GOVERNMENT POLYTECHNIC DHANGAR

Branch: Mechanical Engineering

Semester: 5th

Subject: Workshop Technology - III

Chapter 1: Milling

Chapter 2: Grinding

Chapter 3: Gear Manufacturing and Finishing processes

Chapter 1

Milling

1.1 INDTRODUCTION

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

1.2 WORKING PRINCIPLE

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

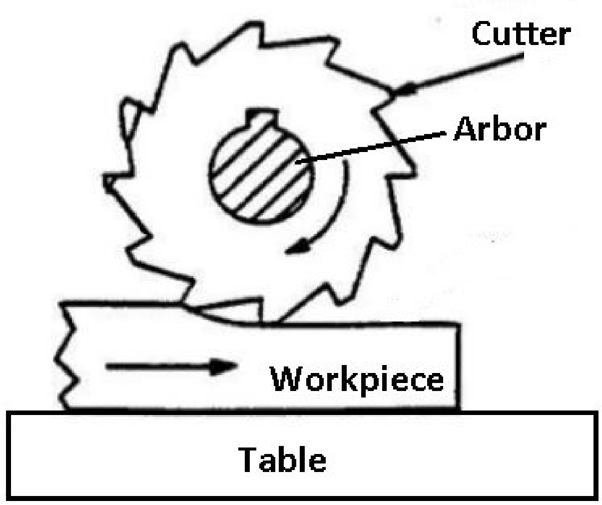


Fig.1.1 Principle of a milling machine

1.3 SPECIFICATION

The size of the milling machine is generally specified by the dimensions of work table in mm i.e. length of table X Width of table. The other main specifications which needs due consideration is:

- longitudinal feed
- cross feed
- Vertical feed
- Spindle speed
- Type of drive
- Power of driving motor etc.

1.4 CLASSIFICATION

The milling machine may be classified in a variety of ways as follow:

According to the design, the distinctive classification is as follows:

A. According to drive:

(a) Cone-Pulley belt drive: The cone pulley at the bottom is connected to the electric motor by a V-belt. So the cone pulley at the bottom rotates at a particular speed. The belt is arranged on any of the four steps to obtain different spindle speeds. The spindle speed is increased if the belt is placed on the smaller step of the driven pulley.

(b) Individual motor drive: Milling machines commonly have self-contained electric drive motors, coolant systems, digital readouts, variable spindle speeds, and power-operated table feeds.

B. According to design:

1. Column and Knee Milling Machines:

(a) Horizontal milling machine: Horizontal milling machines feature a similar design in which a spindle containing a rotating cutting tool presses against a workpiece to remove material from the workpiece as shown in fig.1.2.

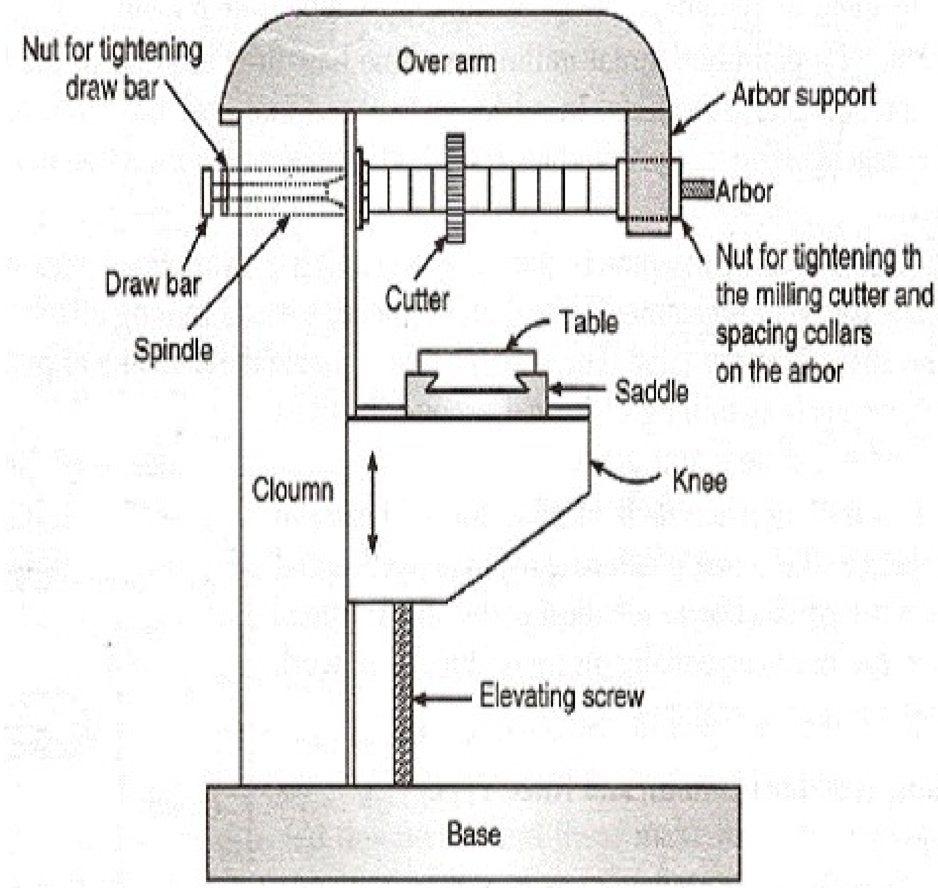


Fig. 1.2 Horizontal Milling Machine

The knee can be moved up and down by elevating screw. Saddle mounted on knee can be moved towards or away from column. Milling table is mounted on the top of saddle to hold the job. This machine is suitable for genral milling work such as surface finishing, gear cutting etc.

(b) Vertical milling machine:

Vertical Machining relies on rotary cutters to remove metal from a workpiece. Vertical machining occurs on a vertical machining center (VMC), which employs a spindle with a vertical orientation. With a vertically oriented spindle, tools stick straight down from the tool holder, and often cut across the top of a workpiece as shown in fig. 1.3.

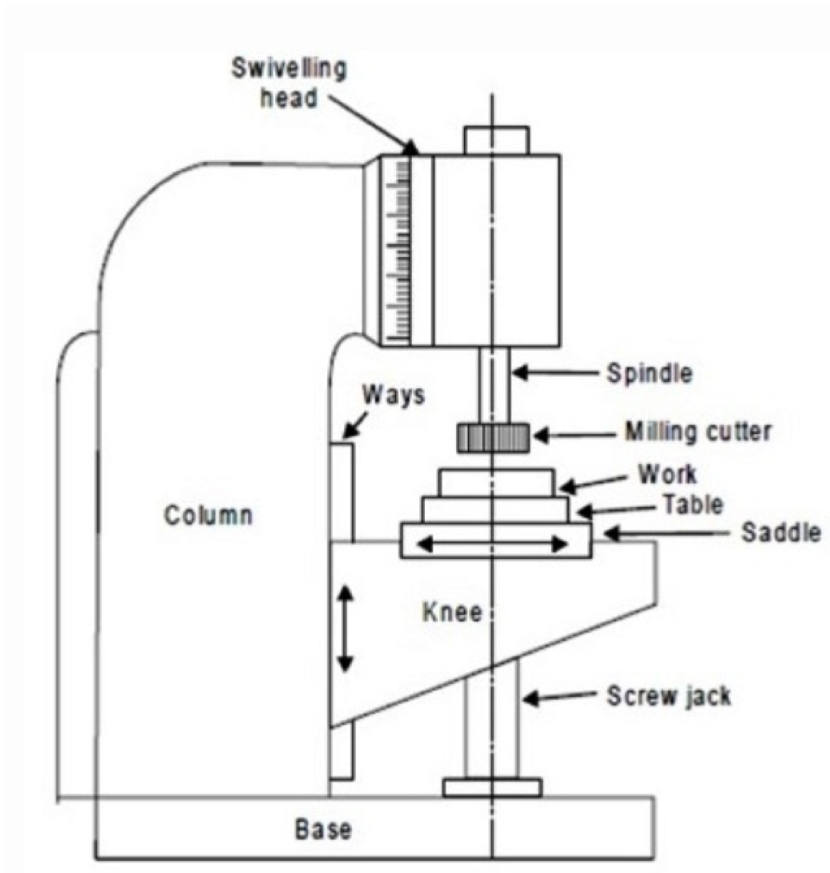


Fig. 1.3 Vertical Milling Machine

The milling head can be swiveled at any oblique position. This machine is usally used for end milling work with end mill cutters.

(c) Universal milling machine: The universal milling machine is similer in appearance in horizontal milling machine. The worktable of this machine is provided with extra swivel movement with a dividing head located at the end of the table. This permits the table to swing up to 45° in either direction for angular and helical milling operations as shown in fig. 1.4.

