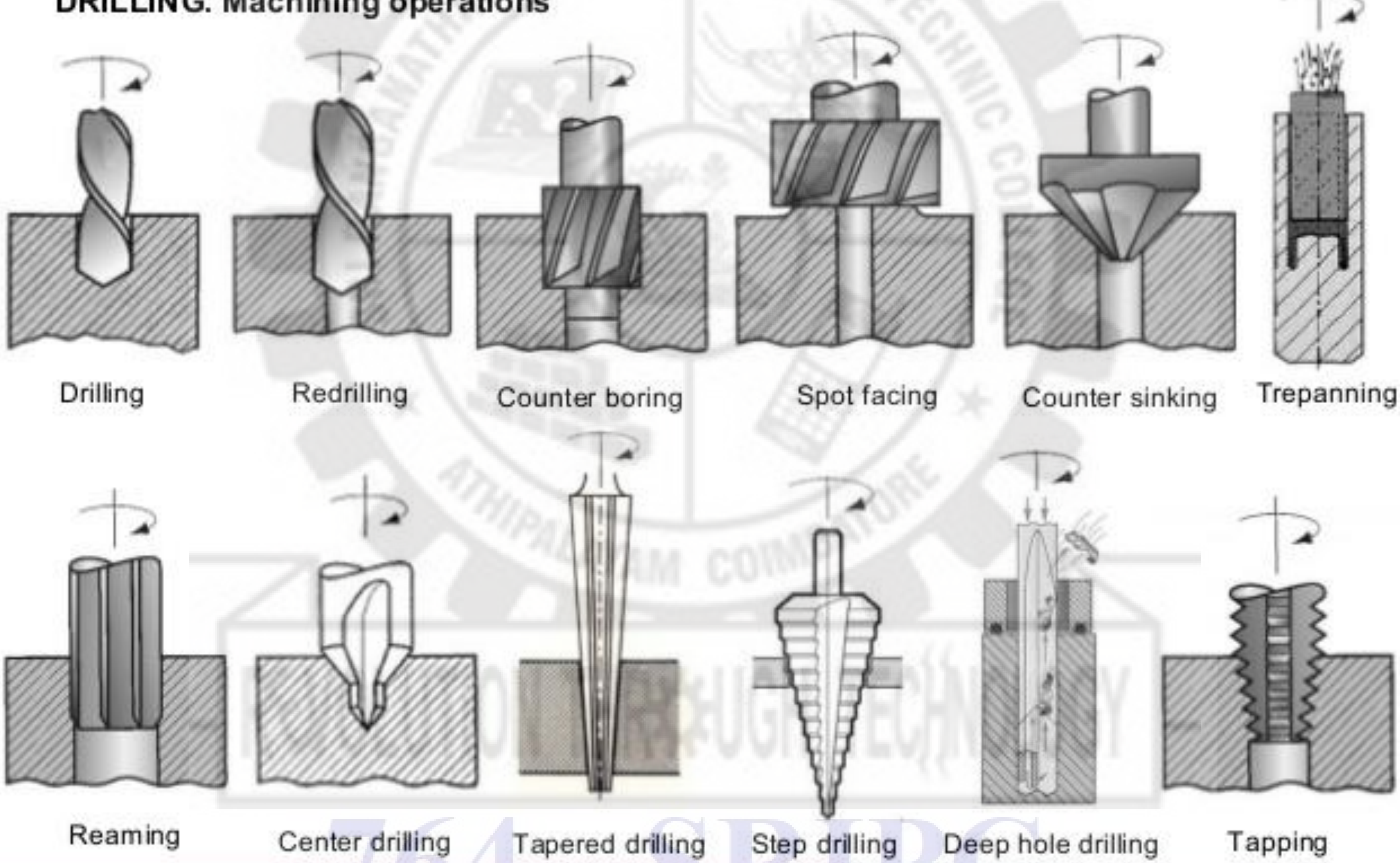
5. Center drilling



6. Spot facing

GOI ESKOLA POLITEKNIKOA FACULTY OF ENGINEERING MONDRAGON UNIBERTSITATEA

DRILLING. Machining operations



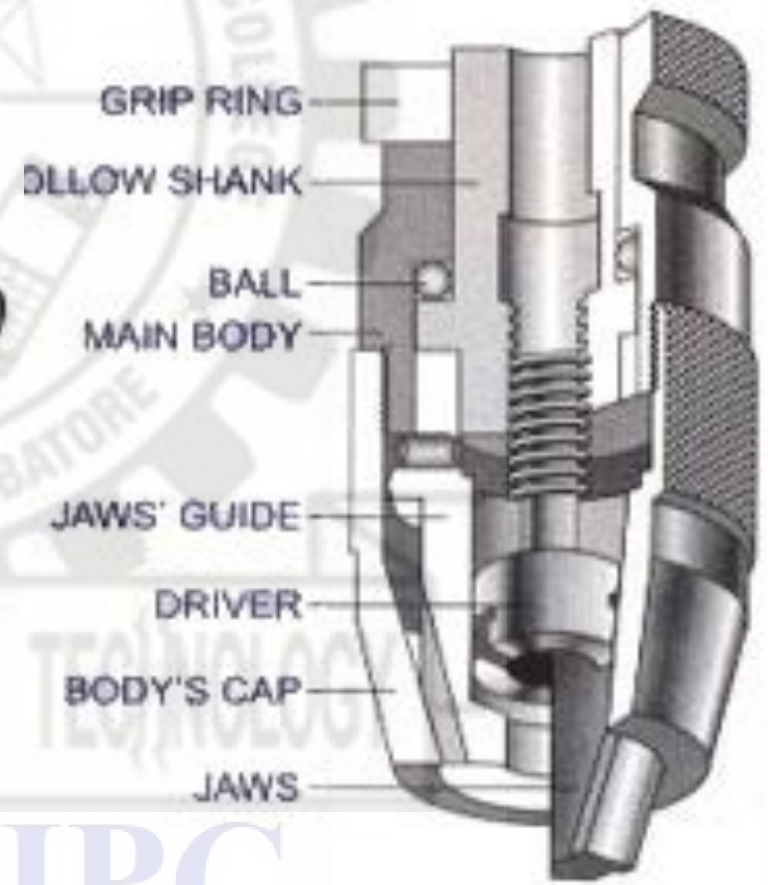
DEEP HOLE DRILLING

SLEEVE

DRILL SOCKET


13mm
B16

DRILL CHUCK


GRIP RING
OLLOW SHANK
BALL
MAIN BODY
JAWS' GUIDE
DRIVER
BODY'S CAP
JAWS

UNIT IV - ABRASIVE PROCESS AND NON- CONVENTIONAL MACHINING PROCESSES

ABRASIVE PROCESSES

INTRODUCTION

Grinding is a metal removal operation in which the metal is removed with the help of a rotating grinding wheel or abrasive wheel. The grinding wheels are made of abrasive materials held together by a bonding material. Grinding process removes very little amount of metal and also it gives very good surface finish with accuracy. This operation is suitable for machining very hard metals.

TYPES OF GRINDING

1.Rough Grinding or non-precision

2.Finish or precision grinding

1.Rough Grinding

Chips, Sharp edges, burr, unwanted projections on the workplaces are removed by Rough grinding process.

2.Precision Grinding

Precision grinding operation used for grinding the cutting tool materials. In this method the grinding wheel with very thin abrasive is used for grinding. So the metal is removed as very small particles. Due to this, the work piece can be machined accurately. Grinding process is classified based on the grinding method. They are given below.

1.External cylindrical grinding

2.Internal surface grinding

3.Surface grinding

4.Form grinding

1.External cylindrical grinding

The grinding operation which is done on a straight or tapered cylindrical workplace is called external cylindrical grinding. The work piece is rotated in its axis and moved across the face of the grinding wheel for grinding the surface of the work piece.

2.Internal cylindrical grinding

The grinding operation which is done on the internal hole of the cylindrical work piece and the inside taper surface of the cylindrical work piece is called internal cylindrical grinding. In this method, the work piece is held in the chuck and rotated in its axis then the rotating grinding wheel is passed inside the work piece for grinding.

3.Surface grinding

In this operation, the flat surface is produced by grinding the surface. For this, the work piece is moved forward and backward under the rotating grinding wheel.

4.Form grinding

The required form of grinding wheel is used for grinding the work piece. So this grinding operation produce the shape of grinding wheel used on the work piece for

grinding.

CLASSIFICATION OF GRINDING MACHINES

1.Cylindrical Grinding

1.Plain cylindrical grinder

2.Universal cylindrical grinder

3.Centreless grinder

2.Internal Grinders

1.Chucking type internal grinders

A.Plain internal grinders

B.Universal internal grinders

2.Planetory internal grinders

3.centreless internal grinders

3.Surface grinders

1.Reciprocating table type

A.Horizontal spindle type

B.Vertical spindle type

1.Rotating table type

A.Horizontal spindle type

B.Vertical spindle type

1.Tool and cutter grinders

1.Universal grinders

2.Special grinders

2.Special and single purpose grinding machines

1. Floor stand grinder

In this grinder, an electric motor fitted in the base. The motor has a horizontal spindle with grinding wheel mounted at each end of the motor shaft extensions.

Floor grinder is used for sharpening the tools, boring tools and drills. The machine has a grinding wheel with coarse grains on one end and a grinding wheel with fine grains on the other end.

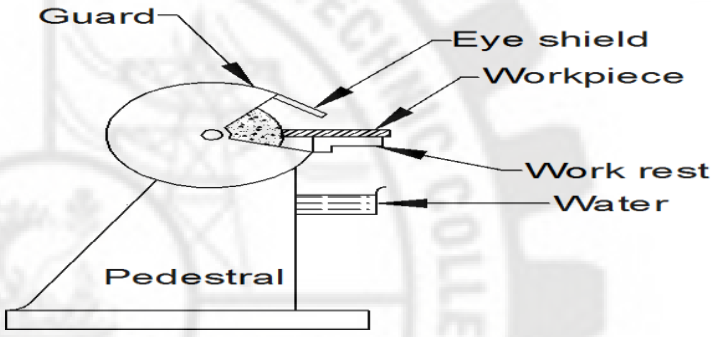


Fig. 4.1. Foot stand Grinder

2. Bench grinder

The appearance of this grinder is similar to the floor grinder. But this machine is placed on the bench. This type of grinder is used for grinding of tools and other small parts.

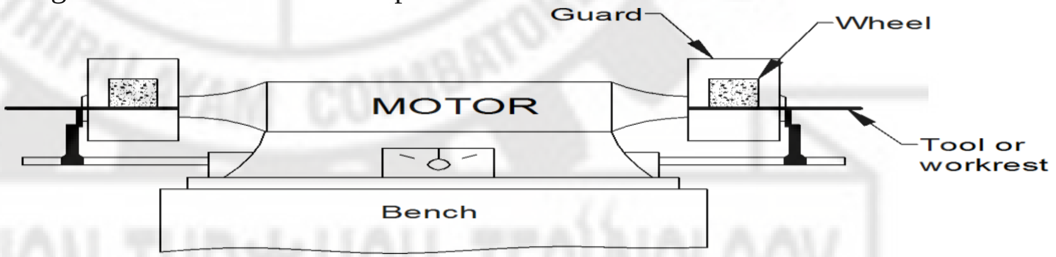


Fig. 4.2. Bench Grinder

3. Portable grinder

The machine can be carried from place to place. A small electric motor is provided in this grinder. A small grinding wheel is attached to the end of the motor. This grinder is suitable for grinding castings, and weld mesh.

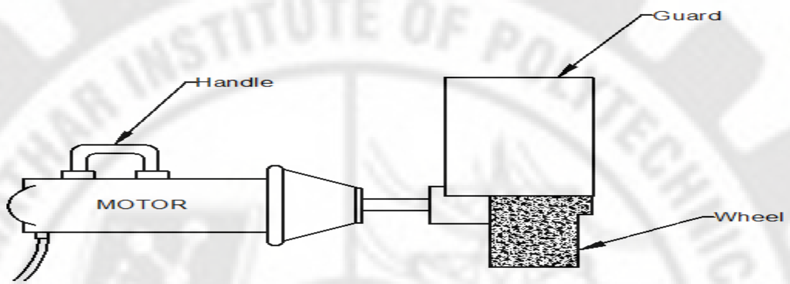


Fig. 4.3. Portable Grinder

4. Swing frame grinder

This type of grinder has horizontal frame to the length from 2 to 4 meter. A grinding wheel is fitted at the one end of the frame and this grinding wheel is attached to the motor. The other end of the frame carries balancing weight. A handle is provided at the wheel end.

It is used for moving the grinding wheel and pressing on the work piece for rough grinding. The grinder is suspended at

area of opera

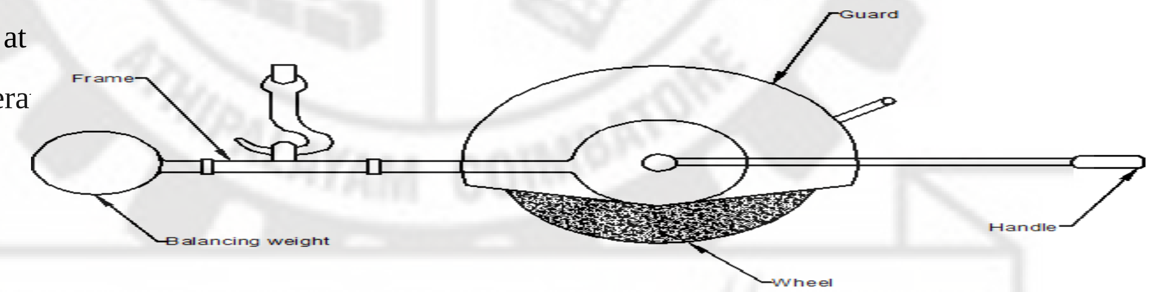


Fig. 4.4. Swing frame grinder

5. Abrasive belt grinder

In this grinder, abrasive belt is used instead of the grinding wheel. An endless belt is placed on the pulley. When this pulley is rotated by an electric motor the abrasive belt also rotates. Then the work piece is fed against this rotating abrasive belt for grinding the surface.

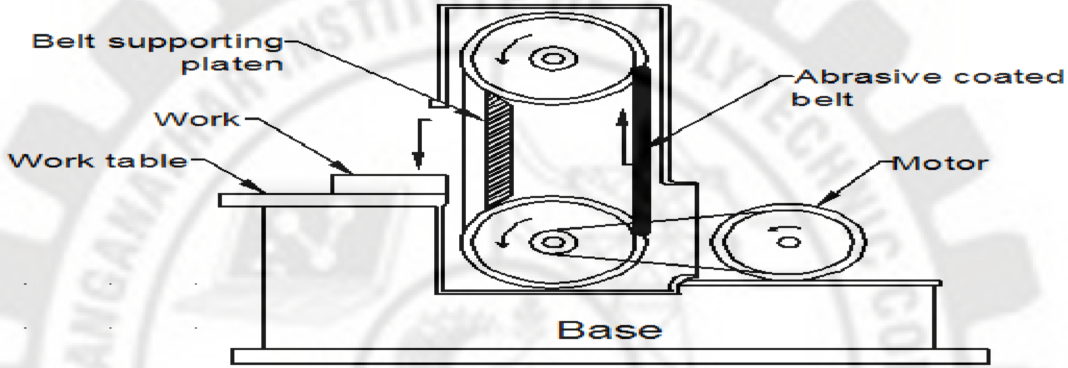


Fig. 4.5. Abrasive belt grinder

PRECISION GRINDERS:

Surface grinding machine, cylindrical grinding machine and internal grinding machine are belonging to the precision grinding machines. In this type of machines,

one end of the work piece is held in the dead centre and the other end is held in the dead centre and the other end is held in the dog or driver of the plate. There are four

movements in this type machines given below.

1. Rotation of work piece

1.

2.

3.

1. Cylindrical grinding

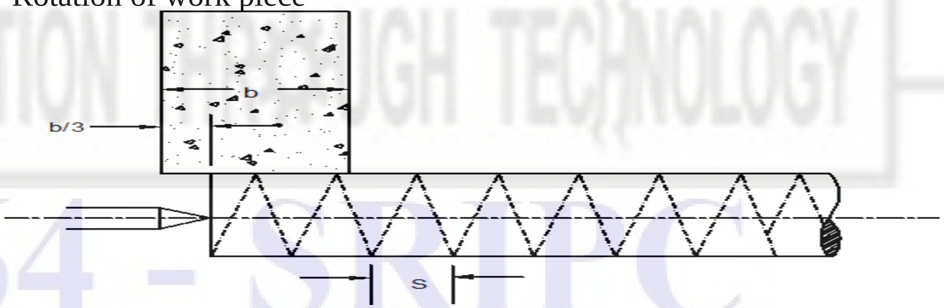


Fig. 4.6. Cylindrical Grinding

1. Traverse grinding

This method is used when the job length is more than the width of the grinding wheel. The work piece is held between two centres. The grinding wheel is made to rotate in a fixed position. The rotating work piece is made to traverse and the grinding is done on the work piece.

2. Plunge grinding

Plunge grinding operation is suitable when the length of the workplace is smaller than the width of the grinding wheel. Here, the work piece need not to be fed longitudinally.

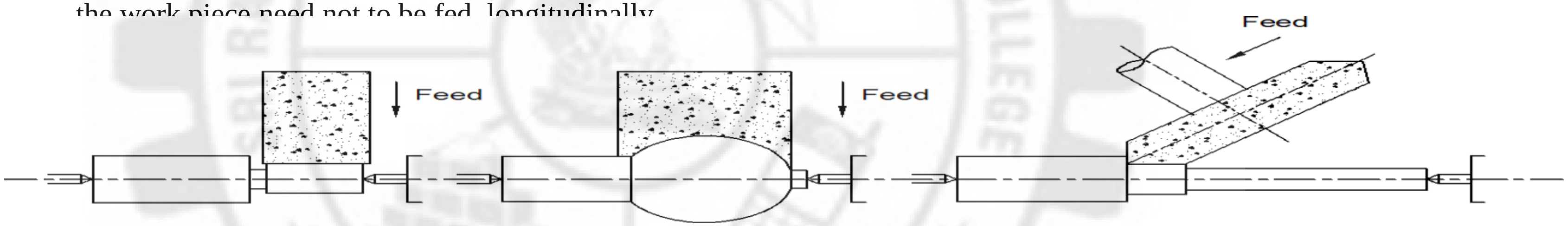


Fig. 4.7. Plunge cut Grinding

Then the grinding is done by grinding is done by giving only the cross feed to the grinding wheel. Plunge grinding is used for grinding shoulders, stepping and various contours.

CYLINDRICAL GRINDING MACHINE (CENTRE TYPE GRINDER)

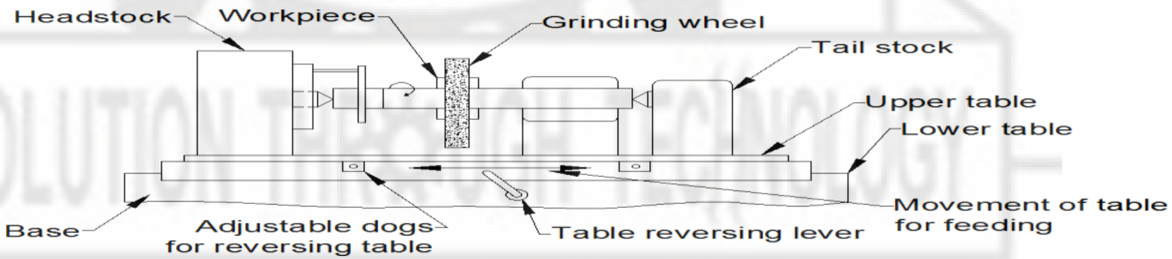


Fig. 4.8. Cylindrical Grinder

1. Base

This is made of CI and rests on the floor and it supports the other parts which are mounted on it. Horizontal guide ways are set on the top of the base. Table slides on these guide ways are set on the top of the base. The table slides on these guide ways for giving traverse motion to the work piece. The driving mechanism for the table is housed inside the base.

2. Table

This machine has two tables such as upper table and lower table. The lower table slides on the bad guide ways to give the longitudinal feed of the work past the grinding

wheel. The table can be moved by hand or by power. The dogs are provided at the side table to reverse the table at the end of the stroke. The upper table is mounted on the lower table.

Head stock and tail stock are mounted on the upper table. The table can be swivelled for the maximum angle up to 100 on either side

3. Head stock

The head stock has dead centre on which the work piece is supported. The work piece is driven by head stock through a dog and driving pin. A separate motor is used in the head stock for rotating the workspace

4. Tail Stock

Different length of work piece is clamped between head stock and tail stock by adjusting the distance through tail stock. The work piece is held between head stock and tail stock.

5. Wheel head

The grinding wheel is held in the wheel head and it is driven by a motor housed in the head stock. The wheel head is placed over the bed at the back side. It can be moved perpendicular to the table guide ways by hand or power.

6. Working

The required work piece is held between centres. It is rotated by a dog or a face plate. Then the grinding wheel is made to rotate in its own axis in the opposite direction of work. Then the grinding wheel is fed by hand or automatically towards the work piece.

be swiveled in a horizontal plane in any angle.

UNIVERSAL CENTRE TYPE GRINDERS

This type is mostly used in tool room for grinding the tools. This machine is similar to the cylindrical grinding machine. But the wheel head and head stock can be swiveled to the

required angle. This machine is provided with the following features.

1. The centre of the head stock spindle can be used alive or dead.
2. The wheel head can be swiveled in a horizontal plane in any angle.
3. The head stock can

4. The wheel head may be arranged for internal grinding.

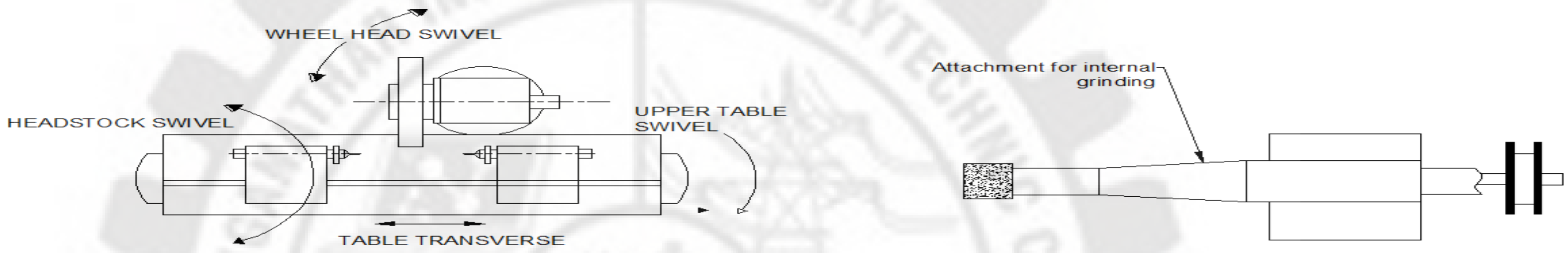


Fig. 4.9. Universal Grinder

The following equipment's are used in universal grinding machine.

1. Support slender work
2. Wheel truing device
3. Arbor
4. Internal grinding spindle
5. Three jaw self-centering chuck

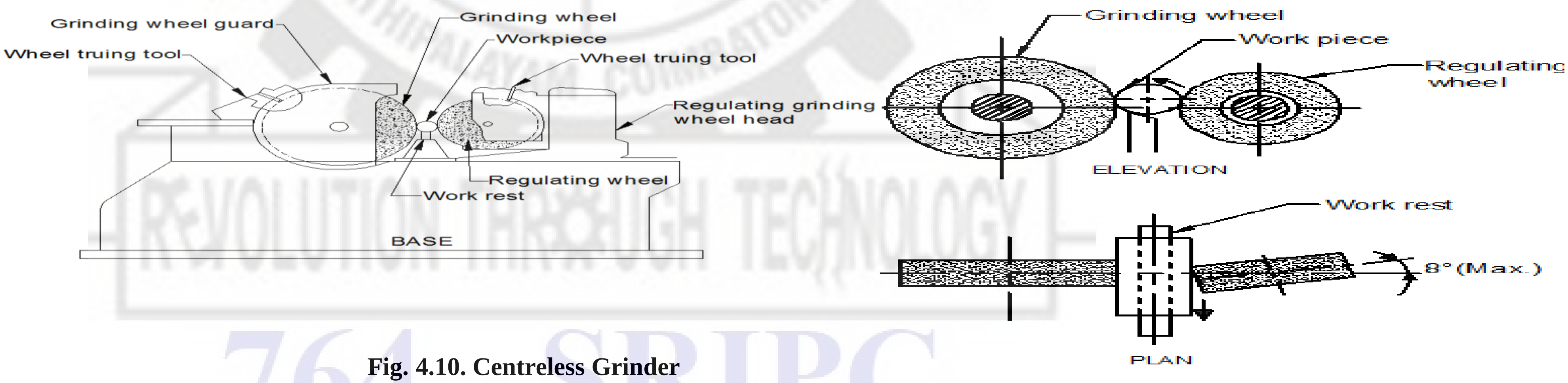


Fig. 4.10. Centreless Grinder

Horizontal Spindle Surface Grinder:

The work piece cannot be held between the centres of the machine can be machined by this type of grinding machine. The external centreless grinding machine has grinding wheel, regulating wheel or backup wheel and work rest. The two wheels are rotated in same direction. The larger grinding wheel revolves at a high speed and small regulating wheel revolves at slow speed. The work rest is placed between the two wheels. The work piece is placed on the rest. The regulating wheel is moved forward for forcing the work against the grinding wheel. This causes friction between the grinding wheels makes the work piece to rotate.

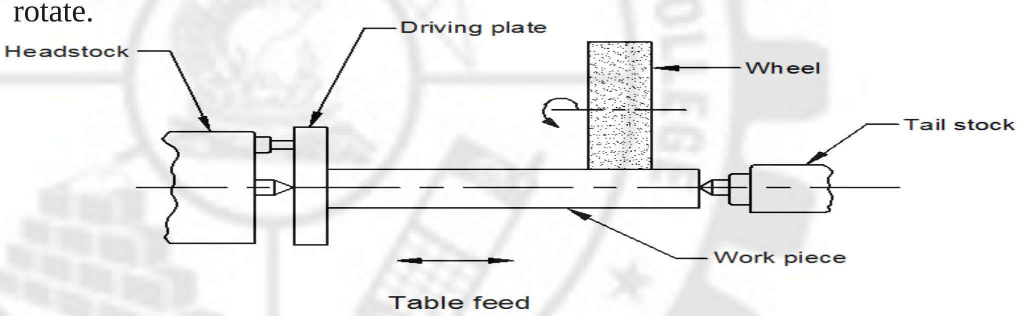


Fig. 4.11. Horizontal Spindle Surface Grinder

Then the rotating work piece is pressed between the two grinding wheels and they grind the surface. The regulating wheel does not remove the metal. The work piece is placed in a floating condition between the grinding wheel and regulating wheel while doing the grinding operation. So, this grinding operation is called centreless grinding.

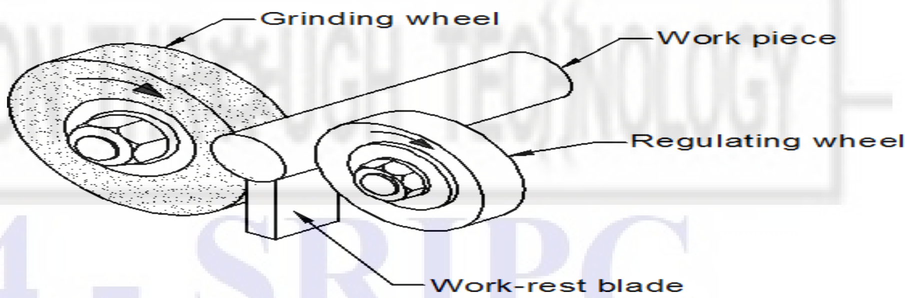


Fig. 4.12. Centreless Grinding

METHODS OF CENTRELESS GRINDING

1. Through feed

1. In feed

1. End feed

1. Through feed

This method is suitable for grinding the long shaft or bars and rollers pins. In this method, the regulating wheel is tilted at a

small angle for moving the

through the space between

heel for guiding the

movement of the work piec

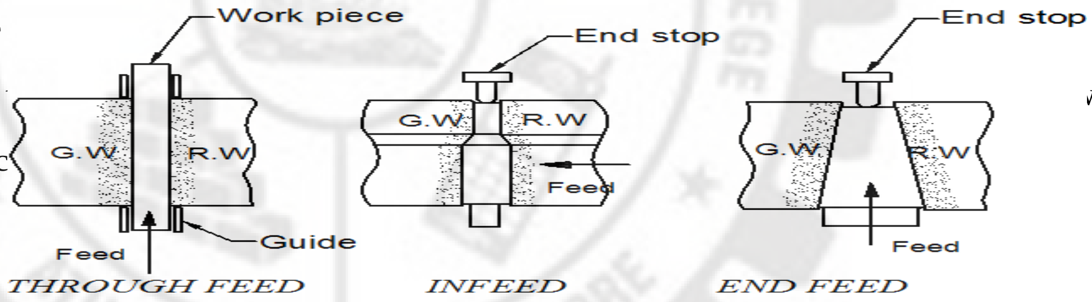


Fig. 4.13. Methods of Centreless Grinding

2. In feed grinding

In this method, the work piece is placed on the work rest against an end stop. Due to this, the axial movement of the work piece is avoided. Then the regulating wheel and the work rest with the work piece are moved towards the grinding wheel by giving hand feed. This method of grinding is similar to the plunge grinding. Shoulders and formed surfaces are ground by this method.

3. End feed grinding

This method is suitable for producing tapered surface. So, the grinding wheel or regulating wheel with required form of taper is used for grinding. The work piece is fed axially between the wheels and ground. An end stop is provided at the rear end of the wheel for stopping the work piece at the required length.

Advantages of centreless grinding

1. Fixtures and other clamping devices are not required for holding the work piece.
2. This is the faster process than the centre type grinding.
3. The size of the job can be controlled easily by the regulating wheel.
4. Skilled operators are not required
5. Suitable for mass production.

Limitations

1. Work piece with steps and multiple diameters as cannot be ground easily
2. The cylindrical surface with a keyway or holes cannot be ground.

INTERNAL GRINDERS

Internal grinder is used for grinding inside surface of the work piece. The inside surfaces may be straight, tapered or formed holes. Generally, the following three type of internal grinder are used.

1. Chucking
2. Planetary
3. Centreless

1. Chucking type internal grinders

In this machine the work piece is held in the chuck and rotated about its axis. The work head is mounted at the left side of the machine and the wheel head is mounted at the right end of the machine. The grinding operation is done on the work piece by reciprocating the rotating grinding wheel through the length of hole in the work piece. This type of machine is suitable of grinding the work piece which can be held in the chuck.

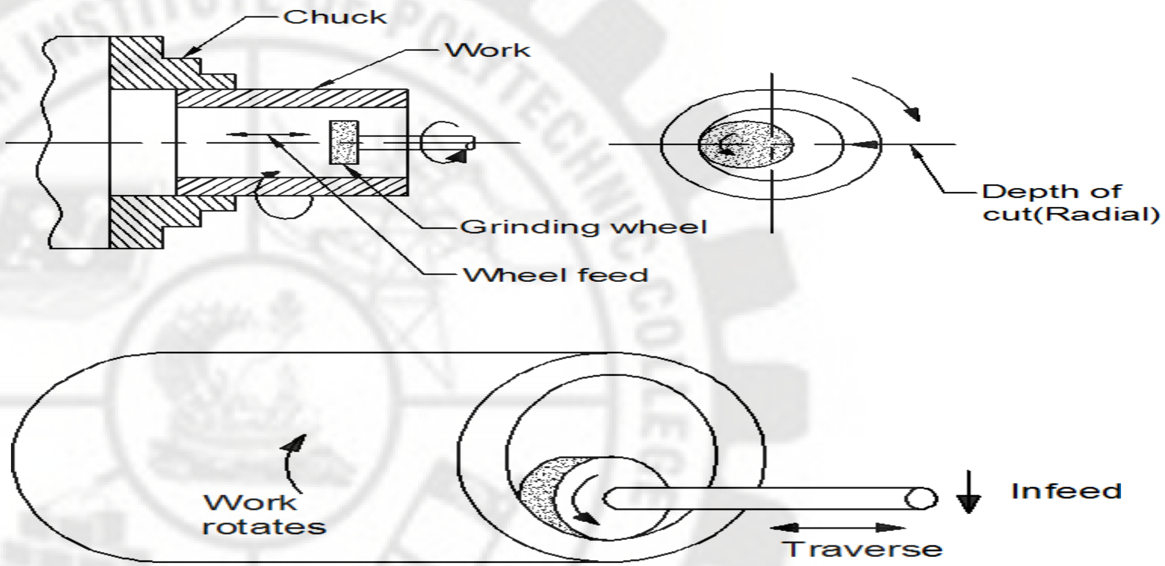


Fig. 4.14. Chucking type Internal Grinder

2. Planetary type grinders

The work piece is held in the reciprocating table and the work piece is clamped rigidly. The work piece will not be moved. But for grinding the work piece, the rotating grinding wheel is moved inside the work piece and reciprocates for grinding the surfac

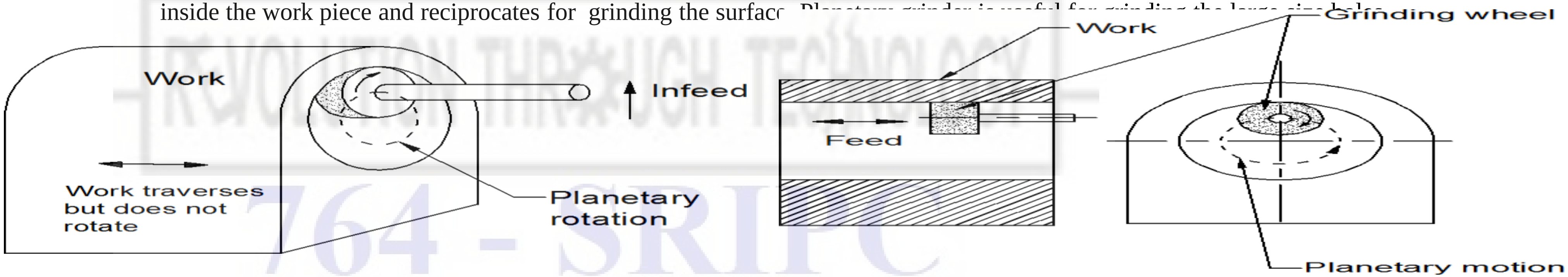


Fig. 4.15. Planetary type Internal Grinder

3. Centreless grinding

In this grinding, the work piece is supported by the three rolls. One is regulating wheel, second is a supporting wheel and other is a pressure roll to hold the work piece against the support and regulating rolls. The regulating wheel makes the work piece to rotate. The rotating grinding wheel is moved inside the diameter of the work piece and reciprocates for grinding the surface. Then the grinding wheel is moved in a cross wise direction for giving depth of cut.

SURFACE GRINDERS:

This machine is suitable for grinding flat and plane surface. Irregular, curved and tapered surfaces also can be ground using this machine. Die, Valve, Piston rings, surface plates are finished by this grinding machine.

HORIZONTAL SPINDLE – RECIPROCATING TABLE SURFACE GRINDER

1. Base

Base is made by casting with rectangular shape. Driving mechanism is housed inside the base. A vertical column is mounted on the back side of base. Horizontal guide ways are in the top of the base and these are perpendicular to the column.

2. Table and saddle

Saddle rests on the base. The saddle moves on the guide ways which are perpendicular to the column and gives cross feed. The table moves on the horizontal guide ways of the saddle. Longitudinal feed is given by moving the table. 'T' slots are provided on the table for holding the work.

3. Wheel head

A separate motor is mounted at the top of the column for operating the wheel head.

The wheel head moves up and down on the vertical guide ways of the column.

Operation

Magnetic chuck or fixtures are used for holding the work piece on the table. The trip dogs are adjusted suitably to get the correct stroke length of the table. Then the table with work piece reciprocates and the periphery of the rotating grinding wheel grinds the work piece. Depth of cut is given by lowering the wheel head or raising the table. Cross feed is given to the work piece at the end of every stroke.

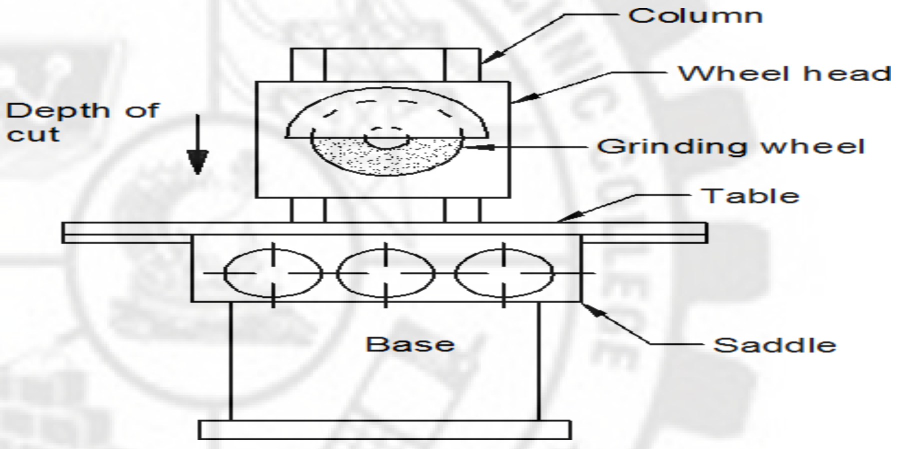


Fig. 4.16. Surface Grinder

HORIZONTAL SPINDLE – ROTARY TABLE SURFACE GRINDER

Rotary Table Surface Grinder

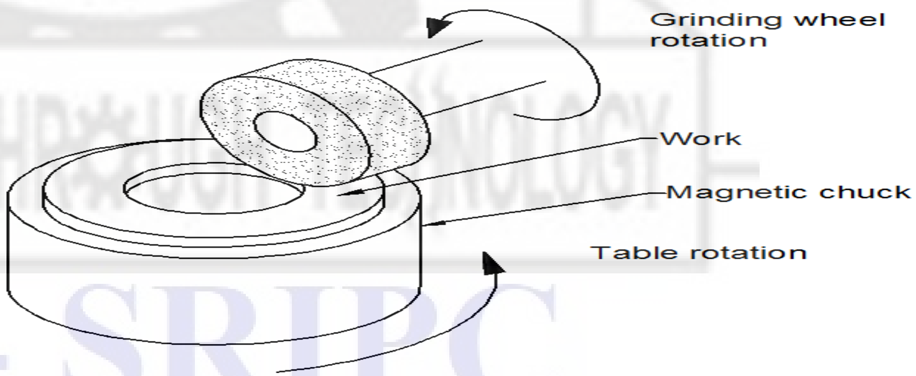


Fig. 4.17. Horizontal spindle Rotary table Surface Grinder

In this grinder, a rotary table is used. Small size work piece is held in the table and rotated. Wheel head of the machine reciprocates in its axis. This movement gives the cross feed. The wheel head is moved down for giving depth of cut. The peripheral surface of the grinding wheel grinding the surface. This machine is suitable for grinding small and medium size works.

VERTICAL SPINDLE RECIPROCATING TABLE SURFACE GRINDER

The work piece is clamped on the reciprocating work table using a magnetic chuck or a fixture. A grinding wheel rotates in its vertical axis. The face or side of the grinding wheel cuts the metal. The wheel head is moved down for giving the depth of cut. The longitudinal and cross feed are given through the table. This machine is useful for grinding the flat surfaces of medium size work piece.

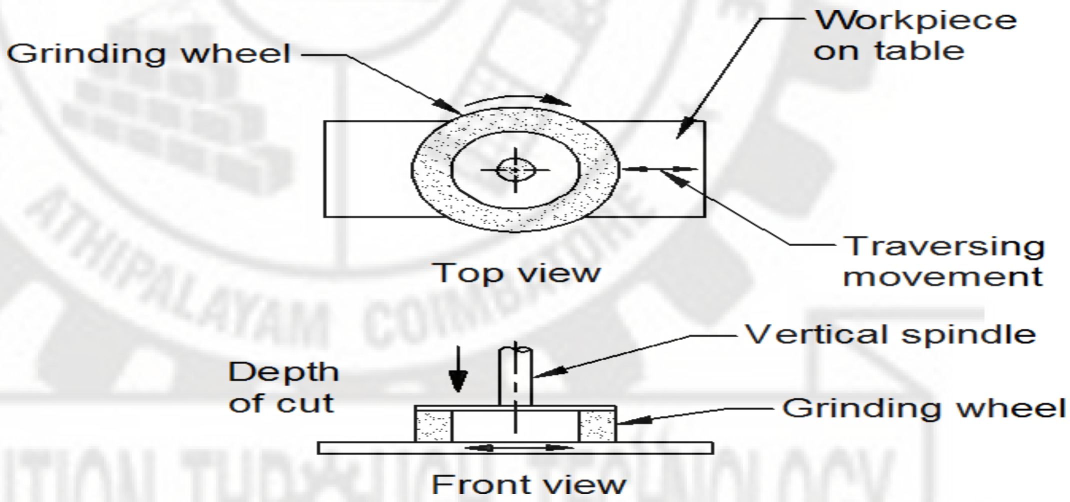


Fig. 4.18. Vertical spindle Reciprocating table Grinder

VERTICAL SPINDLE-ROTARY TABLE SURFACE GRINDER

The grinding spindle is mounted vertically on the face of a column and rotates in fixed position. The grinding wheels are moved down for giving depth of cut and grinding the work piece which are rotating with the rotary table. grinding large quantity of This grinding machine is used for small work piece

GRINDING WHEEL:

Grinding Wheel

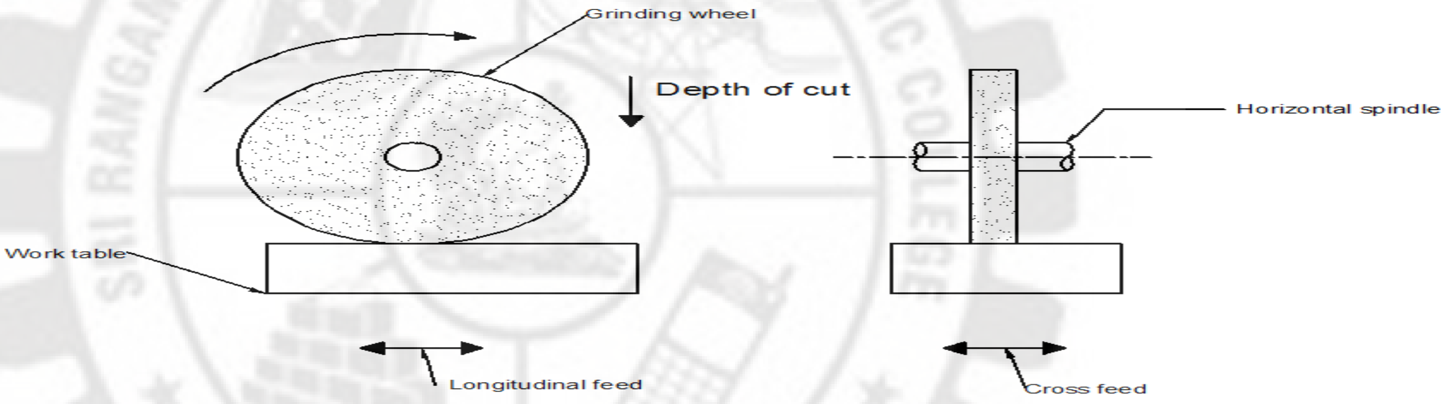


Fig. 4.19. Grinding wheel

Wheel Head

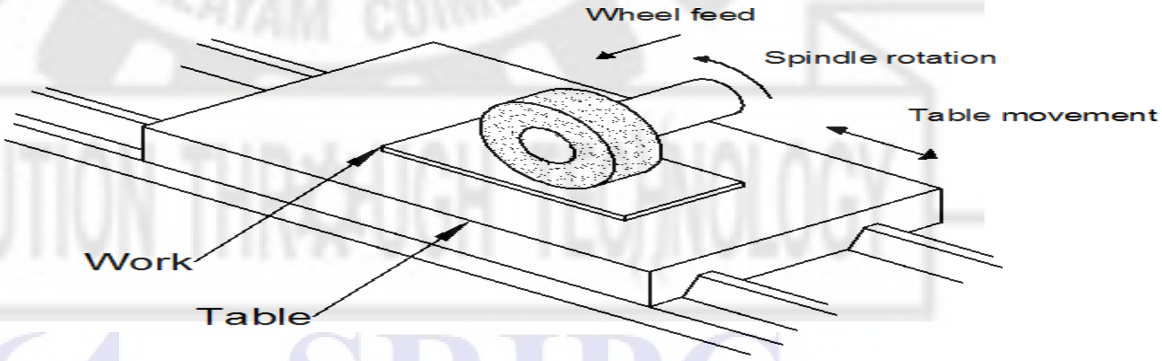


Fig. 4.20. Grinding wheel head

It is made up of small abrasive particles held together by a bonding material.

ABRASIVES

It is a hard material. Small abrasive particles are used in grinding wheel.

Abrasives are classified into two types. They are

1. Natural abrasive 2. Artificial abrasive.

1. **Natural abrasive**

This type of abrasive is available in nature. The following are the natural abrasives.

1. Sand stone
2. Emery
3. Diamond
4. Corundum

2. **Artificial abrasives**

Abrasives particles are manufactured with required quality by artificial method. Mostly artificial abrasives are used for manufacturing the grinding wheels. Quality and the hardness of the artificial abrasives are more than the natural abrasive. The various manufactured abrasives are given below.