Fig. 1.4 Universal Milling Machine

The universal machine can be fitted with various attachments such as the indexing fixture, rotary table, slotting and rack cutting attachments, and various special fixtures.

(d) Omniversal milling machine: This is the modified form of a horizontal milling machine. It consist of two spindle, one of which is in the horizontal plane while the other is carried by a universal swiveling head. The latter can be set in a vertical position and swivelled upto 45° on both sides.

2. Planer type Milling Machine: The planner milling machine is mostly used for facing operations in mass production. These machines are similar to the bed type mill machine, except it can be mounted with various cutters and spindle heads to the machine as shown in fig.1.5. These cutters in the machines can perform the facing operations simultaneously which is a great function.

Fig. 1.45 Planer Type Milling Machine

3. Bed-Type Milling Machine: In this type of machines, the work table is mounted on a fixed bed and it has a longitudinal travel only. It cannot moved up, down or crosswise. The adjustable spindle or spindle head attached to a vertical column can move along vertical ways on the column to adjust tool to the work.

(a) Simplex milling machine: It is a smaller version of planer type milling machine having single adjustable horizontal spindle head.

(b) Duplex milling machine: It is also a smaller version of planer type milling machine having two adjustable horizontal spindle heads each attached to a separate vertical column one each side to the fixed bed as shown in fig.

(c) Triplex milling machine: It has two adjustable horizontal spindle heads like a duplex milling machine attached to two different columns and one vertical spindle head on a cross rail.

4. Special Purpose Milling Machine: These are machine made for some special work.

(a) Rotary table milling machine: The rotary table milling machine consists of a circular table that rotates in a vertical axis. You need to set multiple cutters at different heights. The machine works with one cutter roughing up the workpiece, and the rest of the cutters finishing the surface. The operator can load and unload the workpieces continuously while the machine is working, and that is the most significant advantage of the rotary table milling machine.

(b) Drum milling machine: The drum milling machine is just like a rotary table. The only difference is that this machine has a table that supports the workpiece and is called a drum, which can only rotate horizontally. To remove the metal, you need to place the workpiece on the drum. These cutters have three or four spindle heads. After one complete turn, you need to remove the finished parts and clamp the new one onto it.

(c) Profile milling machine: In appearance, it resembles the vertical spindle machine. It has one to four cutter spindles. The cutter is a small diameter shank type end mill. Its movement is controlled, either by hand or automatically, by the path of a stylus or tracer which has the same diameter and shape as the cutter. In this machine the operation is performed in two dimensions. A good commercial finish and a tolerance of within 0.1 mm can be expected from this machine.

(d) Duplicating milling machine: It is also called by the name of originator, Keller machine, die sinker or automatic tracer controlled miller. In this machine, milling operating can be performed in third dimension also. The template used in this machine must be replica in three dimensions of the work to be performed.

Typical work performed includes the making of forging dies, steel molds for glass, plastic and certain metals, auto body dies, ship propellers and air-craft connecting rods.

(e) Planetary milling machine: It is a unique machine in the sense that the work is held stationary while the revolving cutter or cutters move in a planetary path to finish a circular surface on the work, either internally or externally. Many of the operations would be lathe operations, if the nature of workpiece permits. The cutter may be plain, form or thread cutter and may work on either the inside or the outside of the work or inside and outside simultaneously.

1.5 APPLICATIONS

Milling machines are widely used in the tool and die making industry and are commonly used in the manufacturing industry for the production of a wide range of components. Typical examples are the milling of flat surface, indexing, gear cutting, as well as the cutting of slots and key-ways.

- Milling machines are very versatile. They are usually used to machine flat surfaces, but can also produce irregular surfaces. They can also be used to drill, bore, cut gears, and produce slots.
- A milling machine removes metal by rotating a multi-toothed cutter that is fed into the moving workpiece. The spindle can be fed up and down with a quill feed lever on the head.
- The bed can also by fed in the x, y, and z axes manually. In this clip the z axis is adjusted first, then the y, than the x.
- Once an axis is located at a desired position and will no longer be fed, it should be locked into position with the gibb locks.

- Most milling machines are equipped with power feed for one or more axes. Power feed is smoother than manual feed and, therefore, can produce a better surface finish. Power feed also reduces operator fatigue on long cuts.

1.6 COLUMN AND KNEE TYPE MILLING MACHINE

It is low production machine most commonly used machine in view of flexibility and easier setup. The table of this machine is mounted on the knee which is mounted on the vertical column. The knee can be moved up and down to accommodate various heights of works. The knee can be guided on the guideways provided at the front face of the column.

Principle parts: The principle parts of knee and column type milling machine are shown in fig. 1.2.

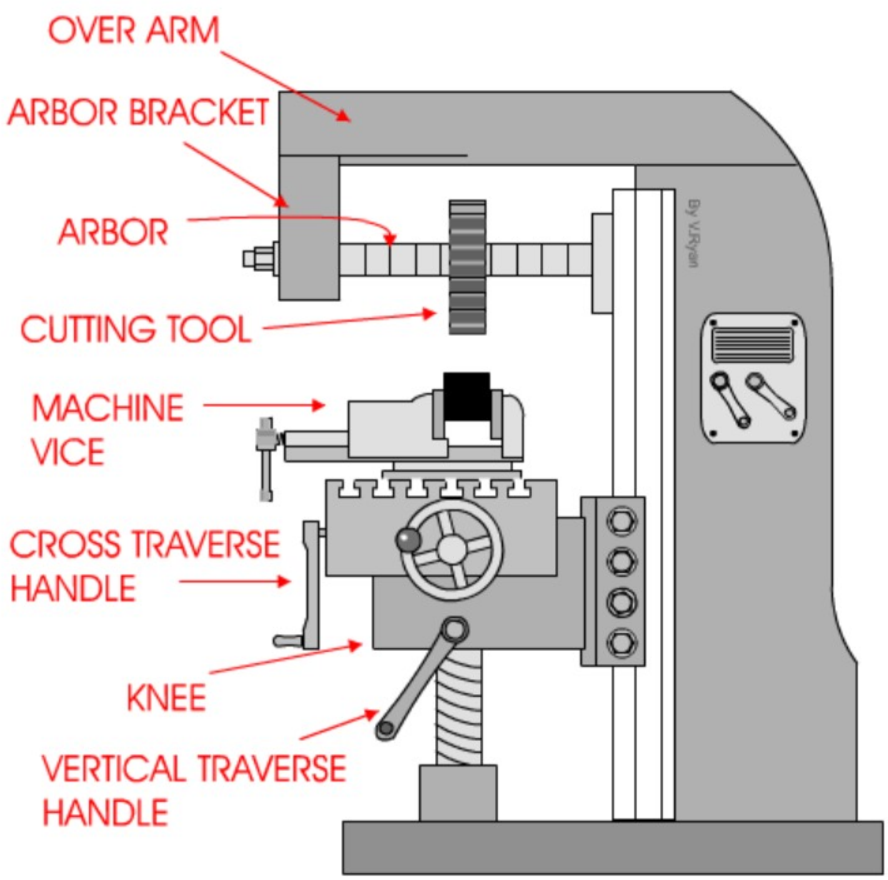


Fig.1.2 Knee and column type milling machine

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

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

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

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

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

a). Vertical (up and down) movement provided by raising or lowering the knee.

b). Cross (in or out) or transverse motion provided by moving the saddle in relation to knee.

c). Longitudinal (back and forth) motion provided by hand wheel fitted on the side of feed screw.

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

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

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

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

1.7 MILLING METHODS

Based upon the directions of movement of the milling cutter and the feeding directions of the workpiece, there are two possible types of milling:

1. Conventional Milling (Up Milling):

In up cut milling, the cutter rotates in a direction opposite to the table feed as illustrated in figure 1.3. It is conventionally used in most milling operations because the backlash between the lead screw and the nut of the machine table can be eliminated.