2. Aluminium oxide
3. Silicon carbide
4. Artificial Diamond
5. Ceramic aluminium oxide
6. Boron carbide

a. Aluminium oxide

This type of abrasives is manufactured from the bauxite mineral. It is manufactured by fusing the bauxite in an electric furnace mixed with coke and iron scrap. After fusing, it is crushed and finally ground. Mostly the grinding wheel with aluminium oxide abrasive is used for grinding the carbon steel, alloy steel, HSS, wrought iron alorite, abrasite, Electrite and Alundum are the other names of the Aluminium

b. Silicon carbide

It is manufactured from the silica sand. Silica sand, coke and wood dust are mixed and kept in the electric furnace for beating them for producing silicon carbide. This made with this abrasive is used for grinding the metals like iron, aluminium and copper.

BONDS

Bond is an adhesive substance which holds the abrasive grains together to form the grinding wheel. Vitrified bond is used for precision grinding. Resinoid bond is used for rough grinding. The following are the different bonding materials.

1. **Rubber bond (R)**

   The regulating wheel which is used in centreless grinder is manufactured by rubber bond. Sulphur with rubber is used for manufacturing rubber bonded grinding wheel.

2. **Shellac bond or Elastic bond (E)**

   Shellac bonded wheels are made by mixing the abrasive grains with shellac in a mixture. Then the mixture is rolled or pressed to the desired shape and hardened about 200˚c for a particular time.

3. **Vitrified bond**

   In this, clay and water is mixed and placed in mould to get the shape of the wheel and air dried at room temperature. Then the moulded wheels are kept about 1260˚C for a few days. Then they are trimmed to the required size. Thus the vitrified bonded grinding wheels are manufactured.

4. **Silicate bond (S)**

   Here, sodium silicate is used as bonding material. Abrasive particles with sodium silicate are mixed and placed in the mould to get the required wheel shape and kept it about 270˚C for 20 to 80 hrs.

5. **Oxy chloride bond**

Oxide and magnesium chlorides are used as bonding material for manufacturing grinding wheel.

6. **Resinoid bond**

Synthetic Resins are used as bonding material. Synthetic resin mixed with abrasive grain and placed in the mould to get the required wheel shape and heated about 2000˚C for several hours. During the heating time, the resin melts and joined with the abrasive grains. This type of bonded wheel can be rotated with higher speed. And used for rough grinding on steel parts and castings.

GRAIN OR GRIT

Abrasive particles size is mentioned as grain or grit. Same or different sizes of grains are used for manufacturing the grinding wheel. The selection of grit or grain size mainly depends on the following:

1. The amount of material to be removed
2. Required finishing
3. Property of the metal

Soft and Elastic materials can be ground by course grit wheels and brittle materials are ground by fine grit wheels. Grain size is mentioned as number. This number indicates the number of meshes per linear inch through which they are passed. The grain sizes are divided as shown in the table.

Grinding Operation	Grit or Grain size						
Coarse	10	12	14	16	20	24	
Medium	30	36	46	54	60		
Fine	80	100	120	150	180		
Very fine	220	240	280	320	400	500	600

GRADE:

Grade indicates the strength, with which bonding material holds the abrasive grains in the grinding wheel. Bonding strength or hardness is indicated by English alphabets. 'A' is the softest wheel and 'Z' is the hardest wheel. The grinding wheel with different grades is shown in the following index.

Soft	A	B	C	D	E	F	G	H		
Medium	I	J	K	L	M	N	O	P		
Hard	Q	R	S	T	U	V	W	X	Y	Z

STRUCTURE OF GRINDING WHEEL

Structure indicates the space between the abrasive grains. Structure is denoted by a number when the spacing between the grains is small, the structure is called dense structure when the spacing between the grains is more, and the structure is called open structure.

The following table shows the structure of grinding wheels.

Structure	Symbol							
Dense	1	2	3	4	5	6	7	8
Open	9	10	11	12	13	14	15	more

WHEEL SHAPES AND SIZES

1. Peripheral grinding wheel

In this the periphery of the wheel is used for grinding and these are mounted on horizontal spindles.

a) Straight wheels

These are used for cylindrical, Internal, Centreless and surface grinding operations.

b) Tapered face wheels

Two sides of the wheel are tapered and these are used for grinding threads on and gear teeth.

c) Recessed wheels

This type of wheel has recess on both sides. The sides and periphery of the wheels are used for grinding.

2. Face grinding wheels

a) Ring or cylindrical wheels

These are suitable for grinding small flat surfaces.

b) Flaring cup wheels

These wheels are used for tool and cutter grinding.

c) Dish wheels

These are also used for tool and cutter grinding

d) Cup wheels

Large flat surfaces are ground by these wheels.

STANDARD MARKING SYSTEM OF GRINDING WHEELS

The grinding wheel is specified by a standard system of marking the grinding wheels. The following are indicated in the marking system Type of abrasives

1. Grit size or grit number
2. Grade of the wheel
3. Structure
4. Type of Bond
5. Manufacturer's code

The standard marking system is shown below.

W A 36 K 5 R 17

Manufacturer's
Manufacturer's
symbol
symbol

Abrasive
A - Aluminium
Silicon carbide

Coarse 10 12 16 20 24
Medium 30 36 46 60

Grade
Soft → A,B,C,D,E,F,G,H
Medium → I,J,K,L,M,N,O,P
Hard → Q,R,S,T,U,V,W,X,Y,Z

Dense 1 2 3 4 5 6 7 8
Open 9 10 11 12 13 14 15

B- Resinoid
R- Rubber
E- Shellac
S- Silicate
O- Oxychloride
V- Vitrified

SELECTION OF GRINDING WHEEL

Selection of suitable grinding wheel is very important one. The selection of grinding wheel depends on the following factors.

1. Constant factors 2. Variable factors

1. **Constant factors**

a. **Physical properties of material to be ground**

Tensile strength and toughness is more in the steel and bronze. So these metals are best ground with aluminium soft bronze, chilled cast iron and aluminium

metals can be ground by silicon carbide wheels. Hard wheels are used for grinding soft metals and soft wheels are sued for grinding hard materials.

a. **Amount and rate of stock to be removed**

Coarse grain and wide spacing abrasive wheels are used for grinding with faster speed. Fine grain and close spacing abrasive wheel are used for grinding the surface with good surface finish.

a. **Area of contact**

The area of contact between the wheel and work affects the pressure over the number of cutting points. If the contact area of the grinding wheel is small, fine grain and close spacing will be useful if the contact area of the grinding wheel is larger, coarse grain and wide spacing is suitable.

a. **Type of grinding machines**

Soft wheels are better for using in heavy rigidly constructed machines. Suitable grinding wheel are selected according to the feeds and speed available in the

machine.

2. Variable factors

a) **Work speed**

The speed at which the work piece traversed across the wheel face is called work speed. If the work speed is more, the wear of grinding wheel will be more, in this case hard wheel is better. If the work speed is slow, the wear will be low on the grinding wheel in this case soft wheel is better.

b) **Wheel speed**

The speed of the grinding wheel is influenced by the grade and bond. If the wheel speed is high, soft wheel is better if the speed is low, hard wheel is better.

Vitrified bonded wheels are suitable for grinding with the speed up 2000m/min. Rubber, Shellac and retinoid bonded wheels are better when the

c) **Condition of the grinding machine**

Soft wheels are better when grinding in dry condition. Hard wheels are better when grinding in wet condition. Well maintained machine can use soft grade wheels. Light machine ash use hard wheels.

d) **Personal factor**

The skill of the worker is very important one. A UN skilled worker cannot handle soft wheels so he must be allowed to work on hard wheels.

MOUNTING O

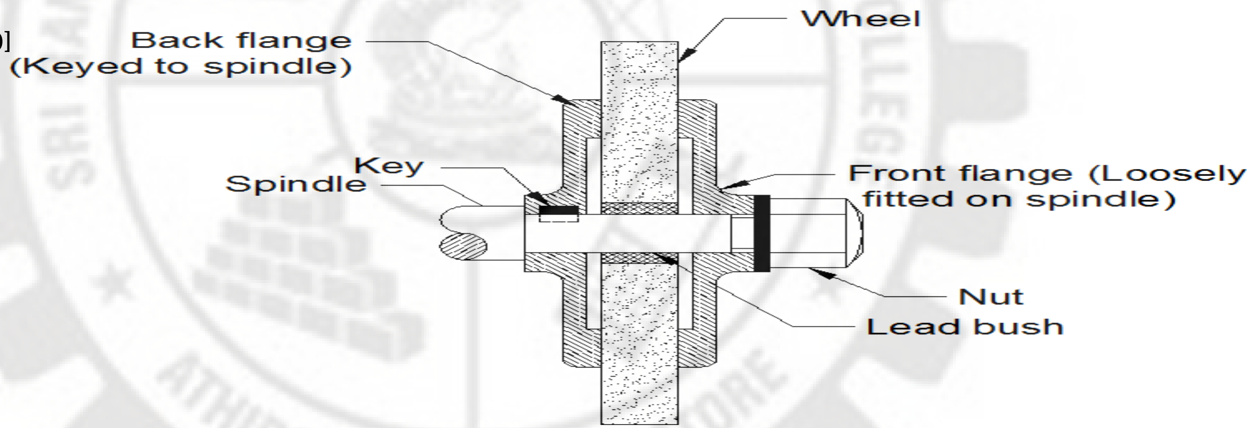


Fig. 4.21. Mounting of Grinding wheel

The grinding wheel rotates at high speed. If it is not fitted properly, it will be dangerous to the operator, before mounting, all grinding wheels should be inspected by ringing test. A good wheel gives a ringing sound on light taping with a metal bar. A cracked wheel will give a dull sound. The following points should be considered while mounting the grinding wheel.

1. Grinding wheel should not be forced on the spindle. The wheel must have sliding fit.
2. A bush is used in the bore of a grinding wheel and it should not project beyond the wheel face.
3. Flanges are used while fitting the wheel. That flanges diameter must be at least equal to half of the wheel diameter.

4. Wheel side and flange side should be perfectly flat.
5. Flanges should have the clearance only on their faces.
6. The inner fixed flange should be keyed to the spindle. The outer flange has a sliding fit with the spindle.
7. Thick compressive washers should be placed on both sides of the wheel faces and flanges for gripping of flanges on the wheel.
8. The nut should be tightened property.
9. Wheel guard should be placed in position.

LOADING IN WHEELS

When grinding a surface, the metal is removed in the form of fine particles. The removed fine particles enter into the spaces between the abrasive particles in a grinding wheel. This is called loading. After the loading, the cutting ability of the wheel will be reduced. Loading of fine particles is removed by dressing.

Glazing

When a grinding wheel is used for a long time, the cutting surface of the grinding wheel becomes smooth and gets a glass like appearance. It is known as glazing. If the grinding wheel gets a glazed surface, then it will not grind the surface effectively.

RECONDITIONING OF GRINDING WHEEL

Due to the long-time usage of grinding wheel, it is affected by glazing and loading. To make the wheel surface in good condition, it must be reconditioned. The grinding wheels are reconditioned by dressing and truing operations.

DRESSING

It is an operation of removing glazing and loading from a grinding wheel.
This is done by using a tool to called dresser.

1. Dressing by star wheel dresser

A star dresser made of steel is used for dressing course grained wheel the dresser tool has hardened teeth on its periphery and it is kept in a tool rest.

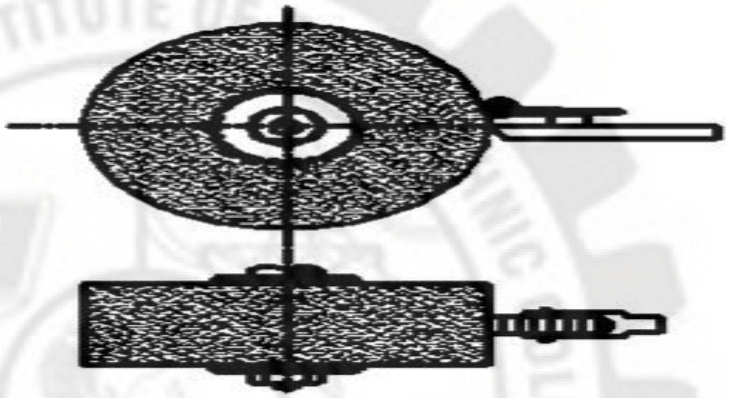


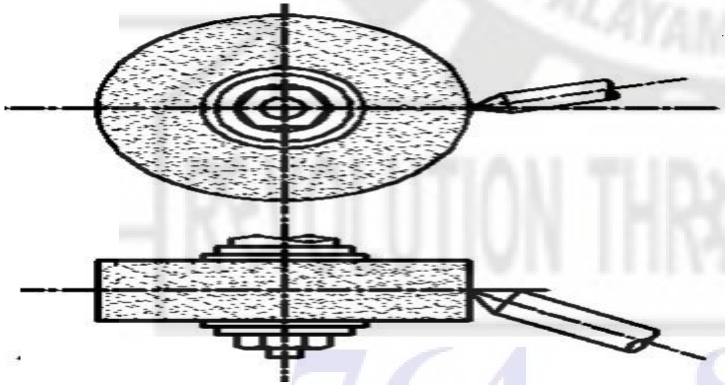
Fig. 4.22. Dressing by star wheel dresser

The dresser is pressed against the periphery of the slowly rotating grinding wheel. The dresser is moved cross wise along the width of the wheel.

2. Round abrasive stick

Bonded abrasives are filled in a tube and it is called round abrasive stick. Dressing is done on the grinding wheel

g wheel face.



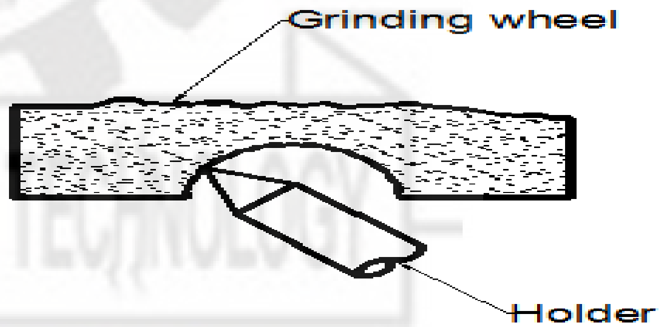


Fig. 4.24. Dressing formed wheel

Fig. 4.23. Diamond tip dresser

3. Diamond dressing tool

A diamond tipped dresser is used for dressing the grinding wheel which are used for precision grinding. The diamond tip is held in a holder and kept at an angle to the wheel. The dresser is pressed against the slowly rotating wheel, and moved cross wise along the width of the bale.

BALANCING OF GRINDING WHEELS

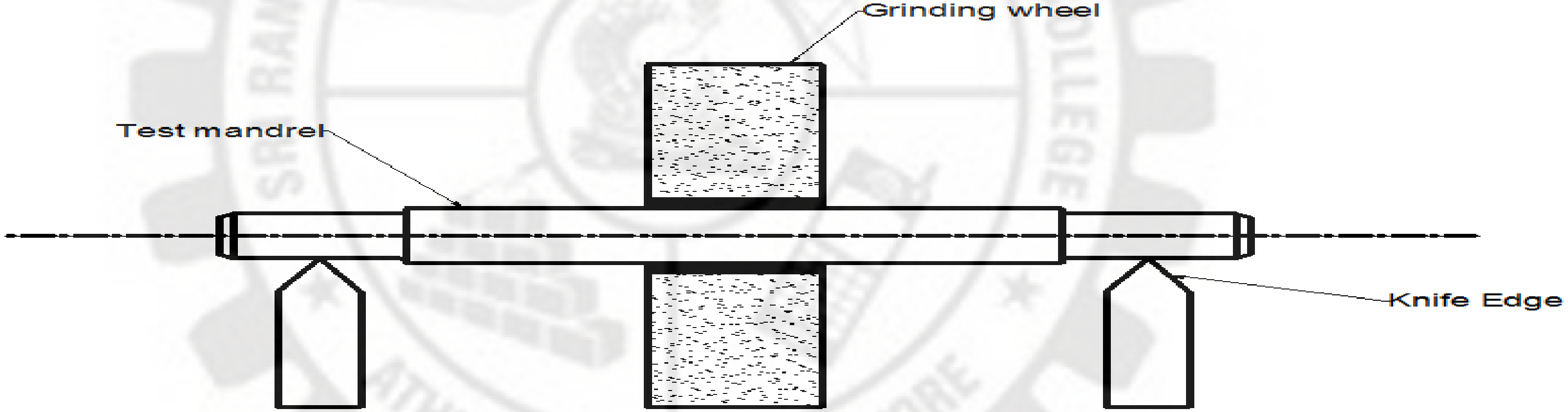


Fig. 4.25. Balancing of grinding wheel

During grinding, the grinding wheel rotates at very high speed. So the weight of the grinding wheel should be evenly distributed throughout the body of the wheel. If it is not distributed uniformly, unbalanced centrifugal force will be developed. It causes to the cracking and breaking of wheel when it rotates with high speed. So, the grinding wheel is balanced by the following ways.

The wheel is fitted to the test mandrel at the middle. The mandrel is placed over the two knife edges. These edges are parallel and placed on truly horizontal plane. The mandrel is slowly rotated to roll over the knife edges. When the wheel comes to rest, a marking is done with paint at the bottom of the wheel. Similarly, the same procedures are done for several times. If the markings arte in various place, then the wheel is in balance. If the markings are at a particular place, then it is considering as unbalanced wheel. For balancing the grinding wheel, the weight at the particular place should be reduced. This is done by removing some lead from the lead bush at this marked place. Again the same procedures are carried out for balancing the wheel correctly.

UNIT II - RECIPROCATING MACHINE TOOLS

Planer, Shaper, slotter are reciprocating type machine tools, used to machine flat surface either horizontal, vertical and inclined surfaces by using single point cutting tool.

Movement	Planer	Shaper	Slotter
Table (Work	Reciprocates	Fixed	Fixed
Tool	Fixed	Reciprocates	Reciprocates
Feed	Given to cutting tool	Given to table	Given to work piece

PLANER MACHINE

Principles of Operation:

- ✓ Metal is cut during forward or cutting stroke.
- ✓ Feed is given at the end of the cutting stroke.
- ✓ During the return stroke no metal is removed and this is called idle stroke.
- ✓ Cutting stroke takes lower speed and return stroke has higher speed.
- ✓ The quick return of the table is obtained by quick return mechanism.

Types of Planer:

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

DOUBLE HOUSING PLANER:

- ❖ This planer is high speed heavy duty machine.
- ❖ It is used to machine large table beds, table key ways, dove tails and sliding surfaces.
- ❖ It is used to machine work piece in both horizontal and vertical directions at the same time.

Parts:

- ➢ Bed
- ➢ Table
- ➢ Columns
- ➢ Cross Rail
- ➢ Tool Heads

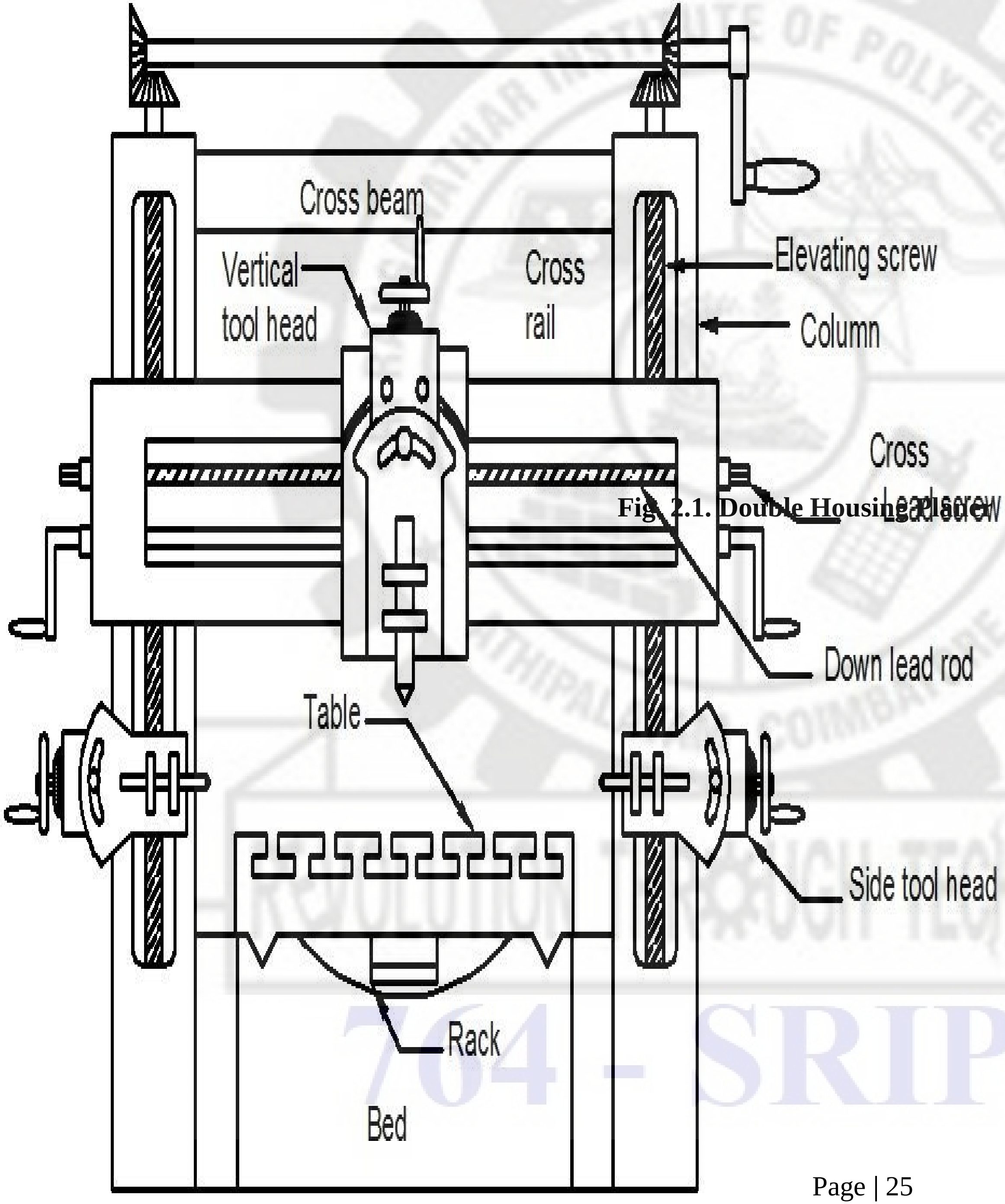


Fig. 2.1. Double Housing Planer

1. **Bed**

- Bed is strong box heavy type casting.
- It is strengthened by cross ribs on top "v" guide ways.
- Table reciprocates on these guide ways.
- It houses driving mechanisms.

2. **Table**

- Table is a box type rectangular casting and it has T-slots on its top.
- It reciprocates over the bed guide ways.
- Work pieces are clamped on the table by using T-bolts and clamps.
- The tip dogs are provided on the sides to adjust the stroke length of the table.

3. **Housing or Column**

- Two columns are mounted on the both sides of the bed.
- Two columns are connected by cross rail at top.
- Vertical guide ways are provided on the column and cross rail slides on it.
- Two side tool heads are slide on it.

- Feed mechanism and power transmission links are housed inside these columns.

4. **Cross rail**

- Cross rail is a horizontal hollow structure.
- It slides up and down vertically on the columns by elevating screw.
- It carries tool feed arrangements.
- Cross rail is clamped at any height.

5. **Tool head**

- Totally four tool heads are in planer.
- Two in cross rail and another two on vertical column.
- They can have operated independently.
- While machining inclined surface, the tool can be tilted to the required angle by tilting the swivel base.

Specifications of a planer:

1. Distance between the two columns
2. Dimensions of the table (l,b,t)
3. Maximum stroke length of table
4. Height from the top of the table of cross rail in its upper position.
5. Net weight of the machine
6. Type of drive
7. Floor area
8. Power of the motor

Planer Quick Return Mechanisms:

To move the planer table faster during the return strike, the following quick return mechanisms are used.

1. Belt drive
2. Electric drive
3. Hydraulic drive

Belt drive:

- This drive is used for smaller planers. An electric motor is used to drive a counter shaft, it is placed under the table.

· The shaft has two larger pulleys of same diameter and one smaller pulley. Open belt is connected to one pulley and cross belt is connected to another pulley.

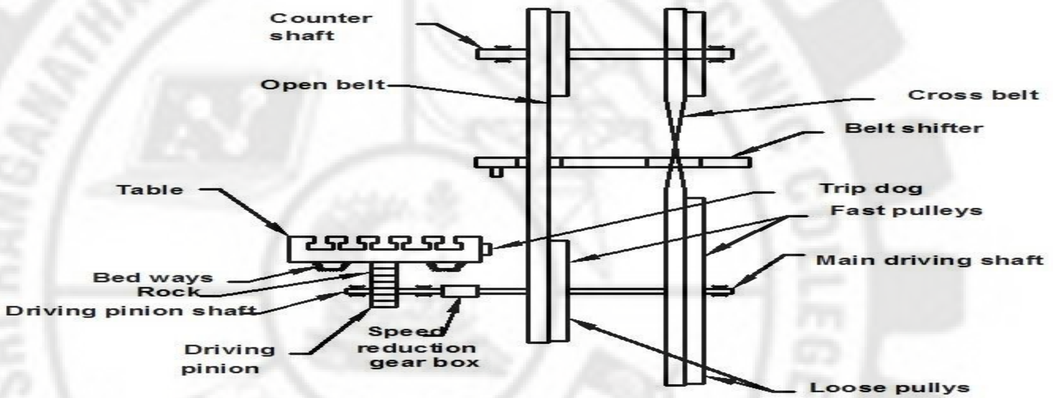


Fig. 2.2 Open & Cross belt drive mechanism

· Driving pinion is fitted to the one end of the shaft. One of the smaller pulley and one larger pulley is keyed to the shaft. They are called as fast pulleys.

· The other two pulleys rotate freely on the shaft. They are called loose pulleys.

· Driving shaft speed can be reduced by using a speed reduction gear box. The driving pinion meshes with the rack provided at the bottom of the table.

· The table reciprocates when the pinion rotates. The position of the open belt and cross belt is changed by a belt shifter.

· During the return stroke, cross belt is connected to the larger loose pulley and open belt is connected to the smaller fast pulleys.

· At the end of the return stroke, the trip dog pushes the belt shifter and both the belts are shifted to the right. Now cross belt connects the larger fast pulley and the open belt connects the smaller loose pulley.

· Next the drive is transmitted to the main shaft through the cross belt on the larger fast pulley. Due to this, the direction of rotation of main shaft is reversed.

· Due to the larger diameter of the pulley, the speed of main shaft is reduced. So, that the table moves slowly during the cutting stroke.

- At the end of the cutting stroke, both the belts are shifted to the previous position by another trip dog. Thus the return stroke and cutting stroke are obtained successively.

Electric drive:

- It is widely used modern method. AC motor is coupled with DC generator. DC generator supply current to variable DC motor.

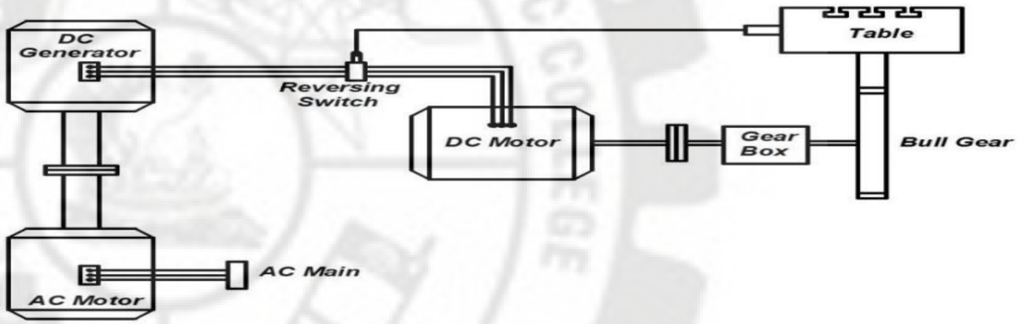


Fig. 2.3. Electric drive mechanism

- Reverse switch is used to change the current direction. DC motor transmit power to bull gear through gear box.
- Bull gear meshed with rack provided on table. Thus the table moves when the bull gear rotates slowly for forward cutting stroke.
- When power supply is given to AC motor, it rotates the DC generator and DC generator supplies current to DC motor. Then the table moves slowly for forward cutting stroke.
- After end of cutting stroke, the trip dog actuate reversing switch and faster return stroke.
- Due to this, DC generator supplies more current in opposite direction. Then DC motor rotates at high speed in opposite direction and table returns at faster speed.

Hydraulic drive:

- The planer table is fitted to piston and it reciprocates with hydraulic oil pressure. Hydraulic oil delivered to cylinder through 4-way valve from pump.

- Trip dogs change the direction of the oil flow in 4-way valve and table is reversed.

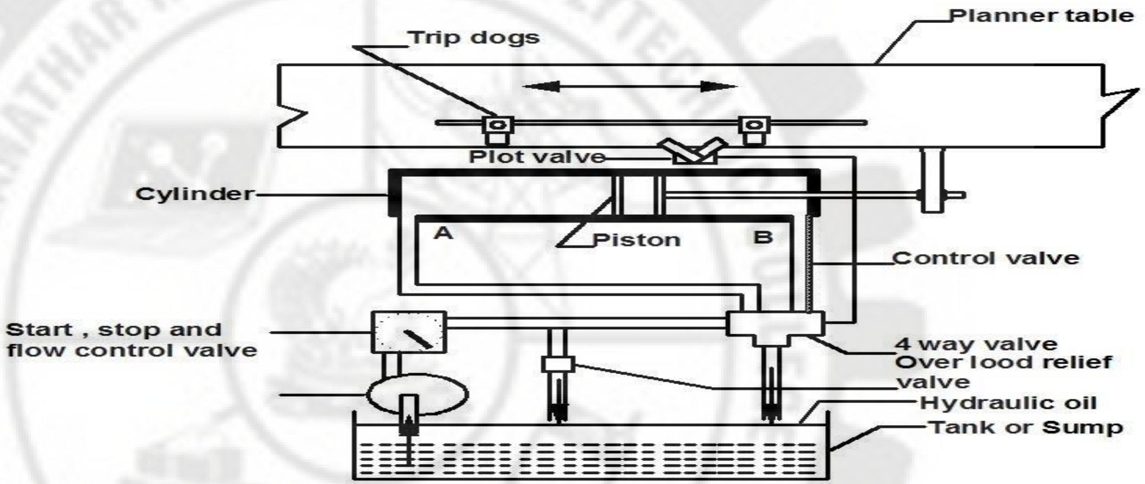


Fig. 2.4. Hydraulic drive mechanism

- During the cutting stroke, the oil enters in to the left side of the cylinder and pushes the piston to move to the right. Now the table moves slowly in forward direction. At the same time, oil in the right side flows to the oil sump through the valve.
- At the end of this stroke, the trip dog actuates the 4 way valve and intensity of pressure will be more compared with the intensity of pressure during forward stroke. Hence the return stroke is occurred at faster rate. Thus the quick return of the table is obtained. The stroke length can be adjusted by adjusting the distance between the trip dogs.

Feed mechanism:

Hand feed:

- The tool is moved in horizontal direction along the cross rail, then the feed is known as cross feed. The cross feed screw is rotated by a handle to move the tool head horizontally.
- The cross feed screw passes through a nut in the back side of the tool head.

- The tool is moved in downward direction is known as down feed. The down feed rod in the cross rail has sliding bevel gear. The bevel gear meshes with another bevel gear attached to the tool slides screw.
- When the down feed rod is rotated by a handle, the tool slide screw rotates and the tool head moves downward to give down feed.

Refer the figure 2.3 for diagram

Automatic feed:

- A vertical splinted shaft is fixed on one side of the planer. A ratchet and pawl mechanism is keyed at the bottom of the shaft. At the end of each stroke, the trip dog hits the strike lever. This lever actuates the pawl plate in both directions.

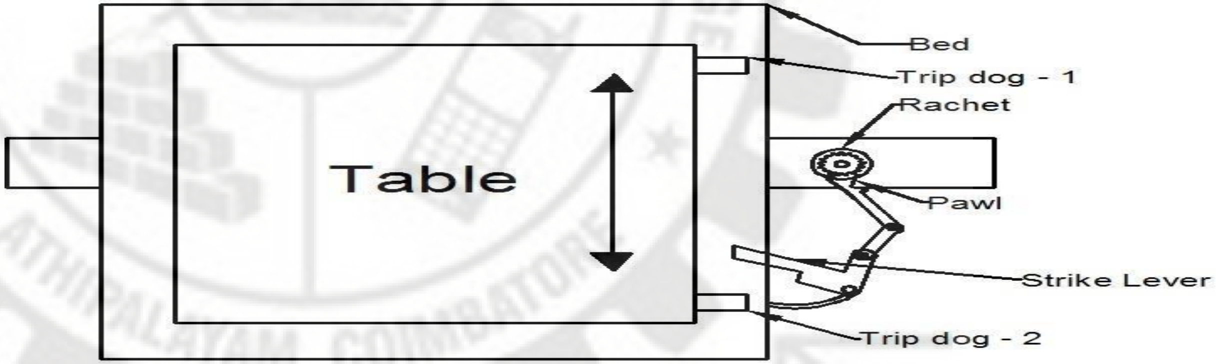


Fig. 2.5 Automatic feed mechanism

- The pawl plate rotates the ratchet when it is actuated in one direction and slips over the ratchet teeth when actuated in another direction. When the ratchet rotates, the splined shafts also rotates.
- There is a spur-bevel integral gear rotates freely on the down feed rod. This bevel gear is meshed with the bevel gear in the splined shaft. Another spur gear is keyed to the cross feed screw meshes with the spur-bevel integral gear.
- The rotation of the splined shaft is transmitted to the cross feed screw through these gears. The cross feed screw passes through a nut attached at the back side of the tool head. So the tool head moves horizontally along the cross rail when the cross feed screw rotates. Thus the automatic cross feed is obtained.

- For giving automatic down feed, the spur gear in the cross feed screw is disengaged by a lever. The spur-bevel integral gear is engaged with the down feed rod by inserting a key.
- Now the rotation of the splined shaft is transmitted to the down feed rod. Thus the automatic down feed is obtained.

Work holding devices:

1. Angle Plate.
2. Stop block.
3. Planer jacks & adjustable screw stop.
4. T bolt & strap clamps for long work pieces.
5. V blocks for cylindrical work pieces.
6.

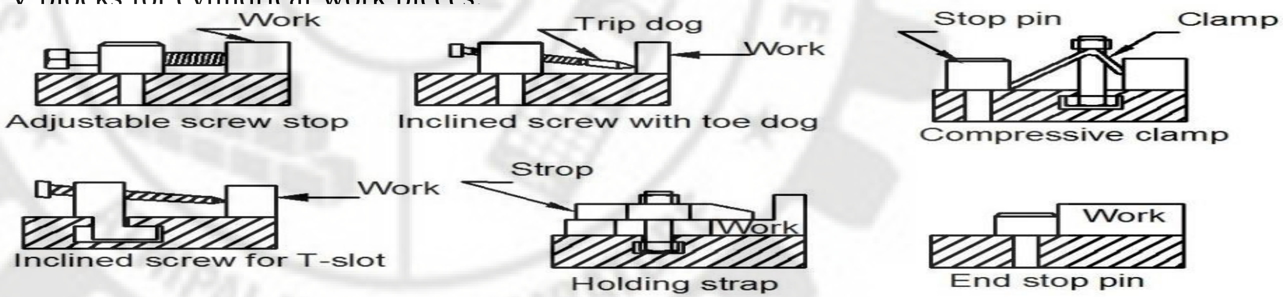


Fig. 2.6. Work holding devices

Setting of work pieces on the planer table requires high skill.

Planning fixtures:

- Planning fixtures are used to clamp the work piece identically.
- The Base of the fixture has two ‘V’ grooves to hold two round rods.
- ‘U’ clamps are inserted in the stand and work piece are clamped by using washer & nut.

Advantages:

- Setting time is reduced
- Production is increased.
- Accurate machining.

Types of tools:

- Single point cutting tool is used.
- For giving heavy cut, the tool must be heavier and larger.

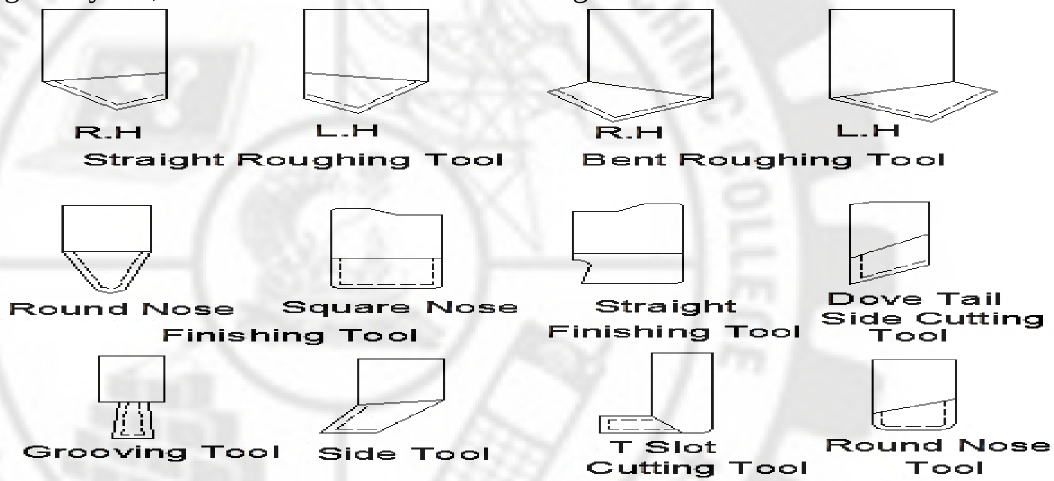


Fig. 2.7. Types of tool

Material:

- Solid
- Forged pit type
- HSS
- Tungsten carbide

Surface	Tool
Horizontal	RH or LH straight tool
Vertical	Bend tool (Down feed is given)
Finishing	Round nose
T slot	T slot cutting tool

Types of Planer operation:

- ✓ Machining Horizontal Surface
- ✓ Machining Vertical Surface
- ✓ Machining Angular Surface
- ✓ Machining 'T' Slots

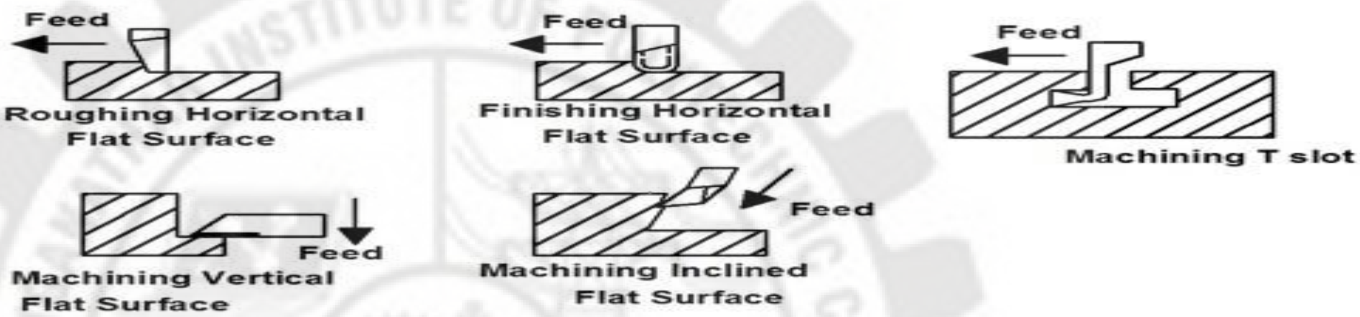


Fig. 2.8. Planer operations

SHAPER

Principle of Operation:

- ✓ It is a reciprocating machine tool used for flat machining.
- ✓ Also used for machining horizontal, vertical and inclined surfaces.
- ✓ Single point cutting tool is used and held in Ram.
- ✓ Ram reciprocates horizontally. Work piece is fixed on table.
- ✓ Metal is remov
- ✓ Metal is cut an

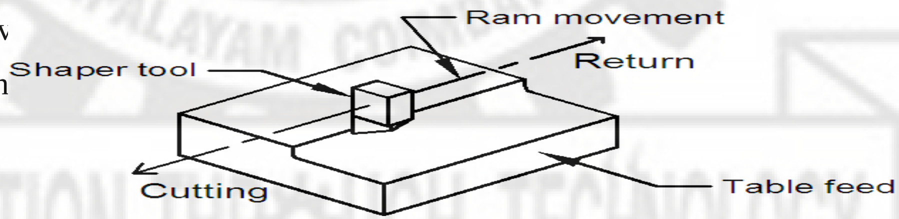


Fig. 2.9. Principle of operation

Types of shaper:

The shapers are classified as follows:

1. According to the type of driving mechanisms

    a) Crack and slotted link drive

    b) White worth mechanism

    c) Hydraulic drive

2. According to the travel of ram

   a) Horizontal shaper

   b) Vertical shaper

3. According to the type of table

   a) Standard or plain shaper

   b) Universal shaper

4. According to the type of cutting

   a) push cut shaper

   b) draw cut shaper

Standard Shaper:

Parts:

Base:

- It is made of CI and takes entire load

Column:

- It is a ho
- It is plac
- Top of th

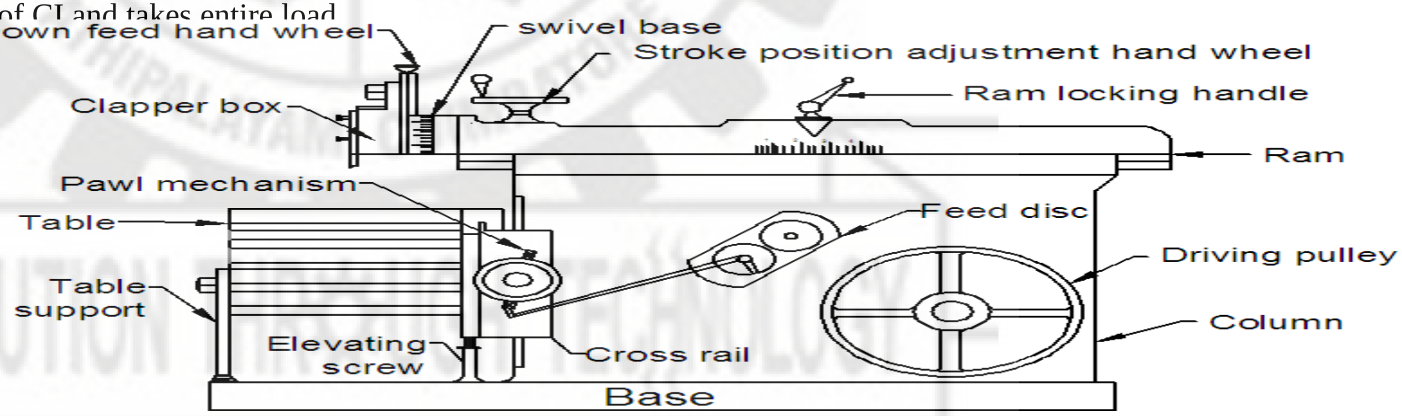


Fig. 2.10. Shaper

Cross rail:

- It is mounted on column.
- Horizontal guide ways are provided and called as saddle.

- The table slides over the saddle.
- The vertical movement of the cross rail elevating screw is provided.

Table:

- It is a rectangular and hollow CI block. It is slides on guide ways.
- It is supported by adjustable table support and it has T slots for clamping work piece.
- Table is moved in horizontally by rotating cross feed screw.
- Table is moved in vertically by rotating elevating screw.

Ram:

- It carries tool head at front end.
- Ram reciprocate along dove tail guide ways on the top of the column.
- It is connected to quick return mechanism.
- The length of the stroke of ram is adjusted by rotating hand wheel on ram.

Tool Head:

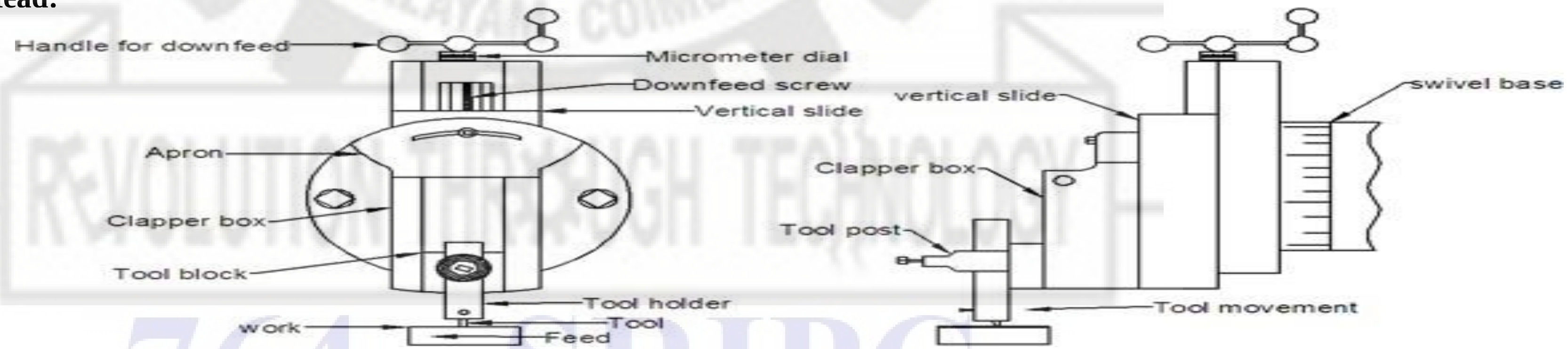


Fig. 2.11 Tool Head

- Apron has a clapper box and tool block is hinged inside in it.

- Tool block holds the tool. During the cutting stroke, the tool block fits rigidly inside the clapper box.
- During the return stroke, the tool block lifts out of the clapper box. This prevents the rubbing of the tool on the job.

Shaper specifications:

1. Maximum length of stroke
2. Maximum crosswise movement of the table
3. Maximum vertical movement of the table
4. Power of the motor
5. Type of driving mechanism
6. Ratio of cutting stroke time to return stroke time
7. Type of shaper – plain or universal
8. Net weight of the shaper
9. Floor space

Quick return mechanism:

- The metal is cut on the work piece in the forward cutting stroke.
- During the return stroke, no metal is cut and it is known as idle stroke.
- To reduce the total machining time, the time taken for the idle stroke must reduce.
- For this the return stroke is made faster than the cutting stroke and it is done by a mechanism called quick return mechanism.

Quick return of the ram can be obtained by the following quick return mechanisms.

1. Crank and slotted link mechanism
2. Whitworth mechanism
3. Hydraulic mechanism

1. Crank and slotted link mechanism:

- An electric motor is used to run the driving pinion at uniform speed and pinion rotates the bull gear at uniform speed.
- Bull gear is a large gear and it is fitted within the column. A slide is fitted along the diameter on the face of the bull gear.

- The bull gear sliding block can slide in the bull gear slide. Its position can be adjusted radially by rotating the stroke adjusting screw. This is done by rotating the bevel gears through a handle from outside.
- A crank pin is fitted to the bull gear sliding block. The rocker arm sliding block is fitted freely over the crank pin. The bottom end of the slotted link or rocker arm is pivoted.
- The upper end of the rocker arm is in the form of a fork. It is freely connected to the ram block by a pin. The slotted link has a slot in length wise. The rocker arm sliding block fits into this slot.
- When the bull gear rotates, the crank pin also rotates. The rocker arm sliding block also rotates on the crank pin circle. At this time, this sliding block slides up and down in the slot of the slotted link (rocker arm).
- It gives an oscillating movement to the rocker arm. It makes the ram to reciprocate.
- When the slotted links is in the position PA, the ram will be at the backward position (at the end of stroke). When the link is at PB, the ram will be at the forward position. PA and PB are tangential to crank pin circle.

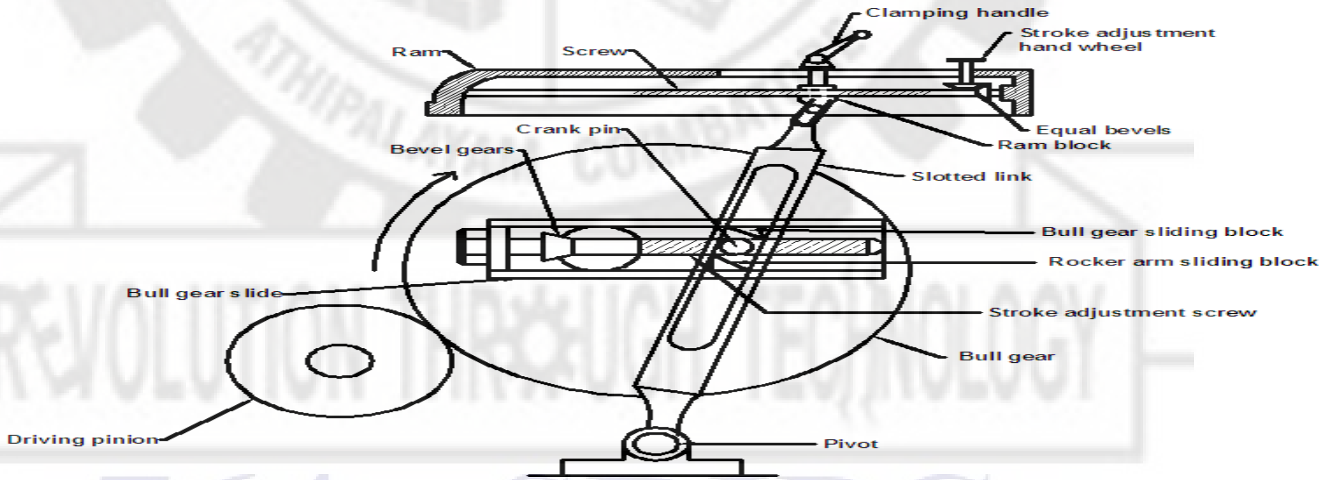


Fig. 2.12. Crank and slotted link mechanism-1

- The forward cutting stroke takes place when the crank pin rotates through the angle C1KC2. The return stroke takes place when the crank pin rotates through the angle C2LC1. Angle C1KC2 is larger than angle C2LC1. The speed of the bull gear is uniform. The length of stroke during forward stroke and return stroke are the same. So the return stroke will take a shorter time.

$$\frac{Cutting\,time}{Return\,time} = \frac{\angle C1\,KC2}{\angle C2\,LC1}$$

The ratio varies from 2:1 to 3:2

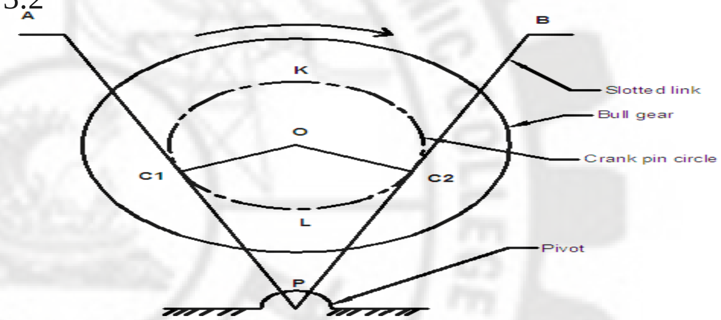


Fig. 2.13. Crank and slotted link mechanism-2

- Cutting speed is not uniform throughout the stroke length. It is minimum at the beginning and at the end of the stroke. It is maximum at the middle of the stroke.

For adjusting the Stroke position:

- The clamping handle on the ram is loosened first. The screw inside the ram will be rotated the stroking position adjustment handle.
- Now the ram moves forward or backward. After adjusting the position of ram, the clamping handle is tightened.

2. Whitworth Quick return mechanism

- An electric motor turns the driving gear at uniform speed and this gear rotates the bull gear at uniform speed.
- The driving pin (D) is fixed on the face of the bull gear. The driving pin fits into the slot in the driving crank. It rotates about the center of the bull gear 'O' and same time it slides along the slot of the driving crank.

- Due to this, the driving crank to rotate about its center P. When the pin D is at A, the ram is at its extreme backward position. When the bull gear rotates (anti clockwise) the pin travels through and angle α and reaches point B.

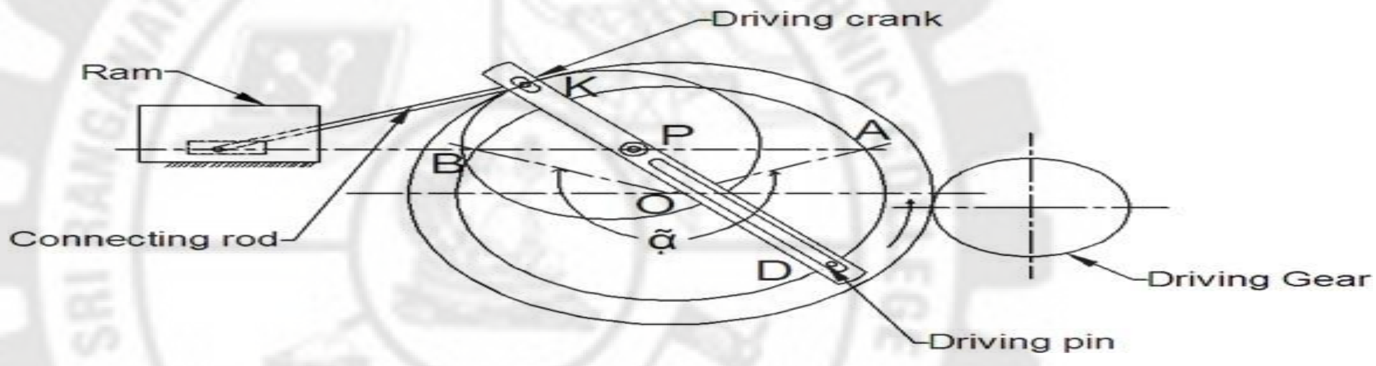


Fig. 2.14. Whitworth Quick return mechanism

- When D is at B, the ram is at its extreme forward position. So the cutting stroke takes place when the crank pin D moves through an angle α from B to A (anti clockwise) through an angle BKA, the return stroke takes place. The angle BKA is smaller than angle α. The speed of the bull gear is uniform.
- Hence the return stroke taking place through a smaller angle BKA will take shorter time.

3. Hydraulic drive

- A hydraulic cylinder is placed inside the hollow ram of the shaper. The cylinder is stationary. A piston moves inside the cylinder. It is connected to the ram by a piston rod.
- When piston moves inside the cylinder, the ram also moves. A gear pump pumps the oil from the reservoir at a constant rate. The oil passes through the 4-way control valve and enters the cylinder at side A.
- Because of the oil pressure, the piston moves forward. Cutting stroke takes place. The oil in the right side of the piston in the cylinder is pushed outside through B. It passes through the 4-way valve and reaches reservoir through the pipe C.

- The trip dog attached to the bottom of the ram shifts the valve lever from position P1. At the end of the forward stroke, the valve lever reaches position P2. Now the 4way valve allows the oil from the pump to enter the cylinder from the side B.

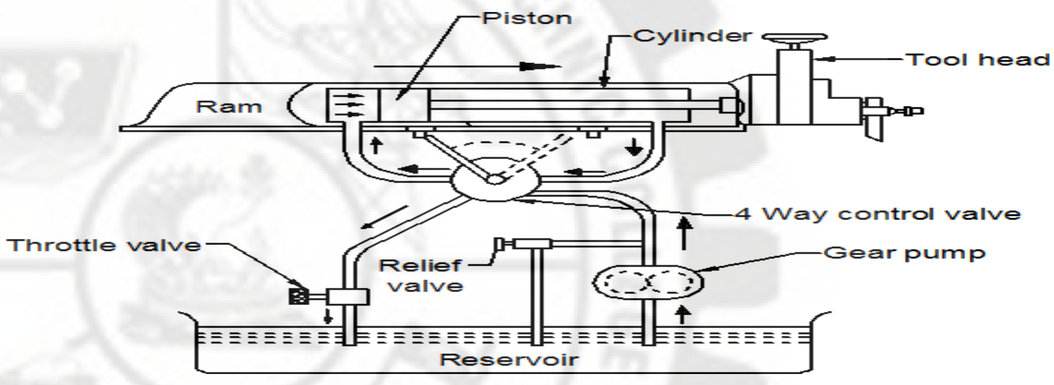


Fig. 2.15. Hydraulic drive

- The oil pressure pushes the piston backward. The ram completes its return stroke. The oil at the lift side of the piston is let out through A. It passes through the 4-way valve and reaches the reservoir through the pipe C. During the return stroke another trip dog shifts the valve lever from position P2 to P1. The cycle is repeated.

Feed mechanism:

In shaper, the feed is given at the end of return stroke. Cross feed is given by hand or automatically. For machining vertical and inclined surfaces, the down feed is given to the tool head by rotating the down feed screw by hand.

1. **Hand feed**

- When the table is moved horizontally in a direction perpendicular to the ram movement, it is called as cross feed. Cross feed can be given by rotating the cross feed screw with a handle. This screw passes through a nut fitted at the back side of the table.
- The table is adjusted vertically to hold work pieces of various heights. A horizontal rod with a bevel gear is meshed with the bevel gear in the elevating screw.

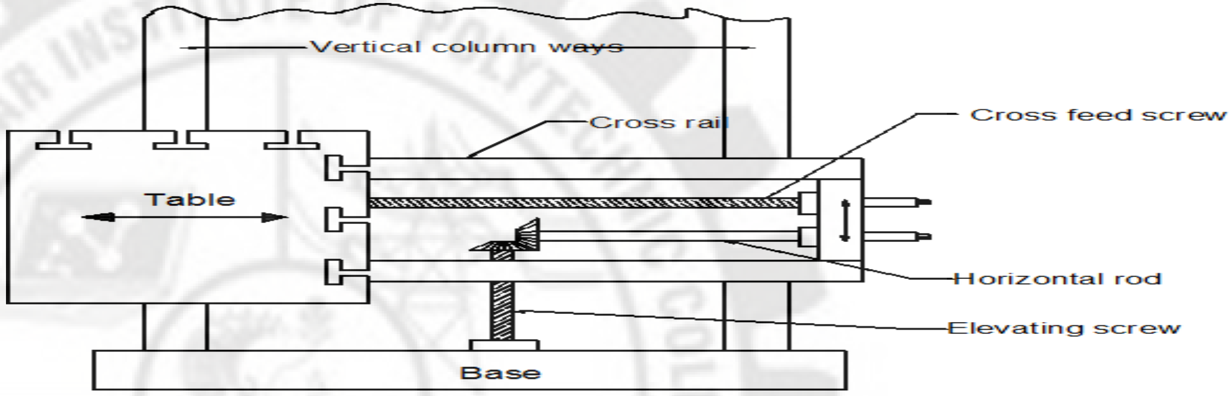


Fig. 2.16. Hand feed mechanism

- The table is moved by rotating the elevating screw through the horizontal rod. The downward movement of the tool is called down feed. Down feed is given to the tool side in the tool head by rotating the down feed screw by hand.

2. Automatic table feed

- The automatic feed mechanism used in the shaper is shown in the figure. A ratchet is keyed to the end of the cross feed screw. The rocker arm is provided at the centre of ratchet. The rocker arm has a spring loaded pawl on its top.
- One side of the pawl is straight and another side is slant. The bottom of the rocker arm is connected to a feed disc through a connecting rod. The feed disc gets drive from the bull gear.
- The feed disc has T-slots along its diameter. A crank pin fits in to this slot. The end of the connecting rod is fitted to the crank pin. When the bull gear rotates the feed disc also rotate. Now the rocker arm oscillates about the centre of the ratchet through the connecting rod.
- When the feed disc rotates half revolution in clock wise direction. The upper part of the rocker arm moves in clockwise direction. The straight side of the pawl fits in to the ratchet teeth and turns the ratchet in anti-clockwise direction.
- Now the ratchet rotates the feed screw. The table connected with feed screw horizontally. This feed is given to the table during return stroke only.

- To change the direction of table movement, the pawl pin is fitted up and turned through 180° and then seated back. As the straight side of the pawl is in opposite direction. This will rotate in opposite direction

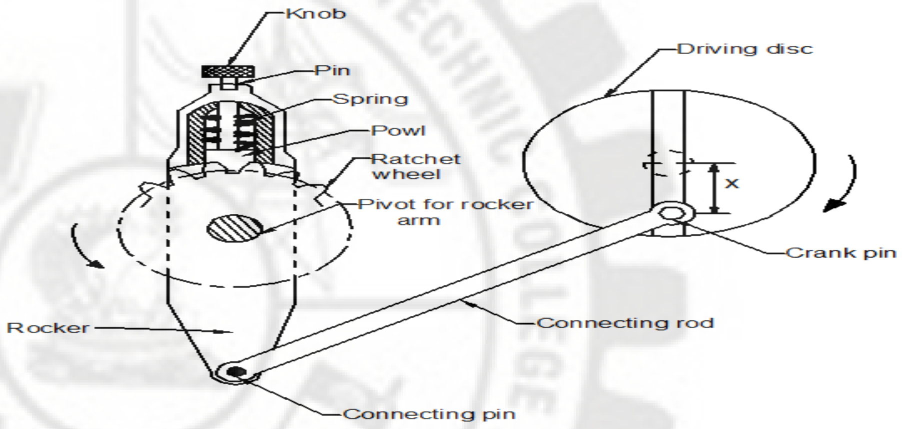


Fig. 2.17. Automatic feed mechanism

- This will rotate the feed screw in opposite direction. So the table movement is reversed. The amount of cross feed can be changed by changing the position of crank pin from the centre of feed disc in radial direction.

Work holding devices

The selection of work holding devices depends upon the type of operation, shape and size of the work piece. The following methods are used in a shaper clamp the work piece firmly.

1. Clamping in a vice
2. Clamping directly on the table
3. Clamping on an angle plate
4. Clamping over a V-block
5. Fixture

1. Clamping in vice:

- The vice is fitted on the table by means of T-bolts and nuts. The work piece is held in between the fixed and movable jaw.

- The work piece is clamped by tightening the screw. A graduated swivel base is provided in the bottom. The body of the vice can be swiveled to required angle. Vice is used to hold regular shaped work pieces quickly and easily.

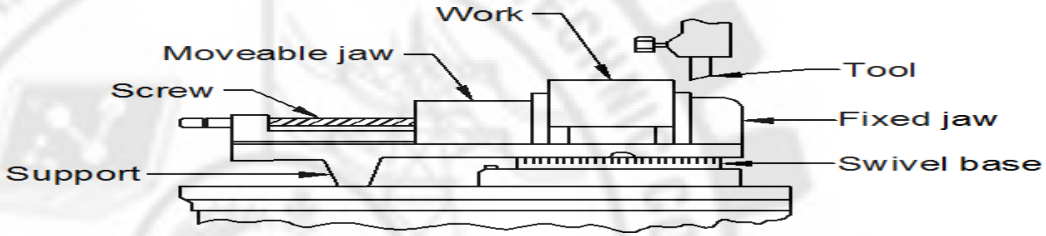


Fig. 2.18. Clamping in Vice

2. Clamping directly on the table - a) Using T-bolt and strap clamp

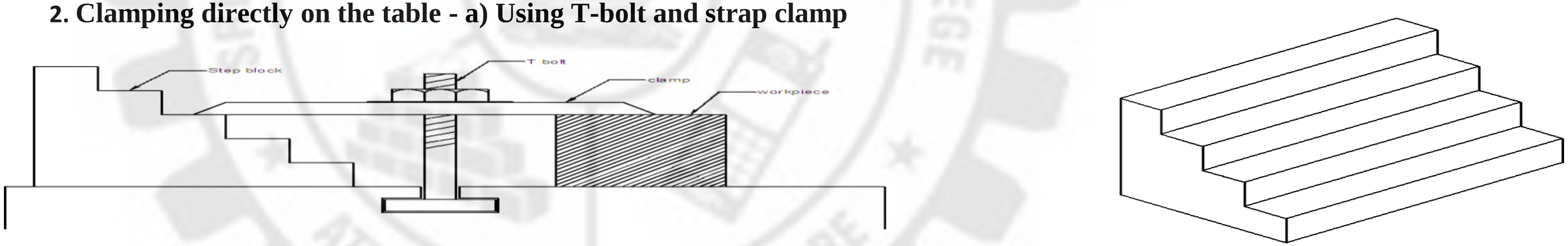


Fig. 2.19. Using T-bolt and strap clamp

- T-bolts are inserted in to the T-slot on the table. A strap clamp with a hole at its centre is inserted in to the bolt. One end of the clamp is made to rest on the Work piece and another end is on the step block. The work piece is clamped by tightening a nut on the bolt. Two or more T-bolt and clamps are used for clamping large work pieces.

b) Using wedge strip and stop pin

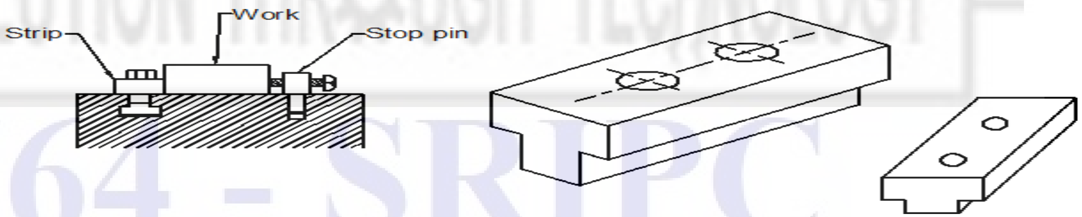


Fig. 2.20. Using wedge strip and stop pin

- This method is used for clamping large work pieces. A wedge strip has a long bar with tongue at its bottom and number of holes on its top. The tongue fits in to the T-slot of the table.
- The strip is tightened with the table by inserting T-bolts on the hole. The work piece is made to touch against the strip. A wedge block is placed on the other side of the work piece. Stop pin screws are tightened to clamp the work piece. A filler block is placed between the wedge block and stop pin to avoid the slipping of wedge block.

3. Clamping on an angle plate

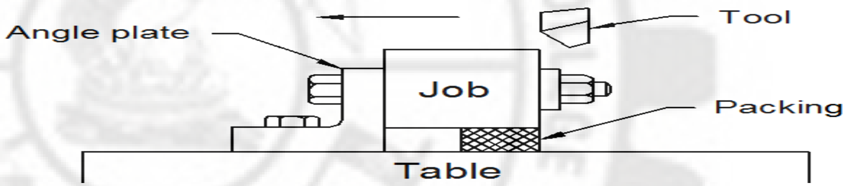


Fig. 2.21. Clamping on an angle plate

- This method is used for holding irregular shaped work pieces having holes. The angle plate is bolted to the vertical face of the angle plate by using bolts and nuts. Packing strips may be used for supporting the work piece at the bottom.

4. Clamping over a 'V' block

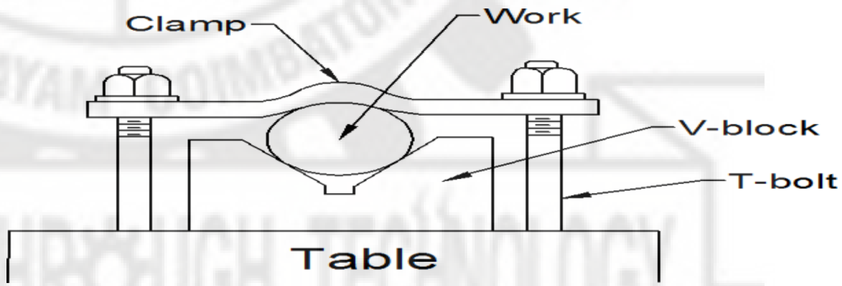


Fig. 2.22. Clamping over a 'V' block

- 'V' block is suitable for holding small cylindrical work pieces. The work pieces are held on the 'V' block and 'V' clamp is placed over it. The clamp is tightened by T-bolts and nuts for clamping the work piece firmly.

5. Fixture

- Fixture is a device used for clamping the work pieces easily and quickly. This reduces the setting time. As the work piece is exactly located, the machining can be done accurately. The productivity is considerably increased by using fixture in mass production.

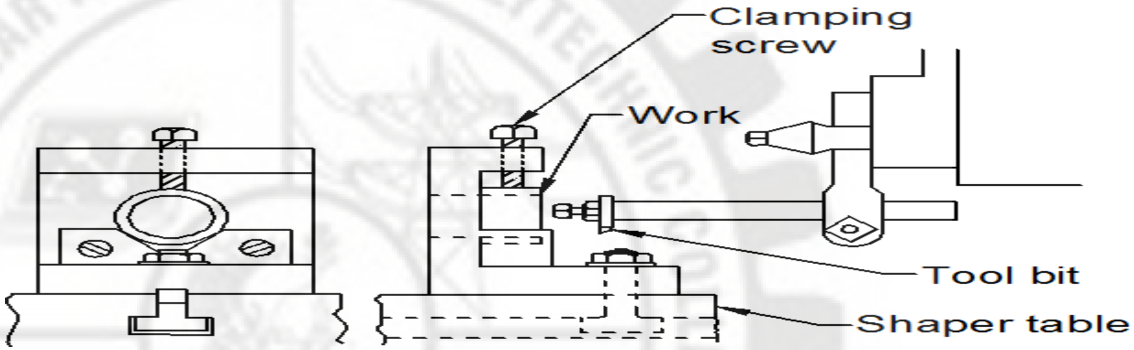


Fig. 2.23. Shaping Fixture

Types of shaping tools:

Single point cutting tools made of HSS or forged steel are used in shaper. The shaper tools are made heavier to withstand cutting forces and shock load. The shaper tools are classified as follows:

1. According to the shape
   Straight tool, cranked tool, goose necked tool
2. According to the movement of tool Left hand tool, right hand tool
3. According to the required surface finish
   Roughing tool, finishing tool
4. According to the type of operation
   Down cutting tool, parting off tool, side tool, squaring tool.
5. According to the shape of cutting edge Round nose tool, square nose tool

Shaping operation:

The various shaping operation done on a shaper are explained below.

1. Machining horizontal surface

- The work piece is held on the table by suitable work holding device. The table is moved vertically to a required height. The tool head is prevents the tool from rubbing over the machined surface of work piece during return stroke

- The stroke length is adjusted so that it will be 20mm longer than the work piece. The stroke position is adjusted so that the tool will have an approach of 12mm and an over travel of 8mm. the cutting aped and feed are selected suitably. Down feed is given by the rotating the down feed screw. The table is moved horizontally by the cross feed screw. Thus machining is done on the horizontal surface of the work piece.

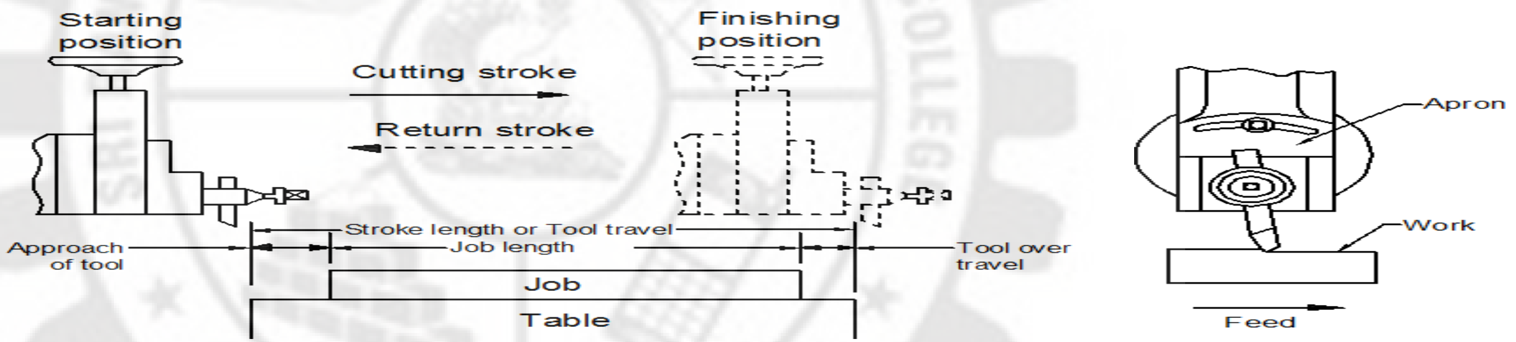


Fig. 2.24. Machining horizontal surface

2. Machining vertical surface

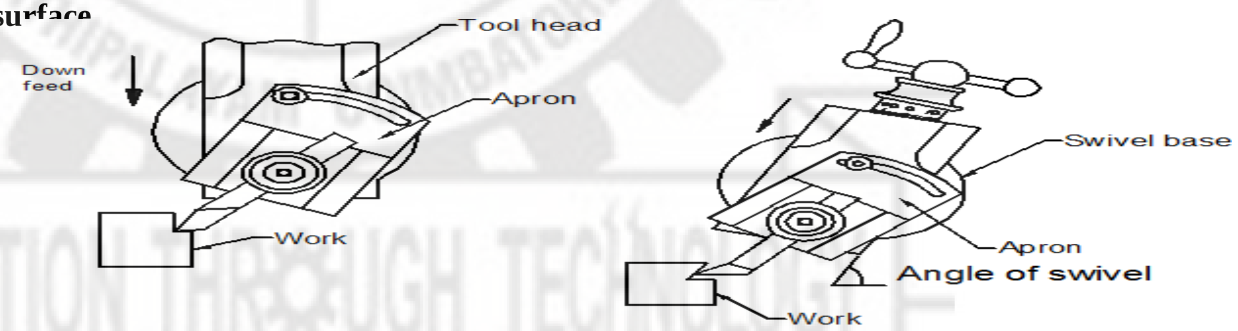


Fig. 2.25. Machining vertical surface and Machining angular surface

- The work piece is held on the table by suitable work holding device. The vertical surface to be machined is set parallel with the ram axis. A side cutting tool is fitted in the tool post with slight inclination. The apron is tilted so that it will be away from the surface to be machined.

- This prevents the tool from rubbing on the machined surface during return stroke. The cutting speed and feed are selected suitably. The depth of cut is given by moving the table horizontally. Feed is given to the tool by rotating down feed screw. Thus machining is done on the vertical surface of the work piece.

3. **Machining angular surface**
   - The work piece is held on the table by suitable work holding device. The vertical surface of the work piece is set parallel with the ram axis. The vertical slide in the tool head is swiveled to the required angle. The apron is tilted so that it will be away from the surface o be machined. The cutting speed and feed are selected suitably. The depth of cut given by moving the table horizontally. Angular down feed is given to the tool by rotating the down feed screw.
   - Dove tail and ‘V’ block can be made by angular machining. To make a dove tail, the vertical slide is tilted to the required angle and angular machining is done on the side. Then the vertical slide is tilted to the same angle on the other side and angular machining is done on that side.

Machining key ways, grooves and slots:

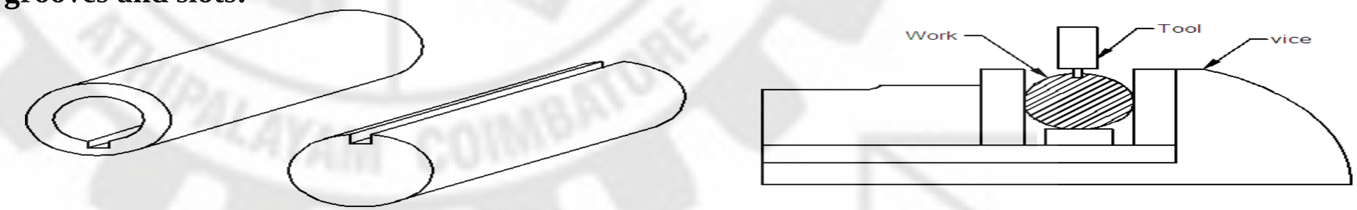


Fig. 2.26. Machining key ways, grooves and slots

- The square nose tool is used for cutting key way and slots. The arrangement for cutting key way piece is held on the table by suitable work holding device. Holes should be drilled at the ends of the key way required depth before machining.
- The stroke length and position are adjusted correctly. The machining is done at a slow speed. For cutting internal keyway, the tool is fitted in a special tool holder as shown in the figure.

Cutting speed:

Cutting speed is defined as the velocity at which the metal removed by the tool from the work piece. It is expressed in m/min.

Cutting speed = length of cutting stroke/ time taken for cutting = N x L (1+m)/1000 (m/min)

Where, N=Speed of bull gear (rpm) L= Stroke length (mm) M= Ratio between return time and cutting time (2/3 or ½)

Feed:

It is the relative movement of the tool or work piece in a direction perpendicular to the ram movement. It is expressed in mm/stroke. The feed is given at the end of the return stroke.

Depth of cut:

It is the thickness of metal removed in one stroke. It is expressed in mm. the depth of cut will be more for roughing operation and less for finishing operation.

Comparison of shaper and planer:

S#	Shaper	Planer
1.	Suitable for small and medium size work pieces.	Suitable for large and heavy work pieces.
2.	Tool reciprocates. Work piece is stationary.	Work piece reciprocates. Tool is stationary.
3.	Cross feed is given by moving the table.	Cross feed is given by moving the tool head.
4.	The machining accuracy is less due to the overhanging of ram.	The machining accuracy is more as the machine is grid.
5.	Heavy cut cannot be given.	Heavy cut can be given.
6.	Machining takes longer time as only one tool is used.	Machining can be done quickly as two or more tools are used.
7.	Only one work piece can be machined at a time.	Number of work piece can be machined at a time.
8.	Work piece can be clamped easily.	High skill is required for clamping the work piece.
9.	Heavy tool is not required.	Heavy tool is required.
10.	The cutting speed is not uniform throughout the stroke length.	The cutting speed is uniform throughout the stroke length.
11.	The cost of the machine is less.	The cost of the machine is more.
12.	Less floor space is sufficient.	More floor space is required.

SLOTTER:

Slotter:

1. **Base:**

It is a heavy casting made of cast iron. It supports all other parts of the slotter. Horizontal guide ways are provided on the base perpendicular to the column.

2. **Column:**

It is a hollow casting made integral with the base. The driving mechanism is placed inside the column. It has vertical guide ways on its front face

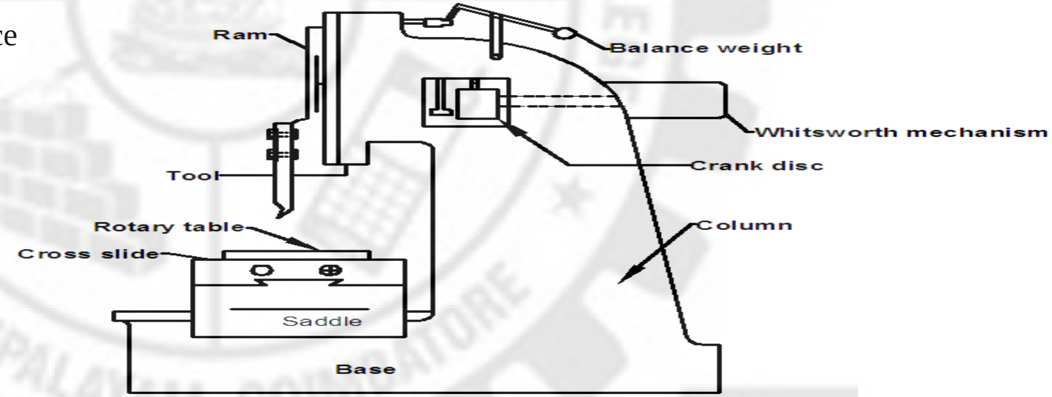


Fig. 2.27. Slotter

3. **Saddle:**

The saddle moves towards or away from the column along the guide ways provided on the base. The top face of saddle has guide ways perpendicular to the guide ways on the base. A cross slide moves crosswise along these guide ways.

4. **Rotary table:**

A circular rotary table is mounted on the top of the cross slide. It can be rotated about a vertical axis parallel with the column. The top of the table has T- slots for fitting the work holding device. The bottom of the table is graduated in degrees.

5. **Ram and tool head:**

The ram reciprocates along the guide ways provided on the face of the column. The ram has a tool head. The cutting tool is fitted in the tool head.

Specification of a slotter:

1. Maximum length of stroke
2. Diameter of circular table
3. The maximum crosswise and longitudinal movement of the table.
4. Type of drive.
5. Net weight of slotter
6. Power of the motor
7. Floor area

Method of operation:

Vertical and curved surfaces are machined by using slotter. Grooves and key ways can also be cut. A single point cutting tool is fitted in the tool head. The work piece is held on the table by suitable work holding device. The required stroke length I adjusted correctly. Metal is removed when the cutting tool reciprocates up and down against the work piece. The feed is given crosswise or in a circular path.

The metal is cut only in the cutting stroke (down ward movement of ram). Cross feed is given at the beginning of cutting stroke. During the return stroke (upward movement of ram), no metal is removed. Hence it is called idle stroke. Therefore, cutting stroke takes place at a slower speed and the return stroke takes place at faster speed. The quick return of the ram is obtained by a quick return mechanism. Various types of quick return mechanisms are used in slotter.

Quick return mechanism

In slotter, the rotary motion of the electric motor will be converted in to reciprocating motion of the ram. Moreover, the return stroke will be faster than the cutting stroke. This is done by any one of the following quick return mechanisms.

1. White worth quick return mechanism
2. Variable speed reversible electric motor drive
3. Hydraulic drive

Whit worth quick return mechanism:

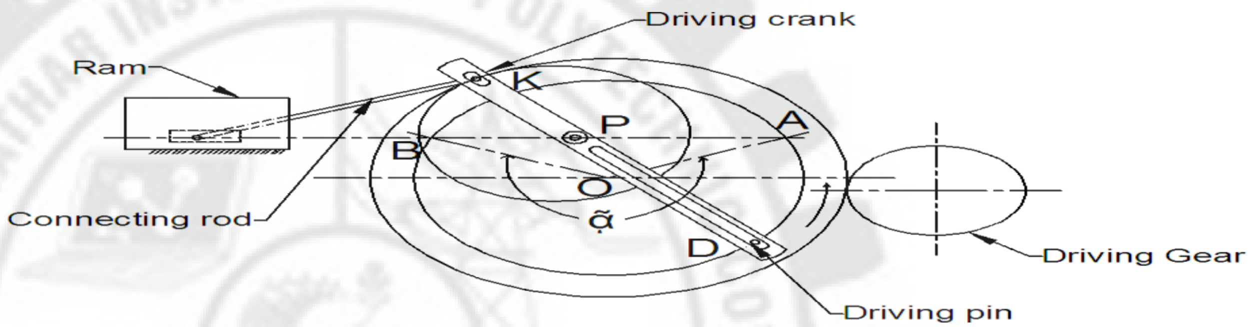


Fig. 2.28. Whit worth quick return mechanism - Slotter

The whit worth quick return mechanism generally used in slotter is shown in figure. An electric motor drives a pinion at constant speed. The pinion drives a bull gear at uniform speed. The bull gear has a crank pin fitted with a sliding block.

A crank plate is pivoted eccentrically on the bull gear at the point O by a pin. The crank plate has a slot along its length. The crank pin with sliding block slides along the slot of the crank plate. The other end of the crank plate is corrected to a connecting rod through a pin P. the ram is fitted to this connecting rod.

When the bull gear rotates, the crank pin rotates about its centre. At the same time, the sliding block slides along the slot of the crank plate. This makes the crank plate to rotate about the point O. thus the rotary motion of the crank plate is converted into the reciprocating motion of the ram to the connecting rod.

Quick return motion

In the figure, C1 and C2 represent those two extreme positions of crank pin with sliding block. During the cutting stroke, the crank pin rotates fromC1 to C2 in anti-clockwise direction through an angleØ1. During the return stroke, the crank pin rotates from C2 to C1 in anti-clockwise direction through an angle Ø2. The speed of the bull gear and the length of stroke during both the strokes are the same. Referring the figure, angle Ø2 is less than angle Ø1. So the time taken for the return stroke is less. Hence the ram moves faster during return stroke.

Feed mechanism

In slotter, the feed is given at the end of cutting stroke. The following feed movements can be given in a slotter.

1. Longitudinal feed: it is given by moving the saddle towards or away from the column.
2. Cross feed: it is given by moving the cross slide parallel to the face of the column.
3. Circular feed: it is obtained by rotating the table about a vertical axis parallel to the column. The feed may be given by hand or automatic.

Automatic feed mechanism

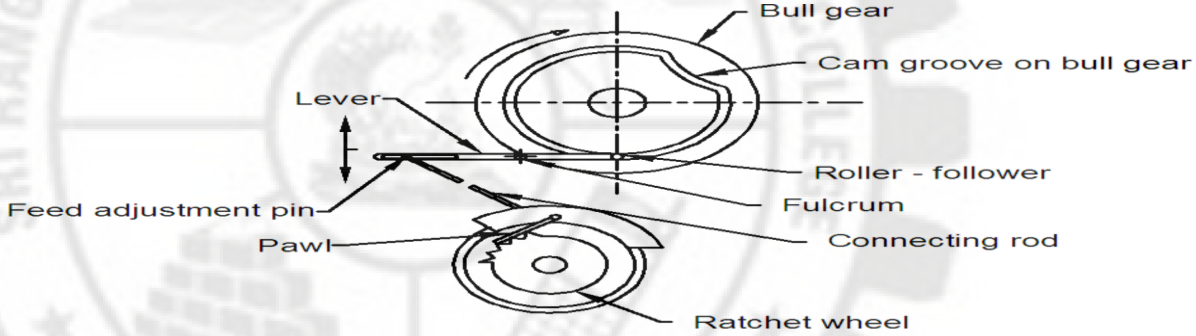


Fig. 2.29. Automatic feed mechanism

The auto feed mechanism used in the slotter is shown in the figure. A cam groove with lobe is cut on the face of the bull gear. A roller follower slides in this groove. The roller is fixed to a lever. The lever is pivoted at the middle. The other end of the lever has a slot. A feed adjustment pin is fitted in the slot. This pin is connected to the feed disc through a connecting rod.

The feed disc has a pawl on its face. The disc has a pawl on its face. The disc rotates freely on the feed shaft. A ratchet driven by the pawl is keyed to the feed disc. When the bull gear rotates, the roller follows the cam grooves. When the lope portion of the groove passes the roller, the lever moves up and down. This makes the connecting rod to rotate the feed disc in both directions.

When the feed disc rotates in anticlockwise direction, the pawl rotates the ratchet wheel. Hence the feed shaft rotates. When the feed disc rotates in clockwise direction, the pawl slips over the teeth of ratchet. Now the feed shaft will not rotate. The feed shaft can be engaged with required feed screw to obtain longitudinal, cross or circular feed. The amount of feed can be changed by adjusting the position the feed adjustment pin in the lever slot.

Work holding devices

The work holding devices used in shaper can be used in slotter. The work piece can be held on the slotter table by using vice, T-bo

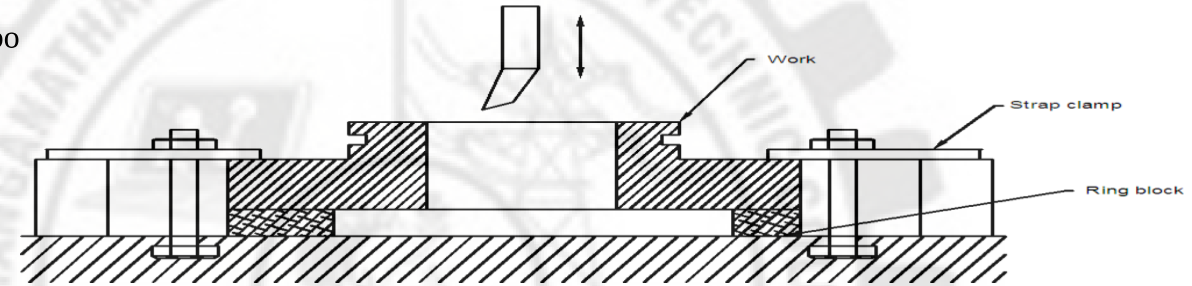


Fig. 2.30. Work holding by using T-bolt and clamp

The arrangement for holding a cylindrical work piece by using T-bolt and clamp is shown in the figure. Ring blocks of sufficient height is provided under the work piece for the over travel of the tool. The upper end of the work piece is clamped by using T-bolt and strap clamp. The centre of the work piece should be aligned with the axis of the rotary table.

Slotting fixtures:

A fixture used for cutting internal key way in a gear blank is shown in the figure. The gear blank is located by cylindrical locater. The cylindrical locater is correctly located by a pin provided at the centre of the travel. Thus the centre of the work piece is aligned with axis of the table. T- bolts and clamping plate are used for clamping the work piece.

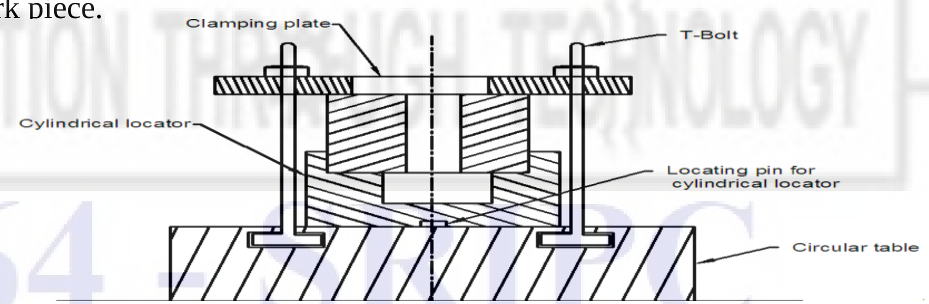


Fig. 2.31. Slotting fixtures

Slotter tools

The slotter tool is fitted vertically. The cutting forces act along the length of the tool. So the tool should have thick cross section.

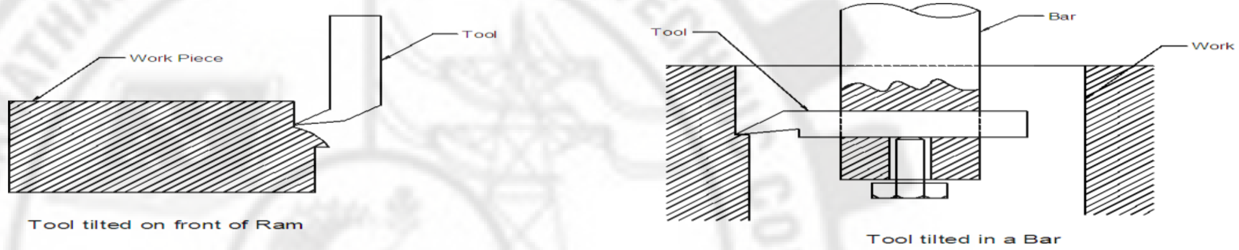


Fig. 2.32. Slotter tools

The tool is provided with front clearance angle, top rake angle and side clearance angle. No side rake angle is given. The nose of the tool is slightly bent away from the shank to give clearance during cutting. Forged type tools are generally used in slotter. The tool with slant cutting edge can be fitted directly in the ram. A straight tool holding bar is also used in slotter.

Slotter operations

The various operations performed in a slotter are explained below.

1. **Machining flat surface**

Ring block of sufficient height is provided for the over travel of the tool.

The work piece is held on the ring block and clamped by using suitable work holding device. The tool is fitted in the ram. The stroke length is adjusted according to the height of the work piece. Suitable cutting speed and feed are selected. Rotating movement of the table is locked. The depth of cut is given by moving the saddle. Feed is given by moving the cross slide parallel to the column. Thus machining is done on the vertical flat surface of the work piece.

2. **Machining grooves and keyways**

The key way to be machined is marked on the work piece. Ring block of sufficient height is provided on the table. The work piece is held on the ring block and clamped by using suitable work holding devices. The centre of the work piece is aligned in line with the centre of the travel. The tool having the width equal to the width of key way is fitted in the ram. The cutting speed, feed and length of stroke are suitably adjusted.