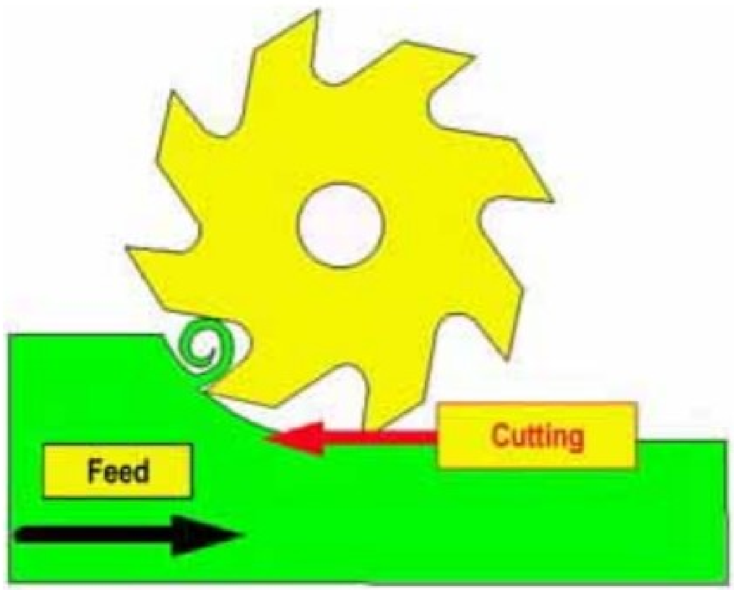


Fig.1.3 Up Milling

2. Climb Milling (Down Milling):

In down cut milling, the cutter rotates in the same direction as the table feed as illustrated in figure 1.4. This method is also known as Climb Milling and can only be used on machines equipped with a backlash eliminator or on a CNC milling machine. This method, when properly treated, will require less power in feeding the table and give a better surface finish on the workpiece.

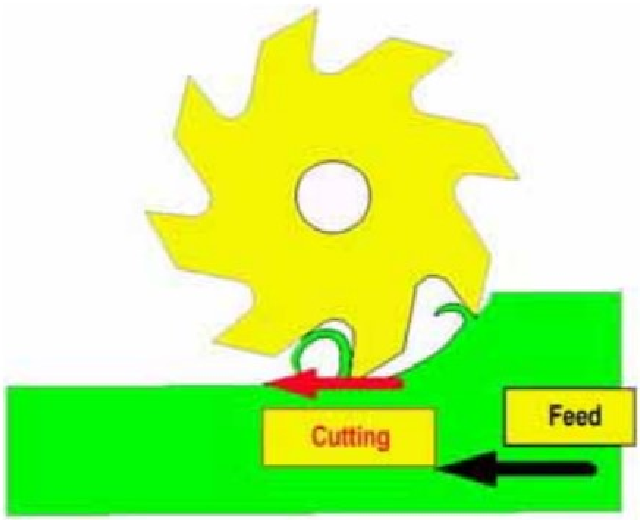


Fig.1.4 Down Milling

1.8 MILLING CUTTERS AND WORK MENDRELS

There are various types of milling cutters. According to purpose or use, there can be classified as follow:

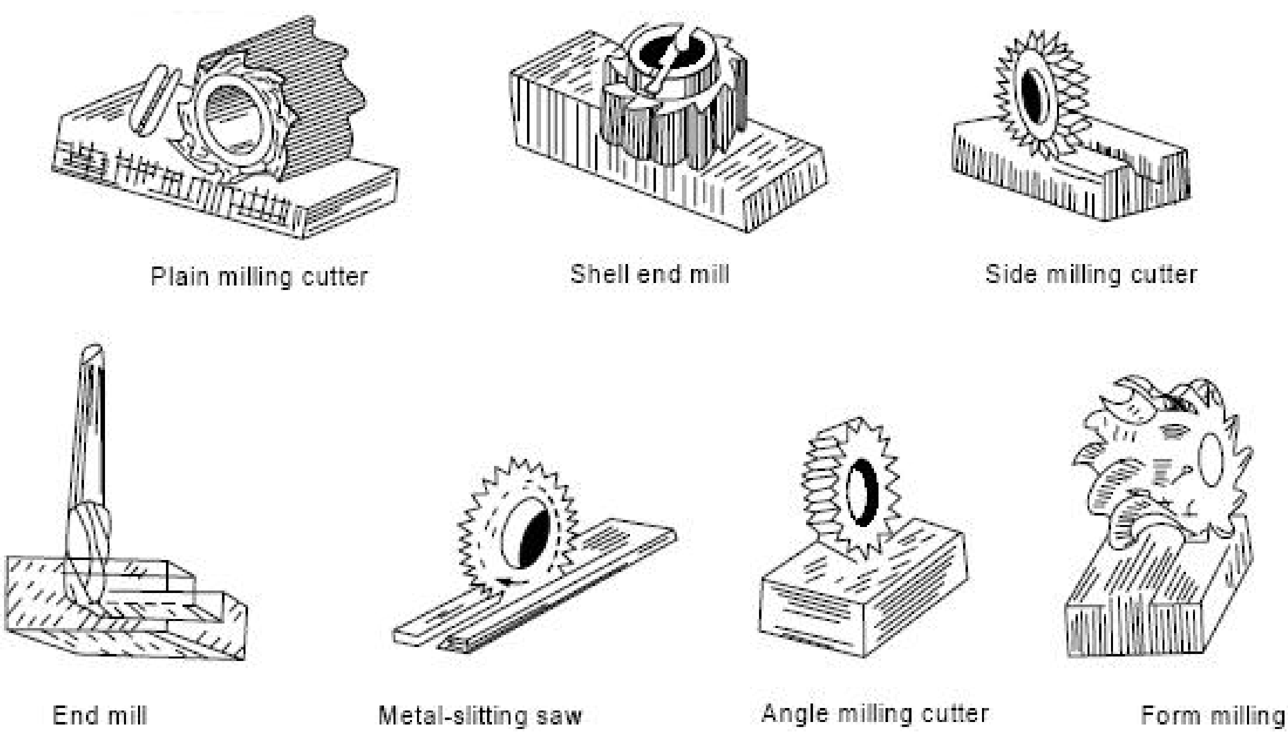


Fig.1.5 Milling Cutters

1. Plain Milling Cutter:

It has straight or helical teeth cut on the periphery of a disc or a cylindrical surface. It may be of solid inserted blade or tipped type, and is usually profile sharpened but may be form relieved also. Generally helical teeth are used if the width of the cutter exceeds 15 mm.

2. Side Milling Cutter:

This cutter is similar to plain cutter except that it has teeth on the side. However, the side milling cutter may have teeth on the periphery and on one or both sides of the tool. These cutters may have straight, spiral or staggered teeth. Further these may be solid, inserted blade or tipped construction, and may be profile sharpened or form relieved.

3. End Mill Cutters:

These cutters have an integral shaft for driving and have teeth on both periphery and ends. These are the cutters with teeth on the periphery and end integral with a shank for holding and driving. These are used to mill flat, horizontal, vertical, bevel, chamfer and slant surfaces, grooves and keyways, and to cut slot and in recess work such as die making etc.

4. Angle Milling Cutters:

Any cutter, angle shaped, comes under this classification. These may have cutters either on only one conical surface (single-angle cutter) or on two conical surfaces (double angle cutter). Angle cutters are used for cutting ratchet wheel, dovetails, flutes on milling cutters and reamers, machining angles and Vs of 30°, 45°, 60° and 90°.

5. T-Slot Cutters:

These are used for milling T-slots in one operation and are available in special sizes for standard T-slots. These resemble plain or side milling cutters which have an integral straight or tapered shaft for driving.

6. Form Milling Cutters:

These have a special curved tooth outline and are used for milling contours of the various shapes. Various other types of form milling cutters are convex milling cutters, concave milling cutters, corner-rounding milling cutters, pocket milling cutters, spindle milling cutters, form milling gang cutters, etc.

1.9 WORK HOLDING DEVICES

A workpiece must be held securely and rigidly on the table of milling machine for accurate milling operation. The various devices used for this purpose are as follows:

1. T- Bolts and clamps:

Bulky workpieces of irregular shapes are clamped directly on the milling machine table by using T- bolts and clamps. Different types of clamps are used for different patterns of work. The common types of clamps are shown in Fig 10 of chapter 5. All these clamps carry a long hole, through which clamping bolt passes. This hole permits the bolts for adjustment according to the size and shape of the job.

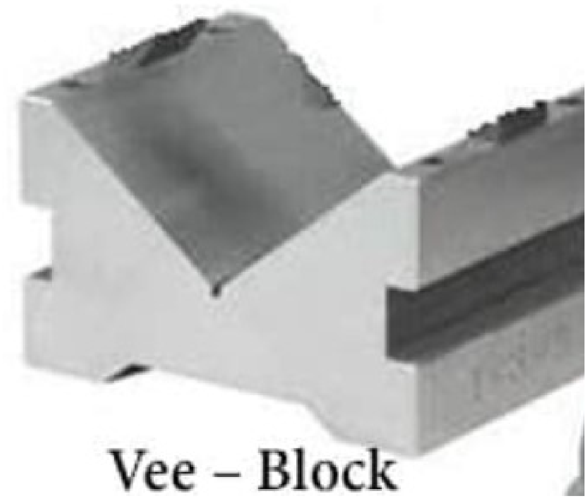
2. Angle plates:

- When work surfaces are to be milled at right angles to another face, angle plates are used for supporting the work.
- The angle plate is made from high-quality material (generally spheroidal cast iron) that has been stabilized to prevent further movement or distortion.

- Slotted holes or “T” bolt slots are machined into the surfaces to enable the secure attachment or clamping of workpieces to the plate, and also of the plate to the worktable.
- Angle plates also may be used to hold the workpiece square to the table during marking-out operations.
- Adjustable angle plates are also available for workpieces that need to be inclined, usually towards a milling cutter.

3. V block:

The V blocks are used for holding shafts on a milling machine table in which keyways and slots are to be milled.



Vee – Block

4. Vices :

Vices are the most common appliance for holding work on milling machine tables. According to its quick loading and unloading arrangement. Vices are of three types,

(a) Plain Vice

The plain vice is directly bolted on the milling machine table is the most common type of vice used on plain milling operations, which involves heavy cuts, such as in slab milling. Its especially low construction enables the work to remain quite close to the table. This reduces the chance of vibration to a minimum. The base carries slots to accommodate ‘T’ bolts to fix the vice on the table. Work is clamped between the fixed and movable jaw and for holding workpieces of irregular shape special jaws are sometimes used.

(b) Swivel Vices

The swivel vice is used to mill an angular surface in relation to a straight surface without removing the work from the vice. It has got a circular base graduated in degrees. The base is clamped on the table by means of T- bolts.

(c) Universal Vices

It can be swiveled in a horizontal plane similar to a swivel vice and can also be tilted in any vertical position for an angular cut. The vice is not rigid in construction and is used mainly in tool room work. It enables the milling of various surfaces, at an inclination to one another, without removing the workpiece.

5. Dividing Head:

Dividing head or indexing head used to hold the workpiece and divide the periphery into the number of divisions required. These are of three types:

(a) Plain dividing head

(b) Universal dividing head

(c) Optical dividing head

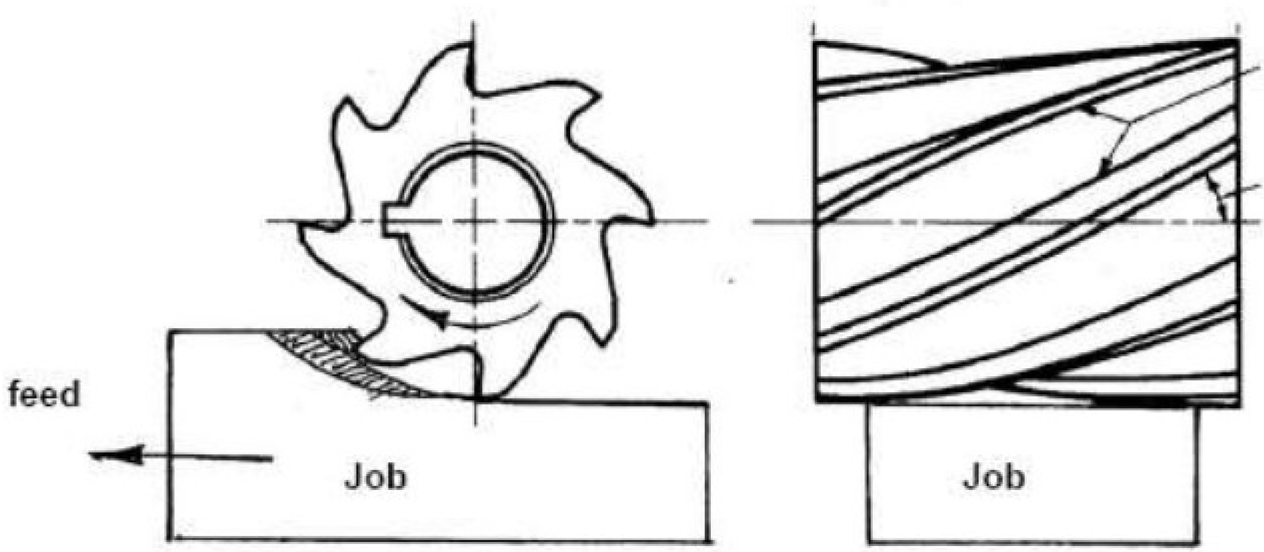
6. Special Fixture :

Work directly mounted on table or Special fixtures. Work directly mounted on the table for heavy nature of jobs or odd-shaped jobs which is not possible to hold by other holding devices, with the help of slots, T- bolts, and nuts. The fixtures are special devices designed to hold work for specific operations more efficiently than standard work holding devices. The fixtures are especially useful when large numbers of identical parts are to be manufactured.

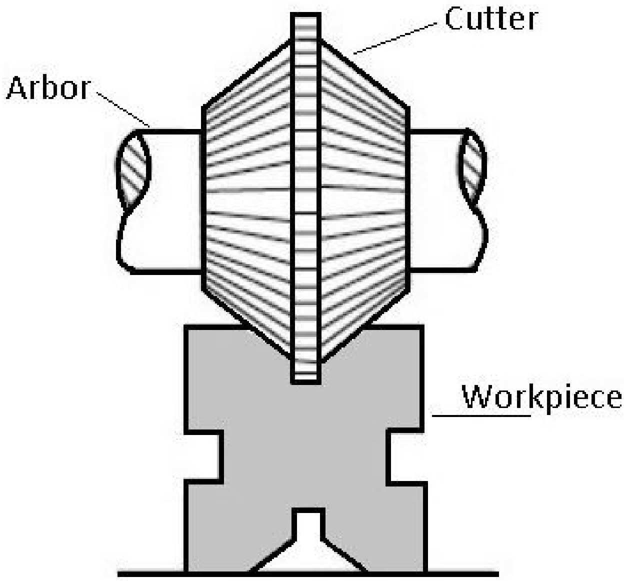
1.10 MILLING OPERATIONS

The following are the different milling operations performed on the milling machine:

1. Face Milling: **Plain Milling**, also called **Surface Milling** or **Slab Milling**, is milling flat surfaces with the milling cutter axis parallel to the surface being milled. Generally, plain milling is done with the workpiece surface mounted parallel to the surface of the milling machine table and the milling cutter mounted on a standard milling machine arbor. The arbor is well supported in a horizontal plane between the milling machine spindle and one or more arbor supports.

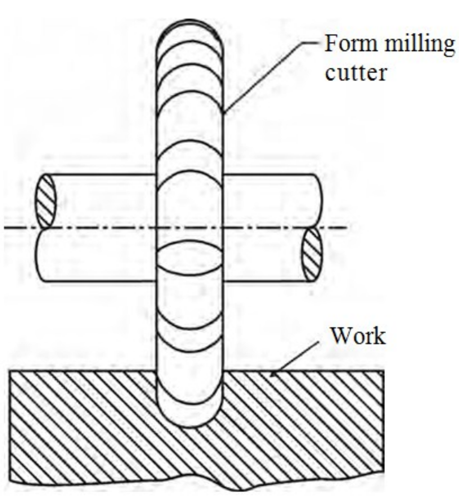


2. Angular milling: It is also known as angle milling, refers to milling operations in which the cutting tool's axis of rotation is at an angle relative to the surface of the workpiece. The process employs single-angle milling cutters—angled based on the particular design being machined—to produce angular features, such as chamfers, serrations, and grooves. One common application of angular milling is the production of dovetails, which employs 45°, 50°, 55°, or 60° dovetail cutters based on the design of the dovetail.



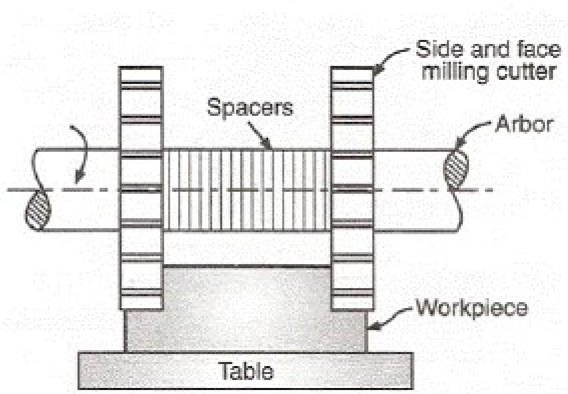
Angular Milling

3.Form milling: THe process of machining special contours composed of curves and straight lines, or entirely of curves, at a single cut. This is done with formed milling cutters, shaped to the contour to be cut, or with a fly cutter ground for the job. The more common form milling operations involve milling half-round recesses and beads and quarter-round radii on the workpieces. This operation is accomplished by using convex, concave, and corner rounding milling cutters ground to the desired circle diameter.