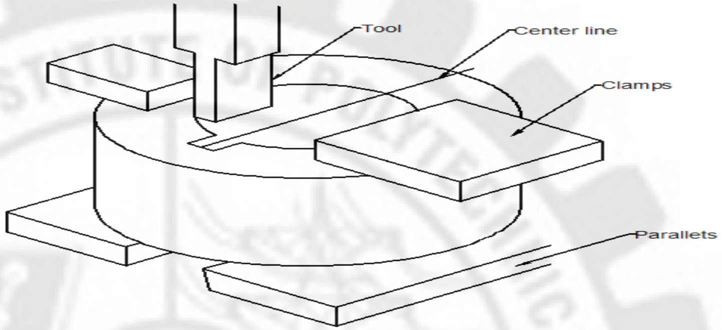


Fig. 2.33. Machining grooves and keyways

The key way and grooves of required length is cut by moving the cross slide. Number of key ways with regular intervals can be cut by indexing the circular table to required angle. Spindle shaft and spindle hole can be produced by this method.

3. Machining curved surface

The work piece is held on the circular table. The centre of the curved surface to be machined is aligned with the centre of the table. The depth of cut is given by moving the saddle. Then the movement of the saddle and cross slide is locked. The curved surface is machined by giving feed to the table.

BROACHING

It is a process of removing metal from a work piece using broach tool has multiple cutting edges arranged along its length. The broach tool has successively higher cutting edges in a fixed path and each tooth removes a particular amount of metal. The work piece is completed in one stroke of the machine. The metal removal rate is less in this operation. Broaching operation is suitable for machining external and internal surfaces.

SPECIFICATION OF A BROACHING MACHINE:

1. Maximum stroke length
2. Maximum force developed by the slide in Tons.
3. Type of drive for the straight line motion
4. Power of the motor
5. Weight of the machine
6. Floor space required

ADVANTAGES OF BROACHING:

- Roughing, Semi finishing and finishing cuts are completed in one pass of the broach.
- External and internal surface can be machined
- Suitable for mass production
- Semi-skilled operator can operate this machine
- Loading and unloading can be done very fatly.

LIMITATION OF BRIACHING:

- Initial cost if the tool is high.
- Broach tool is not suitable for removing large amount of metal.
- Not suitable for producing blind holes.
- Fixture is required for holding the work pieces.
- Not suitable for batch production.

TYPE OF BROACHING MACHINE:

1. According to the cutting motion
   a) Horizontal broaching b) Vertical and continuous broaching
2. According to the purpose
   a) Internal surface broaching b)External surface broaching
3. According to the method of operation
   a) Pull broaching b) Push broaching
4. According to the method of operation
   a) Solid broach b) Inserted c) Progressive cut
5. According to the function
   a) Key way broaching b) Spline broaching c) Surface broaching
6. According to the number of main spindle
   a) Single b) Double or multiple slides.

HORIZONTAL BROACHING MACHINE:

BED: The type of machine has box type bed. The length of the bed is twice the length of stroke. Driving mechanisms are housed inside the bed.

Adopter:

Adopter is used for holding the work piece in the machine. Adopter is fitted at the front face of the machine.

Pulling head:

Pulling head is fitted in the front end of the ram.

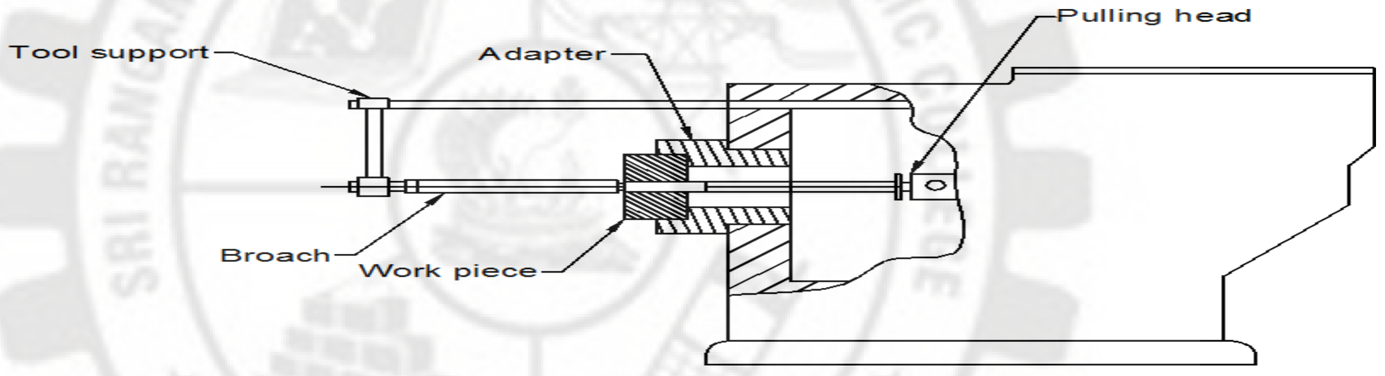


Fig. 2.34. Horizontal Broaching Machine

Ram:

- This part is connected with any one type of driving mechanism and reciprocates for machining.
- The rear end of the broach is supported by a guide. The broach is moved along the guide ways. Automatic stops are provided in this machine for controlling the length of the stroke of ram.
- Horizontal type internal broaching machine is used for small and medium sized works. This machine can be used for machining key ways, Splines, serrations and internal gears.

Horizontal type surface broaching machine:

In this type of machine, the broach is pulled over the top surface of the work piece held in the fixture on the worktable. The broaches are always connected in the draw head while doing surface broaching operation. The cutting speed of this machine is from 3 to 12 rpm and the return speed is upto 30 rpm.

VERTICAL BROACHING MACHINE:

The different types of vertical broaching machines are given below.

1. Pull type
2. Pull down type
3. Pull down type

1. Push down type vertical broaching machine:

This type of machine is used for surface broaching operation. It has a box shaped column, slide and drive mechanism. Broaching tool is mounted on slide which is on the column guide ways. A Hydraulic driving mechanism is used for controlling the slide movement. The broach tool with slides moves at various speeds and obtained by the driving mechanism.

The table is mounted on the base in front of the column. The fixture is clamped to the table. The work piece is fixed in the fixture. Ta the slide with the broach is moved downwards for br

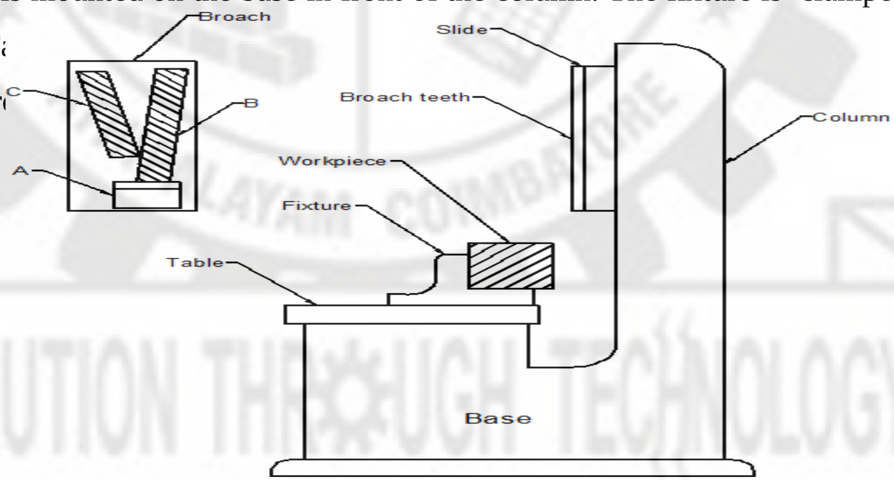


Fig. 2.35. Push down type vertical broaching machine

2. Pull down type vertical broaching machine:

Mostly, this machine is used for internal broaching. The broach is pulled through the job by the machine. The work piece is held in the fixture. The fixture is clamped on the table. The broach tool is automatically engaged by pulley mechanism and it is pulled down through the job. Then the broach returns to its beginning position after the completion of the operation.

3. Pull up type vertical broaching machine:

In this method, the ram slides on the vertical column of the machine. A pulling head is fitted at the bottom of the ram. The broach is in the base of the machine. The pulling mechanism is above the work table. The broach enters the job held against the underside of the table and it is pulled upward. The work piece falls down after the end of the operation.

CONTINUOUS BROACHING

The machines are used for producing small size work pieces with large quantity and available in three types. They are the following

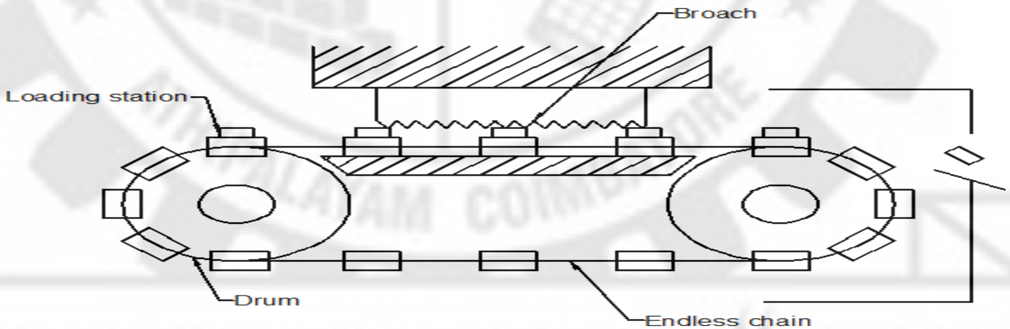


Fig. 2.36. Continuous Broaching

1. Horizontal continuous broaching machine

This machine is a surface broaching machine. It has a driving unit with two sprockets. They are connected by an endless chain. Fixtures are mounted at the interval on the chain. The work pieces are held in that fixture. The broach tool is fixed horizontally in the frame of the machine. A guiding member is arranged under the chain in the place where the work piece passes under the broach.

The endless chain moves continuously when operating the motor. When the fixture passes the loading station, the operator will put the work piece in the fixture and the part is automatically clamped before it reaches the tunnel. The broaching operation is carried out when the work piece moved under the broach. After completion of the operation, the work pieces are automatically released by a cam and they fall out from the fixture at the unloading point.

2. **Vertical continuous broaching machine**

In this machine, the exes of the two sprockets are vertical. So it is called vertical broaching machine. It works like a horizontal continuous broaching machine. The broach tool is placed vertically on the frame of the machine.

3. **Rotary type continuous broaching machine**

Rotary table and vertical column are provided in this machine. Fixtures are continuously arranged on the rotary table for holding the work piece. They move past the stationary broach. This machine is suitable for the broaching of small parts.

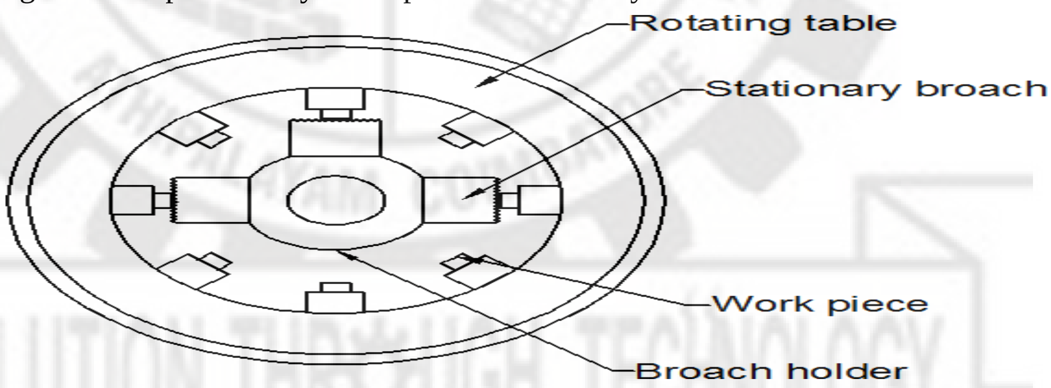


Fig. 2.37. Rotary type continuous broaching machine

TOOL NOMENCLATURE:

A series of teeth is provided in the broach. Every tooth height is slightly higher than the previous one. This rise per tooth is the feed per tooth. Normally a broach tool has three sets of teeth. They are given below.

1. **Roughing teeth:**

   These teeth remove maximum metal from the work piece and have highest rise per tooth.

2. **Semi-finished teeth:**

   These teeth remove smaller amount of metal when comparing to the roughing teeth. Because the teeth have slightly smaller in rise p

Fig. 2.38. Broach Nomenclature

3. **Finishing teeth:**

   These are the last set of teeth used for finishing the surface. These teeth remove very little amount of material. These teeth are all in the same size.

4. **Pull end**

   This is an end and it is connected to the pulling head of the broaching machine.

5. **Front pilot**

   Front pilot is for locating the broach centrally with the hole to be broached.

6. **Rear pilot and follower grip**

   This part gives the support to the broach after the last tooth leaves the surface.

7. **Land**

   The top portion of the teeth is called Land.

8. **Pitch**

   The distance between one teeth to another tooth is called pitch.

9. **Clearance angle**

   It is the relief angle on the land.

TYPES OF BROACHING TOOLS

Broaching tools are classified in the following

1. According to the method of operation
   a. Push broaching
   b. Pull broaching

2. According to the type of operation

    a. Internal broaching
    b. External broaching

3. According to their construction

    a. Solid broach
    b. Built up broach
    c. Inserted tooth broach
    d. Overlapping broach
    e. Progressive cut broach

1. Push broaching tool:

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is made s …

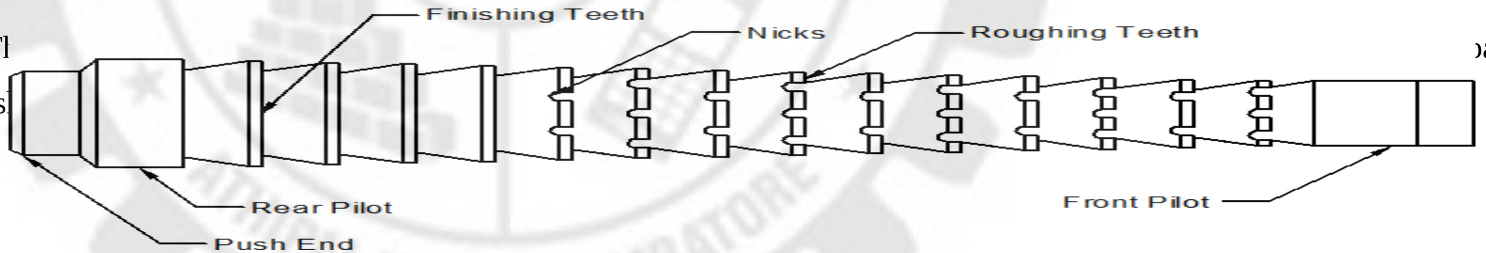


Fig. 2.39. Push Broach

2. Pull broach:

This broach is pulled through the work piece during broaching. chances for bending of tool. So there are no

This broach is made lengthier.

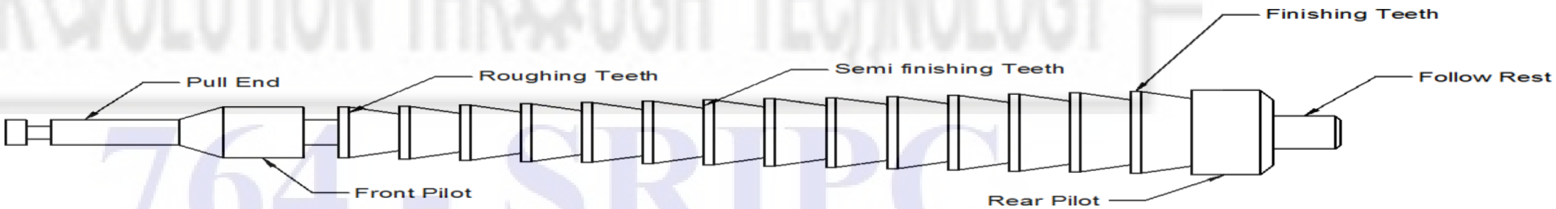


Fig. 2.40. Pull Broach

3. **Solid broach**

Solid broach is manufactured in one part. Internal broaches belong to solid type.

Fig. 2.41. Solid Broach and Progressive Broach

4. **Progressive:**

The teeth of the progressive broach are made with same height and different width. The last set of teeth of progressive broach removes very little amount of metal. The width of the finishing teeth finishes the surface.

BROACHING OPERATIONS:

The various types of broaching operations are given below

1. Broachin

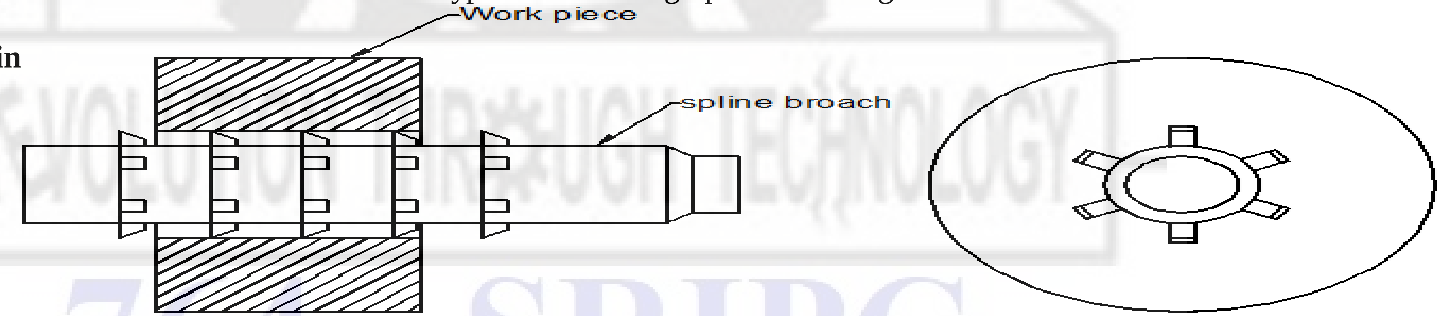


Fig. 2.42. Broaching the splines

A hole with a number of slots is called splines. Spline broaching is very similar to the key way broaching. The broach has four or more rows of teeth on its periphery according to the splines to be produced. The work piece is clamped on the fixture. The broach is inserted in the hole of the work and pulled throughout the work piece. Internal broaching machine is used for this operation.

2. Broaching a keyway:

This operation is also done on internal broaching machines. The guide of the broach is supported by a standard guide bushing with a rectangular slot. Bushing is placed in the bore of the work piece and the front pilot of the broach is pushed in the slot until the first tooth touches the work piece. Then the broach is pushed throughout the work piece for broaching the key way. The same prc

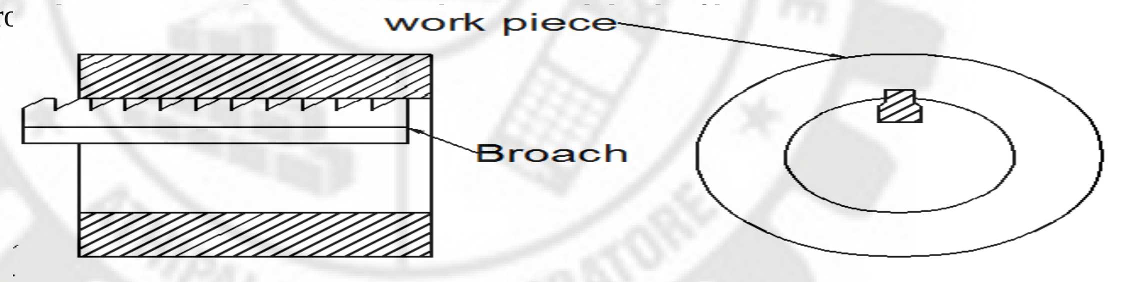


Fig. 2.43. Broaching a keyway

3. Surface broaching:

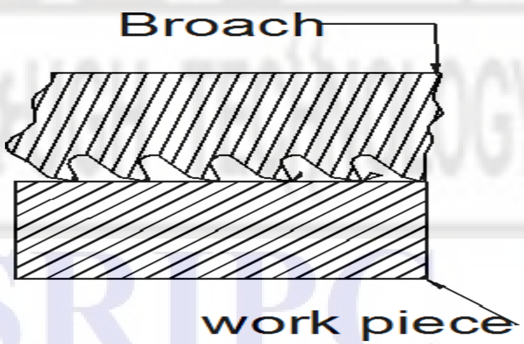


Fig. 2.44. Surface broaching

A push type solid broach is used in a vertical broaching machine. Progressive broach is also used for surfaced broaching the work piece held in a fixture on the machine table then the broach is passed on the work piece and the work piece is broached in the one pass of the broach because the width of the broach is more than the width of the work piece.

4. Hole broaching

This operation is done on a cylindrical work piece. A push type round broach is used in vertical broaching machine. The work piece is held on the fixture or table. Then the broach is pushed on the work piece hole. Roughing and semi-finished teeth remove more amount of metal form the work piece and finally the finishing teeth of the broach finishes the hole of the required shape.

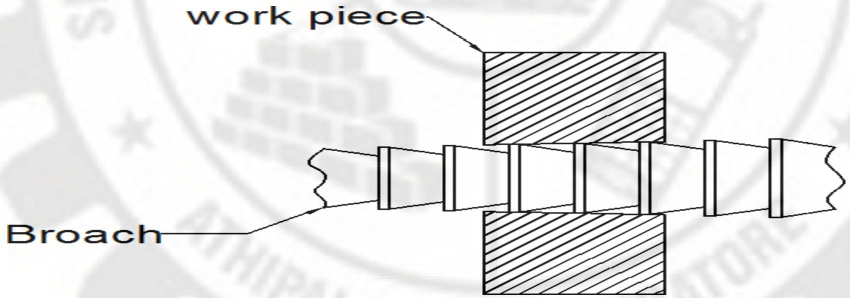


Fig. 2.45. Hole broaching

UNIT III - MILLING MACHINES

Milling is the process of removing metal by a rotating multipoint cutter. The work is fed past the cutter. The metal is removed in the form of small chips. As multipoint cutter is used, metal removal is very fast. One or more number of cutters can be used at a time. Milling produces a good surface finish. The accuracy is high. Hence milling machines are used for production works.

Principles of Operation:

The milling machine has a rotating cutter. The cutter is mounted on a rotating spindle or arbor. The cutter has multiple cutting edges. The work piece is clamped on the table. The cutter rotates at the required cutting speed. The work piece is feed slowly past the cutter. The feed may be longitudinal, cross wise or vertical. Angular feed can also be given in certain milling machines.

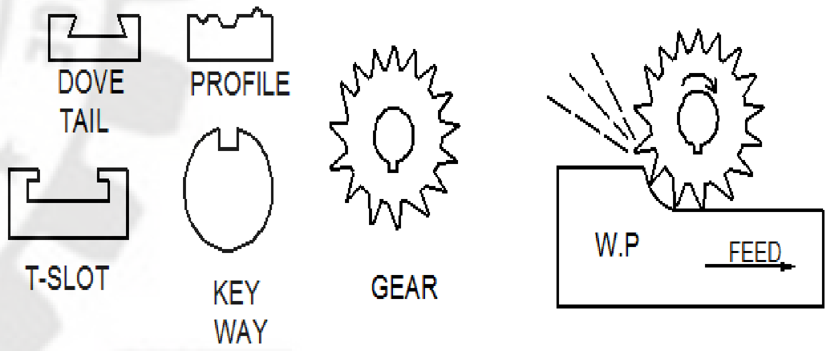


Fig. 3.1. Principles of Operation

As the work is feed, the cutting edges remove metal from the work piece in the form of chips. During the cutting, each cutting edge cuts metal only during a part of the cutter revolution. So in the remaining part of the cutter revolution the cutting edge rotates idle and can cool off. Therefore, the stress on the cutting edge is not continuous. So the cutting will be effective.

Types of Milling Machine:

The milling machines are classified as follows:

I) Column and knee type.

- i. Plain milling machine.
- ii. Universal milling machine.
- iii. Om universal milling machine.
- iv. Vertical milling machine.

II) Plano miller

IV) Special type

i. Rotary table milling machine.
ii. Drum type milling machine.
iii. Planetary milling machine.
iv. Pantograph milling machine.

Column and knee type milling machine:

Column and knee type milling machines are most commonly used. This type of milling machine has vertical column on its base. The column has machined guide ways on its

front face. The knee is mounted on this column. The knee can slide up and down on the guide ways of the column. The knee carries the saddle and work table. The column and

knee type machines are general purpose machines. Different varieties of jobs can be done on these machines.

Plain milling

Plai

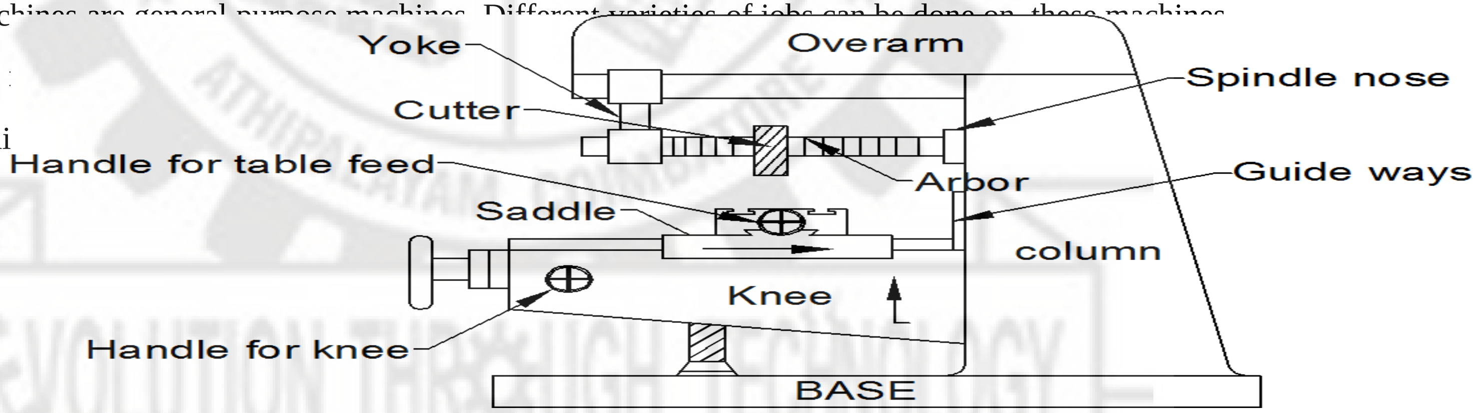


Fig. 3.2 Plain Milling Machine

There is a vertical column on the base. The column houses the main drive and the spindle. The column has vertical dovetail guide ways on its front face. The knee can move vertically on these guide ways. This is done by rotating the elevating screw. The knee at its top has horizontal dove-tail guide ways perpendicular to the front face of the column. The saddle can slide on these guide ways away from the column or towards the column. The top of the saddle has horizontal guide ways parallel to the face of the column.

The table travels longitudinally along these guide ways. The longitudinal travel of the table is perpendicular to the axis of the spindle. The top surface of the table is accurately machined. There are T-slots along the length of the table for holding the work.

The vertical movement of knee, crosswise movement of the saddle and the longitudinal movement of table can be obtained by hand or power. The knee houses the feeding mechanism. The spindle of the machine is located in the upper part of the column. It is rotated by an electric motor through belts and gear.

The front end of the spindle is called nose. The nose just projects from the column face. It has tapered hole. Arbors or various cutting tools can be inserted into this hole. There is an over arm mounted on the top of the column. It acts as support for the arbor. The over arm supports the arbor by means of yoke.

Universal milling

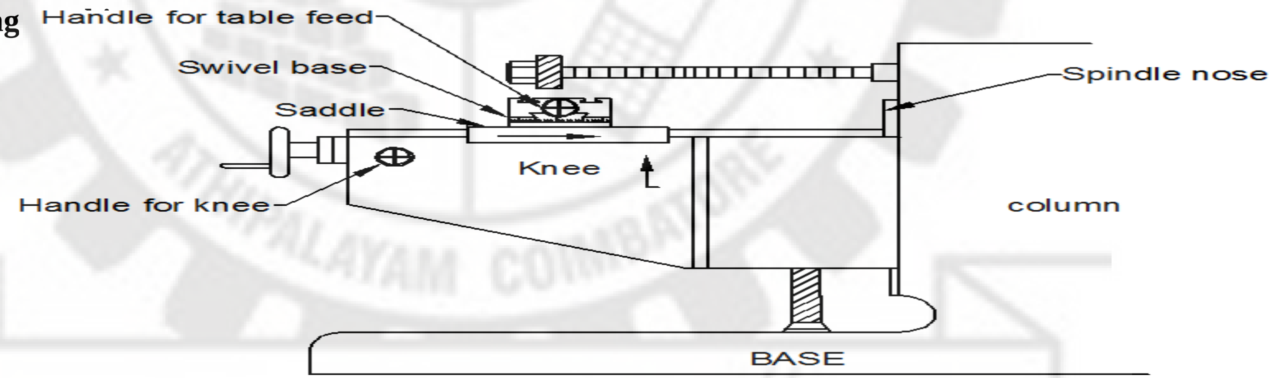


Fig. 3.3. Universal milling machine

The Universal milling machine is similar in all respects to the horizontal plain milling machine except for additional swiveling movement for table. The table is mounted on a swivel base. The swivel base has got degree graduations. The table can be swiveled about a vertical axis. It can be swiveled up to a maximum of 45˚ on either side of the normal position.

Thus the universal milling machine table has the following movements:

- ✓ Vertical movement – through the knee
- ✓ Cross wise movement – through the saddle

✓ Longitudinal movement of the table.

Angular movement of the table – by swiveling the table on the swivel base. By swiveling the table, the work can be fed at an angle to spindle axis. This is used in helical milling operations.

Special attachments like dividing head, Vertical milling attachment, and rotary table attachment are used in the universal milling machines. Using these attachments, the machine can procedure spur gear, helical gear, bevel gear, twist drill and reamers.

Omniversal milling machine:

The table of this machine has all the four movements of the universal milling machine. In addition, it has one more adjustment for the table. The table can also be swiveled about a horizontal axis “XX” parallel to the spindle.

In this machine, the knee has a swiveling arrangement. Using additional swiveling movement, we can machine tapered spiral grooves in reamers, bevel gears etc. Universal milling machine is a tool roo

Vertical milling machine:

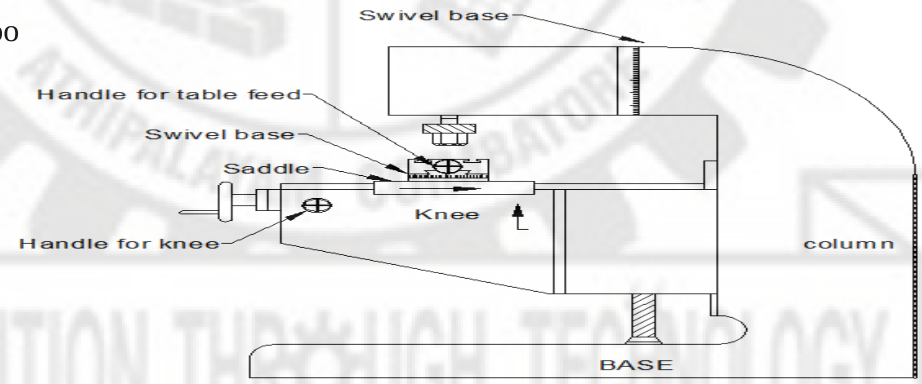


Fig. 3.4. Vertical milling machine

In a vertical milling machine, the spindle is vertical. The table may be plain type or universal type. The vertical column is mounted on the base. The front face of the column has vertical guide ways. The knee moves on these vertical guide ways. The knee has horizontal guide ways on its top surface. The saddle can move cross wise on these guide ways perpendicular to the spindle axis away from the column or towards the column. The saddle has guide ways on its top. The table can move longitudinally along these guide ways. This movement is perpendicular to the spindle axis.

The spindle head is mounted on top of the column and it has swivel base. So the head can be tilted at an angle. This permits machining of angular surfaces. In some machines, the spindle can be adjusted up or down. The vertical movement of the knee, cross wise movement of the saddle and the longitudinal movement of the table can be obtained by hand or power. The knee houses the feeding mechanism. This machine is used for machining

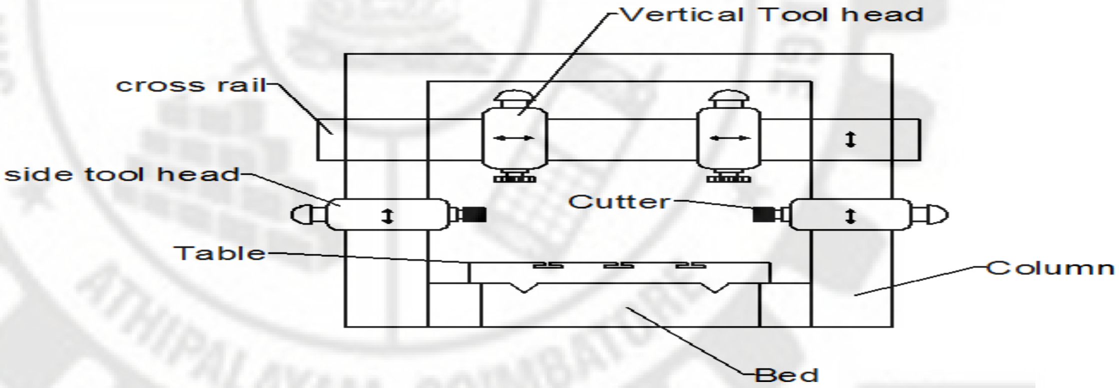


Fig. 3.5. Plano Miller

Construction of a Plano miller is similar to a double housing planer. The working of the Plano miller is similar to the planning machine. The machine has a fixed bed and the bed has longitudinal guide ways. The table reciprocates longitudinally over these guide ways.

There are two vertical columns one each on the sides of the bed. A cross rail slides vertically along the column guide ways. The cross rail carries vertical cutter heads. These cutter heads can slide along the cross rail. There are two cutter heads mounted on the vertical columns. These can slide over vertical guide ways on the column. These vertical and horizontal tool heads have separate motors for driving the cutter. All the four cutter heads can be used to machine the work surfaces at a time. The cutter heads can also be swiveled for machining angular surfaces.

This machine is used for heavy duty production work. Lathe bed ways, other machine bed ways etc. are machine using the Plano miller.

Specification of a Milling Machine

- The table length and width 1120 x 280 mm
- Maximum longitudinal, cross and vertical travel of the Table - 558 x 229 x 406 mm
- Number of spindle speeds and feeds 6
- Floor space and net weight 2000 kg
- Spindle nose taper size ISO 40
- Type Universal

Work Holding Devices:

The following work holding devices are used in milling machine.

- Plain vice.
- Swivel vice.
- Universal vice.
- Indexing head.
- Milling fixture.

Plain vice:

The plain vice is bolted directly to the table. Base of the vice has slots for clamping the vice to the table.

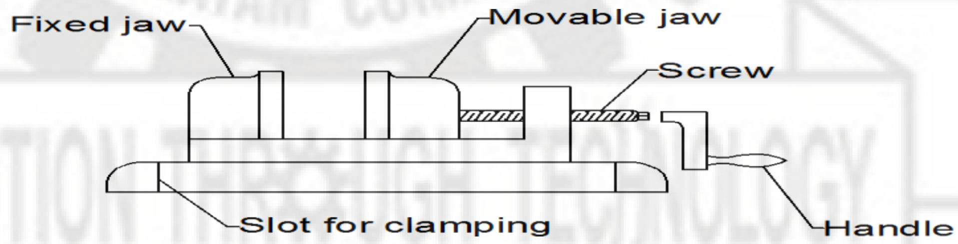


Fig. 3.6. Plain vice

The vices may be positioned on the table with their jaws either parallel or at right angles to the T-slots. The work piece is held between the jaws. Plain vice is used for simple milling operation on the work piece.

Swivel vice:

This vice has a swivel base, graduated in degrees. The base of the vice is clamped on the table by T-bolts. For clamping the vice, lugs with slots are available in the base. The vice is swiveled over the swivel base after loosening the clamping bolt. After setting the vice to the required angle the clamping bolts are tightened. The swivel vice is used for milling angular surface on the work piece.

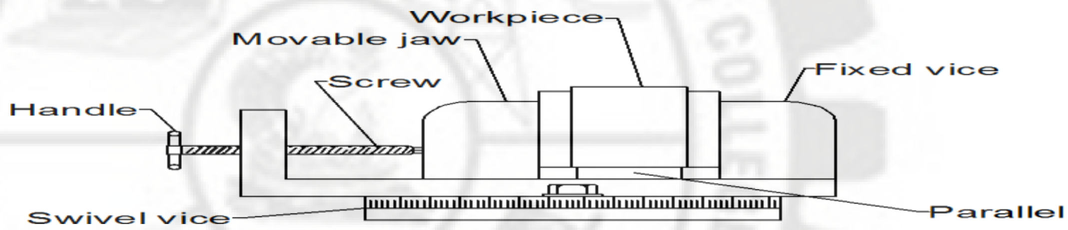


Fig. 3.7. Swivel vice

Universal vice:

The universal vice can be tilted in a horizontal plane, similar to swivel vice. It can also be tilted in a vertical plane. The cutting edge of the tool may be straight or spiral. The base of the vice is clamped on the table by T-bolt. There is a horizontal swivel base, on the base of the vice. This swivel base is used for tilting the vice in horizontal plane. A vertical swivel arrangement is provided over the horizontal swivel base. The vice body is fitted to the vertical swivel arrangement. The vice body can be tilted in a vertical plane using the vertical swiveling arrangement. After setting the vice to the required angle, the vice is clamped in position by clamping nuts.

Using this universal vice, surfaces with compound angles can be machined. This vice is not rigid in construction. It is mainly used in tool rooms.

Indexing Head:

Indexing head is a device which is used for dividing the periphery of the work pieces into any number of equal divisions. Indexing is necessary for cutting gears, splines on shafts

and for cutting helical grooves on drill and reamers. Indexing head is also known as dividing head. The indexing head is clamped to lathe table by using T-bolts.

Indexing head has a head stock and a tail stock. The work piece is held between the centres of head stock and tail stock. Short work pieces can be held in a chuck fitted to the

The crank movement is transmitted to the work piece through a worm and worm wheel. An indexing plate is provided in the head stock. With the help of this indexing plate, the required movement of the crank is obtained.

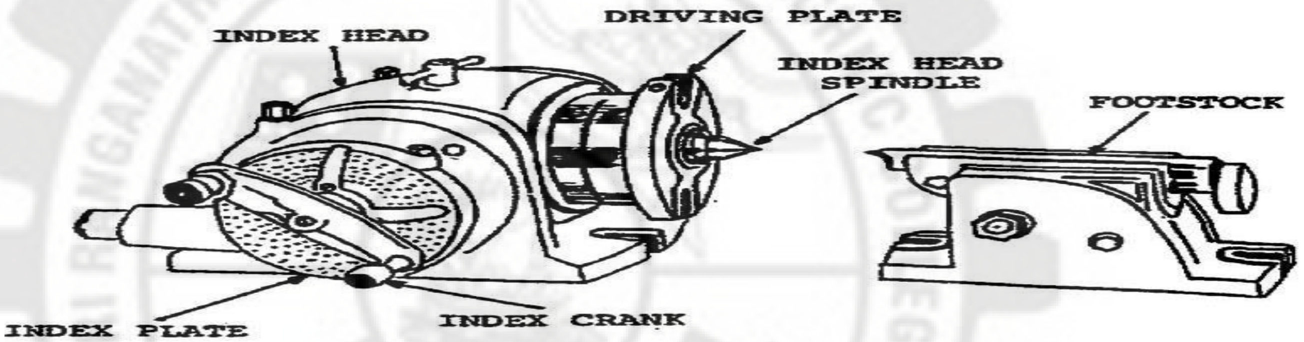


Fig. 3.8. Indexing Head

Milling fixture:

Milling fixtures are used for locating and clamping the work in correct position with respect to milling cutter. Milling fixtures are used when large number of identical work pieces is to be machined. By using fixtures, loading, locating, clamping and unloading time are very much reduced.

Vice jaw milling fixture:

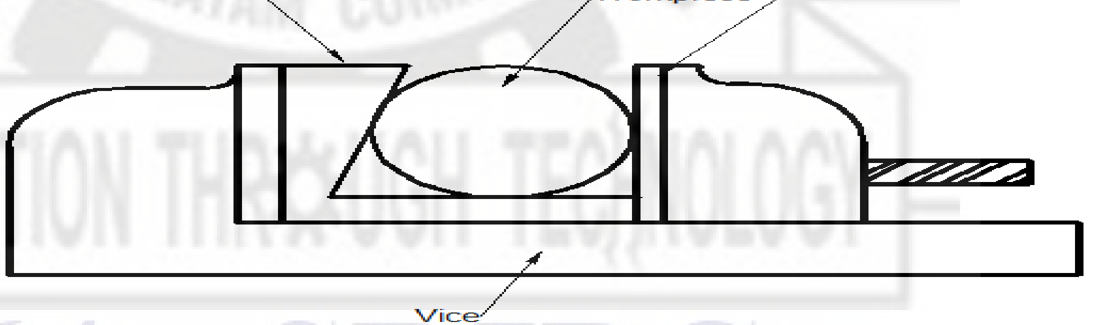


Fig. 3.9. Vice jaw milling fixture

The jaws of the machine vice are modified to suit the type of the work piece.

The vice has extended jaws. The work piece is clamped between the extended jaws. For proper alignment of jaws, the movable jaw has a guide pin. A bush is provided in the fixed jaw to receive the guide pin.

Figure shows an arrangement for holding cylindrical work pieces. The vice has a vice shaped fixed jaw. The movable jaw is a regular one. The work piece is firmly held between the two jaws.

Plain Milling Fixture or slot milling fixture or string milling fixture:

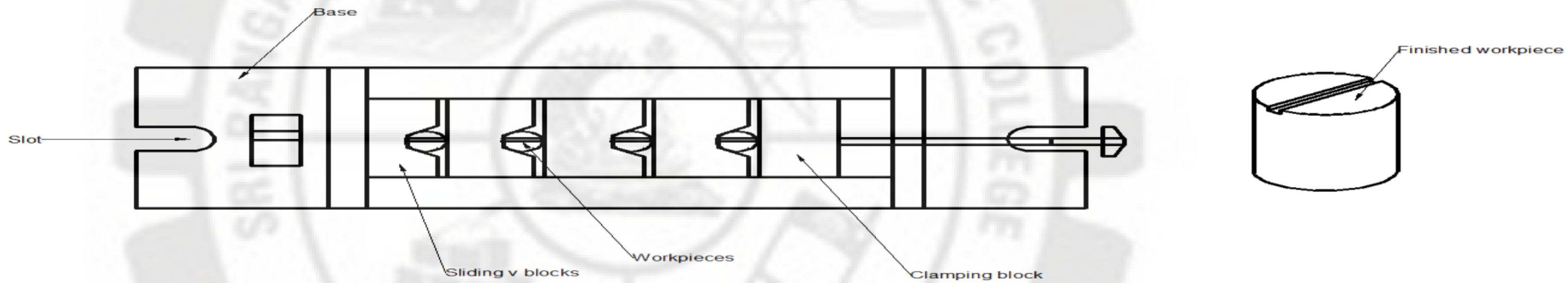


Fig. 3.10. String milling fixture

Plain milling fixture is designed to hold a single component. Plain milling fixture is used when a small number of components are to be milled. In the fixture has a slot has to be milled in the component. Big hole ‘A’ in the component is located by a cylindrical locator. One of the small holes ‘B’ is located by a diamond pin locator. The bottom surface of the component rests on the fixture base. Two strap clamps are used for clamping the component. There are two tension strips at the bottom of the fixture base. (One tension at each end of base). These tension strips are interested through slots of machine table for locating the fixture in the required position.

A setting block is fitted stop of fixture base by two screws and two dowels. The fixture is clamped firmly to machine table by using T bolts through the four U – grooves in fixture base.

Tool Holding Devices

The different tool holding devices used in milling machine are

1. Arbors

   (a) Standard arbor (b) Stub arbor

2. Adapters
3. Spring collets

Arbor: Standard arbor:

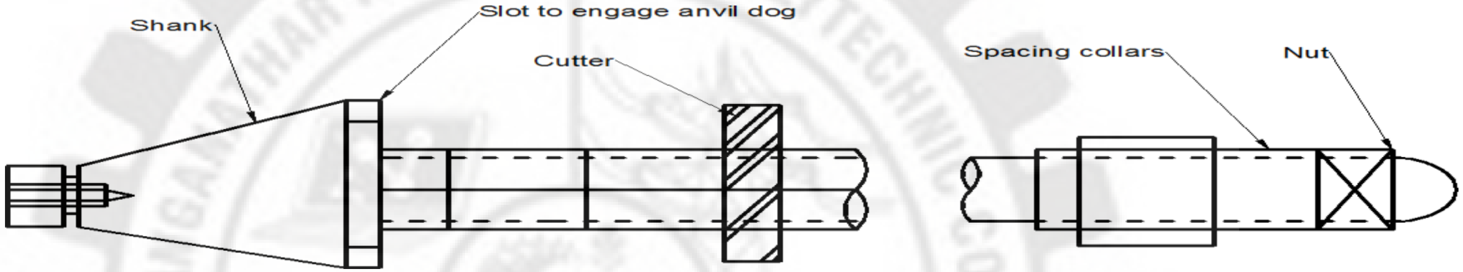


Fig. 3.11. Standard arbor

Cutters having a central bore are mounted on a standard arbor. Arbor is a short shaft, one end of which is fitted to the taper bore in the spindle nose. A draw bolt holds the arbor in position. The draw bolt is introduced into the spindle bore from the back of the milling machine column. The draw bolt is used to pull in or push out the arbor from the spindle. The slots on the flange of the arbor engage the driving lugs of the spindle. A key runs for the whole length of the arbor. The cutter is mounted on the arbor. The key way of the cutter bore fits on the arbor. Spacing collars are used on both sides of the cutter for adjusting the position of the cutter along the length of the arbor.