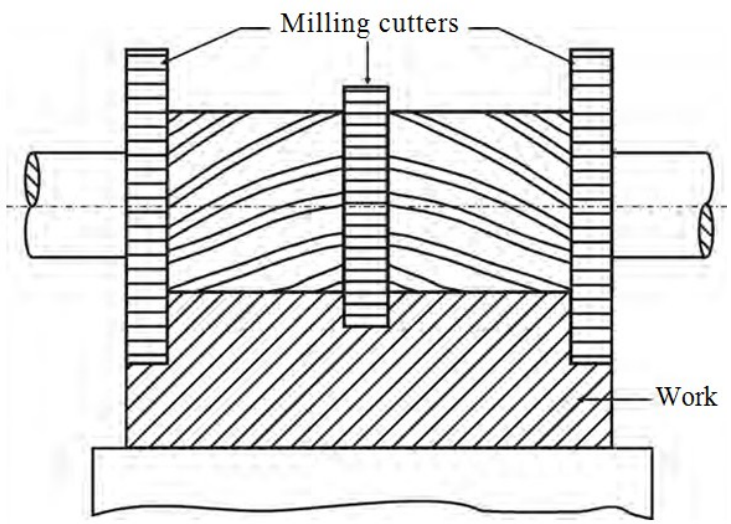
Form Milling Operation

4.Straddle milling: When two or more parallel vertical surfaces are machined at a single cut, the operation is called straddle milling. Straddle milling is accomplished by mounting two side milling cutters on the same arbor, set apart so that they straddle the workpiece. The diagram below illustrates a typical example of straddle milling. In this case a spline is being cut, but the same operation may be applied when cutting squares or hexagons on the end of a cylindrical workpiece.



Straddle milling

5.Gang milling: The term applied to an operation in which two or more milling cutters are used together on one arbor when cutting horizontal surfaces. The usual method is to mount two or more milling cutters of different diameters, shapes and/ or widths on an arbor as shown in the following diagram. The possible cutter combinations are unlimited and are determined in each case by the nature of the job.



Gang Milling Operation

1.11 CUTTING SPEED AND FEED

1. Cutting Speed: The cutting speed of milling cutter is its peripheral linear speed resulting from rotation. In simple words, the cutting speed of a milling cutter is the travel of one revolution of one cutting tooth. It is expressed in meter per minute.

Cutting Speed (v) = $(\pi \times D \times n)/1000$ m/min

2. Feed: The feed in a milling machine may be defined as the rate with which the workpiece advances under the cutter. The feed is expressed in a milling machine by the following three different methods:

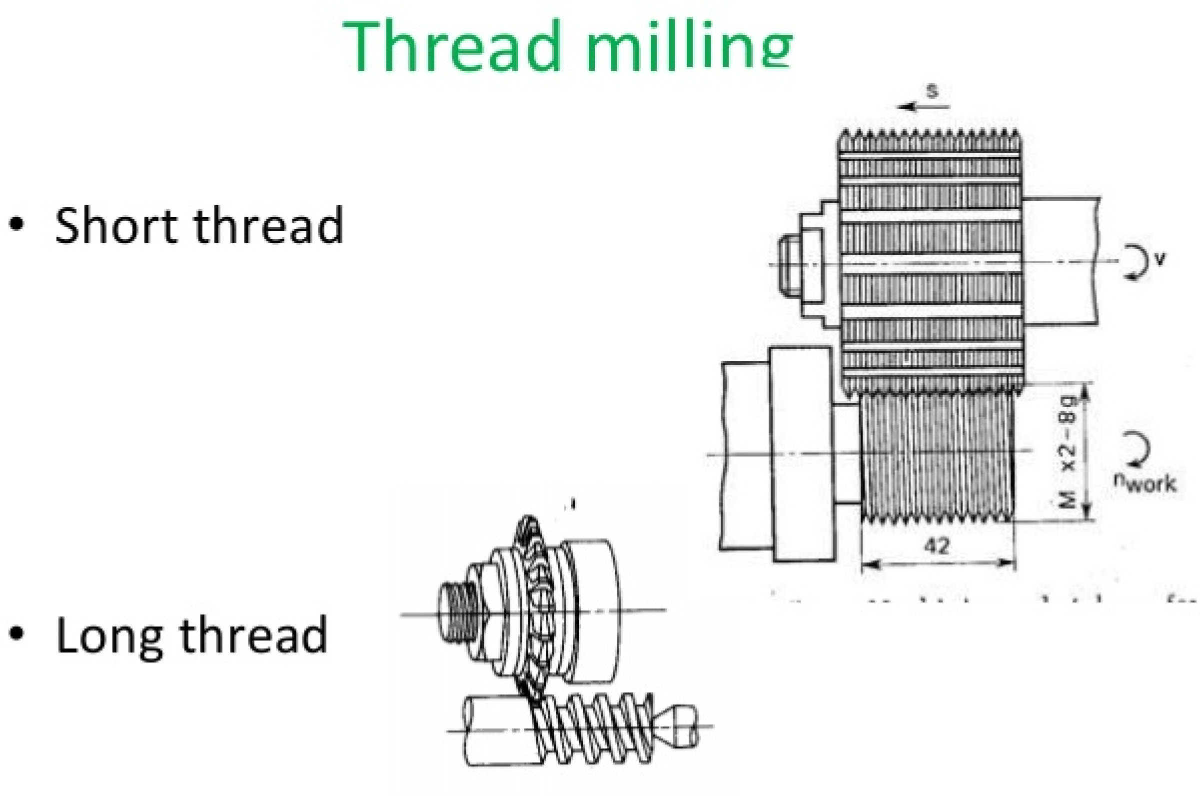
i. Feed per minute

ii. Feed per tooth

iii. Feed per revolution

1.12 Thread Milling

Thread milling is used to produce internal or external threads by using a single or multiple thread milling cutters. The operation is performed on a special thread milling machine to produce accurate threads in small or large quatities.

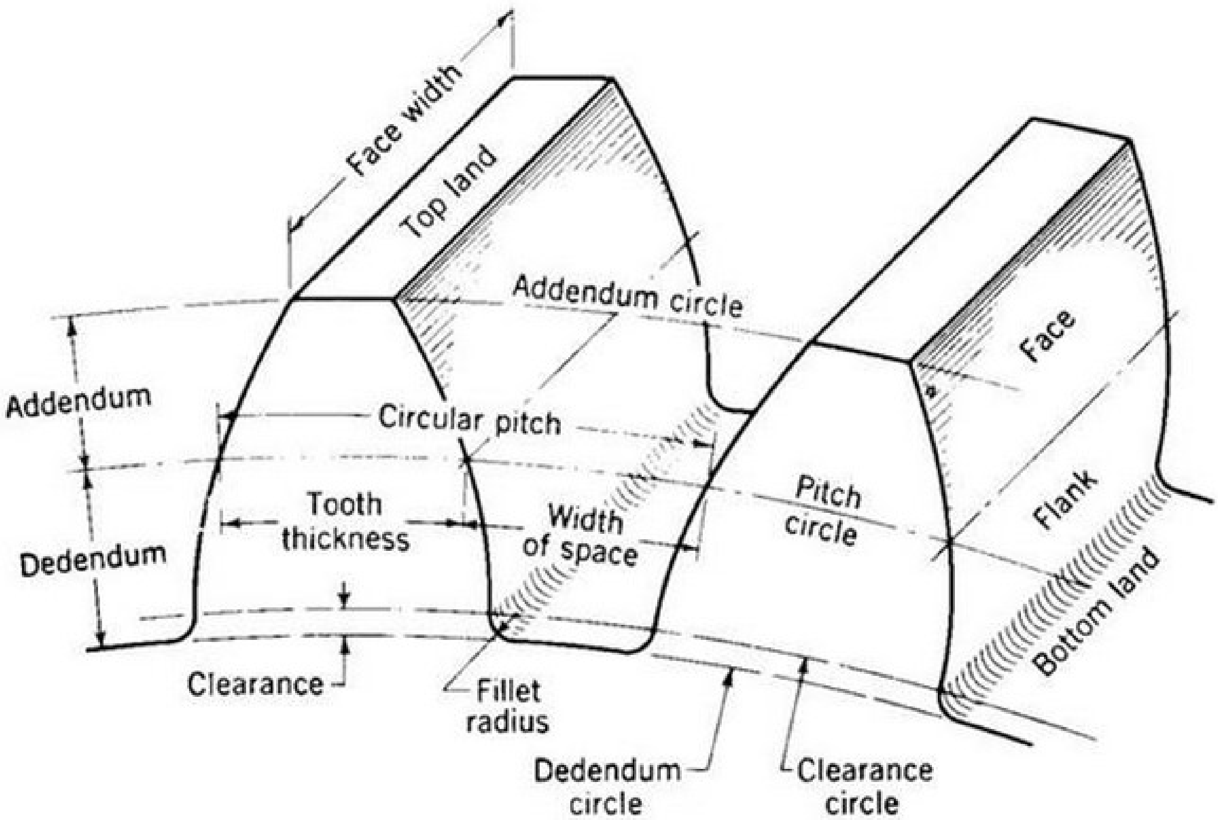


Chapter 2

Gear Manufacturing and Finishing Process

Gear

A toothed wheel that works with others to alter the relation between the speed of a driving mechanism (such as the engine of a vehicle) and the speed of the driven parts (the wheels).

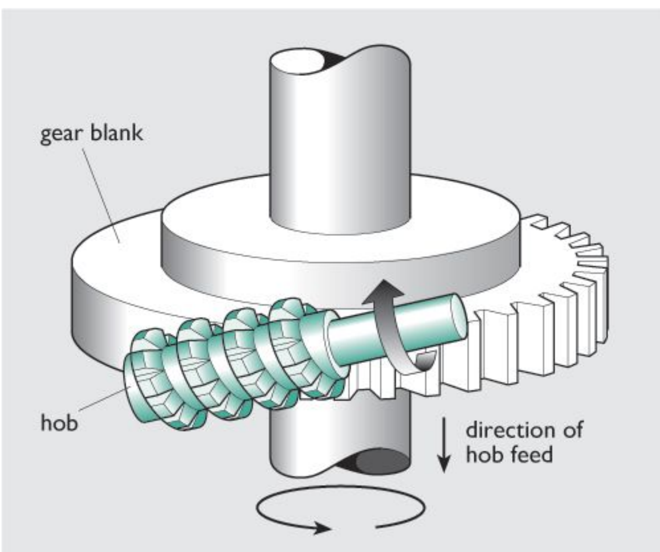


Gear Hobbing:

Gear Hobbing is a machining process for gear cutting, cutting splines, and cutting sprockets on a hobbing machine, which is a special type of milling machine. The teeth or splines are progressively cut into the workpiece by a series of cuts made by a cutting tool called a hob.

Gear Hobbing uses a hobbing machine with two skew spindles, one mounted with a blank workpiece and the other with the hob. The angle between the hob's spindle (axis) and the workpiece's spindle varies, depending on the type of product being produced. For example, if a spur gear is being produced, then the hob is angled equal to the helix angle of the hob; if a helical gear is being produced then the angle must be increased by the same amount as the helix angle of the helical gear. The two shafts are rotated at a proportional ratio, which determines the number of teeth on the blank; for example, for a single-threaded hob if the gear ratio is 40:1 the hob rotates 40 times to each turn of the blank, which produces 40 teeth in the blank. If the hob has multiple threads the speed ratio must be multiplied by the number of threads on the hob. The hob is then fed up into the workpiece until the correct tooth depth is obtained. Finally the hob is fed through the workpiece parallel to the blank's axis of rotation.

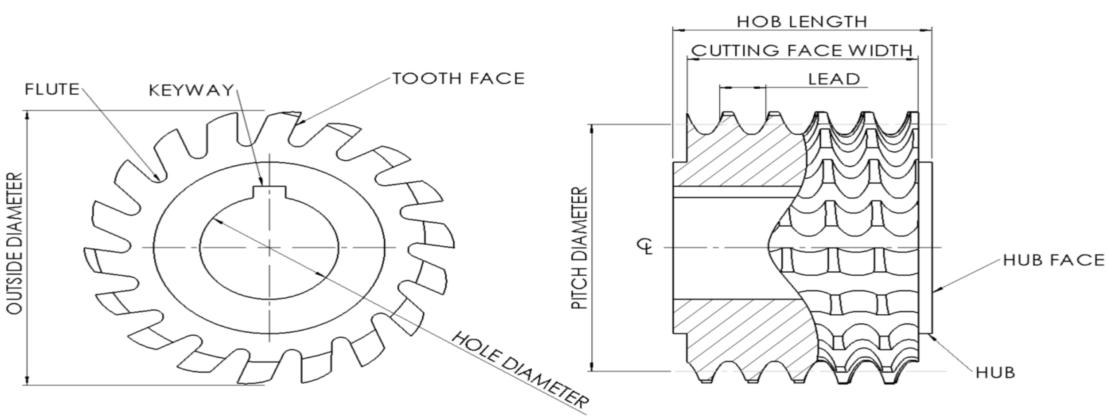
Often multiple blanks are stacked, and then cut in one operation. For very large gears the blank can be gashed to the rough shape first to make hobbing easier.



Gear Hobbing Machine:

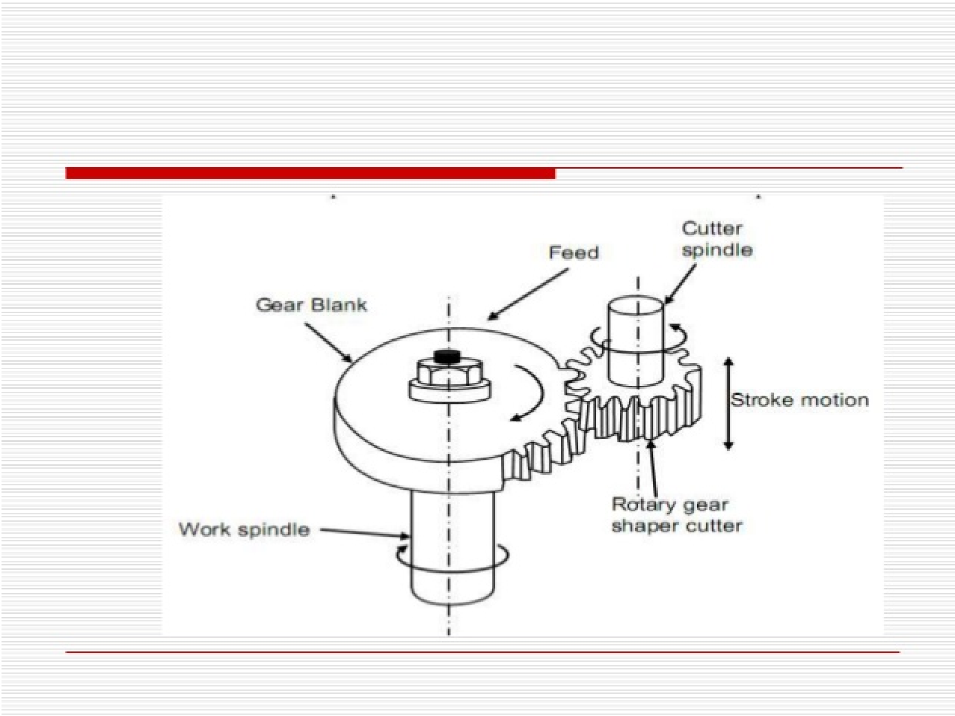
Hobbing machines, also known as hobbers, are fully automated machines that come in many sizes, because they need to be able to produce anything from tiny instrument gears up to 10 ft (3.0 m) diameter marine gears. Each gear hobbing machine typically consists of a chuck and tailstock, to hold the workpiece or a spindle, a spindle on which the hob is mounted, and a drive motor.

For a tooth profile which is a theoretical involute, the fundamental rack is straight-sided, with sides inclined at the pressure angle of the tooth form, with flat top and bottom. The necessary addendum correction to allow the use of small-numbered pinions can either be obtained by suitable modification of this rack to a cycloidal form at the tips, or by hobbing at other than the theoretical pitch circle diameter. Since the gear ratio between hob and blank is fixed, the resulting gear will have the correct pitch on the pitch circle, but the tooth thickness will not be equal to the space width.Hobbing machines are characterised by the largest module or pitch diameter it can generate. For example, a 10 in (250 mm) capacity machine can generate gears with a 10 in pitch diameter and usually a maximum of a 10 in face width. Most hobbing machines are vertical hobbers, which means the blank is mounted vertically. Horizontal hobbing machines are usually used for cutting longer workpieces; i.e. cutting splines on the end of a shaft.



<u>Gear Shaping:</u>

Gear shaping is a machining process for creating teeth on a <u>gear</u> using a cutter. Gear shaping is a convenient and versatile method of gear cutting. It involves continuous, same-plane rotational cutting of gear.