The arbor is supported at the other end by the yoke. A clamping nut is used at the end of the arbor to hold the cutter in position. Arbors of different diameters are used to suit the central bore of the cutter.

Stub arbor:

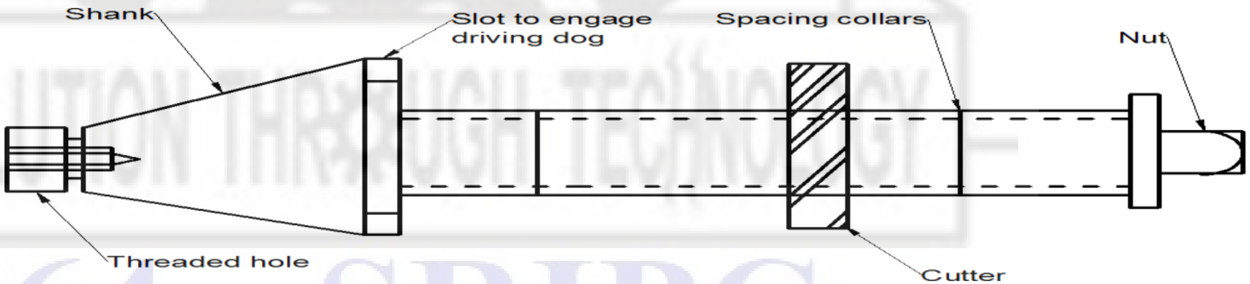


Fig. 3.12. Stub arbor

It is a short arbor. This is used for holding shell end mills, T-slot cutters and key way cutters. The Stub arbor has a tapered shank which fits into the main spindle of the milling machine.

The slots in the flange portion of the stub arbor fit into the main spindle of the milling machine. The slot in the flange portion of the stub arbor fits into the diving lugs of the spindle nose. A clamping screw is used to clamp the cutter to the arbor.

Adapter:

If the size of the cutter is small, it cannot be fitted in the nose of the spindle. An adapter is used in this case. The adapter has taper bore to receive the shank of the cutter to be held. The flange or collar of the adapter has two slots. These slots fit over the driving lugs of the spindle. The rear end of the adapter has a threaded hole. The end of the

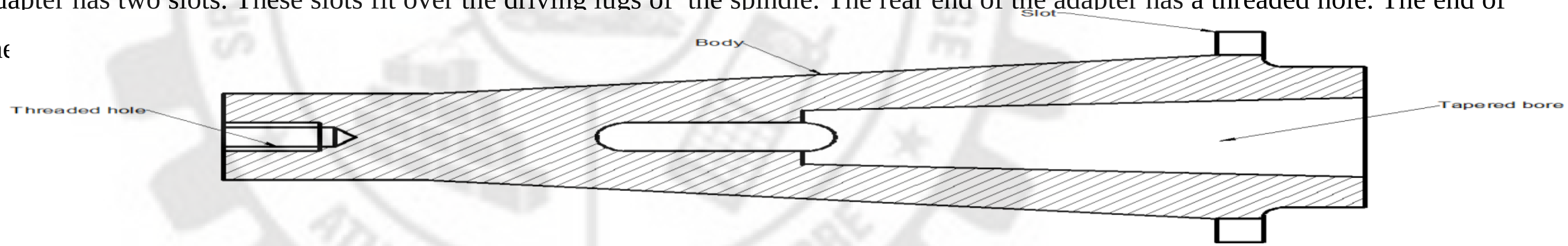


Fig. 3.13. Adapter

Spring Collets:

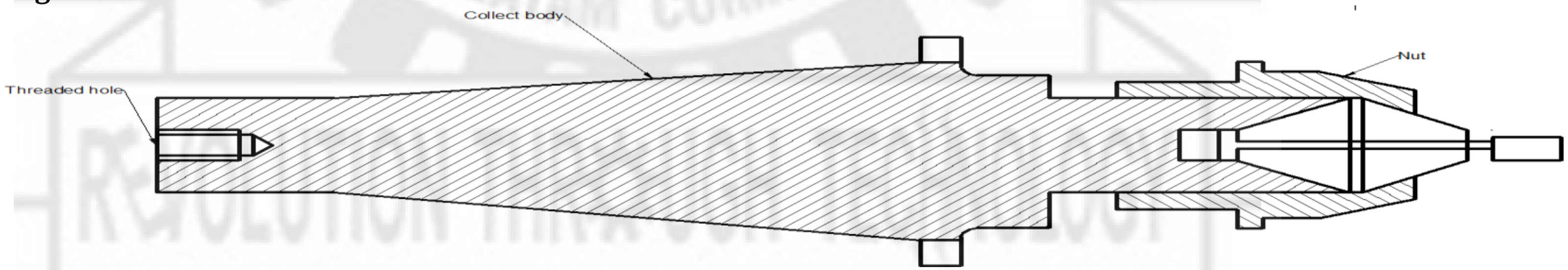


Fig. 3.14. Spring Collets

Spring collet is used for holding straight shank milling cutters. End mill cutters, woodruff key cutters etc. are held using spring collet. The front portion of the collet is tapered. The tapered portion is spilt by three equally spaced slots. After the tapered portion there are external threads. A special nut fits over the taper and the threaded portion. The front end of the collet has straight cylindrical hole. The front end of the collet has straight cylindrical hole. The straight shank of the cutter is introduced into this hole. When the nut is tightened, the split jaws of the collet close over the straight shank of the cutter.

Thus the tool is held firmly on the Collet. The rear of the collet has a taper shank to fit into the spindle nose. The two slots in the collar fit over the driving lugs of the spindle. The back of the collet has a threaded hole to receive the draw bit.

Milling cutters:

The following milling cutters are commonly used in milling.

- Cylindrical milling cutter
- Slab milling cutter.
- Slitting saw.
- Side milling cutter
- Angle milling cutter
- End milling cutter
- T-slot milling cutter.
- Woodruff key slot milling cutter
- Fly cutter

Form cutter

Most of the cutters are made ... ilable. The cutters may be held on arbors. These cutters will have centr... can also be held directly on the spin... ht or taper shank ends.

Cylindrical milling cutter

Fig. 3.15. Cylindrical milling cutter

This milling cutter is cylindrical in shape. It has cutting teeth only on its periphery. It is used for machining flat surfaces parallel to its axis. The cutter may have straight or helical teeth. The figure shows a cutter with helical teeth. Helical teeth produce a smooth surface.

The cutter has a central bore with key way. This is for mounting the cutter in a standard arbor. Cutters of various diameters and widths are available. Roughing cutters will have less number of teeth. Finishing cutters will have more number of teeth, for the same diameter.

Slab milling cutter:

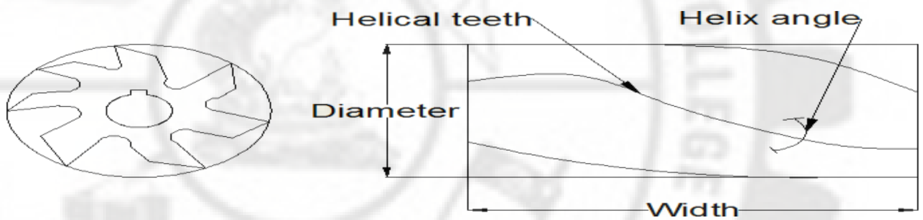


Fig. 3.16. Slab milling cutter

This is a cylindrical milling cutter having a width more than its diameter. This is used for rough machining with coarse feed. The cutter has less number of teeth. The teeth will have larger helix angle. Long slab milling cutter will have nicked teeth. The cutting edges will not be continuous. The nicking is done to break the chips.

Slitting saw:

Fig. 3.17. Slitting saw

Slitting saw is used for slotting for cutting off operations. The cutter is very thin. Its width varies from 0.8 to 5mm. The sides of the cutter are ground concave. This is to prevent the sides from rubbing the work piece.

Side milling cutters:

Side milling cutter has cutting edges on its periphery and also on the sides. This cutter is used for removing metal from the side of the work pieces. It is also used for cutting slots.

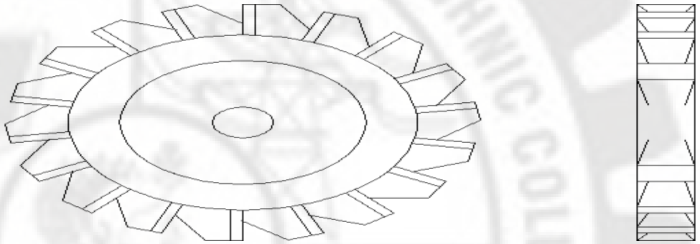


Fig. 3.18. Side milling cutter

Cutters of various diameters and widths are available. Figure shows plain side milling cutter having straight teeth. The cutters can also have staggered teeth.

The cutters are used for milling deep and narrow slots

Angle milling cutters

Angle milling cutters are used for producing angular surfaces Fig. shows a single angle milling cutter. The cutter has inclined teeth on its conical periphery. It also has teeth

on its large flat side. The angle of the ... ry and the large flat

side of the cutter. The angle cutter v

particular angle. Cutters with differer

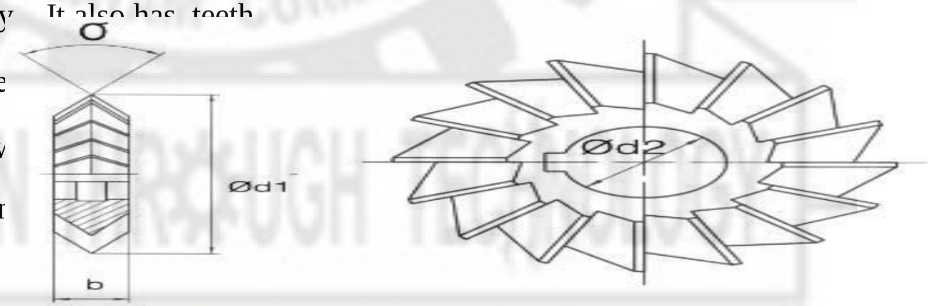


Fig. 3.19. Angle milling cutters

It has two conical surfaces. The conical surfaces are at angles to the end faces. The conical surfaces have cutting teeth. These cutters have equal angles on both sides. But they may also have unequal angles. These cutters are used for producing spiral grooves. The angle milling cutters have central bores with key-slots. These cutters are held in arbors.

End milling cutter:

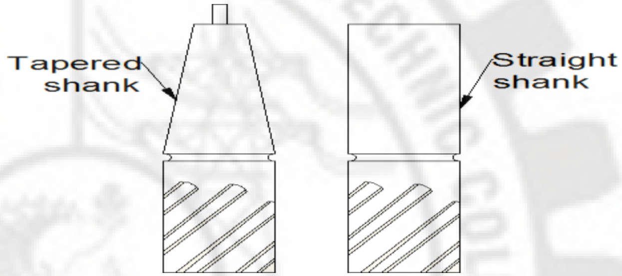


Fig. 3.20. End milling cutter

An end mill is a cylindrical cutter. It has cutting teeth on the end and also at the cylindrical periphery. The teeth on the periphery may be straight or helical. The end mill cutter is similar in construction to a twist drill or reamer. The main difference is that the end

mill has cutting edges on the ends also. The cutter may have a tapered or straight shank. Tapered shank cutters are fitted to the spindle using adapters. Straight shank cutters are fitted

to the spindle using collets.

End mills are commonly used for ve

machining slots, accurate holes and produci sinking and profile milling.

T-slot Milling Cutter

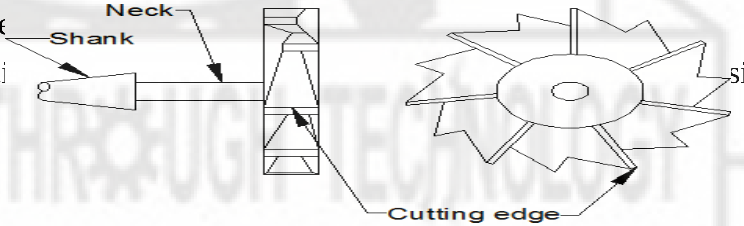


Fig. 3.21. T slot milling cutter

It is used of producing T-slots. The arrangement of cutting teeth is similar to that of a side milling cutter. But this cutter has a tapered shank. A neck is formed between the cutting face and the shank. The cutter has cutting teeth on its periphery (A) and on its sides (B & C). The cutter is fitted to machine spindle, using an adapter.

Woodruff key slot milling cutter:

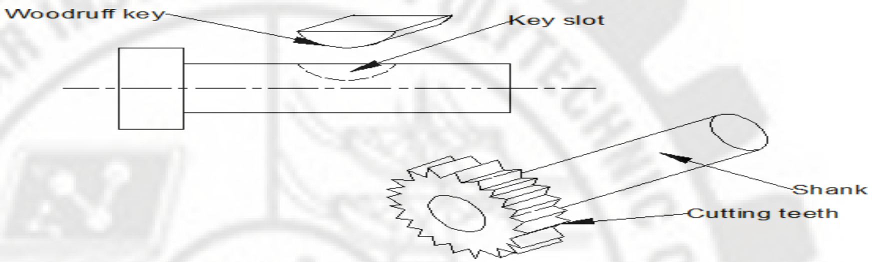


Fig. 3.2. Woodruff key slot milling cutter

The cutter is similar to a small, thin plain milling cutter. It has a tapered shank and a neck. The cutter may have straight or staggered teeth. The sides of the cutter are ground concave. This gives clearance for the cutter movement. This cutter is used for cutting woodruff key slots on shafts.

Fly cutter:

This is a special cutter. It is used in milling machine when standard cutters are not available. A single point cutting tool is fitted to the end of a bar using clamping screws. The

bar is fitted to the spindle. The cutting ... r removes metal when it rotates. The rate of metal removal will be very

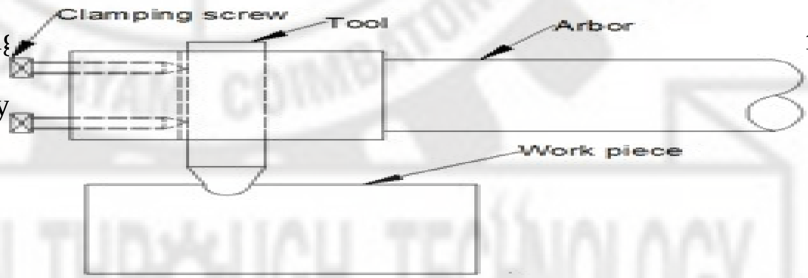


Fig. 3.23. Fly cutter

Form cutters

Form cutters are used to produce the required shape on the work pieces. The cutting edges are ground to the required profile. So the cutter will produce only the form on its teeth. Some of the form cutters are explained below:

Convex Form Milling cutter

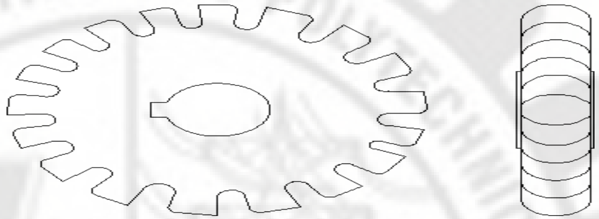


Fig. 3.24. Convex Form Milling cutter

This cutter has teeth curved outward on its periphery. The cutter will produce a concave semi-circular surface on the work piece. Cutters of various diameters and widths are available.

Concave Form Milling Cutter

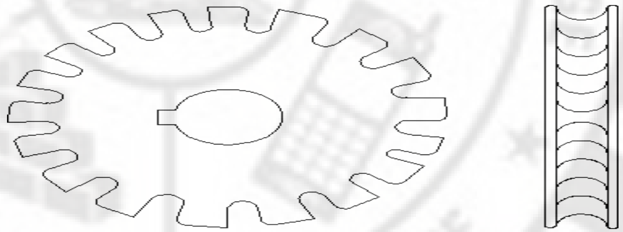


Fig. 3.25. Concave Form Milling Cutter

This cutter has teeth curved inwards on its periphery. The cutter will produce a convex semi-circular surface on the work piece. Cutters of various diameters and widths are available.

Involute Gear Tooth Cutter

The cutter has formed cutting edges. The shape of the cutter teeth is involute. The cutter will produce groove of the involute shape.

An involute gear tooth is formed between two grooves milled by the cutter. The profile of the gear tooth depends upon the module and the number of teeth on the gears. So, for cutting different number of gear teeth of same module, different cutters are required. In practice, a set of eight cutters are available for each module. The range of teeth is from 12 to infinity (rake).

Nomenclature of Cylindrical Milling Cutter Face of tooth

Face is the front portion of the tooth. The chip cut by the cutting edge slides over the face.

Land

It is the portion of the tooth which is adjacent to the cutting edge.

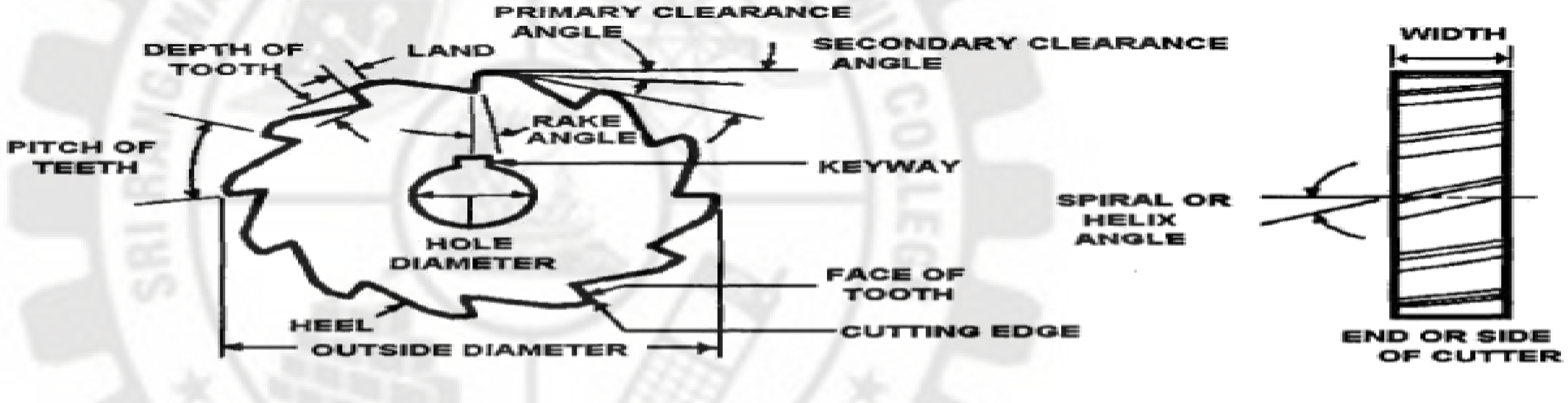


Fig. 3.26. Nomenclature of Cylindrical Milling Cutter

Cutting edge:

This is the chisel like edge which cuts the metal. It is the edge formed by the face of the tooth and the land.

Back of tooth:

It is the portion of the tooth behind the land. It slopes downwards from the land. It gives clearance to the tooth.

Gash:

It is the gap between the teeth. It provides space for chip flow.

Fillet:

It is the curved surface at the bottom of gash.

Outside diameter:

This is the diameter of the circle passing through the cutting edges of the teeth.

Root diameter:

This is the diameter of the circle passing through the bottom of the fillet.

Cutter Angles: Relief angle:

It is the angle between the land and the cutting edge.

Primary clearance angle:

This is the angle between the back of tooth and the tangent to the outside circle.

Secondary clearance angle:

This is the angle between the sloping surface of the tooth and the tangent to the outside circle.

Radial rake angle:

It is the angle between the face of the tooth and the radial line passing through the cutting edge.

Lip angle:

It is the included angle between the land and the face of the tooth.

Milling Processes Up milling:

It is also called conventional milling. Metal is removed when the cutter teeth move upwards. Here the cutter rotates opposite to the direction of feed of work piece. In up milling, the chip thickness is minimum at the end of tl n at the beginning of the cut.

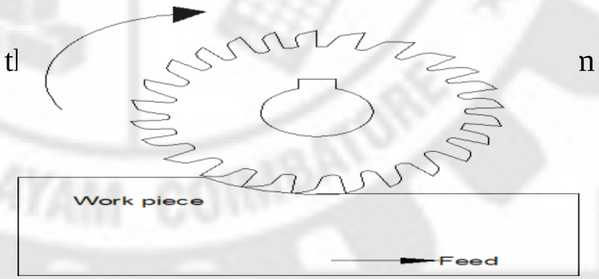


Fig. 3.27. Up milling

The stress increases gradually and is maximum at the end of the cut. The cutting action of the teeth is upwards. So it will try to lift the work piece from the vice. The machined surface is not very smooth. Applying the coolant at the cutting zone. So chip removal is difficult. Chips interfere with the cutting action.

Down Milling:

It is also called Climb milling. Metal is removed when the cutter teeth move downwards. Here the cutter rotates in the same direction as the feed for work piece. In down milling, the thickness decreases to the minimum at the end of the cut. Here the maximum stress acts on the teeth at the beginning of the cut.

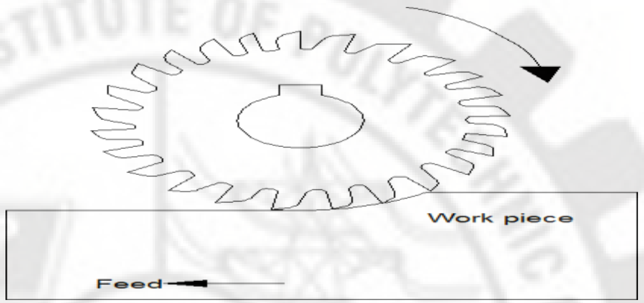


Fig. 3.28. Down Milling

This gives shock load to the teeth. The cutting action of the teeth presses the work piece downwards. This helps clamping of the work pieces. Down milling will give better surface finish. Coolant can be effectively applied on the cutting edge. The chips accumulate at the back of the cutter away from the cutting zone. So chip removal is easy. Chips do not interfere with the cutting action.

Milling Operations

- Plain milling
- Form milling
- Face milling
- Side milling
- End milling
- T-slot milling
- Straddle milling
- Gang milling

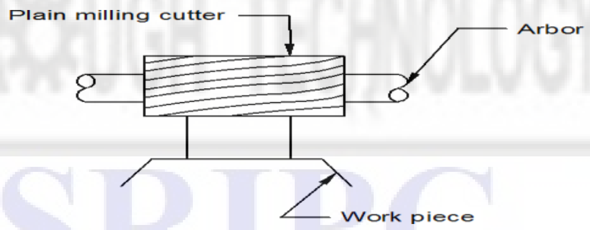


Fig. 3.29. Plain milling

Plain milling

Figure shows plain milling operation. Plain milling is the operation of producing flat, horizontal surface. A cylindrical milling cutter is used here. The cutter is held in the arbor. The work piece is held in a vice or a fixture. The depth of cut is adjusted by raising the table. The axis of the cutter is parallel to the flat surface machined.

Form milling

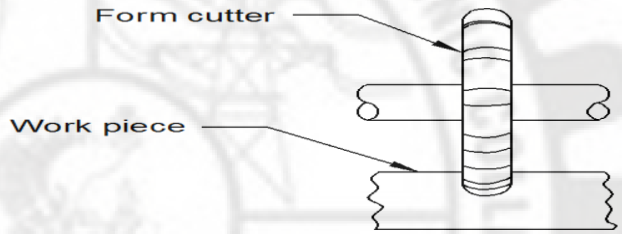
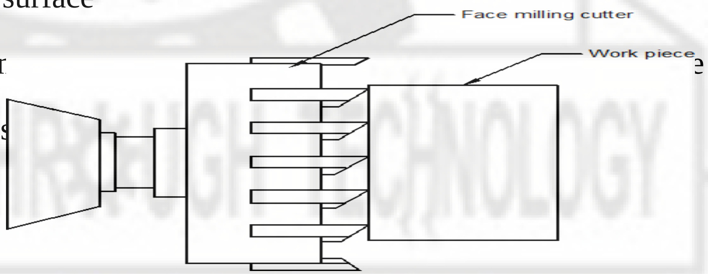


Fig. 3.30. Form milling

Figure shows the form milling operations. Form milling is the operation of producing the required profiles on the work piece. A form milling cutter is used. The cutter is held in the arbor. The cutting speed is slightly lesser than plain milling operations.

Face Milling

Figure shows face milling operations. Face milling is the operation of milling flat surface on the face of the work piece. The axis of the cutter is perpendicular to the surface machined. A face milling cutter is used. Norr



e mounted directly on to the spindle or using a stub arbor. Depth of cut is giving cross feed to the table.

Fig. 3.31. Face Milling

Side Milling

Figure shows side milling operation. A side milling cutter is used for milling the vertical side of the work piece. The cutter has teeth on the periphery and also at its sides.

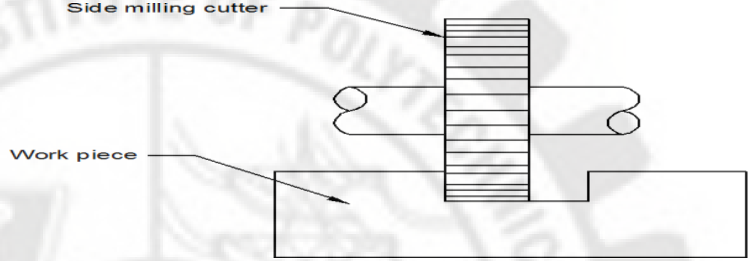


Fig. 3.32. Side Milling

End milling

End milling is the operation of producing narrow slots, grooves and key ways using end mills. The slots produced may be vertical or horizontal.

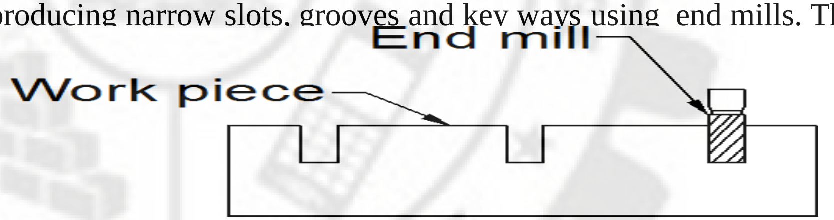


Fig. 3.33. End milling

End milling is normally done is a vertical milling machine. Fig. shows an end milling operation. An end mill is held in the spindle of the vertical milling machine. It is held using adapters or collets. The work piece is clamped to the machine table. By giving longitudinal feed to the work piece, the slot is cut. Depth of cut is given by raising the table. To complete a slot, several cuts may be needed.

T-slot milling

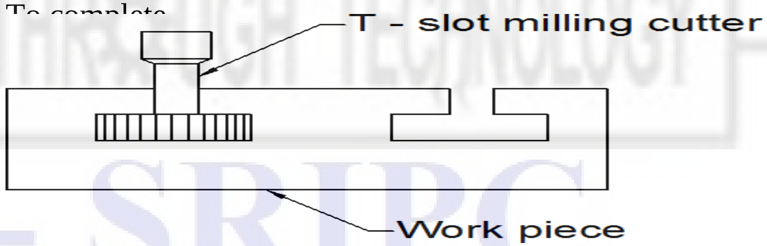


Fig. 3.34. T-slot milling

A T-slot is produced by using a T-slot cutter. Figure shows a T-slot milling operation. First a plain slot is cut on the work piece using an end mill. Then the T-slot cutter is fed from the end of the work piece. The neck portion of lathe cutter passes through the already milled plain slot.

Straddle milling

Figure shows the straddle milling operation. It is the operation of machining two vertical surfaces of the work piece at a time. The vertical surfaces are at a fixed distance between them. Two side milling cutters are used. The cutters are mounted on the arbor with the fixed distance 'X' between them. The given distance 'X' between the cutters is obtained by using spacing collars.

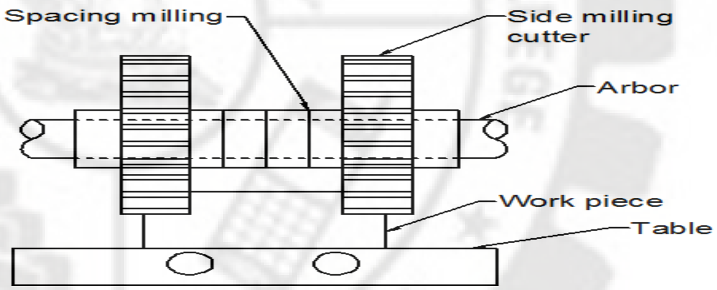


Fig. 3.35. Straddle milling

Longitudinal feed is given through the table. The depth of cut is given by raising the table. Straddle milling is very commonly used for milling square and hexagonal surfaces. A component produced by straddle milling is shown in figure.

Gang milling

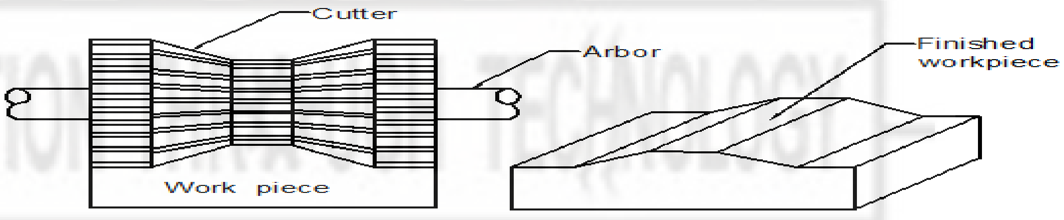


Fig. 3.36. Gang milling

Figure shows a gang milling operation. Gang milling is the operation of milling several surfaces of the work pieces at a time. Number of cutters are mounted on the arbor. There is no gap between the cutters. The figure shows a gang of three side milling cutters and two cylindrical milling cutters fitted to the arbor. The two cylindrical milling cutters have helical teeth of opposite hands. (Right hand and left and helix)

By this arrangement, the axial thrust is balanced. Longitudinal feed is given through the table. The depth of cut is given by raising the table. A component produced by gang milling is shown in figure. Gang milling operation is used in mass production.

Vertical Milling Attachment

Vertical milling attachment is used for doing vertical milling operations on a horizontal milling machine. It is shown in figure. The over arm of the milling machine is pushed back. Then the vertical milling atta[illegible]n face. The attachment can be swiveled about the machine spindle axis [illegible] swivel block.

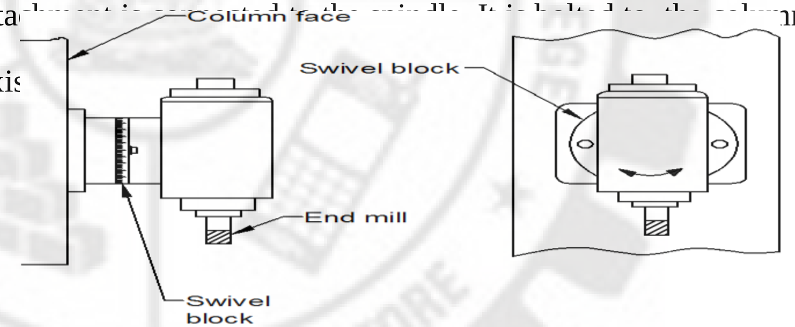


Fig. 3.37. Vertical Milling Attachment

End milling cutter is held to the vertical spindle of the attachment. This vertical spindle gets the drive from the machine spindle through a set of gears. By using this attachment grooving, T-slot milling and face milling operations can be done. Angular surfaces can be milled by tilting the attachment to the required angle. The depth of cut is given by raising the table.

Cutting speed, feed and depth of cut

Cutting Speed is the linear velocity with which the cutting edge passes the work.

$$\text{Cutting Speed m/mt} = \frac{\pi DN}{1000}$$

Where D= Diameter of cutter in mm, N= Speed of cutter in rpm

Feed in a milling machine is the rate at which the work piece moves under the cutter. Feed can be expressed as feed in mm per tooth or mm per revolution or mm per minute.

Depth of cut is the thickness of the material removed in one pass of the work under the cutter. This expressed in mm.

Index plate

It helps to accomplish indexing (dividing) of the work into equal divisions. It is a circular plate approximately 6 mm thick, with holes (equally spaced) arranged in concentric

circles. The space between two subsequent holes is same for each circle; however, it is different for different circles. A plate can have through holes or blind holes on its faces.

For a plain dividing head, the index plate is fixed to the body of the dividing head while in the case of universal dividing head it is mounted on the sleeve of the worm shaft.

Various manufactures in U.S.A. and other countries have produced index plates with different number of hole circles.

For example, The index plates available with the Brown and Sharpe milling machines are:

Obverse (A)	-	24, 25, 28, 30, 34, 37, 38, 39, 41, 42, 43
Reverse (B)	-	46, 47, 49, 51, 53, 54, 57, 58, 59, 62, and 66

The index plate used on the Cincinnati and Parkinson milling machine 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 plates made in Germany are:

Plate No. 1	-	23, 25, 28, 31, 39, 43, 51, 59
Plate No. 2	-	16, 27, 30, 33, 41, 47, 53, 61
Plate No. 3	-	22, 24, 29, 36, 37, 49, 57, 63

The high number index plates are used to increase the indexing capacity. These index plates are similar to those discussed earlier except that these contain very large number of holes. Cincinnati Milling Machine Co. U.S.A. produces a set of three plates with holes on both sides of the plate as given below:

Plate No. 1	Obverse (A)	-	30, 48, 69, 91, 99, 117, 129, 147, 171, 177, 189
	Reverse (B)	-	36, 67, 81, 97, 111, 127, 141, 157, 169, 183, and 194
Plate No 2	Obverse (A)	-	34, 46, 79, 93, 109, 123, 139, 153, 167, 181, 197

	Reverse (B)	-	32, 44, 77, 89, 107, 121, 137, 151, 163, 179, and 193
Plate No. 3	Obverse (A)	-	26, 42, 73, 87, 103, 119, 133, 149, 161, 175, 191
	Reverse (B)	-	28, 38, 71, 83, 101, 113, 131, 143, 159, 173, and 187

It is importance to note that there is no standard followed internationally in this regard. The number of plates supplied varies with different manufacturers. However, this does not change the principle of indexing. It should be put up with in mind that larger the number of plates, and more the hole circles and holes wider is the range of indexing and accuracy.

Types of dividing heads

The various dividing heads used with milling machines are:

Plain indexing head

A plain dividing head has a fixed spindle axis and the spindle rotates only about a horizontal axis.

Universal indexing head

In this, the spindle can be rotated at different angles in the vertical plane from horizontal to vertical. This head performs the following functions: indexes the work piece, imparts a continuous rotary motion to the work piece for milling helical grooves (flutes of drills, reamers, milling cutters etc.) and setting the work piece in a given inclined position with reference to the table.

Optical indexing head

These models are used for high precision angular setting of the work piece with respect to the cutter. For reading the angles, an optical system is built into the dividing head.

Methods of indexing

The various methods of indexing are discussed below:

Direct indexing

In this, the index plate is directly mounted on the dividing head spindle. The intermediate use of worm and worm wheel is avoided. For indexing, the index pin is pulled out on a hole, the work and the index plate are rotated the desired number of holes and the pin is engaged. Both plain and universal heads can be used in this manner. Direct indexing is to those available with the index plate. With a standard indexing plate having 24 holes, all factors of 24 can be indexed, that is, the work can be divided into 2,3,4,6,8,12 and 24 parts.

Simple or plain indexing

In this, the 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 a hole in the index plate. The work piece 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 divisions on the job circumference (that is number of indexing) needed is z, then the number of turns (n) that the crank must be rotated for each indexing can be found from the formula:

n = $\frac{40}{z}$ turns.

Example 3.1: Indexing 28 divisions.

The rotation of the index crank = $\frac{40}{z} = \frac{40}{28} = \frac{10}{7} = 1\frac{3}{7}$ turns

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

One full rotation + 9 holes in 21 hole circle in plate No. 2. One full rotation + 21 holes in 49 hole circle in plate No. 3.

Example 3.2: Indexing 62 divisions.

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

This can be done as follows using the Brown and Sharpe plates. 20 holes in 31 hole circle in plate No. 2.

Compound Indexing

The word compound indexing is an indicative of compound movements of indexing crank and then plate along with crank. In this case indexing plate is normally held stationary by a lock pin, first we rotate the indexing crank through a required number of holes in a selected hole circle, then crank is fixed through pin. It is followed by another movement by disengaging the rear lock pin, the indexing plate along with indexing crank is rotated in forward or backward direction through predetermined holes in a selected hole circle, then lock pin is reengaged.

Example

Let us make 69 divisions of work piece circumference by indexing method. (Using compound indexing)

Solution

Follow the steps given below:

- Factor the divisions to be make (69 = 3 X 23) N = 69.
- Select two hole circles at random (These are 27 and 33 in this case, both of the hole circles should be from same plate).
- Subtract smaller number of holes from larger number and factor it as (33 – 27 = 6 = 2 X 3).

Differential indexing

This is an automatic way to carry out the compound indexing method. In this the required division is obtained by a combination of two movements:

m … tial indexing.

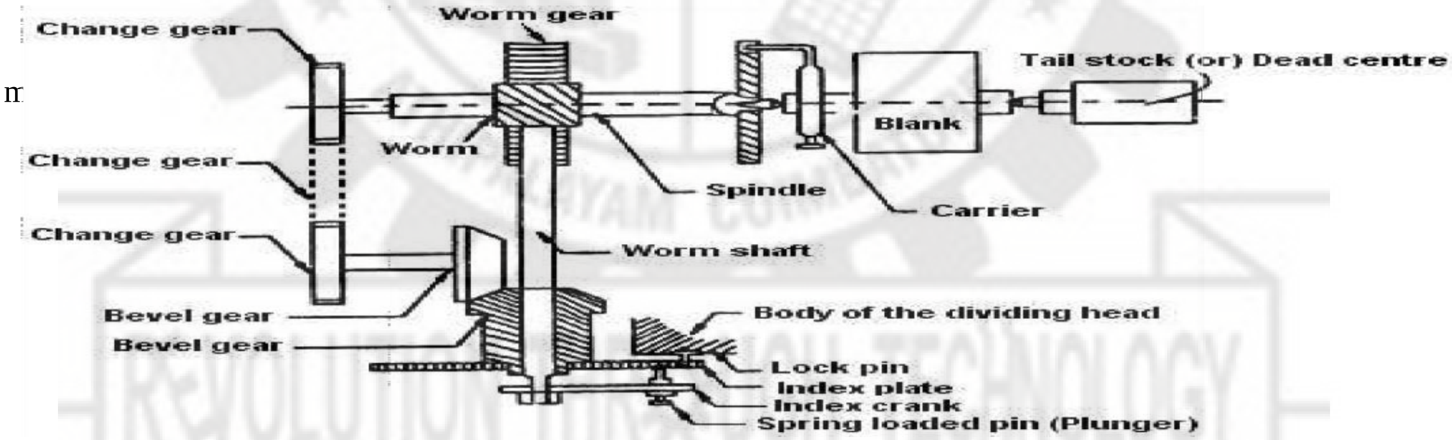


Fig. 3.38. Differential indexing

In differential indexing, the index plate is made free to rotate. A gear is connected to the back end of the dividing head spindle while another gear is mounted on a shaft and is connected to the shaft of the index plate through bevel gears as shown in figure. When the index crank is rotated, the motion is communicated to the work piece spindle. Since the work piece spindle is connected to the index plate through the intermediate gearing as explained above, the index plate will also start rotating. If the chosen indexing is less than the required one, then the index plate will have to be moved in the same direction as the movement of the crank to add the additional motion. If the chosen indexing is more, then the plate should move in the opposite direction to subtract the additional motion.

The direction of the movement of the index plate depends upon the gear train employed. If an idle gear is added between the spindle gear and the shaft gear in case of a simple gear train, then the index plate will move in the same direction to that of the indexing crank movement. In the case of a compound gear train an idler is used when the index plate is move in the opposite direction. The procedure of calculation is explained with the following example. The change gear set available is 24 (2), 28, 32, 40, 44, 48, 56, 64, 72, 86

and 100.

Example: Obtain the indexing for 97 divisions.

The required indexing is 40/97 which cannot be obtained with any of the index plates available. Choose the nearest possible division. For example, the indexing decided is 40/100

= 2/5 = 8/20.

$$40 - \frac{97 \text{ X } 40}{100} = \frac{3 \text{ X } 40}{100} = \frac{6}{5}$$

The actual indexing decided is 8 holes in a 20 hole circle. This indexing will be less than required. Ideally the workpiece should complete one revolution when the crank is moved through 97 turns at the above identified indexing. The actual motion generated when the crank is moved 97 times is

$$\frac{6}{5}$$

Hence the index plate has to move forward by this amount during the 97 turns to compensate for the smaller indexing being done by the index crank. Hence the gear ratio between the spindle and the index crank is

$$\frac{\text{Gear on spindle}}{\text{Gear on index}} = \frac{6}{5}$$

The change gear set used is $= \frac{48}{40}$

An idler gear is to be used since the index plate has to move in the same direction.

Gear Generating Process

It is based on the fact that any two involute gears of the same module will mesh together. Here one of the meshing gears is made as the cutter. The other gear rotates and also reciprocates along the width of the gear blank. Because of the relative rolling motion of cutter and the blank, gear teeth are generated on the gear blank. The gears may be generated by a rack cutter, pinion cutter or a hob. Using the generating method, profile of the gear teeth can be very accurately produced.

The following generating methods are used for gear production

1. Gear shaping.
2. Gear planning.
3. Gear hobbing.

Gear shaping

It is done on a special type of machine called gear shaper. In gear shaping, a pinion type cutter is used. The cutter teeth are ground with a top rake and clearance. It is mounted on

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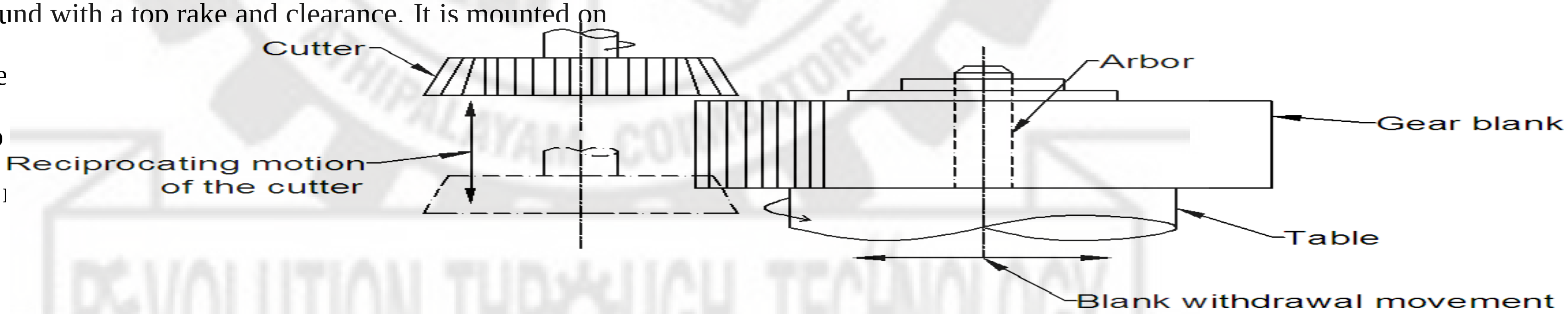


Fig. 3.39. Gear Shaping

The cutter reciprocates in a vertical direction along the width of the blank. The pinion cutter is feed radially into the gear blank to give the depth of cut. The cutter and the blank slowly rotate together till all the teeth are generated on the blank.

During each return stroke of the cutter, the blank is withdrawn. This is done to prevent rubbing of the cutting edges and damage to gear teeth being cut.

The different movements are given below:

1. Rotary motion of the cutter and the blank.
2. Vertical reciprocating motion of the cutter.
3. Radial feed of the cutter towards the blank.
4. With drawl motion of the blank away from the cutter during return stroke.

Application:

Gear shaping is used for cutting external and internal spur gears. Helical gears can also be shaped using special attachments.

Advantages:

1. Single cutter can be used for cutting spur gears of any number of teeth having the same module as that of cutter.
2. Internal gears can be easily cut.
3. As the cutting action is continuous, the rate of production is high.
4. Cluster gears can be cut.

Limitations:

Worm g

Gear hobbing:

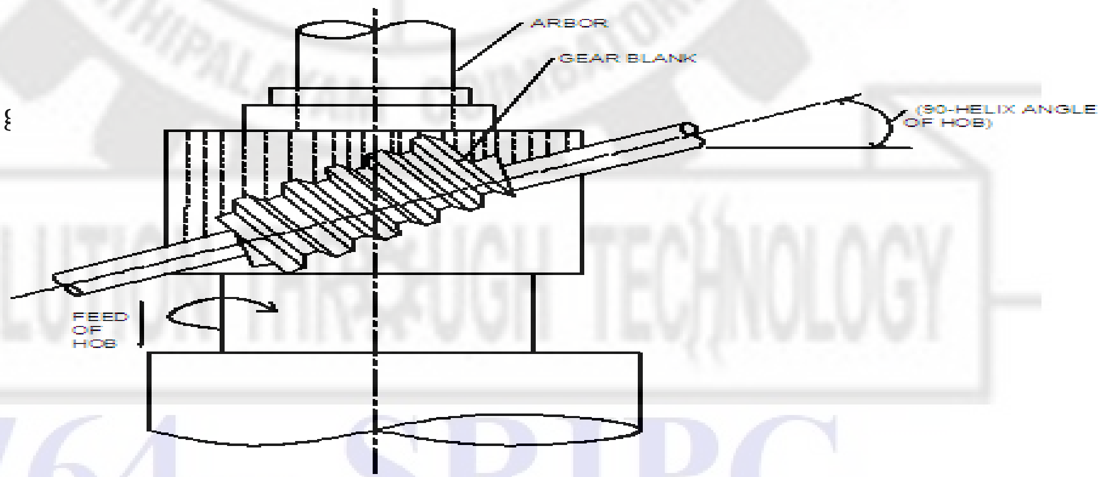


Fig. 3.40. Gear Hobbing

It is a process of generating a gear by using a rotating cutter called hob and hob has helical threads. Grooves are cut in the threads parallel to the axis and this will provide the cutting edges. Proper rake and clearance angles are ground on these cutting edges. The rotating hob acts like a continuously moving rack as it cuts. The gear blank is mounted on a vertical arbor. The hob is mounted on a rotating arbor.