The types of cutters used for gear shaping can be grouped into four categories: disk, hub, shank, and helical cutters. The cutters are essentially gears that are used to form the teeth. This method of gear cutting is based on the principle that any two gears will mesh if they are of the same pitch, proper helix angle, and proper tooth depth and thickness.

Gear Finishing Processes

The tooth profile of the gear must be accurate and smooth for the efficiently working of the gears. The various finishing operations for gears are explained below:

1. Lapping: The term "lapping" is used to describe a number of various surface finishing operations where loose abrasive powders are used as the grinding agent at normally low speeds. It is a process reserved for products that demand very tight tolerances of flatness, parallelism, thickness or finish.

2. Honning: Honing is an abrasive machining process that produces a precision surface on a metal workpiece by scrubbing an abrasive grinding stone or grinding wheel against it along a controlled path. Honing is primarily used to improve the geometric form of a surface, but can also improve the surface finish.

3. Gear shaving: Gear shaving is a free-cutting gear finishing operation which removes small amounts of metal from the working surfaces of the gear teeth. Its purpose is to correct errors in index, helical angle, tooth profile and eccentricity. The process can also improve tooth surface finish and eliminate, by crowned tooth forms, the danger of tooth end load concentrations in service. Shaving provides for form modifications that reduce gear noise. These modifications can also increase the gear's load carrying capacity, its factor of safety and its service life.

4. Gear Burnishing: Burnishing can be defined as a process in which a smooth but hard tool using sufficient pressure burnishing is rubbed on the surface of the metal. This helps to flatten the high spots by allowing plastic flow of the metal.The edges of the metal can be smoothened by pushing it through a die that will smooth out the burrs and the blanked edge caused by the die break.

5. Super Finishing Process: Superfinishing, also known as micromachining, microfinishing, and short-stroke honing, is a metalworking process that improves surface finish and workpiece geometry. This is achieved by removing just the thin amorphous surface layer left by the last process with an abrasive stone or tape; this layer is usually about 1 μm in magnitude. Superfinishing, unlike polishing which produces a mirror finish, creates a cross-hatch pattern on the workpiece

Chapter 3

GRINDING

INTRODUCTION:

Grinding is a subset of cutting, as grinding is a true metal-cutting process. Each grain of abrasive functions as a microscopic single-point cutting edge. Grinding is a process of removing material in the form of small chips by means of rotating abrasive particles bonded together in a grinding wheel to produce flat, cylindrical or other surfaces. A wheel used for grinding various types of surfaces is known as grinding wheel. Example of work is: Sharpening of turning tool and milling cutter, debarring of a lever.

PURPOSES OF GRINDING

1. It is used for sharpening the cutting tools.
2. Cylindrical grinding process is used for grinding the outer surface of cylindrical object
3. Centerless grinding process is used for preparing the transmission bushing, shouldered pins and ceramic shafts for circulator pumps.
4. Internal grinding process is used for finishing the tapered, straight and formed holes precisely.
5. There are few special grinders used for sharpen the milling cutters, taps, other various machine cutting tool cutter and reamers.
6. It is used for grinding thread in order to have close tolerances and better finish.

7. It is used to produce surfaces with a higher degree of smoothness.
8. It is also used for higher metal removal rate.

GRINDING ACTION

Grinding is the most common form of abrasive machining. It is a material cutting process which engages an abrasive tool whose cutting elements are grains of abrasive material known as grit.

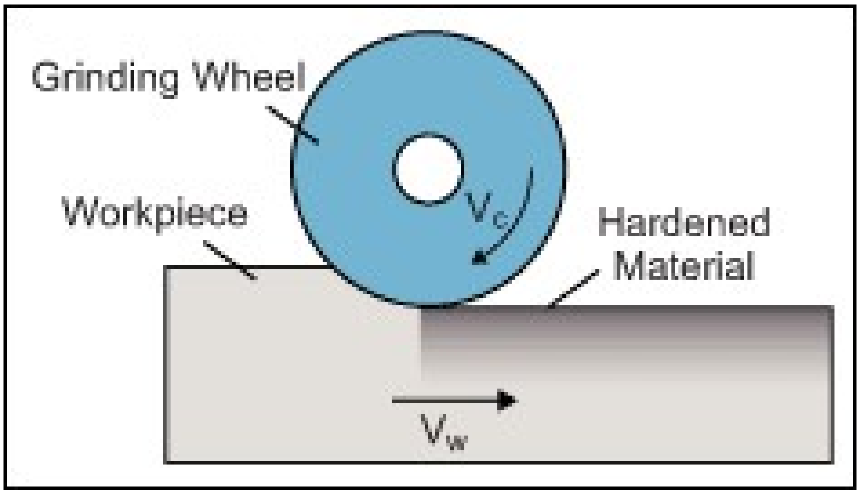


Fig. 3.1 Grinding action

When a moving abrasive surface contacts a workpiece, if the force is high enough, material will be removed from the part and the abrasive surface will wear. Those two things will always occur; however, the force level determines how fast the mutual removal rates will be, how rough the remaining surface will be, and whether the workpiece will be metallurgical damaged or not. The purpose of this section is to provide relationships between variables and to illustrate how changes to a system affect its performance.

Elements of Grinding Wheel:

Abrasive grain

The abrasive aggregate is selected according to the hardness of the material being cut.

- Aluminum oxide (A)
- Silicon carbide (S)
- Ceramic (C)
- Diamond (D, MD, SD)
- Cubic boron nitride (CBN)

Grinding wheels with diamond or CBN grains are called super abrasives. Grinding wheels with aluminum oxide (corundum), silicon carbide, or ceramic grains are called conventional abrasives.

Grain size

From 10 (coarsest) to 600 (finest), determines the average physical size of the abrasive grains in the wheel. A larger grain will cut freely, allowing fast cutting but poor surface finish. Ultra-fine grain sizes are for precision finish work. Generally grain size of grinding wheel in alphabetical A-E = SOFT, F-V = MEDIUM SIZE, W-Z= HARD

Wheel grade

From A (soft) to Z (hard), determines how tightly the bond holds the abrasive. A to H for softer structure, I to P for moderately hard structure and Q to Z for hard structure. Grade affects almost all considerations of grinding, such as wheel speed, coolant flow, maximum and minimum feed rates, and grinding depth.

Structure

Spacing or structure, from 1 (densest) to 17 (least dense). Density is the ratio of bond and abrasive to air space. A less-dense wheel will cut freely, and has a large effect on surface finish. It is also able to take a deeper or wider cut with less coolant, as the chip clearance on the wheel is greater.

Wheel bond

How the wheel holds the abrasives; affects finish, coolant, and minimum/maximum wheel speed.

Bond name	**Symbol**	**Bond description**
Vitrified	V	Glass-based; made via vitrification of clays and feldspars
Resinoid	B	Resin-based; made from plants or petroleum distillates
Silicate	S	Silicate-based
Shellac	E	Shellac-based
Rubber	R	Made from natural rubber or synthetic rubber
Metal	M	Made from various alloys
Oxychloride	O	Made from an oxohalide

COMMON WHEEL SHAPE

The shape and size of grinding wheels depends upon the design of the machine, the power of the machine, the operation to be performed, the shape and size of the workpiece and the grinding conditions.