The hob axis is tilted through the hob lead angle **α** so that its teeth are parallel to the axis of the gear blank.

Then $\alpha = (90° - \alpha)$

Where $\alpha 1$ = helix angle of the hob thread.

The hob axis is inclined at α° with the horizontal as shown in the figure 3.40. (Note: hob lead angle = 90°- hob helix angle)

The hob is rotated at suitable cutting speed. It is fed across the blank face. The hob and blank are made to rotate in correct relationship to each other i.e., they rotate like a worm and worm gear in mesh. (In case of single start hob).

For cutting helical gears, the axis of the hob is inclined to horizontal by α° where

$\alpha = \theta - (90° - \alpha 1)$ (If the helix of the hob and the helix of the gear to be cut are both right handed or both left handed)

$\alpha 1 = \theta$ $(90° - \alpha 1)$ (If the helix of the hob and the helix of the gear to be cut are different i.e., one is right handed and another left handed)

Where θ = Helix angle of the helical gear to be cut and α1 = Helix angle of the hob.

Applications:

Hobbing is used for generating spur, helical and worm gears.

Advantages:

1. A single hob with the given module can be used for generating gear with any number of teeth of the same module.
2. The same hob can be used for spur and helical gears.
3. Operations are continuous. So very fast rate of production.
4. Perfect tooth shape is obtained.
5. Process is automatic and so less skilled operator is sufficient.
6. Worm gears are generated only by hobbing.

Limitations:

1. Internal gears cannot be generated.
2. Hobbing cannot be used for producing gear teeth very near to shoulders.

S#	Gear Planning	Gear hobbing
1.	Can cut spur helical and bevel gears.	In addition to these, worm gear can also be cut.
2.	Rack type cutter is used.	Cylindrical hob is used.
3.	Cutting is intermittent.	Cutting is continuous.
4.	Production rate is moderate.	Production rate is very fast.
5.	Internal gears cannot be cut.	Internal gears cannot be cut.
6.	Cluster gears can be cut.	Cluster gears cannot be cut.
7.	Tooth profile is very accurate.	Tooth profile is accurate.
8.	Cutter reciprocates and moves originally.	Cutter rotates and moves parallel to the axis of the blank.
9.	Cutter fed against the blank.	The gear blank is moved in towards the hob axis.

GEAR FINISHING PROCESSES

Gears manufacturing by different machining processes will have rough surfaces. The machined gears may have errors in tooth profiles, concentricity and helix angles. For quiet and smooth running of gears, these errors and rough surfaces should be removed. Gear finishing operations are done for this purpose.

Gear burnishing:

This is a method of finishing of gear teeth which are not hardened. This is a cold working process. This method is used to improve the surface finish of the gear teeth. This also increases the hardened at the teeth surface. The principle of working of a burnishing process is shown in figure. In burnishing, the gear to be finished is rolled between three burnishing gear. The teeth of burnishing gears are very hard, smooth and accurate. They are arranged at 120° position around the work gear. Power drive is given to one of the burnishing gears. The other two gears are idlers. Burnishing pressure is applied to the idlers. The gears are rotated in one direction for some period. Then they are rotated in the reverse direction for the same period.

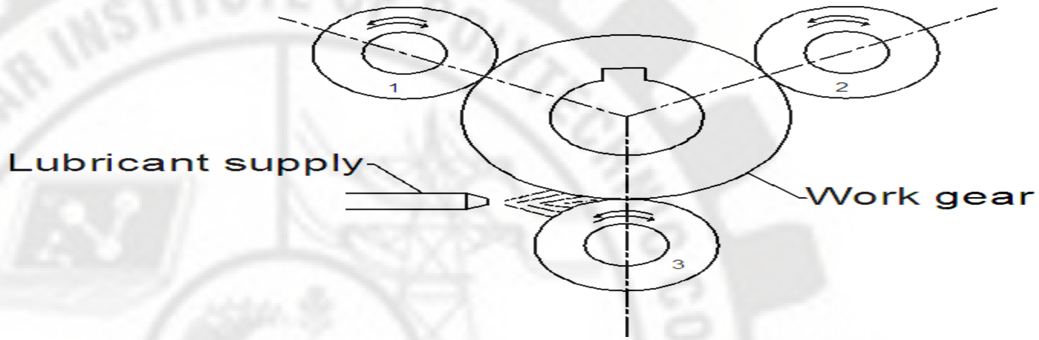


Fig. 3.41. Gear Burnishing

The pressure is applied by the harder burnishing teeth on the work gear. The surface hardness of teeth in the work gear is also increased. The teeth are finished on both the faces

uniformly. This is obtained by the rotation of the gears in both the directions. A lubricant is applied between the teeth to get smooth

surface finish. T'

Gear shaving:

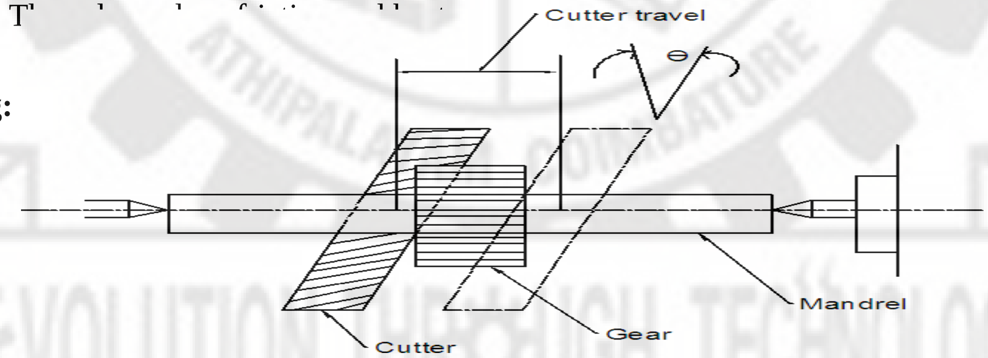


Fig. 3.42. Gear Shaving

This is the most common method of gear finishing. In this method, a very hard gear shaving cutter is used to remove fine chips from the gear teeth. The shaving cutter may be in the form of a rack or a pinion. The rotary method using pinion cutter is used on all types of gears. The rotating cutter will have helical teeth of about 15° helix angle. The tooth form of a cutter is shown in figure. The cutter has a number of serrations on its periphery. These act as cutting edges.

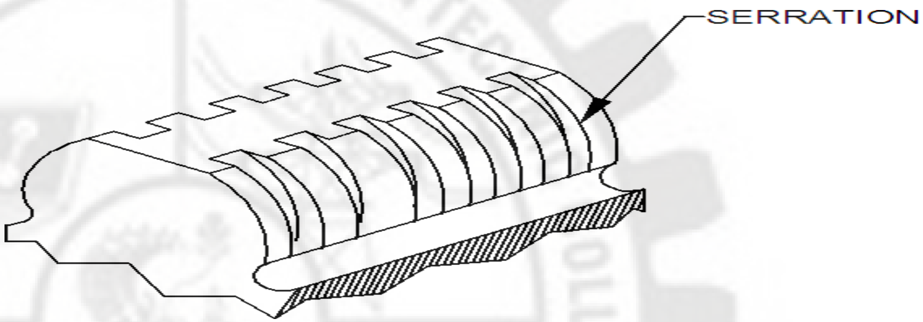


Fig. 3.43. Gear Shaving tooth cutter

The work gear is held between centres and is free to rotate. The shaving cutter meshes with the work gear. The axis of the cutter is inclined to the gear axis at an angle equal to the helix angle of the cutter (θ). When the gear and the cutter rotate, the cutter reciprocates in a direction parallel to the gear axis. The cutting edges of the shaving cutter remove burns, nicks and high points on the surface of the work gear. If can remove from the teeth flank, chips up to 0.01 mm thick.

Gear grinding:

Gear grinding is used for finishing gears after hardening. Gear grinding is done for

a) Increasing the accuracy of gears.
b) Improving the surface finish.
c) Removing the distortion due to heat treatment. There are two method of gear grinding. They are 1. Formed wheel grinding 2. Generation gear grinding

a) Formed wheel grinding:

In formed wheel grinding, the grinding wheel is dressed to the form of tooth space of the gear (involute profile). The grinding wheel is moved parallel to the work gear axis. After grinding one tooth space, the work gear is indexed to the next tooth space. About three passes are required to finish the tooth space. Proper coolant should be used while finishing by grinding.

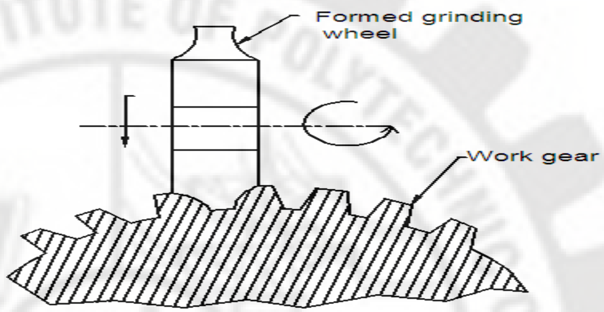


Fig. 3.44. Formed wheel Gear grinding

b) Generation Gear Grinding:

The work gear is rolled along an imaginary rack. Rolling is done in both the direction to grind both sides of the tooth. The grinding wheel reciprocates along the length of the tooth. The grinding wheel is dressed in the form of rack teeth. This work gear rotates about its axis. The gear is also given a linear motion along its axis. The linear motion and rotary motion are opposite to each other. These two motions together give a generating motion. Bevel gears are also ground by type grinding wheel as shown in the figure.

Gear lapping:

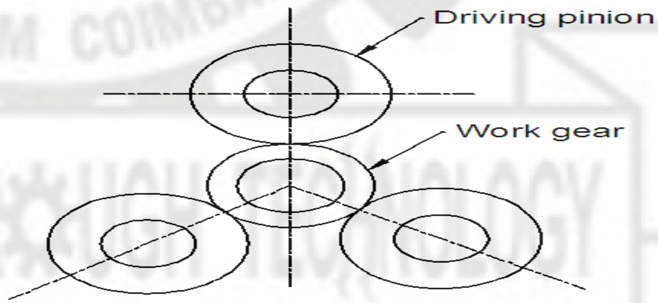


Fig. 3.45. Gear lapping

The hardened gears are finishing accurately by lapping process. Lapping removes very small amount of metal (not more than 0.05 mm). The work gear is rolled between three lapping gears. The lapping gears are made of cast iron. The lapping gears are arranged at 120° position around the work gear.

The axis of the two lapping gears (2&3) are inclined at about 4° to the work gear axis. The axis of the other lapping gear (1) is parallel to the work gear axis. The drive is given through this gear. When gear rotate, a lapping compound is applied between them. The compound is a mixture of a very fine abrasive powder and kerosene. The lapping process improves the tooth contact.

Gear materials:

The selection of materials depends upon the load transmitted and smoothness of operation required. It also depends upon the surface finish and accuracy required on the teeth profile. The material selection also depends on the cost of material and the size of the gear required.

The following materials are generally used for the manufacture of gears.

1. Cast iron 2. Steel 3. Alloy steel 4. Brass

5. Bronze 6. Aluminum 7. Nylon 8. Fibre

Cast Iron:

Cast iron is widely used for the manufacture of gears. Cast iron is used where strength is not very important but good wear resistance is required. It is cheaper one and it absorbs vibrations. Large size gears are easily made by cast iron. But cast iron is relatively weak and brittle. Cast iron can be easily machined. To improve the strength and shock resistance, nickel and chromium are alloyed with cast iron. Cast iron gears are used as bull gears and in construction equipment.

Steel:

Steel is also widely used for manufacturing gears. Gears can be manufacturing from steel by various method. They are

- Machining
- Forging
- Rolling

- Casting
- Blanking

It is stronger. Hence it can transmit heavy loads. Steel also take shock loads also. By using steel as a gear material we can achieve our required property on the surface by heat treatment. Carburizing and nitrating can be done to increase the surface hardness. Hardened steel gears are used for heavy duty service i.e. automobiles, machine tools etc.

Steel alloys:

Properties of steel can be improved by adding the following alloying elements; nickel, manganese, chromium and molybdenum. Nickel increase toughness and corrosion resistance. Manganese increase strength and wear resistance. Chromium improves the wear resistance. Molybdenum increase toughness. Alloy steel can take heavy loads. By adding proper alloying elements, wear resistance, corrosion resistance, impact strength etc. can be increased. Alloy steels are always costly.

Brass:

Brass gears are made using die casting and cold drawing processes. It is very high resistant to corrosion. Very surface finish and smooth operation are achieved in brass. Small motors, instruments, cameras, electrical appliances, toys etc. Use brass gears. It is not suitable for heavy load transmission. Generally brass gears are driven with steel pinions. Hence it reduces friction and gives long life.

Bronze:

Bronze is used for producing highly wear resistant gears. Worms and worm gears are generally made bronze. According to the alloying element added, bronze is classified as phosphor bronze, manganese bronze, aluminium bronze and silicon bronze. Bronze gears are used in gear pumps worm and worm gear drives, motor armature etc. Bronze gears are produced in die-casting and cold drawing processes. Bronze gears run without noise.

Aluminium:

Aluminium gears have light weight. They are used in small gear boxes for weight reduction. Because of light weight, the inertia effect is very less. Alloyed aluminium is used for making gears. Gears in aluminium are generally produced by centrifugal casting. Aluminium gears are used for light duty work only. By anodizing, the aluminium gear surface can be made hard. Anodized aluminium gears will have wear and corrosion resistance. Aluminium gears are used in instruments, toys, cameras, electrical appliances etc.

Nylon:

Nylon is used for production of gears in large quantity. Nylon gears are cheaper. These gears are generally produced in injection moulding process. It is a self-lubricating one. So no lubrication is necessary. Nylon develops low friction and runs very smoothly without noise. They have good impact and tensile strength. When run by steel pinion, nylon gears give good performance. Very low inertia is caused while running. Nylon gears are used in instruments, counters, time gears, cameras, projectors, television sets etc. nylon gears are used for light duty operation. These gears are used for transmitting motion only. It is not suitable for transmitting power. Nylon is anti-corrosive. Nylon is affected by moisture. Nylon gears cannot withstand high heat.

UNIT IV - ABRASIVE PROCESS AND NON- CONVENTIONAL MACHINING PROCESSES

ABRASIVE PROCESSES

INTRODUCTION

Grinding is a metal removal operation in which the metal is removed with the help of a rotating grinding wheel or abrasive wheel. The grinding wheels are made of

abrasive materials held together by a bonding material. Grinding process removes very little amount of metal and also it gives very good surface finish with accuracy. This operation is

suitable for machining very hard metals.

TYPES OF GRINDING

1. Rough Grinding or non-precision
2. Finish or precision grinding

3. Rough Grinding

Chips, Sharp edges, burr, unwanted projections on the workplaces are removed by Rough grinding process.

2. Precision Grinding

Precision grinding operation used for grinding the cutting tool materials. In this method the grinding wheel with very thin abrasive is used for grinding. So the metal is

removed as very small particles. Due to this, the work piece can be machined accurately. Grinding process is classified based on the grinding method. They are given below.

1. External cylindrical grinding
2. Internal surface grinding
3. Surface grinding
4. Form grinding

1.External cylindrical grinding

The grinding operation which is done on a straight or tapered cylindrical workplace is called external cylindrical grinding. The work piece is rotated in its axis and moved across the face of the grinding wheel for grinding the surface of the work piece.

2.Internal cylindrical grinding

The grinding operation which is done on the internal hole of the cylindrical work piece and the inside taper surface of the cylindrical work piece is called internal cylindrical grinding. In this method, the work piece is held in the chuck and rotated in its axis then the rotating grinding wheel is passed inside the work piece for grinding.

3.Surface grinding

In this operation, the flat surface is produced by grinding the surface. For this, the work piece is moved forward and backward under the rotating grinding wheel.

4.Form grinding

The required form of grinding wheel is used for grinding the work piece. So this grinding operation produce the shape of grinding wheel used on the work piece for

grinding.

CLASSIFICATION OF GRINDING MACHINES

1. Cylindrical Grinding
    1. Plain cylindrical grinder
    2. Universal cylindrical grinder
    3. Centreless grinder
2. Internal Grinders
    1. Chucking type internal grinders
        A. Plain internal grinders
        B. Universal internal grinders
    2. Planetory internal grinders
    3. centreless internal grinders
3. Surface grinders
    1. Reciprocating table type
        A. Horizontal spindle type
        B. Vertical spindle type
    2. Rotating table type
        A. Horizontal spindle type
        B. Vertical spindle type
4. Tool and cutter grinders
    1. Universal grinders
    2. Special grinders
5. Special and single purpose grinding machines

1. Floor stand grinder

In this grinder, an electric motor fitted in the base. The motor has a horizontal spindle with grinding wheel mounted at each end of the motor shaft extensions.

Floor grinder is used for sharpening the tools, boring tools and drills. The machine has a grinding wheel with coarse grains on one end and a grinding wheel with fine grains on the other end.

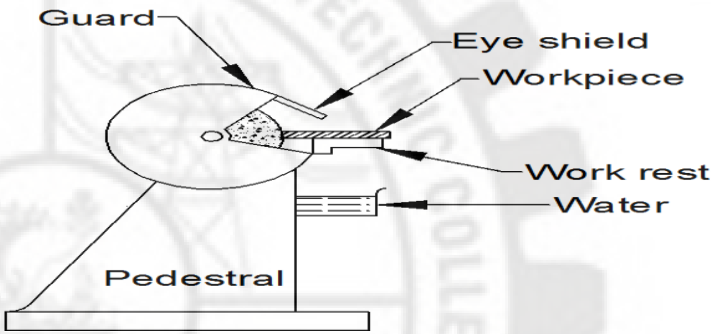


Fig. 4.1. Foot stand Grinder

2. Bench grinder

The appearance of this grinder is similar to the floor grinder. But this machine is placed on the bench. This type of grinder is used for grinding of tools and other small parts.

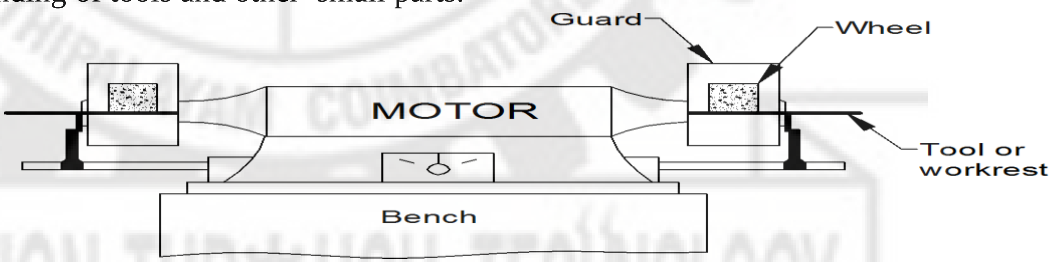


Fig. 4.2. Bench Grinder

3. Portable grinder

The machine can be carried from place to place. A small electric motor is provided in this grinder. A small grinding wheel is attached to the end of the motor. This grinder is suitable for grinding castings, and weld mesh.

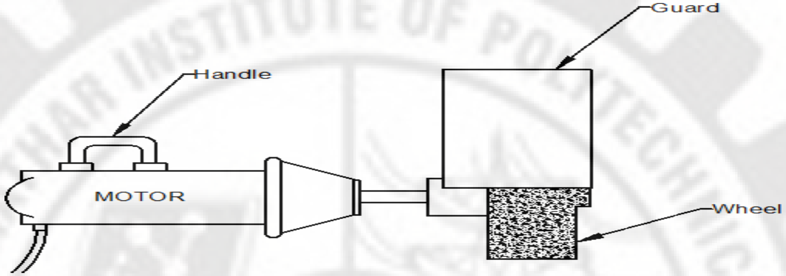


Fig. 4.3. Portable Grinder

4. Swing frame grinder

This type of grinder has horizontal frame to the length from 2 to 4 meter. A grinding wheel is fitted at the one end of the frame and this grinding wheel is attached to the motor. The other end of the frame carries balancing weight. A handle is provided at the wheel end.

It is used for moving the grinding wheel and pressing on the work piece for rough grinding. The grinder is suspended at

area of opera

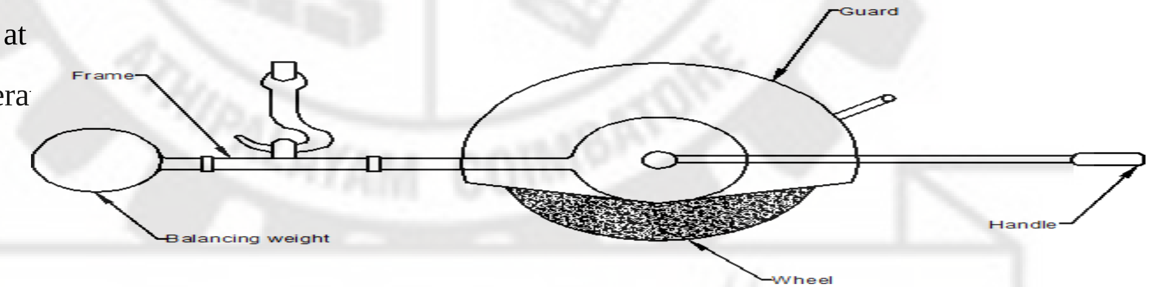


Fig. 4.4. Swing frame grinder

5. Abrasive belt grinder

In this grinder, abrasive belt is used instead of the grinding wheel. An endless belt is placed on the pulley. When this pulley is rotated by an electric motor the abrasive belt also rotates. Then the work piece is fed against this rotating abrasive belt for grinding the surface.

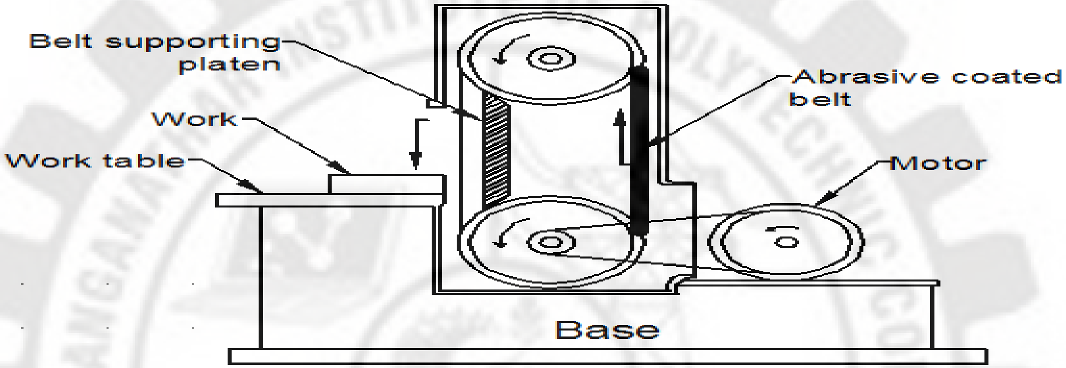


Fig. 4.5. Abrasive belt grinder

PRECISION GRINDERS:

Surface grinding machine, cylindrical grinding machine and internal grinding machine are belonging to the precision grinding machines. In this type of machines,

one end of the work piece is held in the dead centre and the other end is held in the dead centre and the other end is held in the dog or driver of the plate. There are four

movements in this type machines given below.

1. Rotation of work piece

1.

2.

3.

1. Cylindrical grinding

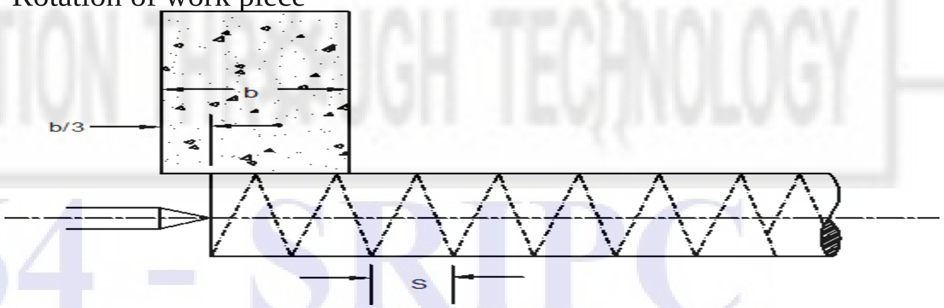


Fig. 4.6. Cylindrical Grinding

1. Traverse grinding

This method is used when the job length is more than the width of the grinding wheel. The work piece is held between two centres. The grinding wheel is made to rotate in a fixed position. The rotating work piece is made to traverse and the grinding is done on the work piece.

2. Plunge grinding

Plunge grinding operation is suitable when the length of the workplace is smaller than the width of the grinding wheel. Here, the work piece need not to be fed longitudinally

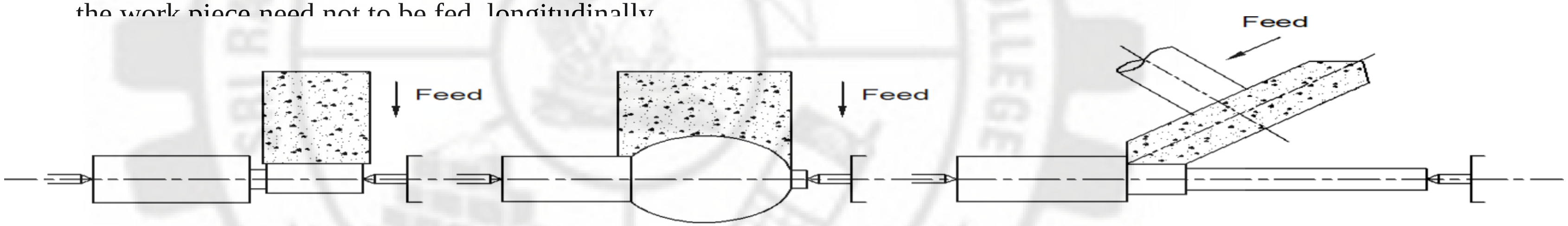


Fig. 4.7. Plunge cut Grinding

Then the grinding is done by grinding is done by giving only the cross feed to the grinding wheel. Plunge grinding is used for grinding shoulders, stepping and various contours.

CYLINDRICAL GRINDING MACHINE (CENTRE TYPE GRINDER)

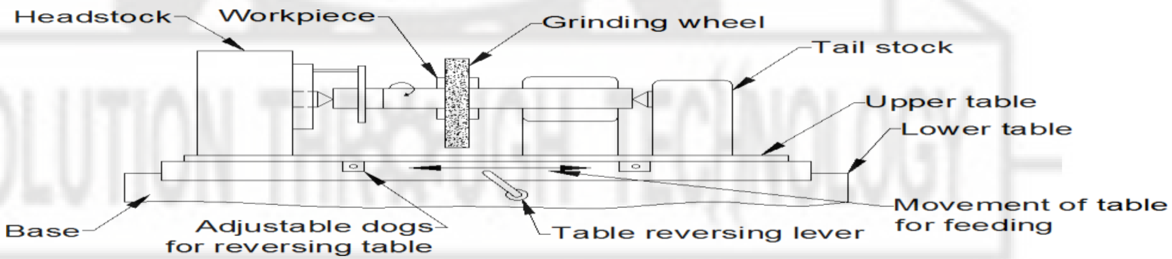


Fig. 4.8. Cylindrical Grinder

1. Base

This is made of CI and rests on the floor and it supports the other parts which are mounted on it. Horizontal guide ways are set on the top of the base. Table slides on these guide ways are set on the top of the base. The table slides on these guide ways for giving traverse motion to the work piece. The driving mechanism for the table is housed inside the base.

2. Table

This machine has two tables such as upper table and lower table. The lower table slides on the bad guide ways to give the longitudinal feed of the work past the grinding

wheel. The table can be moved by hand or by power. The dogs are provided at the side table to reverse the table at the end of the stroke. The upper table is mounted on the lower table.

Head stock and tail stock are mounted on the upper table. The table can be swivelled for the maximum angle up to 100 on either side

3. Head stock

The head stock has dead centre on which the work piece is supported. The work piece is driven by head stock through a dog and driving pin. A separate motor is used in the head stock for rotating the workspace

4. Tail Stock

Different length of work piece is clamped between head stock and tail stock by adjusting the distance through tail stock. The work piece is held between head stock and tail stock.

5. Wheel head

The grinding wheel is held in the wheel head and it is driven by a motor housed in the head stock. The wheel head is placed over the bed at the back side. It can be moved perpendicular to the table guide ways by hand or power.

6. Working

The required work piece is held between centres. It is rotated by a dog or a face plate. Then the grinding wheel is made to rotate in its own axis in the opposite direction of work. Then the grinding wheel is fed by hand or automatically towards the work piece.
be swiveled in a horizontal plane in any angle.

UNIVERSAL CENTRE TYPE GRINDERS

This type is mostly used in tool room for grinding the tools. This machine is similar to the cylindrical grinding machine. But the wheel head and head stock can be swiveled to the

required angle. This machine is provided with the following features.

1. The centre of the head stock spindle can be used alive or dead.
2. The wheel head can be swiveled in a horizontal plane in any angle.
3. The head stock can

4. The wheel head may be arranged for internal grinding.

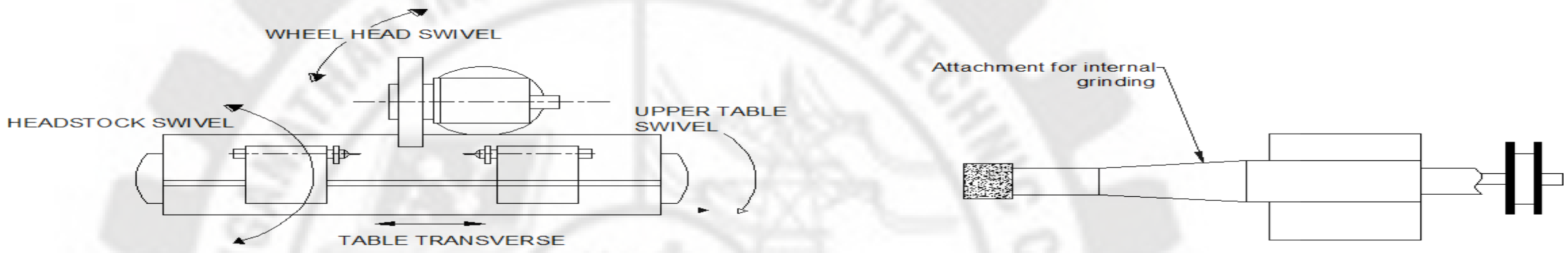


Fig. 4.9. Universal Grinder

The following equipment's are used in universal grinding machine.

1. Support slender work
2. Wheel truing device
3. Arbor
4. Internal grinding spindle
5. Three jaw self-centering chuck

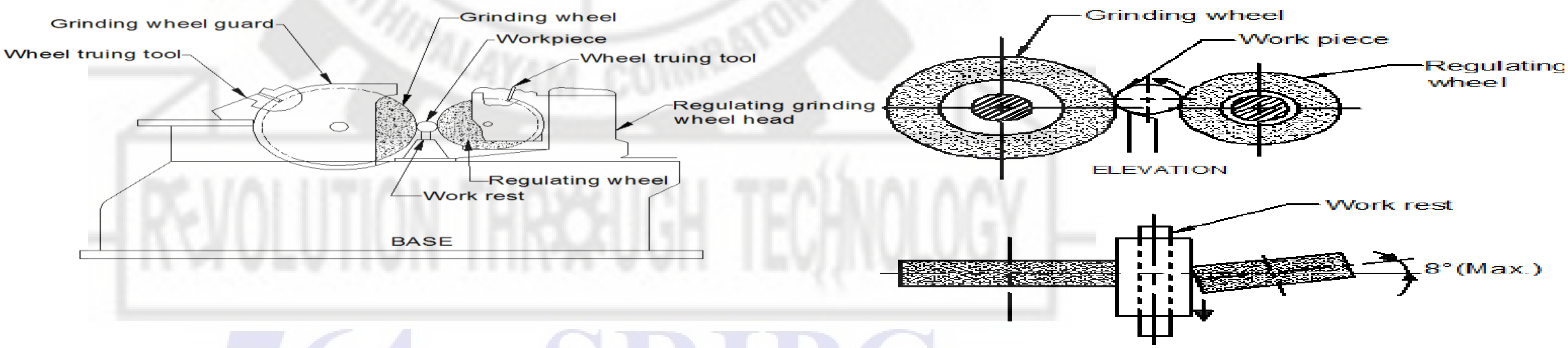


Fig. 4.10. Centreless Grinder

Horizontal Spindle Surface Grinder:

The work piece cannot be held between the centres of the machine can be machined by this type of grinding machine. The external centreless grinding machine has grinding wheel, regulating wheel or backup wheel and work rest. The two wheels are rotated in same direction. The larger grinding wheel revolves at a high speed and small regulating wheel revolves at slow speed. The work rest is placed between the two wheels. The work piece is placed on the rest. The regulating wheel is moved forward for forcing the work against the grinding wheel. This causes friction between the grinding wheels makes the work piece to rotate.

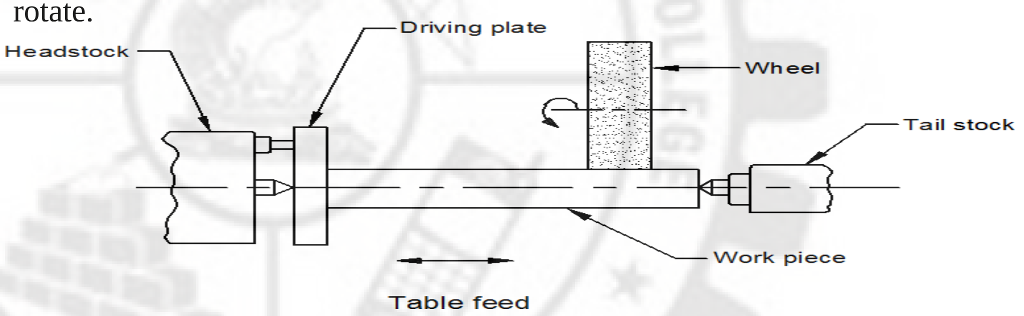


Fig. 4.11. Horizontal Spindle Surface Grinder

Then the rotating work piece is pressed between the two grinding wheels and they grind the surface. The regulating wheel does not remove the metal. The work piece is placed in a floating condition between the grinding wheel and regulating wheel while doing the grinding operation. So, this grinding operation is called centreless grinding.

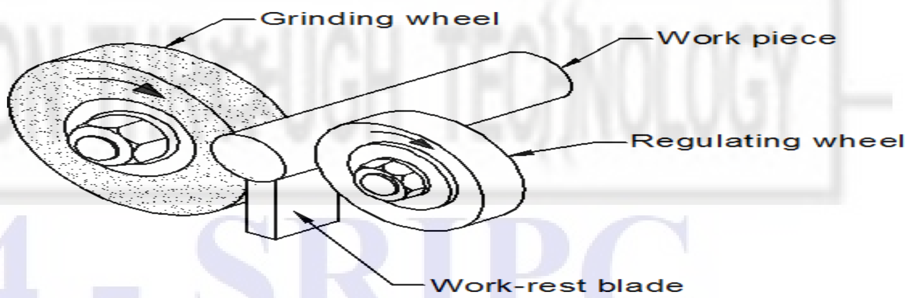


Fig. 4.12. Centreless Grinding

METHODS OF CENTRELESS GRINDING

1. Through feed

1. In feed

1. End feed

1. Through feed

This method is suitable for grinding the long shaft or bars and rollers pins. In this method, the regulating wheel is tilted at a small angle for moving the through the space between wheel for guiding the movement of the work piec

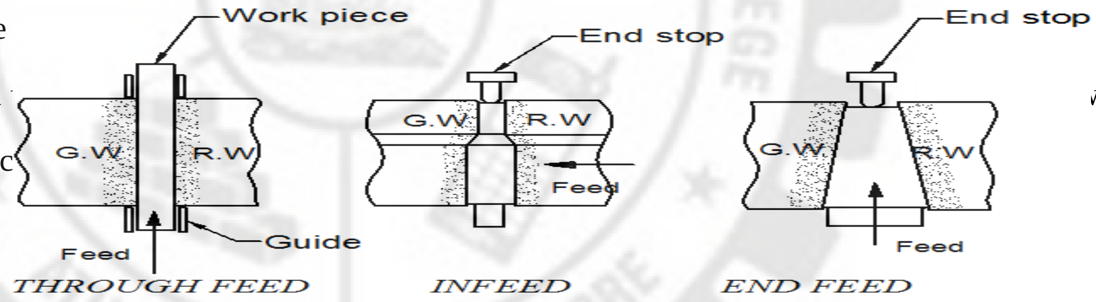


Fig. 4.13. Methods of Centreless Grinding

2. In feed grinding

In this method, the work piece is placed on the work rest against an end stop. Due to this, the axial movement of the work piece is avoided. Then the regulating wheel and the work rest with the work piece are moved towards the grinding wheel by giving hand feed. This method of grinding is similar to the plunge grinding. Shoulders and formed surfaces are ground by this method.

3. End feed grinding

This method is suitable for producing tapered surface. So, the grinding wheel or regulating wheel with required form of taper is used for grinding. The work piece is fed axially between the wheels and ground. An end stop is provided at the rear end of the wheel for stopping the work piece at the required length.

Advantages of centreless grinding

1. Fixtures and other clamping devices are not required for holding the work piece.
2. This is the faster process than the centre type grinding.
3. The size of the job can be controlled easily by the regulating wheel.
4. Skilled operators are not required
5. Suitable for mass production.

Limitations

1. Work piece with steps and multiple diameters as cannot be ground easily
2. The cylindrical surface with a keyway or holes cannot be ground.

INTERNAL GRINDERS

Internal grinder is used for grinding inside surface of the work piece. The inside surfaces may be straight, tapered or formed holes. Generally, the following three type of internal grinder are used.

1. Chucking
2. Planetary
3. Centreless

1. Chucking type internal grinders

In this machine the work piece is held in the chuck and rotated about its axis. The work head is mounted at the left side of the machine and the wheel head is mounted at the right end of the machine. The grinding operation is done on the work piece by reciprocating the rotating grinding wheel through the length of hole in the work piece. This type of machine is suitable of grinding the work piece which can be held in the chuck.

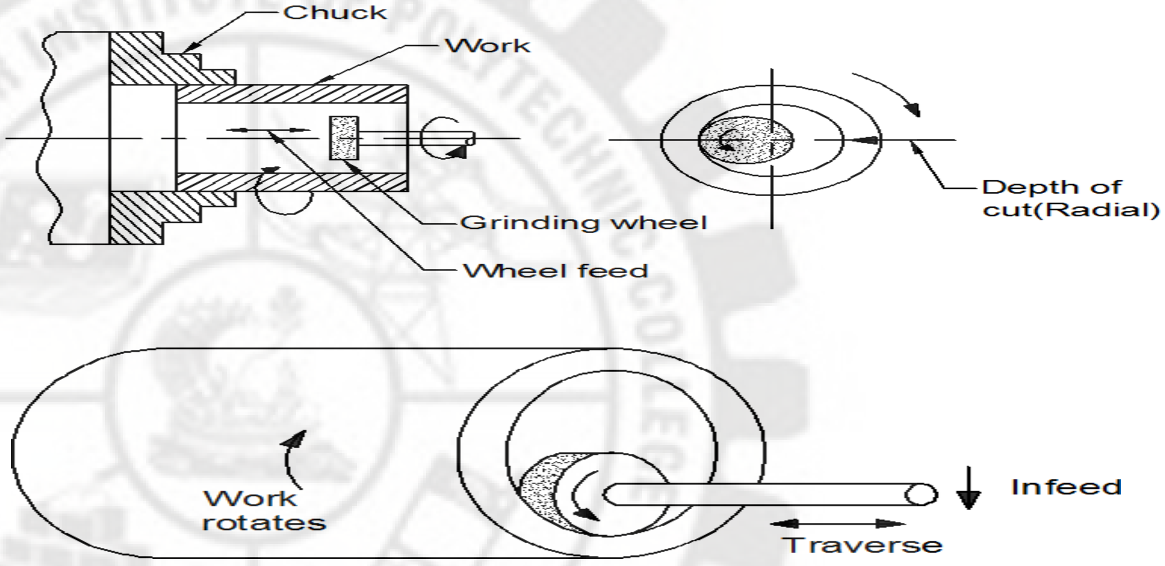


Fig. 4.14. Chucking type Internal Grinder

2. Planetary type grinders

The work piece is held in the reciprocating table and the work piece is clamped rigidly. The work piece will not be moved. But for grinding the work piece, the rotating grinding wheel is moved inside the work piece and reciprocates for grinding the surfac

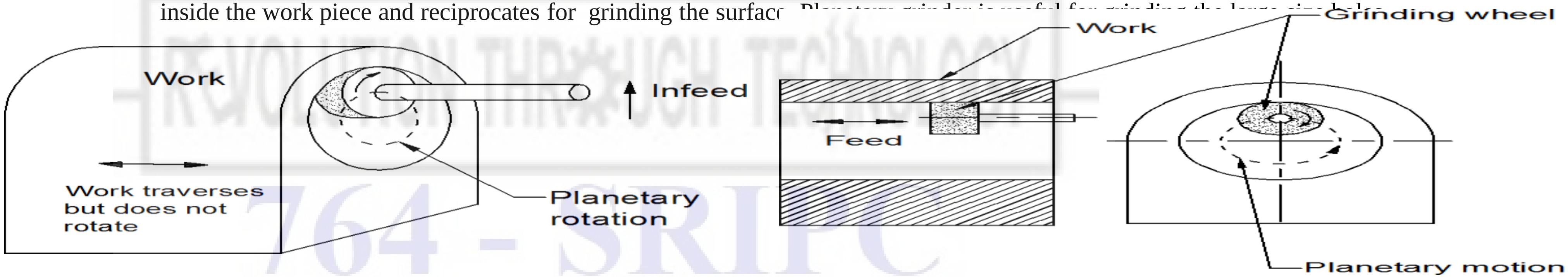


Fig. 4.15. Planetary type Internal Grinder

3. Centreless grinding

In this grinding, the work piece is supported by the three rolls. One is regulating wheel, second is a supporting wheel and other is a pressure roll to hold the work piece against the support and regulating rolls. The regulating wheel makes the work piece to rotate. The rotating grinding wheel is moved inside the diameter of the work piece and reciprocates for grinding the surface. Then the grinding wheel is moved in a cross wise direction for giving depth of cut.

SURFACE GRINDERS:

This machine is suitable for grinding flat and plane surface. Irregular, curved and tapered surfaces also can be ground using this machine. Die, Valve, Piston rings, surface plates are finished by this grinding machine.

HORIZONTAL SPINDLE – RECIPROCATING TABLE SURFACE GRINDER

1. Base

Base is made by casting with rectangular shape. Driving mechanism is housed inside the base. A vertical column is mounted on the back side of base. Horizontal guide ways are in the top of the base and these are perpendicular to the column.

2. Table and saddle

Saddle rests on the base. The saddle moves on the guide ways which are perpendicular to the column and gives cross feed. The table moves on the horizontal guide ways of the saddle. Longitudinal feed is given by moving the table. 'T' slots are provided on the table for holding the work.

3. Wheel head

A separate motor is mounted at the top of the column for operating the wheel head.

The wheel head moves up and down on the vertical guide ways of the column.

Operation

Magnetic chuck or fixtures are used for holding the work piece on the table. The trip dogs are adjusted suitably to get the correct stroke length of the table. Then the table with work piece reciprocates and the periphery of the rotating grinding wheel grinds the work piece. Depth of cut is given by lowering the wheel head or raising the table. Cross feed is given to the work piece at the end of every stroke.

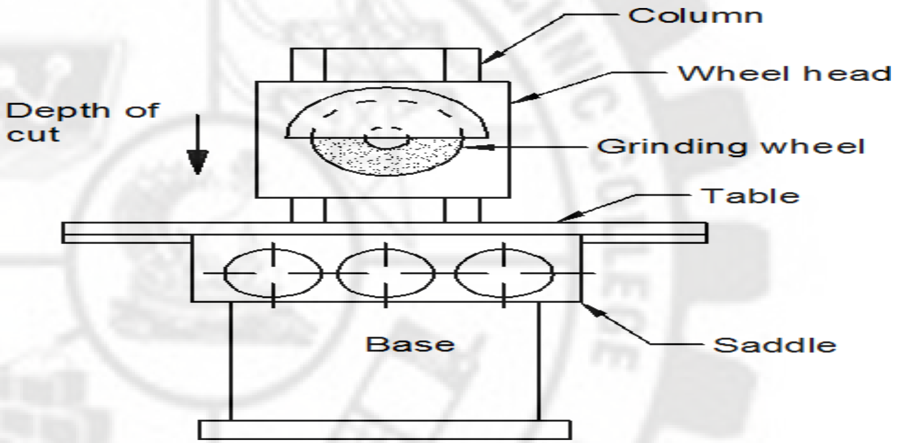


Fig. 4.16. Surface Grinder

HORIZONTAL SPINDLE – ROTARY TABLE SURFACE GRINDER

Rotary Table Surface Grinder

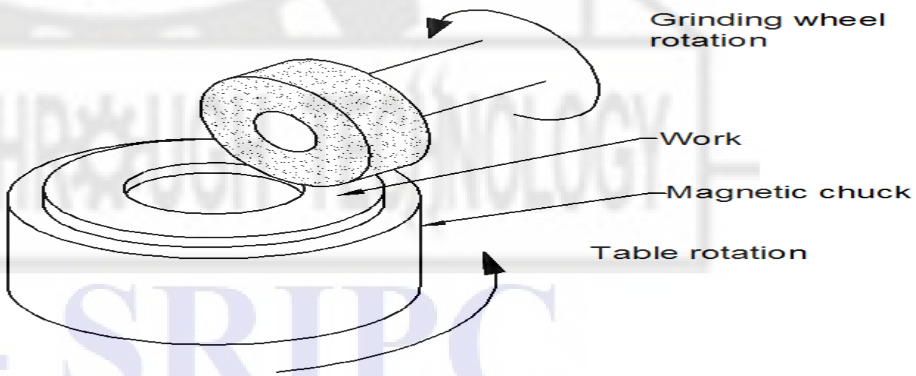


Fig. 4.17. Horizontal spindle Rotary table Surface Grinder

In this grinder, a rotary table is used. Small size work piece is held in the table and rotated. Wheel head of the machine reciprocates in its axis. This movement gives the cross feed. The wheel head is moved down for giving depth of cut. The peripheral surface of the grinding wheel grinding the surface. This machine is suitable for grinding small and medium size works.

VERTICAL SPINDLE RECIPROCATING TABLE SURFACE GRINDER

The work piece is clamped on the reciprocating work table using a magnetic chuck or a fixture. A grinding wheel rotates in its vertical axis. The face or side of the grinding wheel cuts the metal. The wheel head is moved down for giving the depth of cut. The longitudinal and cross feed are given through the table. This machine is useful for grinding the flat surfaces of medium size work piece.

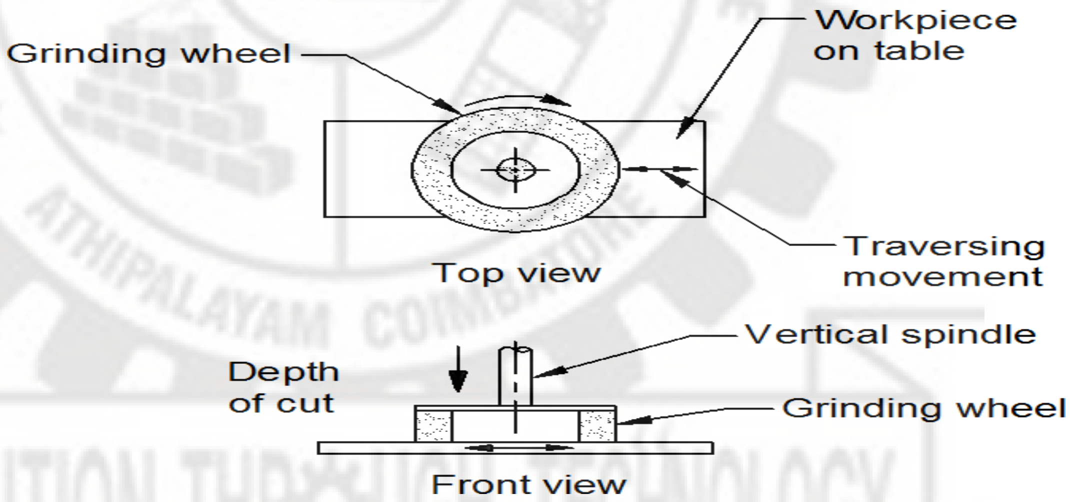


Fig. 4.18. Vertical spindle Reciprocating table Grinder

VERTICAL SPINDLE-ROTARY TABLE SURFACE GRINDER

The grinding spindle is mounted vertically on the face of a column and rotates in fixed position. The grinding wheels are moved down for giving depth of cut and grinding the work piece which are rotating with the rotary table. grinding large quantity of This grinding machine is used for small work piece

GRINDING WHEEL:

Grinding Wheel

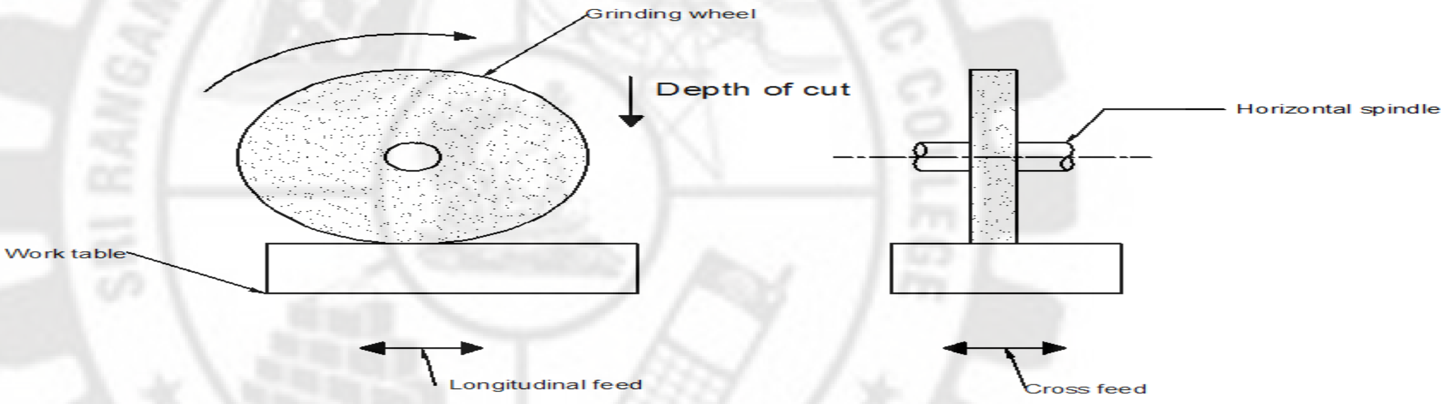


Fig. 4.19. Grinding wheel

Wheel Head

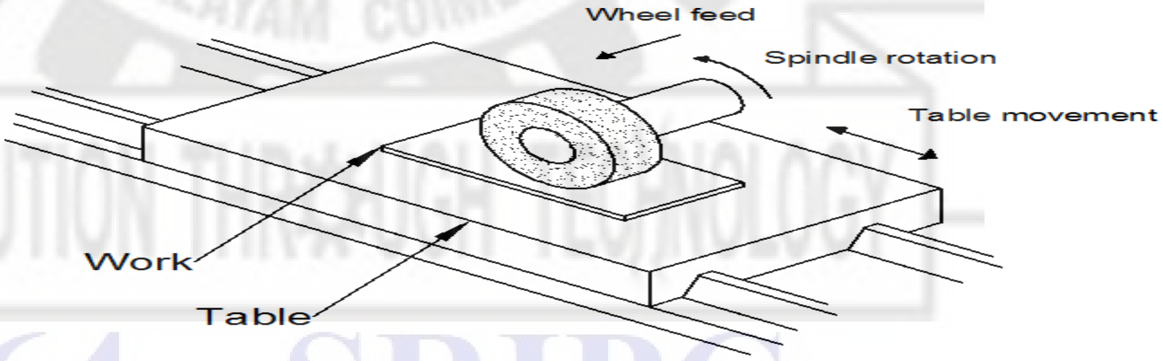


Fig. 4.20. Grinding wheel head

It is made up of small abrasive particles held together by a bonding material.

ABRASIVES

It is a hard material. Small abrasive particles are used in grinding wheel.

Abrasives are classified into two types. They are

1. Natural abrasive 2. Artificial abrasive.

1. Natural abrasive

This type of abrasive is available in nature. The following are the natural abrasives.

1. Sand stone
2. Emery
3. Diamond
4. Corundum

2. Artificial abrasives

Abrasives particles are manufactured with required quality by artificial method. Mostly artificial abrasives are used for manufacturing the grinding wheels. Quality and the hardness of the artificial abrasives are more than the natural abrasive. The various manufactured abrasives are given below.

2. Aluminium oxide
3. Silicon carbide
4. Artificial Diamond
5. Ceramic aluminium oxide
6. Boron carbide

a. Aluminium oxide

This type of abrasives is manufactured from the bauxite mineral. It is manufactured by fusing the bauxite in an electric furnace mixed with coke and iron scrap. After fusing, it is crushed and finally ground. Mostly the grinding wheel with aluminium oxide abrasive is used for grinding the carbon steel, alloy steel, HSS, wrought iron alorite, abrasite, Electrite and Alundum are the other names of the Aluminium

b. Silicon carbide

It is manufactured from the silica sand. Silica sand, coke and wood dust are mixed and kept in the electric furnace for beating them for producing silicon carbide. This made with this abrasive is used for grinding the metals like iron, aluminium and copper.

BONDS

Bond is an adhesive substance which holds the abrasive grains together to form the grinding wheel. Vitrified bond is used for precision grinding. Resinoid bond is used for rough grinding. The following are the different bonding materials.

1. **Rubber bond (R)**

   The regulating wheel which is used in centreless grinder is manufactured by rubber bond. Sulphur with rubber is used for manufacturing rubber bonded grinding wheel.

2. **Shellac bond or Elastic bond (E)**

   Shellac bonded wheels are made by mixing the abrasive grains with shellac in a mixture. Then the mixture is rolled or pressed to the desired shape and hardened about 200˚c for a particular time.

3. **Vitrified bond**

   In this, clay and water is mixed and placed in mould to get the shape of the wheel and air dried at room temperature. Then the moulded wheels are kept about 1260˚C for a few days. Then they are trimmed to the required size. Thus the vitrified bonded grinding wheels are manufactured.

4. **Silicate bond (S)**

   Here, sodium silicate is used as bonding material. Abrasive particles with sodium silicate are mixed and placed in the mould to get the required wheel shape and kept it about 270˚C for 20 to 80 hrs.

5. **Oxy chloride bond**

Oxide and magnesium chlorides are used as bonding material for manufacturing grinding wheel.

6. **Resinoid bond**

Synthetic Resins are used as bonding material. Synthetic resin mixed with abrasive grain and placed in the mould to get the required wheel shape and heated about 2000˚C for several hours. During the heating time, the resin melts and joined with the abrasive grains. This type of bonded wheel can be rotated with higher speed. And used for rough grinding on steel parts and castings.

GRAIN OR GRIT

Abrasive particles size is mentioned as grain or grit. Same or different sizes of grains are used for manufacturing the grinding wheel. The selection of grit or grain size mainly depends on the following:

1. The amount of material to be removed
2. Required finishing
3. Property of the metal

Soft and Elastic materials can be ground by course grit wheels and brittle materials are ground by fine grit wheels. Grain size is mentioned as number. This number indicates the number of meshes per linear inch through which they are passed. The grain sizes are divided as shown in the table.

Grinding Operation	Grit or Grain size						
Coarse	10	12	14	16	20	24	
Medium	30	36	46	54	60		
Fine	80	100	120	150	180		
Very fine	220	240	280	320	400	500	600

GRADE:

Grade indicates the strength, with which bonding material holds the abrasive grains in the grinding wheel. Bonding strength or hardness is indicated by English alphabets. 'A' is the softest wheel and 'Z' is the hardest wheel. The grinding wheel with different grades is shown in the following index.

Soft	A	B	C	D	E	F	G	H		
Medium	I	J	K	L	M	N	O	P		
Hard	Q	R	S	T	U	V	W	X	Y	Z

STRUCTURE OF GRINDING WHEEL

Structure indicates the space between the abrasive grains. Structure is denoted by a number when the spacing between the grains is small, the structure is called dense structure when the spacing between the grains is more, and the structure is called open structure.

The following table shows the structure of grinding wheels.

Structure	Symbol							
Dense	1	2	3	4	5	6	7	8
Open	9	10	11	12	13	14	15	more

WHEEL SHAPES AND SIZES

1. Peripheral grinding wheel

In this the periphery of the wheel is used for grinding and these are mounted on horizontal spindles.

a) Straight wheels

These are used for cylindrical, Internal, Centreless and surface grinding operations.

b) Tapered face wheels

Two sides of the wheel are tapered and these are used for grinding threads on and gear teeth.

c) Recessed wheels

This type of wheel has recess on both sides. The sides and periphery of the wheels are used for grinding.

2. Face grinding wheels

a) Ring or cylindrical wheels

These are suitable for grinding small flat surfaces.

b) Flaring cup wheels

These wheels are used for tool and cutter grinding.

c) Dish wheels

These are also used for tool and cutter grinding

d) Cup wheels

Large flat surfaces are ground by these wheels.

STANDARD MARKING SYSTEM OF GRINDING WHEELS

The grinding wheel is specified by a standard system of marking the grinding wheels. The following are indicated in the marking system Type of abrasives

1. Grit size or grit number
2. Grade of the wheel
3. Structure
4. Type of Bond
5. Manufacturer's code

The standard marking system is shown below.

W A 36 K 5 R 17

Manufacturer's

Manufacturer's

symbol

symbol

Abrasive

A - Aluminium

Rubber Silicon

carbide Shellac

Silicate

Oxychloride

Coarse Vitrified

Medium

10 30

12 36

16 46

20 60

24

Dense 1 2 3 4 5 6 7 8

Open 9 10 11 12 13 14 15

B- Resinoid

R-

E-

S-

O-

V-

Grade
- Soft → A,B,C,D,E,F,G,H
- Medium → I,J,K,L,M,N,O,P
- Hard → Q,R,S,T,U,V,W,X,Y,Z

SELECTION OF GRINDING WHEEL

Selection of suitable grinding wheel is very important one. The selection of grinding wheel depends on the following factors.

1. Constant factors 2. Variable factors

1. Constant factors

a. Physical properties of material to be ground

Tensile strength and toughness is more in the steel and bronze. So these metals are best ground with aluminium soft bronze, chilled cast iron and aluminium

metals can be ground by silicon carbide wheels. Hard wheels are used for grinding soft metals and soft wheels are sued for grinding hard materials.

a. Amount and rate of stock to be removed

Coarse grain and wide spacing abrasive wheels are used for grinding with faster speed. Fine grain and close spacing abrasive wheel are used for grinding the surface with good surface finish.

a. Area of contact

The area of contact between the wheel and work affects the pressure over the number of cutting points. If the contact area of the grinding wheel is small, fine grain and close spacing will be useful if the contact area of the grinding wheel is larger, coarse grain and wide spacing is suitable.

a. Type of grinding machines

Soft wheels are better for using in heavy rigidly constructed machines. Suitable grinding wheel are selected according to the feeds and speed available in the

machine.

2. Variable factors

a) Work speed

The speed at which the work piece traversed across the wheel face is called work speed. If the work speed is more, the wear of grinding wheel will be more, in this case hard wheel is better. If the work speed is slow, the wear will be low on the grinding wheel in this case soft wheel is better.

b) Wheel speed

The speed of the grinding wheel is influenced by the grade and bond. If the wheel speed is high, soft wheel is better if the speed is low, hard wheel is better.

Vitrified bonded wheels are suitable for grinding with the speed up 2000m/min. Rubber, Shellac and retinoid bonded wheels are better when the

c) Condition of the grinding machine

Soft wheels are better when grinding in dry condition. Hard wheels are better when grinding in wet condition. Well maintained machine can use soft grade wheels. Light machine ash use hard wheels.

d) Personal factor

The skill of the worker is very important one. A UN skilled worker cannot handle soft wheels so he must be allowed to work on hard wheels.

MOUNTING O

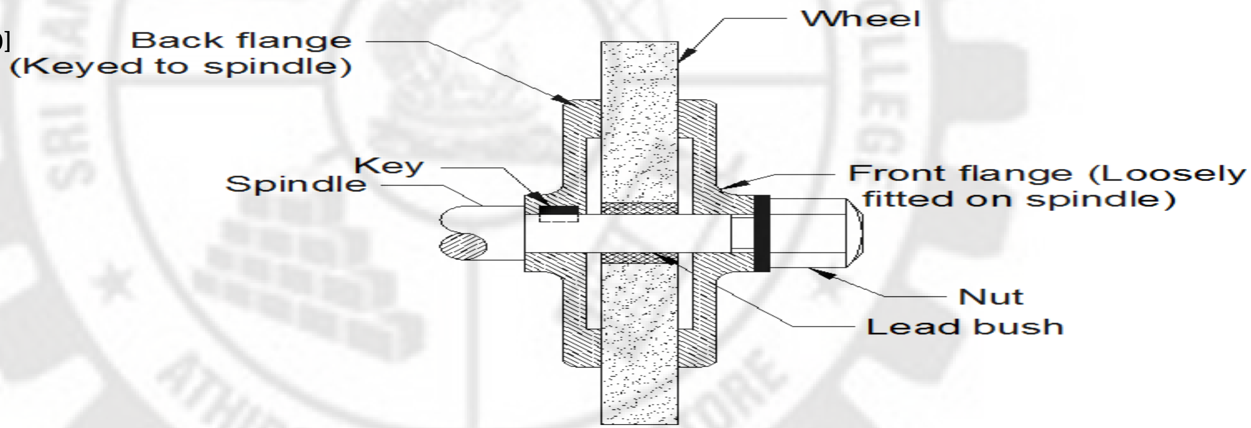


Fig. 4.21. Mounting of Grinding wheel

The grinding wheel rotates at high speed. If it is not fitted properly, it will be dangerous to the operator, before mounting, all grinding wheels should be inspected by ringing test. A good wheel gives a ringing sound on light taping with a metal bar. A cracked wheel will give a dull sound. The following points should be considered while mounting the grinding wheel.

1. Grinding wheel should not be forced on the spindle. The wheel must have sliding fit.
2. A bush is used in the bore of a grinding wheel and it should not project beyond the wheel face.
3. Flanges are used while fitting the wheel. That flanges diameter must be at least equal to half of the wheel diameter.

4. Wheel side and flange side should be perfectly flat.
5. Flanges should have the clearance only on their faces.
6. The inner fixed flange should be keyed to the spindle. The outer flange has a sliding fit with the spindle.
7. Thick compressive washers should be placed on both sides of the wheel faces and flanges for gripping of flanges on the wheel.
8. The nut should be tightened property.
9. Wheel guard should be placed in position.

LOADING IN WHEELS

When grinding a surface, the metal is removed in the form of fine particles. The removed fine particles enter into the spaces between the abrasive particles in a grinding wheel. This is called loading. After the loading, the cutting ability of the wheel will be reduced. Loading of fine particles is removed by dressing.

Glazing

When a grinding wheel is used for a long time, the cutting surface of the grinding wheel becomes smooth and gets a glass like appearance. It is known as glazing. If the grinding wheel gets a glazed surface, then it will not grind the surface effectively.

RECONDITIONING OF GRINDING WHEEL

Due to the long-time usage of grinding wheel, it is affected by glazing and loading. To make the wheel surface in good condition, it must be reconditioned. The grinding wheels are reconditioned by dressing and truing operations.

DRESSING

It is an operation of removing glazing and loading from a grinding wheel.
This is done by using a tool to called dresser.

1. Dressing by star wheel dresser

A star dresser made of steel is used for dressing course grained wheel the dresser tool has hardened teeth on its periphery and it is kept in a tool rest.

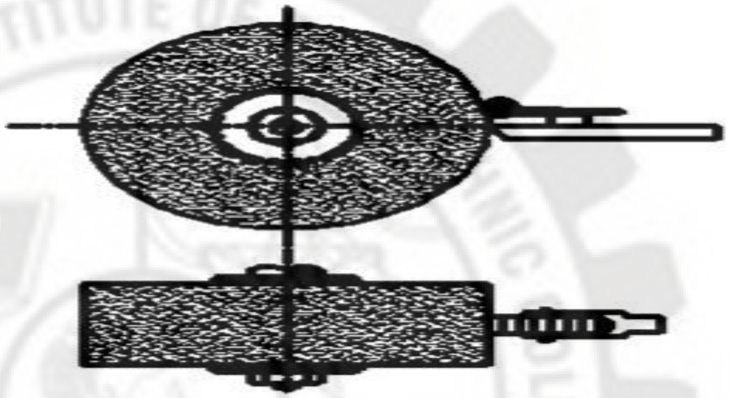
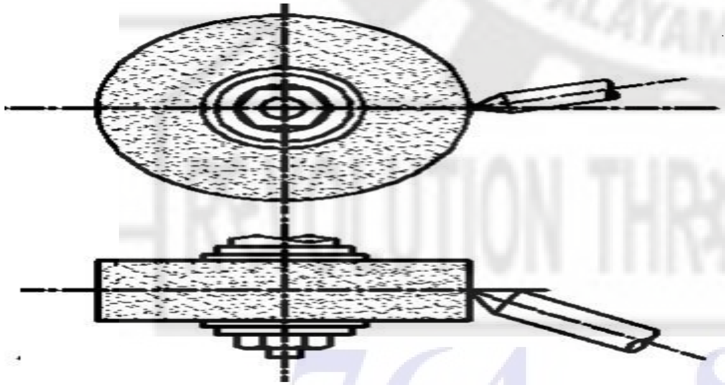


Fig. 4.22. Dressing by star wheel dresser

The dresser is pressed against the periphery of the slowly rotating grinding wheel. The dresser is moved cross wise along the width of the wheel.

2. Round abrasive stick

Bonded abrasives are filled in a tube and it is called round abrasive stick. Dressing is done on the grinding wheel g wheel face.



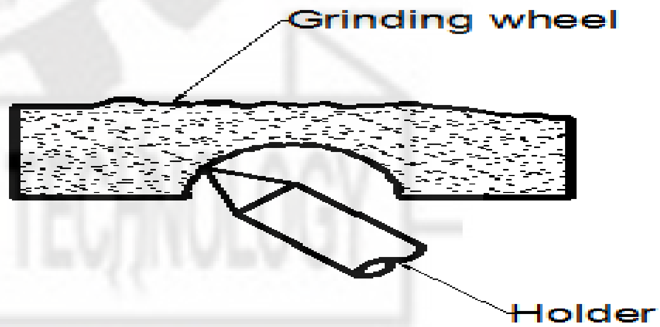


Fig. 4.24. Dressing formed wheel

Fig. 4.23. Diamond tip dresser

3. Diamond dressing tool

A diamond tipped dresser is used for dressing the grinding wheel which are used for precision grinding. The diamond tip is held in a holder and kept at an angle to the wheel. The dresser is pressed against the slowly rotating wheel, and moved cross wise along the width of the bale.

BALANCING OF GRINDING WHEELS

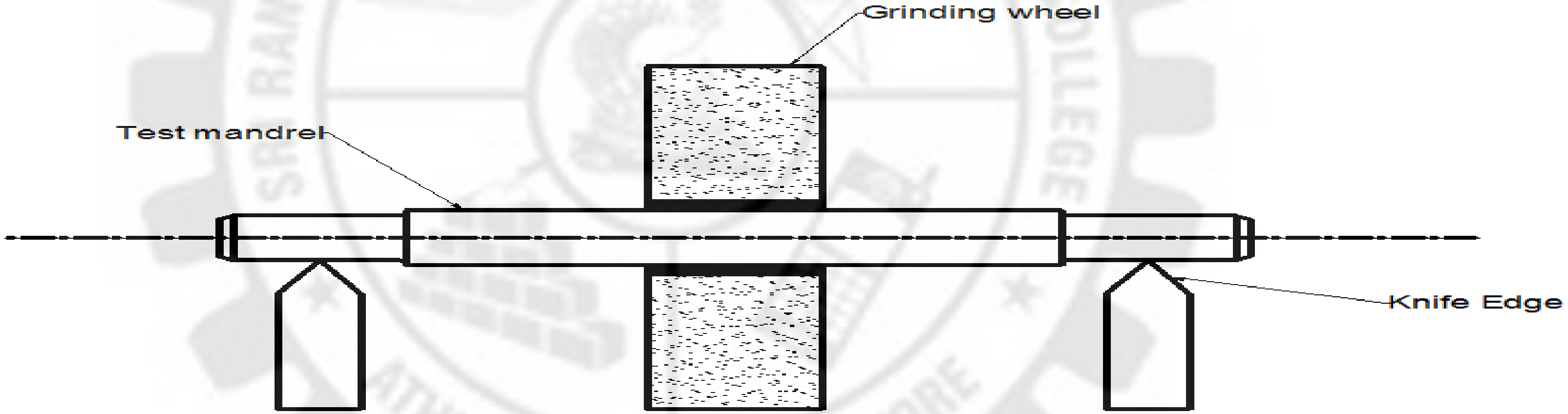


Fig. 4.25. Balancing of grinding wheel

During grinding, the grinding wheel rotates at very high speed. So the weight of the grinding wheel should be evenly distributed throughout the body of the wheel. If it is not distributed uniformly, unbalanced centrifugal force will be developed. It causes to the cracking and breaking of wheel when it rotates with high speed. So, the grinding wheel is balanced by the following ways.

The wheel is fitted to the test mandrel at the middle. The mandrel is placed over the two knife edges. These edges are parallel and placed on truly horizontal plane. The mandrel is slowly rotated to roll over the knife edges. When the wheel comes to rest, a marking is done with paint at the bottom of the wheel. Similarly, the same procedures are done for several times. If the markings arte in various place, then the wheel is in balance. If the markings are at a particular place, then it is considering as unbalanced wheel. For balancing, the grinding wheel, the weight at the particular place should be reduced. This is done by removing some lead from the lead bush at this marked place. Again the same procedures are carried out for balancing the wheel correctly.

Modern machining process / Unconventional machining process:

Modern machining process is defined as a group of processes that remove excess material by various techniques involving mechanical, thermal, electrical or chemical energy or combinations of these energies but do not use a sharp cutting tools as it needs to be used for traditional manufacturing processes. **Modern machining process are also known as Non-traditional machining process / Unconventional machining process.**

Difference between Conventional and Unconventional machining process:

S#	Conventional machining process	Unconventional machining process
1	The cutting tool and work piece are always in ***physical contact***, with a relative motion against each other, which results in friction and a significant tool wear.	In Unconventional processes, there is ***no physical contact*** between the tool and work piece. Although in some non-traditional processes tool wear exists, it rarely is a
2	***Material removal rate*** of the traditional processes is ***limited*** by the mechanical properties of the work material	Non-conventional processes ***easily*** deal with such ***difficult-to-cut materials*** like ceramics and ceramic based tool materials and super
3	In conventional processes, the ***relative motion*** between the tool and work piece is typically ***rotary or reciprocating***. Thus, the ***shape*** of the work surfaces is ***limited*** to circular or flat	It is not as such in the non-conventional process as a lot of ***variety of shape*** can be given to the work piece
4	Machining of small ***cavities, slits, blind or through holes is difficult*** with conventional	It is ***not a problem*** as such in these processes.
5	Traditional processes are well established; use relatively simple and ***inexpensive*** machinery and readily available cutting tools.	Non-traditional processes require ***expensive*** equipment and tooling which increases significantly the capital cost.

Needs / Importance of Modern machining process

- Extremely hard and brittle materials are difficult to machine by traditional machining processes such as turning, drilling, shaping and milling.
- Need to machine newly developed metals and non-metals with special properties that make them difficult or impossible with special properties that make them difficult or impossible to machine by conventional methods.

- Need to avoid surface damage that often accompanies Need to avoid surface damage that often accompanies conventional machining.
- Very hard fragile materials difficult to clamp for traditional machining.
- Temperature rise or residual stress in the work piece are undesirable.

The Unconventional machining process slightly overcome the above mentioned problems

Classifications of Modern machining process.

The non-conventional manufacturing processes may be classified on the basis of type of energy namely, mechanical, electrical, chemical, thermal or magnetic, apply to the work piece directly and have the desired shape transformation or material removal from the work surface by using different scientific mechanism.

S#	Energy	Process
1.	Mechanical Energy	1. Ultrasonic machining process (USM) 2. Abrasive jet machining process (AJM) 3. Water jet machining process (WJM)
2.	Electrical Energy	1. Electrical discharge machining process (EDM) 2. Wire cut electro discharge machining process (WCEDM)
3.	Chemical and Electro- chemical Energy	1. Chemical machining (CHM) 2. Electro chemical machining (ECM) 3. Electro chemical grinding (ECG)
4.	Thermal Energy	1. Electron beam machining (EBM) 1. Laser beam machining (LBM) 1. Ion beam machining (IBM)

ULTRASONIC MACHINING PROCESS (USM)

Principle

In this method with the help of piezoelectric transducer tool is vibrate at high frequency in a direction normal to the surface being machined abrasive slurry are used for the remove the metal from work piece.

Working

In ultrasonic machining, the tool vibrates at very high frequency i.e. 20 KHz. Per second. An abrasive slurry is applied between the tool and work piece. By this, very minute particles of work piece are removed by erosion and abrasion. The tool is slowly fed on the work piece. The tool shape is reproduced in work piece. The ultrasonic equipment has a transducer, tool holder and the tool. The transducer has nickel laminations wound with a coil.

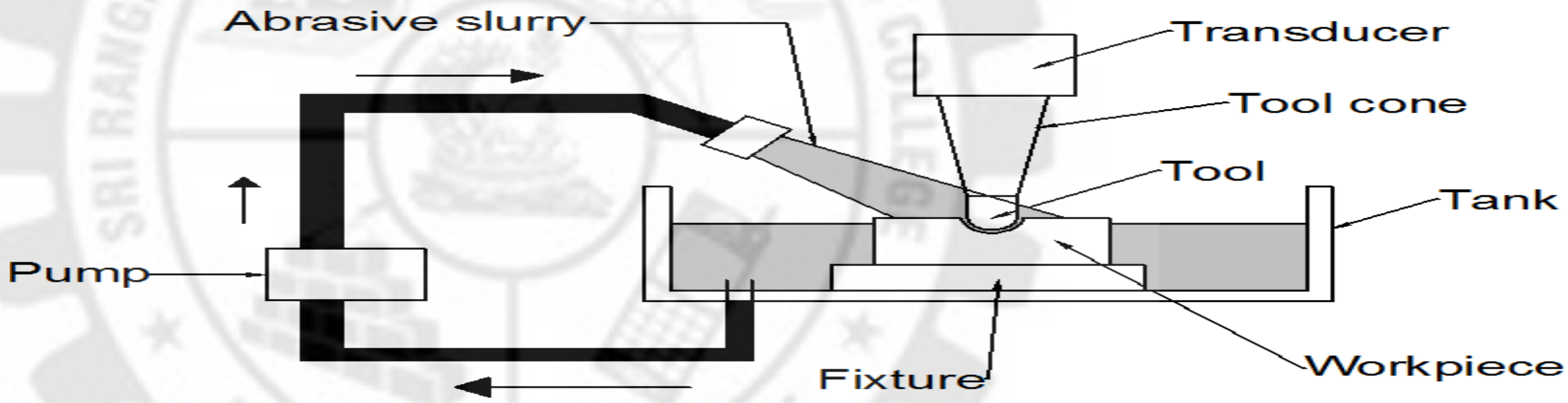


Fig. 4.26. Ultrasonic machining process

A high frequency current is supplied to the coil of the transducer. The transducer converts this high frequency current into mechanical vibration. These mechanical vibrations are transmitted to the tool through the tool holder. The tool vibrates axially with an ***amplitude of 0.05 mm*** and a ***frequency of about 20 KHz.*** An abrasive slurry is applied between the work surface and the tool. The slurry is made of a mixture of water and fine grains (***800 to 1000 grit size***) of aluminium oxide, silicon carbide or boron carbide.

Because of the tool vibration, the abrasive grains in the slurry are hammered into the work surface. Hence by abrasion and erosion, the metal is removed from the work as minute particles. By this action, the shape of the tool is reproduced in the work. The tool is fed downwards very slowly. Maximum ***feed rate is 0.1 mm/sec.***

The tool is made 0.01 mm smaller than the required hole. The tool is made of soft ductile material such as soft steel, copper or brass. The tool holder is made of stainless steel. Dimensional accuracy up to 0.05mm is possible.

The abrasive particles, as they indent, the work material, would remove the same,
particularly if the work material is brittle, due to crack initiation, propagation and brittle fracture of the material. Hence, ***USM is mainly used for machining brittle materials***

{which are poor conductors of electricity and thus cannot be processed by Electrochemical and Electro-discharge machining (ECM and EDM)

Applications of USM:

- For drilling holes in hard and brittle materials like ceramics, glass, boride, ferrite, carbides, precision stones like diamond and hardened steel.
- For making wire drawing dies in tungsten carbide or diamond.
- For engraving, die sinking, slicing and broaching of hard materials,
- For machinery both conducting and non-conducting materials.
- For machining precision stones and ceramics.

Advantages of USM:

- Very hard and brittle materials like carbide and tungsten are easily machined by this process. These materials cannot be machined by the ordinary process.
- Set up of the machine is simple. Less skilled operator is sufficient.
- It is possible to make holes of any shape (circular and non-circular) for which a tool can be made.
- Set up time is less and Production cost is less and Accuracy is more.
- It can be used for machining both machining both conducting and non-conducting material.

Limitations of USM:

- Very slow metal removal; hence machining time is more.
- High power consumption.
- Not suitable for heavy stock removal.

CHEMICAL MACHINING (CHM):

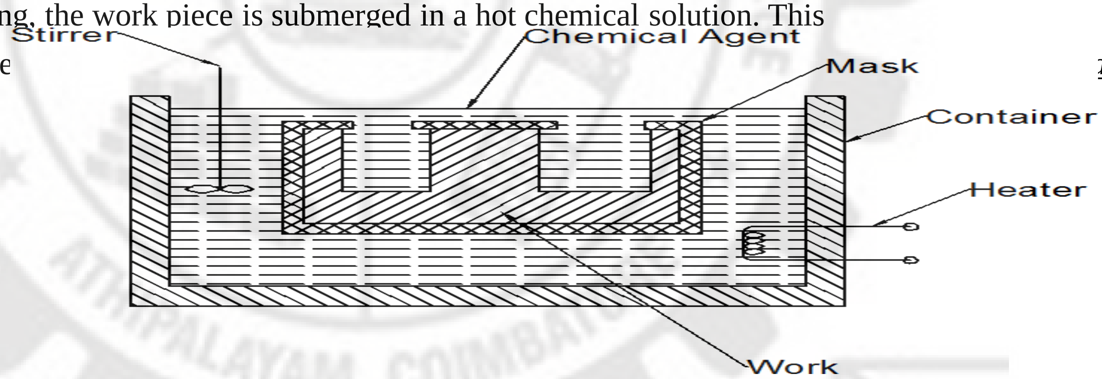
1. **Cleaning**

    The wok piece surface is thoroughly cleaned.

2. **Masking**

    The portions of the work piece which do not require machining is covered with masking sheets. The sheet is cut and removed from the area where ***machining is required.*** Templates are used for this purpose. If the entire area of the work piece is to be machined, masking is not necessary usually ***vinyl, neoprene and rubber based materials*** are used as mask sheets.

3. **Etching**

    After masking, the work piece is submerged in a hot chemical solution. This solution is called the 

ıgnesium and titanium alloys.

Fig. 4.27. Chemical machining process

The etchant removes the metal from work piece by chemical action. The rate of metal removal is about ***<u>0.025 mm per minute.</u>*** The rate of metal removal depends upon the concentration and the temperature of the etchant.

Higher the concentration and temperature, more is the rate of metal removal. The amount of metal removal also depends upon the time duration for which the work piece is immersed in the etchant.

4. Demasking

After etching, the work piece is ***taken out from the etchant***. The work piece is cleaned in water. Then the marking is removed.

Applications:

- Chemical machining is effectively used for removing metal from a curved or irregular surface.
- It is used for machining on very thin surface.
- It is used to produce special profiles in aeroplane parts, automobile parts, electronic equipment's and instruments.
- Sheets having taper on its surface can be produced in this process.
- Chemical machined parts are used in tape-recorders, Computers, cameras, T.V. sets, electric motors, timers, telephones, medical instruments, etc.

Advantages:

- Very low operating costs.
- Low skill of the operator.
- Parts of any profile can be machined.
- The process does not produce any stress in the work piece. The process can be used for any metal.
- Parts of large size as well as thin sections are machined in the process.
- Uniform metal removal in all surface. Metal removal is easily controlled.
- All the slides of the work piece at machined at the same time.

Limitations:

- Very slow process.
- Heavy stock material removal is not possible.
- Chemical vapours are injurious to health.
- Larger floor space is required.

ELECTRO CHEMICAL GRINDING (ECG)

Electro chemical grinding is also called electrolytic grinding. Metal is removed from the surface of the work piece by electro chemical action and also by abrasive action of a

grinding wheel. 90% of metal is removed by electro chemical action and 10% of metal is removed by the abrasive action of the grinding wheel.

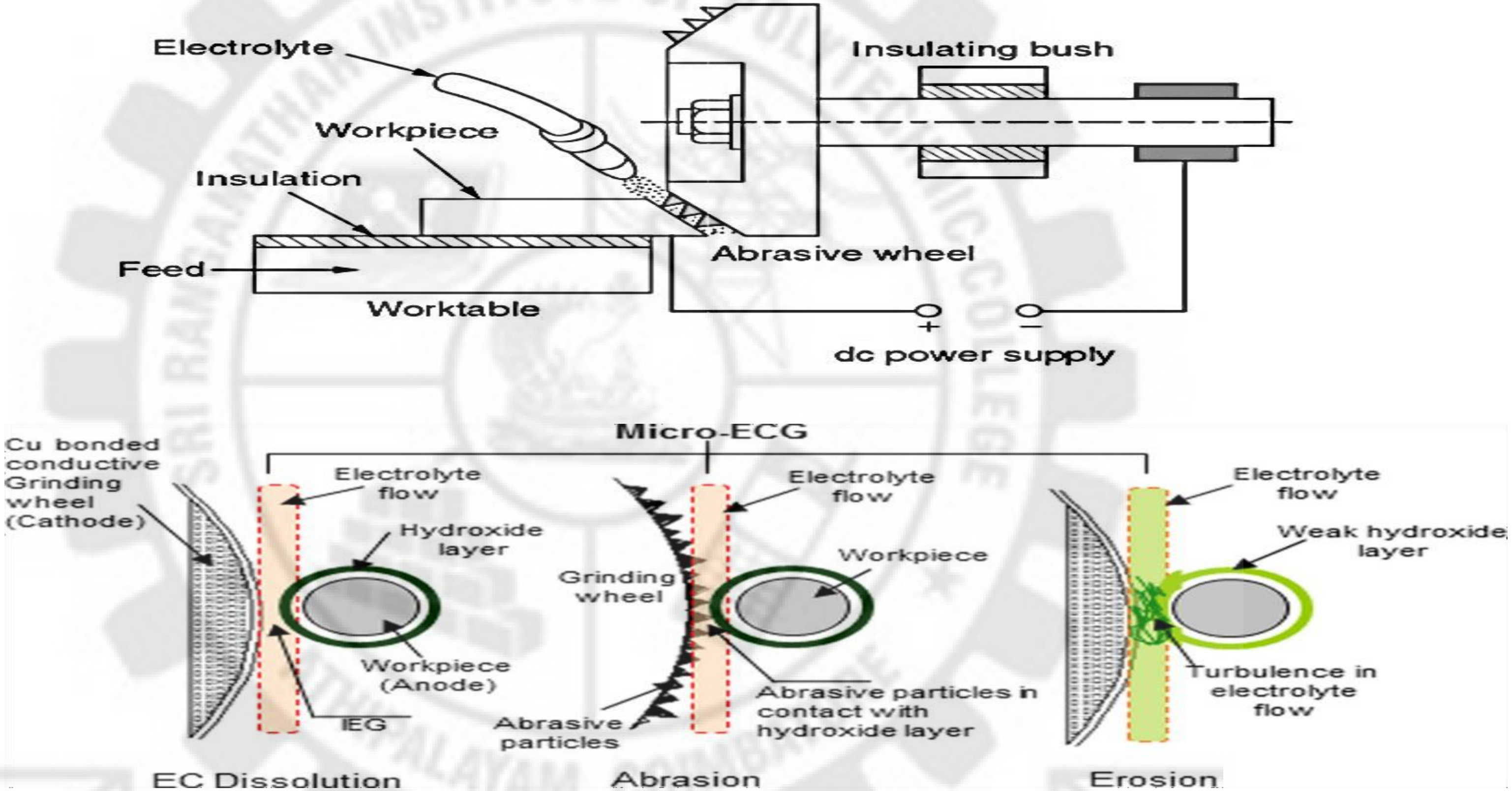


Fig. 4.28. Electro chemical grinding process

The equipment has a metal bonded grinding wheel. Brass, bronze and copper are bonded with abrasive grains in the grinding wheel. Diamond abrasive is used for grinding tungsten. Aluminium oxide abrasives is used for other metals.

The wheel is held in a horizontal spindle. The spindle is supported on insulated bearings. The work piece is held in a fixture against the grinding wheel. A gap of about 0.01 mm is maintained between the wheel and the surface of the work piece. The work piece is connected to the –ve terminal of a D.C. supply. The grinding wheel is connected to the –ve terminal. 4 to 16V, 300 to 1000 Amps D.C supply is applied.

A mixture of sodium chlorite, sodium chlorate or sodium nitrate and water is used as the electrolyte. The electrolyte solution is made to flow between the work piece and the grinding wheel. Electro chemical action takes place. Metal from surface of the work piece is removed in small particles. In addition to this, the rotating grinding wheel also removes metal from the work surface by abrasion. The small particles of metal removed from the work piece are carried away by the electrolyte. The electrolyte is collected in a reservoir.

It is filtered and recirculated by a pump. Electrolyte also acts as a coolant. The work piece is slowly fed towards the grinding wheel maintaining a constant gap between the work piece and the grinding wheel.

Applications:

- Used for machining hard material which are conductive to electricity.
- Used for grinding of tungsten carbide tool tips and hard steels.
- Used tom grinding, form grinding, plunge grinding and surface grinding operations are done using this process.
- Used for machining refractory materials, high strength steels, nickel and cobalt base alloys etc.,

Advantages:

- Very fine finish is obtained (0.2 to 0.4 microns cab be obtained)
- Suitable for machining very hard materials like carbides. Carbides are difficult to machine by other processes.
- No heat is generated during the process. No distortion to the work piece
- No burrs are produced. Fast operation.
- Thin materials can be ground without deflection as the grinding wheel does not press the work piece.
- No heat is generated so there is no danger of burning or heat distortion.
- Tolerances of about ±0.02mm can be obtained.

Limitations:

- This process can be used to machine only metals which are conductive.
- Sharp corners of the work piece cannot be machined.
- Electrolytic solution is corrosive.
- Initial cost of the equipment is high when equipped with larger power supplies.
- Intricate shapes may not be formed.

Electrical Discharge Machining (EDM) Principle of metal removal:

Electro Discharge Machining (EDM) is an electro-thermal non-traditional machining process, where electrical energy is used to generate ***electrical spark and material removal***

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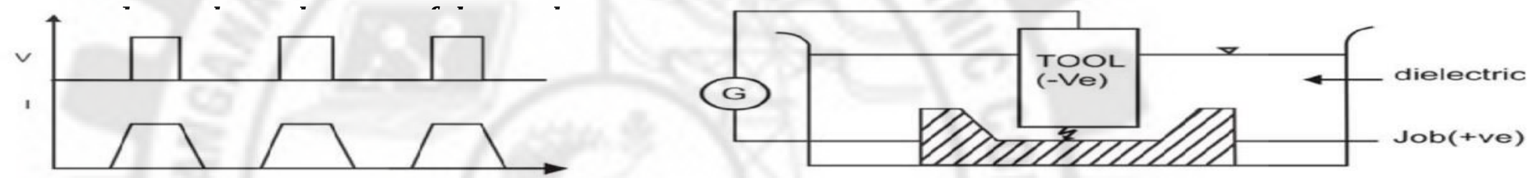

Fig. 4.29. Electrical discharge machining process

Working:

Whenever ***sparking takes place between two electrical contacts***, a small amount of material is removed from both the contacts. This eroding effect of an electric spark is used in EDM. This process is also known as Spark Erosion Machining. If both electrodes are made of same material, greater erosion *takes place at positive (+) electrode*; therefore the

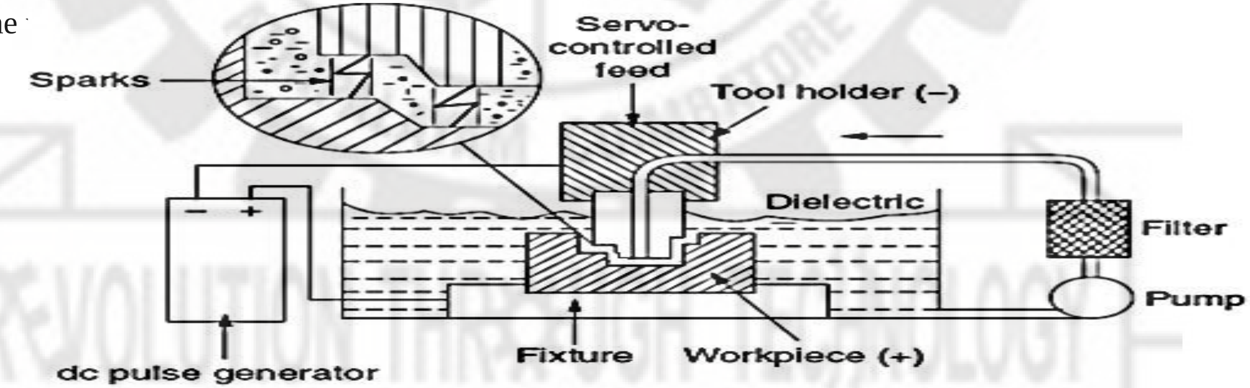

Fig. 4.30. Electrical discharge machining process

EDM arrangement is illustrated in the figure. Electric power is supplied from an A.C. source to a rectifier. D.C. output from rectifier (***80-100 Volt***) is then fed to the spark

generating circuit. The tool and work are connected to the circuit.

The tool and work are submerged in a ***dielectric fluid (kerosene, paraffin, transformer oil).*** Dielectric fluid does not conduct electric current. The servo mechanism maintains a very small gap (***0.025 to 0.075***) between work and tool. The tool is fed down into work piece surface. Now sparking takes place. When the tool fully enters the work, sparking takes place across whole area of tool front face.

This reproduces tool shape upon the work surface. Again and again spark takes place in an interval of ***10 to 30 micro second***. Temperature of approximately ***1200°C*** is generated. Thus, thousands of spark discharge takes place per second. Work piece material is eroded.

The dielectric fluid acts as coolant. It carries away the eroded metal particles.

Application of EDM

- Fine cutting with thread shaped electrode (wire cutting EDM)
- Die sinking, making: stamping tools, complicate mould cavities, wire drawing dies, extrusion dies, forging dies.
- Machining very hard material like tungsten carbide to make complicate cavities & shapes.
- Drilling very small (0.15 mm dia) holes in orifices, fuel injection nozzles.
- Making blanks from sheet metals. Curved hole drilling.
- Sharpening of tools, cutters and broaches.

Advantages of EDM:

- All metals and non-metals that conduct electricity can be machined.
- Complicated shapes can be produced.
- There is no cutting force. Therefore, thin work pieces can be machined.
- Very good surface finish is produced (0.2 micron). Machining accuracy is good (±0.05 mm)
- Very hard and even hardened materials can be machined.

Limitations of EDM:

- Power consumption is high.
- Only electrically conducting materials can be machined.
- Square corners can be produced.
- Work piece surface is heated. This changes metallurgical properties.
- Tool wear is high.

PLASMA ARC MACHINING (PAM)

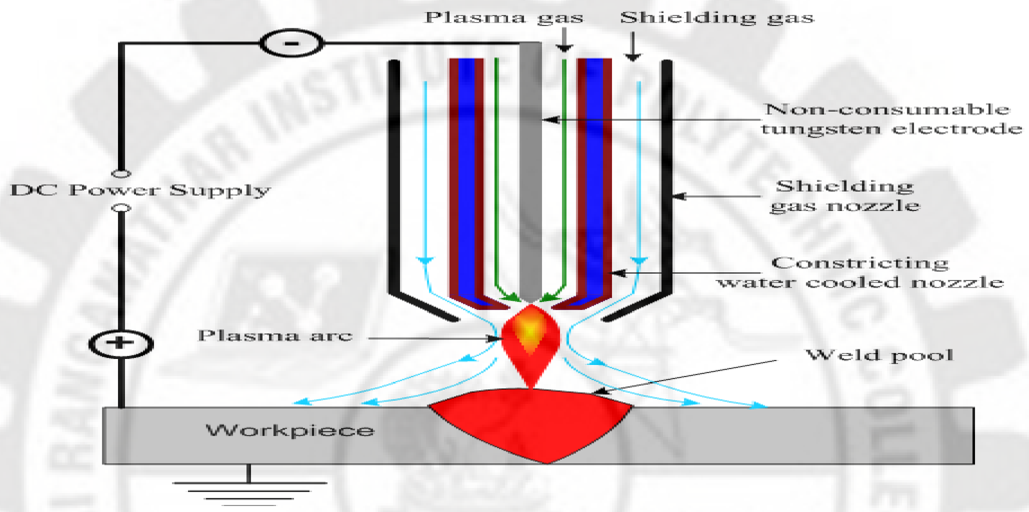

Fig. 4.31. Plasma arc machining process

When a flowing gas is heated to a very high temperature (about 1600°C) it becomes partially ionised. This ionised gas is known as plasma. In Plasma Arc

Machining, metal is removed from the work piece surface by means of high temperature plasma. Metal is also removed due to electron bombardment.

The equipment has a chamber with a copper nozzle at the bottom. A tungsten electrode is held vertically in the gas chamber. The tungsten electrode is connected to the

–ve terminal of a 400 V, 200 kW D.C. supply. The nozzle is connected to the +ve terminal.

When the supply is given, an arc is produced between the tungsten electrode (cathode) and the copper nozzle (anode). A di-atomic gas, usually H_2, N_2 or O_2 is passed

through the gas chamber. The gas passes through the arc. It is heated and gets ionised by the arc because of the high temperature. The ionised gas flows out of the nozzle as plasma

flame. The plasma flame is forced on the work surface.

Because of the high temperature of the gas, the surface of the work piece gets melted. Due to the bombardment of ions on the surface of the work piece, the metal is eroded. The rate of metal removal can be increased by increasing the gal flow. Nozzle is water cooled. In due course, the tungsten electrode tip gets eroded due to high temperature. So the position of the electrode has to be adjusted

Applications:

- Used for cutting stainless steel and aluminium alloys.
- Used for profile cutting and slitting in hard materials such as super alloy steels.

Advantages:

- This process can be used to cut any metal.
- The cutting action is very fast.
- It is possible to cut thick material up to 150mm

Limitations:

- Because of the high heat, metallurgical change takes place on the work piece.
- The pro

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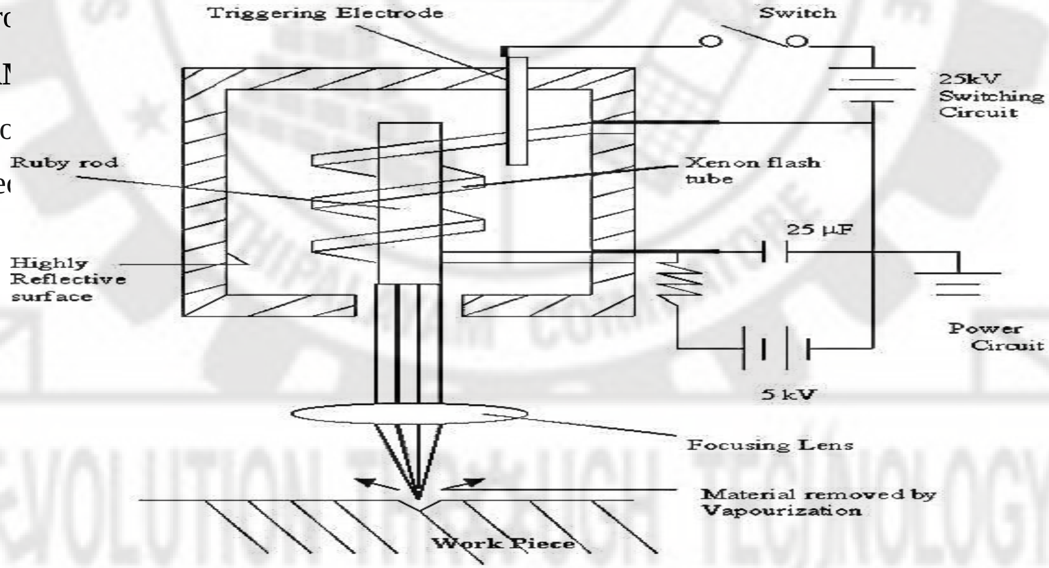

Fig. 4.32. Laser beam machining process

Principle:

- It is a beam of light having the same wave length (monochromatic light).
- This beam can be focussed by a lens on a very small spot on a work piece, the laser beam emits high heat which can melt and vaporises any material in the world.

- The equipment has a ruby crystal. The crystal is placed inside a flash lamp coil (1000 w) as shown in figure. The flash lamp is filled with Xenon gas. When the flash lamp is switched on, it gives high intensity light. The ruby crystal is stimulated and it emits the laser beam.
- By using a lens, the beam is focussed on the work piece. The work piece is fed past the beam. The portion of the metal is melted and vaporised.

Applications:

- Laser beam machining is a micro machining method. It is used for producing very fine and minute holes (0.005 mm) dia.
- It is used for drilling in small nozzle, orifices in very hard materials.
- Laser beams can be used in surgery.
- Used for drilling holes in surgical needles, oil or gas orifices and relief holes in pressure plugs.
- Used for cutting complex profiles in thin and hard materials like ceramics.

Advantages:

- It can melt and vaporise any known material. There is no tool wear.
- The machining operation is localised. Precision location can be achieved.
- Welding dissimilar metals can be done using laser beam.
- Can be used for machining materials that are less sensitive to heat-like ceramics.
- No mechanical force on the work piece and it machine both metals and non-metals.
- Holes can easily be drilled on curved or angular surfaces and holes are burr free.
- No direct tool content with work piece, so heat is extremely localised.

Disadvantages:

- High cost
- Large amount of metal removal is not possible.
- It cannot be used for cutting metal of high heat conductivity of high reflectivity (e.g. AL, Cu, and their alloys)
- Machined holes will not be perfectly round.
- Life of flash lamp is short and Efficiency of the process is low.
- The laser beam can be dangerous if it not used carefully.

S#	Aspects	LBM	PAM	CHM
1.	Principle of material removal	High electro- magnetic energy is (by laser beam) focussed on small work piece surface. Metal melts and vaporises.	Material is removed by striking on work-piece surface with a jet of high velocity and high temperature (16500°C) ionised gas. (Plasma). Metal melts and vaporises.	Materials is removed by chemical action by an etchant. (0.025 mm / min)
2.	Tool	Laser Beam	Plasma Beam	Etchant removes material
3.	Electrolyte or Chemicals used	--------------------	----------------------	Etchants are used. Depending upon work piece material etchant is selected. Caustic soda for Aluminium. Acids for steel Hydrogen fluoride for Titanium & Silicon. Ferric Chloride for stainless steel, lead, Nickel & copper.
4.	MRR (Metal Removable Rate)	70 mm3/min.	Cutting rate 250 to 1700 mm/min.	Very slow metal removal 0.015 to 0.03 cm3 per minute. Depends upon the etchant, time duration of etching & area of work surface machined.

S#	Aspects	ECG	USM	EDM
1.	Principle of material removal	Material is removed by the combined effect of electro-chemical action & abrasive grinding action. 90% metal removal by electro-chemical action. 10% by grinding.	Abrasive grains mixed in water erode material as minute particles – by striking work at very high ultrasonic vibrations (20 KHz)	Material is eroded by electric sparks, produced across the gap (0.025-0.075 mm) between tool & work piece surface. 12000°C is generated. Spark erosion takes place by vaporisation & also by ionisation.
2.	Tool	Rotating metal bonded of aluminium oxide grinding wheel. (-ve terminal)	Fine grains (80-1000 grit size) of aluminium oxide, silicon carbide or boron carbide are mixed with water. Kerosene, benzene, glycerol or thin oil are also used.	Petroleum based hydro-carbon fluids, paraffin, white spirit, kerosene transformer oil, mineral oil and mixture of these.
3.	Electrolyte or Chemicals used	Borax, Sodium Nitrate, Sodium Silicate, Sodium Nitrite	Tool is made of mild steel, monel, stainless, steel, copper or brass. Its shape is reproduced in work piece. It is 0.1 mm lesser than the size of shape to be produced. Tool axially vibrates at 20 KHz. Amplitude 0.05 mm.	Copper, brass, Zinc & tin alloys, hardened plain carbon steel, copper tungsten carbide, copper-graphite and graphite (- ve terminal)
4.	MRR (Metal Removable Rate)	Depends upon the electrolyte, pressure between grinding wheel & work surface (up to 15 mm3/sec)	Depends upon hardness of abrasive grains, grain size, amplitude of tool vibration, the gap between tool and work piece.	Depends upon electric current, duration of sparking and pulse generators. Heavy currents for roughing. Low current for finishing.

UNIT V - CNC MACHINE AND ITS COMPONENTS CNC MACHINES

NUMERICAL CONTROL (NC)

Numerical control can be defined as a form of programmable automation in which the process is controlled by letters, numbers and symbols.

Numerical control (NC) of machines tools is a method of automatic control that uses symbolically. Coded instructions are to cause the machine to perform a specific series of operations. Basically, it is control of machin

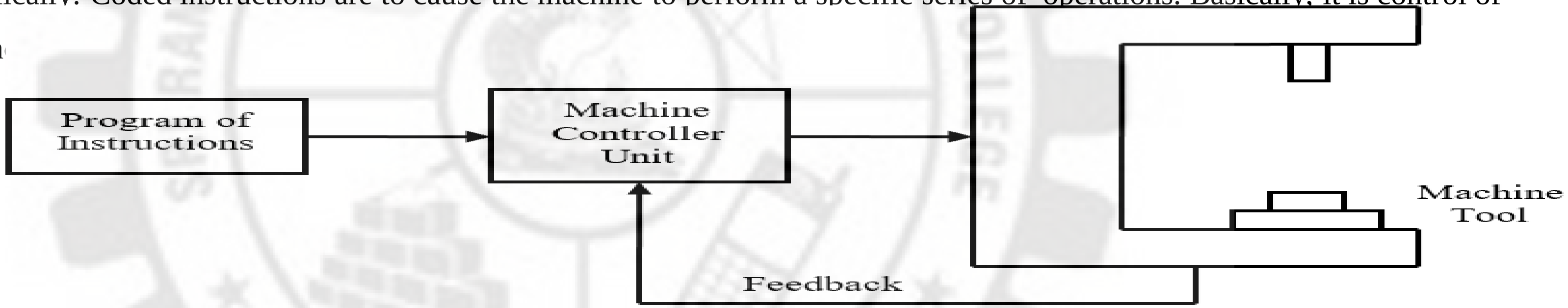

Fig. 5.1. NC system

In NC machine tools one or more of the following functions may be automatic.

1. Starting and stopping of machine tool spindle.
2. Controlling the spindle speed.
3. Positioning the tool tip and desired locations and guiding it along desired paths by automatic control of the motion of slides.
4. Controlling the rate of movement of tool tip i.e., feed rate.
5. Changing of tool in the spindle

CNC (COMPUTER NUMERICAL CONTROL)

CNC may be defined as NC systems where in a dedicated, stored program computer is used to perform some or all of the basic numerical control functions in accordance with control programs stored in the read write memory of the computers.

In CNC, the program is entered once and they stored in the computer memory. Direct entry of programs in the CNC became possible only when keyboards came in use as input devices. A block diagram of CNC is shown in the figure.

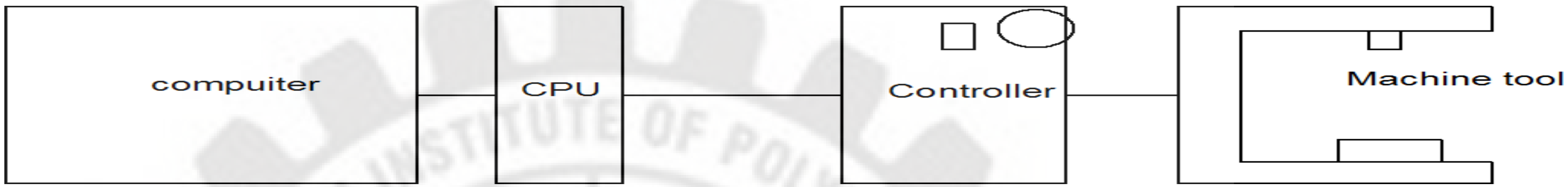

Fig. 5.2. CNC system

In CNC systems the part program is fed into the computer. Then the instructions are read and interrupted by the controller to convert it into signals that activate the machine tool. The signals are sent to the machine tool for performing different operations.

Advantages of CNC

1. High accuracy and repeatability
2. Longer tool life
3. Reduction in production lead time
4. Reduced inspection
5. Reduced the rejected number of the component
6. Greater flexibility
7. Graphic tool path display is available
8. Require no special tool setting
9. Automatic adjustments of the speed and depending on the machining conditions etc.
10. CNC provides a total manufacturing system.

Difference between NC and CNC

S#	NC	CNC
1	NC Systems use punched tapes as	In CNC input in given directly through the computer
2	Tape reader is least reliable	Computer memory is more reliable,
3.	Tape reading at the remote place	Reading and editing at the machine site itself.
4.	Metric conversion is not possible	Automatic conversion is possible
5.	Modification and editing of programs	Modification and editing of programs are possible

6.	Modern manufacturing technique of	CIM and FMS can be implemented.
7.	The program cannot be changed	Any part program can be changed during the progress of work
8.	NC programmers are skilled persons	Programmer not necessarily a skilled person
9.	Control is hard wired	Computer controls the NC systems.

Adaptive Control (AC)

The term adaptive control denotes a control system that measures certain output process variables and uses these to control speed and feed. Some of the process variables that have been used in adaptive control machining systems include spindle deflection or force, torque, cutting temperature, vibration amplitude, and horsepower. The typical measure of performance in machining have been metal removal rate and cost per volume of metal removed. The figure shows the schematic diagram for adaptive NC system.

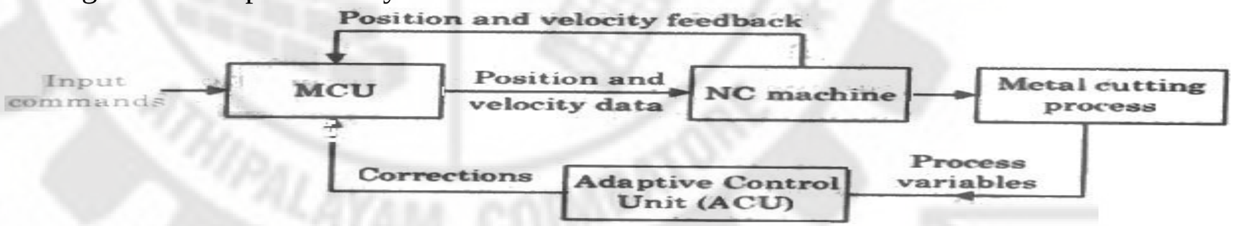

Fig. 5.3. Schematic Diagram for adaptive NC system

The following characteristics can be used to identify situations are adaptive control can be beneficially applied.

1. The cutter is engaged in the work piece more than 40% of the time it is on the machine.
2. The cost of operating the machine tool is high.
3. The typical jobs are ones involving steel, titanium and high strength alloys.
4. Degree of variability in machining.
5. Variable geometry of cut in the form of changing depth or width of cut.
6. Variable work piece hardness and variables machinability.
7. Variable work piece rigidity.

8. Tool wear
9. Air gaps during cutting

The benefits of adaptive control machining are,

1. Increased production rates
2. Increased tool life
3. Greater part production
4. Less operator intervention
5. Easier part programming

TURNING CENTRES / CNC LATHE

Main parts of the CNC chucking and turning centre are bed head stock, tailstock turrets, servo system and MCU. The various work holding devices are,

- Self-centering chuck
- Collect chuck
- Counter centrifugal chuck

Classification of Turning Centers

1. Horizontal machines
   a. CNC chucking centre
   b. CNC turning centre
   c. Universal lathes
2. Vertical Machines

1. Horizontal machines

a) CNC chucking centre

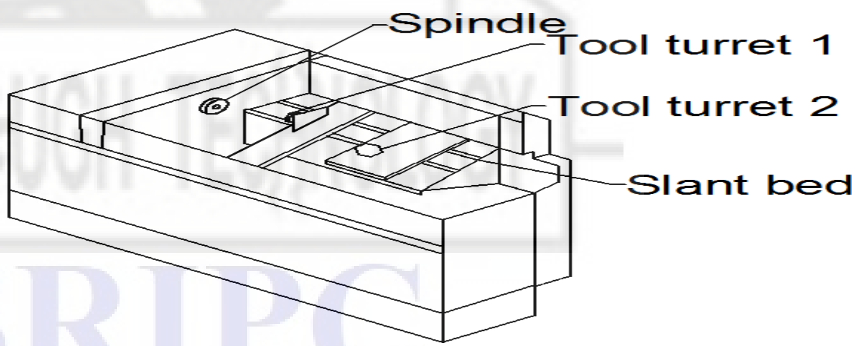

Fig. 5.4. CNC chucking centre

CNC chucking centre is designed to machine most work that is held in a chuck. Chucking machines usually have shorter beds and a single saddle with single drum type turret which accommodates both ID and OD tools or two independent saddles with turret is shown in the figure. The four axes chucking centre incorporates two turrets operating independently on separate slides, machining the work piece simultaneously.

b) CNC turning centre (Shaft Lathes)

CNC turning centers are designed mainly for machining shaft-type work pieces which are supported by a chuck and a heavy duty tailstock centre.

c) Universal lathes

Universal lathes are suitable for both chucking and for bar work. Four axes machines have two turrets each mounted on an independent slide and facilitate simultaneous machining with two tools. Some lathes have rotation tools in the turrets to facilitate off axis machining such as drilling milling reaming, tapping, boring etc. These machines have in addition to the conventional X and Z axes. CNC control of the spindle rotation, C axes. Such machines are known as turning centers.

Tooling and Turret slide

The present trend is to have single heavy drum type turret capable of accommodating both external and internal working tools. Some machines have two independent slides with one turret on each slide, one for external working tools and the other for internal tools. This arrangement will need four axes CNC. External and internal machining can be carried out simultaneously.

Some machines have an automatic tool changer with multi station tool magazine and a tool clamping arrangement on a single slide. This is common in flexible turning centers. Linear tooling system is used in some of the less expensive CNC lathes.

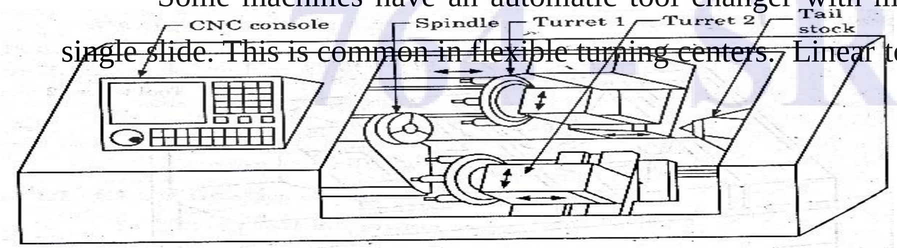

Fig. 5.5. Tooling and Turret slide

2. Vertical CNC lathes

Vertical CNC lathes widely used for machine heavy components. The figure shows a typical vertical CNC lathe. Some of these machines can also be used for milling operations. Such machines are sometimes known as turn - mill centers.

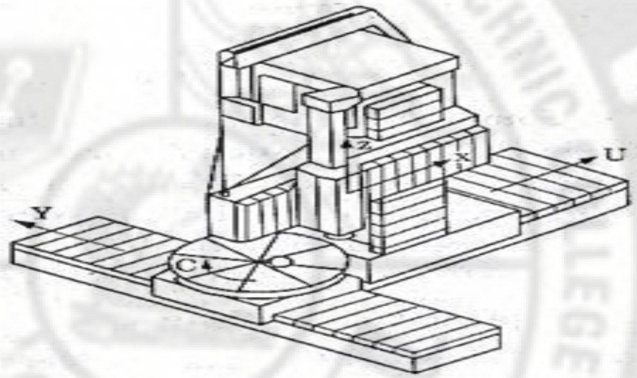

Fig. 5.6. Vertical CNC lathe

MACHING CENTRES (MILLING CENTRE)

A machining centre consists of machine tools, usually numerically controlled, capable of automatically drilling, reaming, and tapping, milling and boring multiple faces of a part.

They are often equipped with a system for automatically changing cutting tools.

Main parts of a machining centre are Bed, saddle, column, table servo-system, spindle, tool-changers and MCU.

Machine axes for a five axes machining centre are

1. X, Y and Z axes for linear movements.
2. A axes for tilt/contour spindle.
3. B axes for rotary table.

Type of work holding devices are Swivel-base vice, angle plates, V-blocks, step blocks, parallels, support jocks and clamps.

Classification of Milling Centers

1. Horizontal spindle machining centre
2. Vertical spindle machining centre

1. Horizontal spindle machining centre

Horizontal spindle machining centers are generally single spindle machine with automatic tool changers. Some exceptions consist of multi-spindle turrets, combination of horizontal/vertical spindles etc. Horizontal spindle machining centers are generally bad type machines with the structural configuration as shown in the figure.

In this type of machines x axis traverse is provided by table or column and Y axis provided by spindle head. The Z axis traverse is provided by the saddle or column or headstock or spindle head. These machines are invariably used with a rotary indexing table to facilitate multi-face machining at different angles in a single set UP. The axis of rotary table is parallel to Y axis and is called 'B' axis. The rotary of the table can be used for machining contour surfaces of work pieces located on the rotary table, if

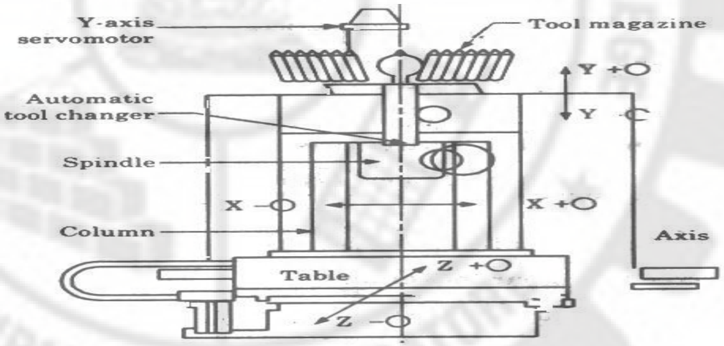

Fig. 5.7. Horizontal spindle machining centre

The present day trend is to build the machined with traveling column construction with all the movements behind the tool so that the work module is independent of the basic machine. This enables choice of work holders to suit the user's requirements and also enables the use of machining centre in NC transfer lines.

2. Vertical spindle machining centre

Vertical spindle machining centers are also bed type machines with (a) Single spindle and auto tool changers (b) Multi spindle with turret head (turret machining centers). The structural configuration is as follows,

X-axis traverse provided by table or the column.

Y-axis traverse provided by the saddle or the columns or ram. Z-axis traverse provided by the

Vertical spindle machines are not suitable for large widths as this increase the throat distance. For very large widths horizontal spindle configuration or bridge type configuration (double column planer type) is used.

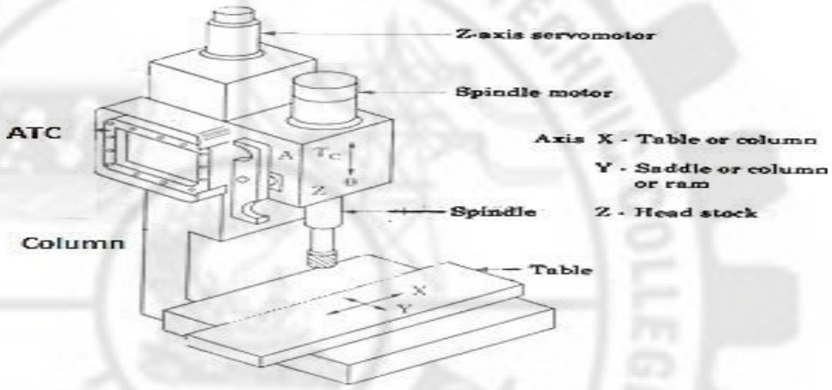

Fig. 5.8. Vertical spindle machining centre

A rotary / index table could be used also with a vertical machining centre with the axis of the table usually parallel to 'X' axis i.e. 'A' axis. The figure shows the typical vertical machining centre. There are many variations of vertical machining center. Profilers are a class of vertical machining centers which are used for large material removal involving several pocketing operations. Such machines find wide applications in aircraft industry.

3. Universal machining centre

These are similar to horizontal machining centers but with the spindle axis capable of tilting from horizontal to the vertical position continuously under the computer control. This constitutes the fifth axis of the machine. In some cases, this movement is provided by tilting of the table indeed of the spindle. Such machines facilitate approach to the top surface pf work piece mounted on the table in addition to the multiple side faces in a single set up. The fifth axis facility is essential for machining of some components which require the cutter axis to be perpendicular to the surface being machined.

Recently new designs of machining centers have been introduced which can be used as either horizontal or vertical machines.

Direct computer control CMM or CNC-CMM

The probe is programmed to move to the desired location. Programming can be done by,

a. Manual lead through method as in robots
b. Conventional CNC part programming

Movement of the probe is done by the CMM controller, and recording and processing of the data are done by the computers.

Measuring Capabilities of a CMM

1. Dimension measurements
2. Determination of hole location and diameter
3. Determination of cylinder axes and diameter.
4. Checking parallelism between two planes
5. Definition of a plane
6. Determination of angles between two planes
7. Flatness
8. Determination of angle and point of intersection of lines

Benefits of CMM

1. Flexibility
2. Increased productivity
3. Unmanned operation in CNC-CMM
4. Greater accuracy
5. Reduced operator error
6. Easy integration with FMS or CIM

C

NC COMPONENTS
SLIDE MOVEMENT
ELEMENTS

Precise positioning and repeatability of machine tool slides are the major functional requirements of CNC machines. The inaccuracies that caused are mainly due to the stick slip motion when plain slide ways (metal to metal contact) are used.

To fulfill the requirements of elimination of stick-slip, there are different sideways systems such of rolling friction slide ways and sideways with low friction. These have low wear, negligible stick-slip, good vibration, damping, easy machinability, low price and low co-efficient of friction properties.

Requirements of a good slide way system

1. Low co-efficient of friction at varying slide velocities.
2. Low rate of wear
3. Sufficient damping
4. High stiffness at the sliding joints.

PLASTIC COATED SLIDEWAYS

The cross section of a slide way sy d is shown in the figure.

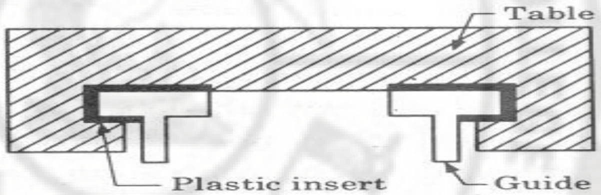

Fig. 5.11. PLASTIC COATED SLIDEWAYS

The inserts are thermoplastics (Turcite - B) or thermosetting types. In these coated slide ways, the static coefficient of friction is less than the dynamic coefficient of friction.

With increase in speed, dynamic coefficient of friction increases to a value and remains constant.

These inserts are made of two or more materials. These reduce coefficient of friction, increase strength, and wear resistance and load bearing capacity. They also have self-lubricating property. Ad thout the need for any machining of bed ways.

LINEAR MOTION BEARING

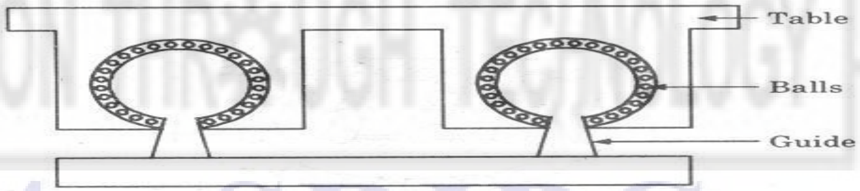

Fig. 5.12. Linear Motion Bearing Systems

Linear motion guide system is shown in the figure. The unit consists of a bearing block and rail. Two race ways are provided on one side of the bearing block where two rows of rolls are retained and caused to recirculate by means of retainer and two end plates.

The unit is constructed in such a manner that each of the rows of balls, rolling over the rail comes into contact with the race-way at an angle of 45 degree. The race is in line contact rather than the conventional point contact. The ball has 13 more times allowable carrying capacity than conventional point contact system. The system is capable of withstanding equal load in any direction.

RECIRCULATION BALL SCREW

Ball screws are primarily employed in feed mechanism of CNC machine tools. The balls provide only physical contact between the nut and the lead screw. The balls are recirculated from one end to the other by return tubes.

When the lead screw rotates, the balls in the groove between the nut and lead screw push the nut affecting its liner motion. The ball screws provide many advantages.

1. Low coefficient of friction due to point contact by the rolling members

A leac

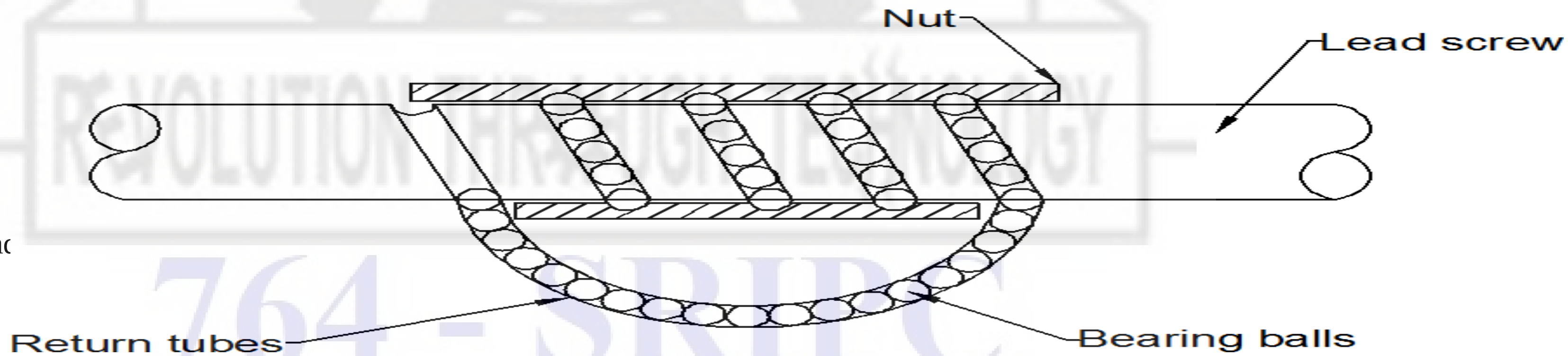

Fig. 5.13. Recirculation Ball Screw

ATC (AUTOMATIC TOOL CHANGER):

ATC is an important part of a machining centre. ATC picks up a tool from the magazine and keeps it ready for swapping with the tool in the spindle which is presently cutting. Time for tool change varies between 3 to 7 seconds.

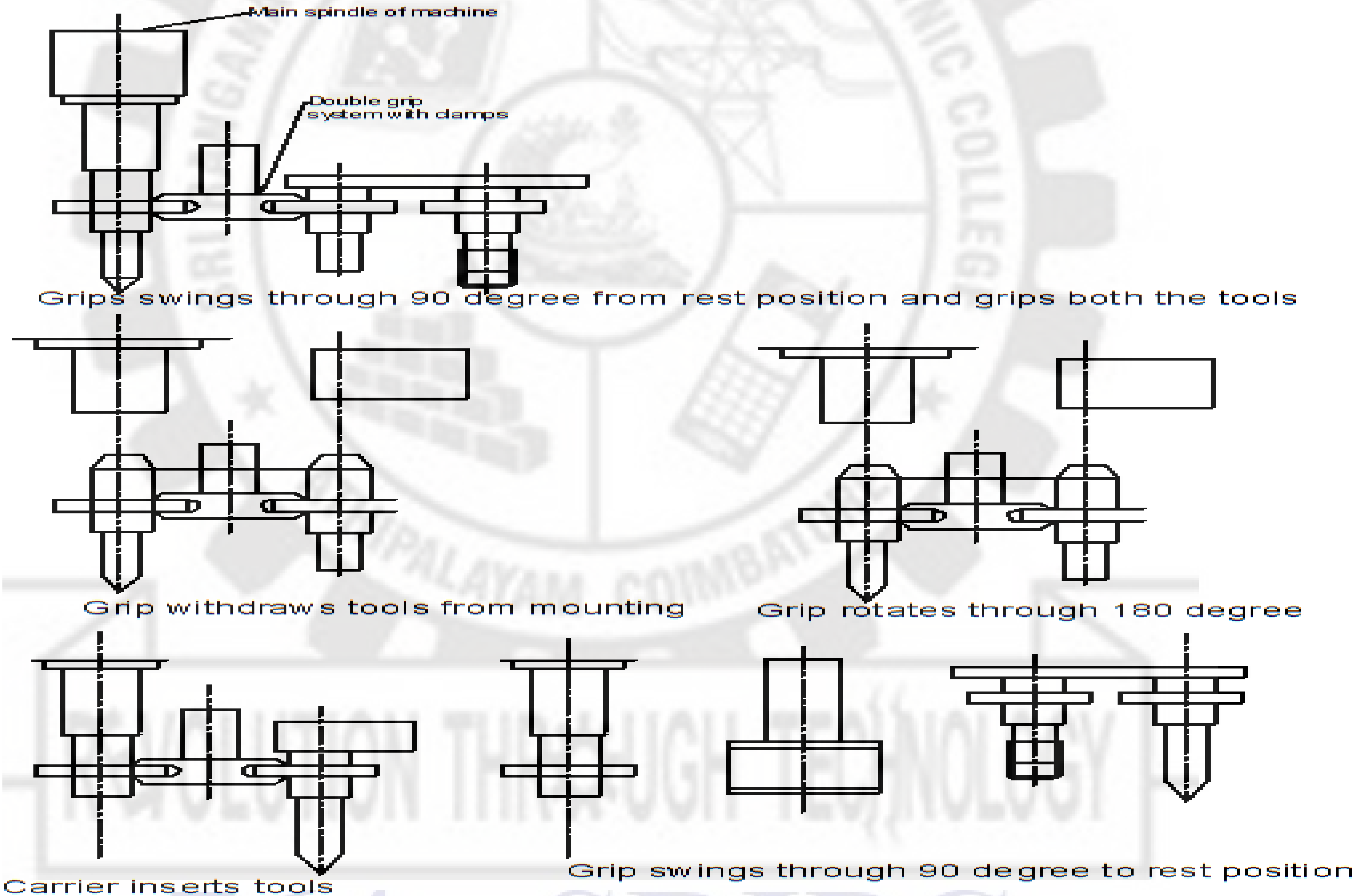

Fig. 5.14. ATC

Operation of a double-ended arm type ATC is shown in the figure. The desired tool is collected from the magazine in one end of the special arm. At the moment of tool change, the empty end of the arm grips the tool in the spindle, removes it, indexes 180 and inserts the new tool into the spindle

Quill-type spindles generally move out towards the stationary (after rotation) arm to accept a new tool or replace a sued one.

Non quill-spindles machines, the double-end arm incorporates an in-out motion to insert or extract the tool from the spindle taper.

The magazine not only transport the tool during storage and keep it clean and free from damage but it also keeps track of which tools are where. This can be done by coding the tools physically either on the tool itself or in the magazine adjacent to the tool when the pocket is loaded.

Types of ATC and Magazine

The concept of the ATC is that the range of tools for a specific job shall be made available for automatic selection and positioning. ATC can be,

Turret head type : Used on drilling machines; strictly speaking, it is not on ATC.

Drum type : For holding small number of tools usually not more than 30, on periphery of drum. Tool search speed is faster.

Chain type : For more number of tools (30-40or more tools can be used). Tool search speed is lees.

Characteristic of Tool Magazines

Tool magazines should satisfy the following requirements.

1. Tools magazine has to be compact and as simple as possible.
2. Interchange of tools should not interfere with the work piece space and tool space
3. Easier and safer manual exchange of tools in the tool magazine during loading and unloading
4. All preparatory works for tool exchange should be made during machining.
5. Tool magazine must be capable of holding enough tools needed for performing complete operations for some typical work piece on the machining centers.

Classification of ATC

1. According to the kind of cutting tools,
    a. Single tool
    b. Multi tool heads
    c. Special tools such as micro bores

2. According to the system tool exchange,
    a. With tool parking change arm
    b. With tool parking position
    c. With tool chance arm
3. According to the position of axes of tool and spindle,
    a. With parallel axes
    b. With intersecting axes
4. According to tool position,
    a. With horizontal tool position
    b. With vertical tool position

ROTARY ENCODER DISC

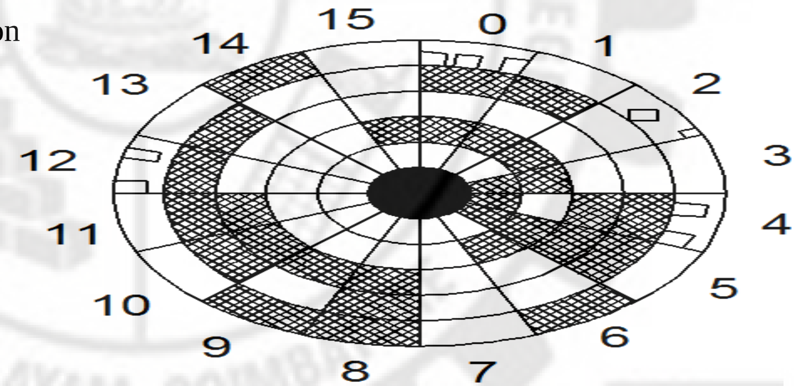

Fig. 5.15. Rotary Encoder Disc

A NC system in which all positional dimensions are measured with respect to a common datum point is called a digital absolute system. The transducers give a direct reading of position with reference to the common datum.

All position commands are given as absolute distances from the datum point (zero point). Main advantage of the absolute system as compared with the incremental one is in case of interruption that forces the operator to stop the machine. The figure shows an absolute rotary encoder. These devices the angle positions directly from the code pattern of the graduated disc and convert it into a coded signal which corresponds to one definite angle position. Multi-turn absolute rotary encoders provide electronically coded measured values for several revolutions.

The code pattern on the disc has several tracks. The number of tracks depends upon the desired resolution and the type of code. Each track is assigned its own solar cell so that all tracks can be read simultaneously. Most frequently used code is gray code. Gray code measured value can be electronically converted to corresponding positions.

TRANSDUCER

Transducer is an instrument which receives the messages in one form and transfers the same into a form which the receiver can accept. There are two types of transducer in CNC machine.

1. Rotary (angular) transducers
2. Linear transducers

Rotary transducer is fixed in drive shaft or lead screw. The gives the displacement of the rotating disc. From this the linear position

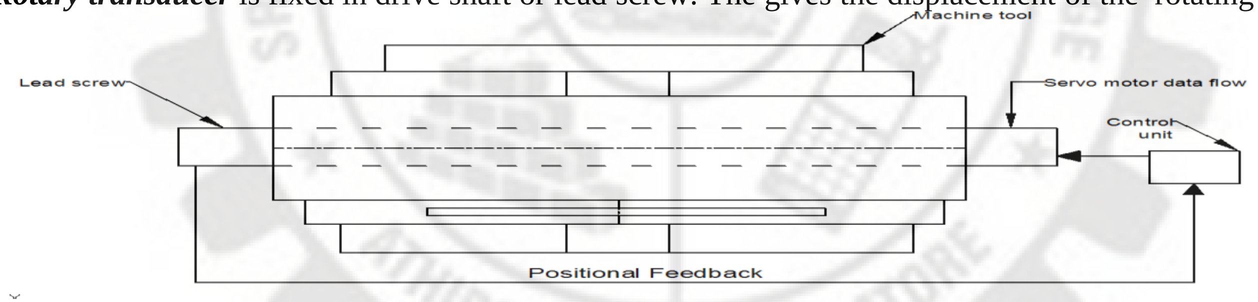

Fig. 5.16. Rotary transducer

Linear transducer is fixed near to the axis sideway. It is used to measure the linear position directly.

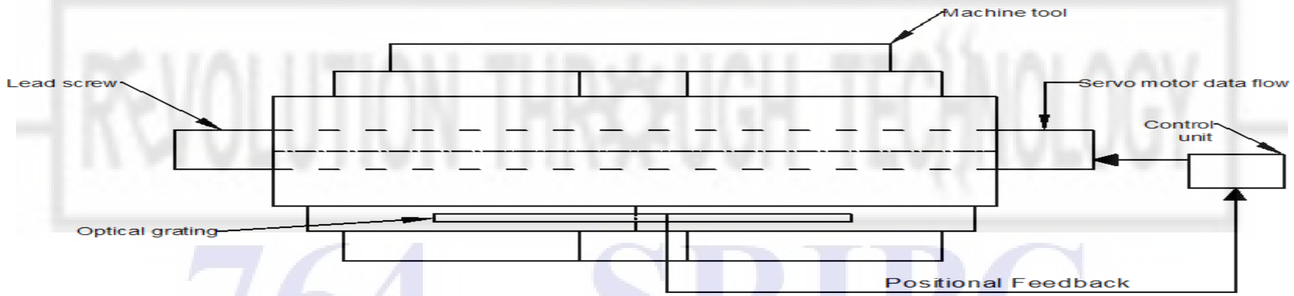

Fig. 5.17. Linear transducer

The following techniques are used to measure the rotary and linear transducer.

1. Binary encoders
2. Engraved gratings
3. Moire fringe grating
4. Synchro - resolvers

IN PROCESS PROBING

In-process part-gaging and probe-assisted tool setting right on the machine tool is proving to be valuable in the quest for consistent quality machined parts. The technology is now refined and growing in popularity. Today, many new CNC machining centres and turning centres along with some transfer lines and indexing machines come equipped with probes, software, and electronic controllers for in-process probing. An increasing number of grinding machines and systems are being equipped for in-process probing. The hardware and software details differ from those on spindle-type machines, but the principles and applications are the same.

For one thing, in-process, on-machine part-gaging allows a CNC controller to catch its own errors. The system automatically compensates for effects of tool wear and temperature fluctuations, so you can meet specs on every part. Further, application of this technology eliminates the need for extremely precise fixturing and orientation of part to spindle. The CNC finds each part on its own, referencing the machining program to part features rather than to a single point on the fixture.

In setup, on-machine probing and tool setting nullifies many types of operator errors, and speeds the setup process. On spindle-type machines, tool length and diameter can be checked before and during machining, while the tool is held in its spindle or turret. The system enters and updates offsets automatically.

One of the most important advantages of 100% parts inspection is the feedback to the manufacturing process that is obtained to permit the process to be altered before the targeted process deteriorates or before scrap is produced.

Part handling is one of the manufacturing variables which must be considered with 100% inspection of parts.

High-speed steel is generally used on aluminum and other nonferrous alloys, while tungsten carbide is used on high-silicon aluminums, steels, stainless steels, and exotic metals.

Ceramic inserts are used on hard steels and exotic metals. Inserted carbide tooling is becoming the preferred tooling for many CNC applications.

For the full utilization of CNC machines it is essential to pay due attention to the selection and usage of tooling, namely tool holders, cutting tools and work holding devices. The tools for CNC machines must be quickly changeable to reduce non-cutting time, preset and reset outside the machine, high degree of interchangeability, increased reliability and high rigidity.

The cutting tools can be classified on the basis of setting up of tool, tool construction and cutting tool material:

On the Basis of Setting up of Cutting Tool

(a) Preset tools

(b) Qualified tools

(c) Semi qualified tools

On the Basis of Cutting Tool Construction

(a) Solid tools

(b) Brazed tools

(c) Inserted bit tools

On the Basis of Cutting Tool Material

(a) High speed steel (HSS)

(b) High carbon tool steel (HCS)

(c) Cast alloy

(d) Cemented carbide

(e) Ceramics

(f) Boron Nitride

(g) Diamond

(h) Sialon