According to shape, the various grinding wheels are shown in the figure

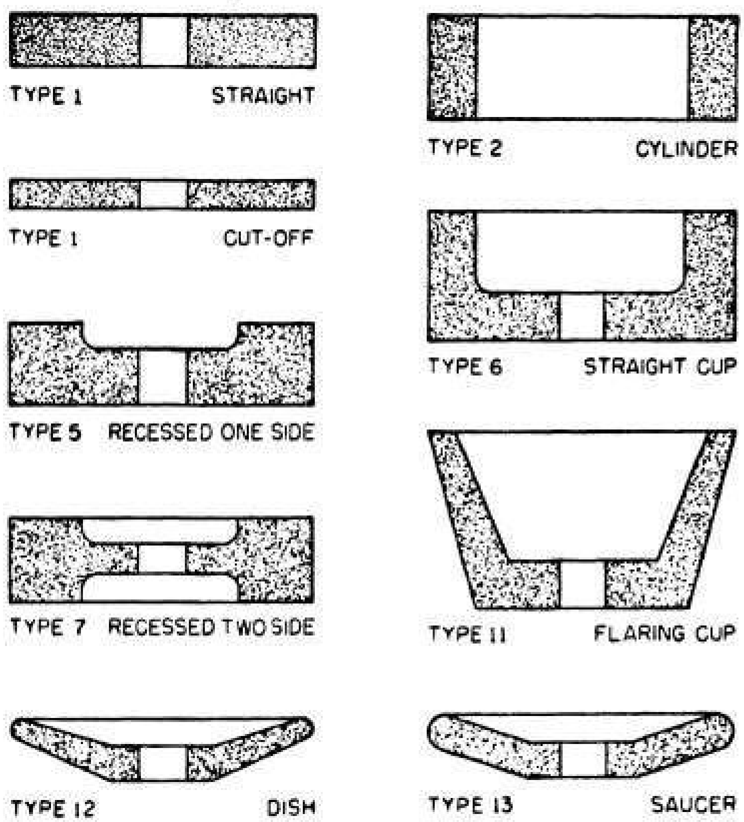
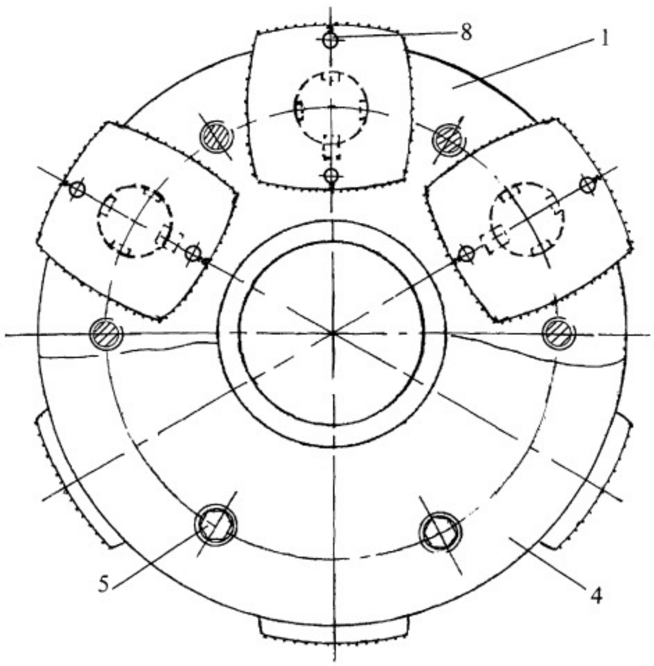


Fig. 3.2 Standard grinding wheel shapes

TYPES OF GRINDING WHEELS

1. Built up Wheels

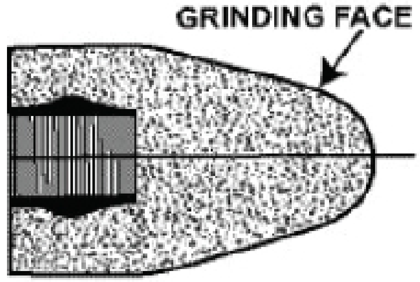
Grinding wheel includes metallic body supporting segments in the form of tetrahedral inserts. Faces of said inserts are coated with rubber for increasing contact zone with blank, they are stretched with grinding belt and have radius equal to radius of wheel working surface.



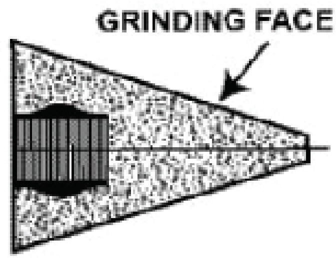
Фиг. 1

2. Cone and Plug Shape Wheels

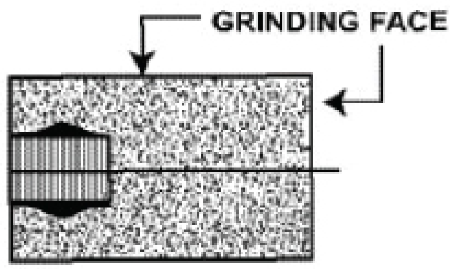
Cones and plugs are designed for removing burrs and flash and finishing any type of metal surface in a confined area. Cone and plug shaped grinding wheels are typically used for heavy metal removal in various casting industries.



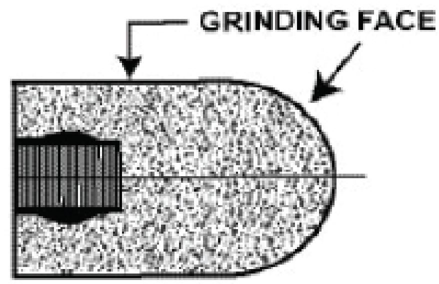
Type 16



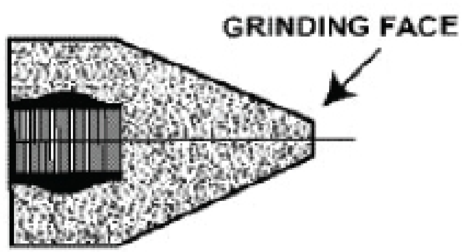
Type 17



Type 18



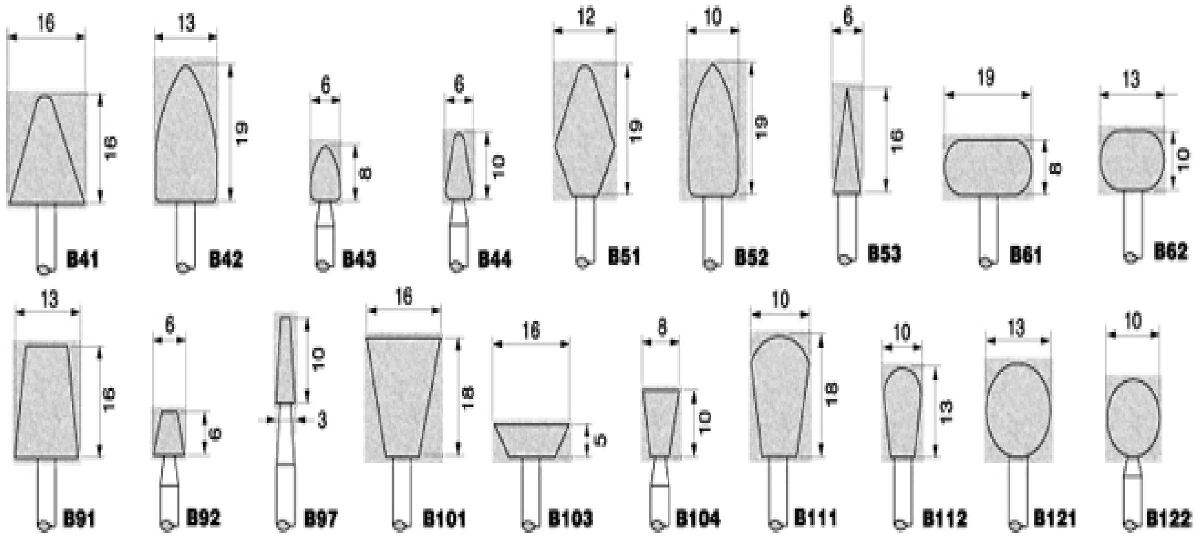
Type 18R



Type 19

3. Mounted Wheels

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



4. Diamond Wheels

A diamond grinding cup wheel is a metal-bonded diamond tool with diamond segments welded or cold-pressed on a steel (or other metal, such as aluminum) wheel body, which usually looks like a cup.

SPECIFICATION OF GRINDING WHEEL AS PER B.I.S.

IS: 551-1996 lays down the rules for the making system of grinding wheels. The marking system comprises of following symbols. These are:

1. Type of Abrasives

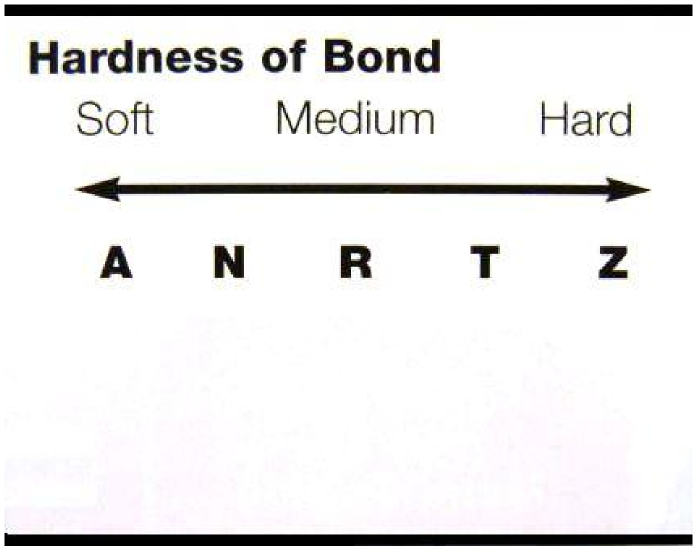
Abrasive	**Symbol**
Aluminium oxide	A
Silicon Carbide	C
White Aluminium Oxide	WA
Green Grit	GC

2. Grain Size

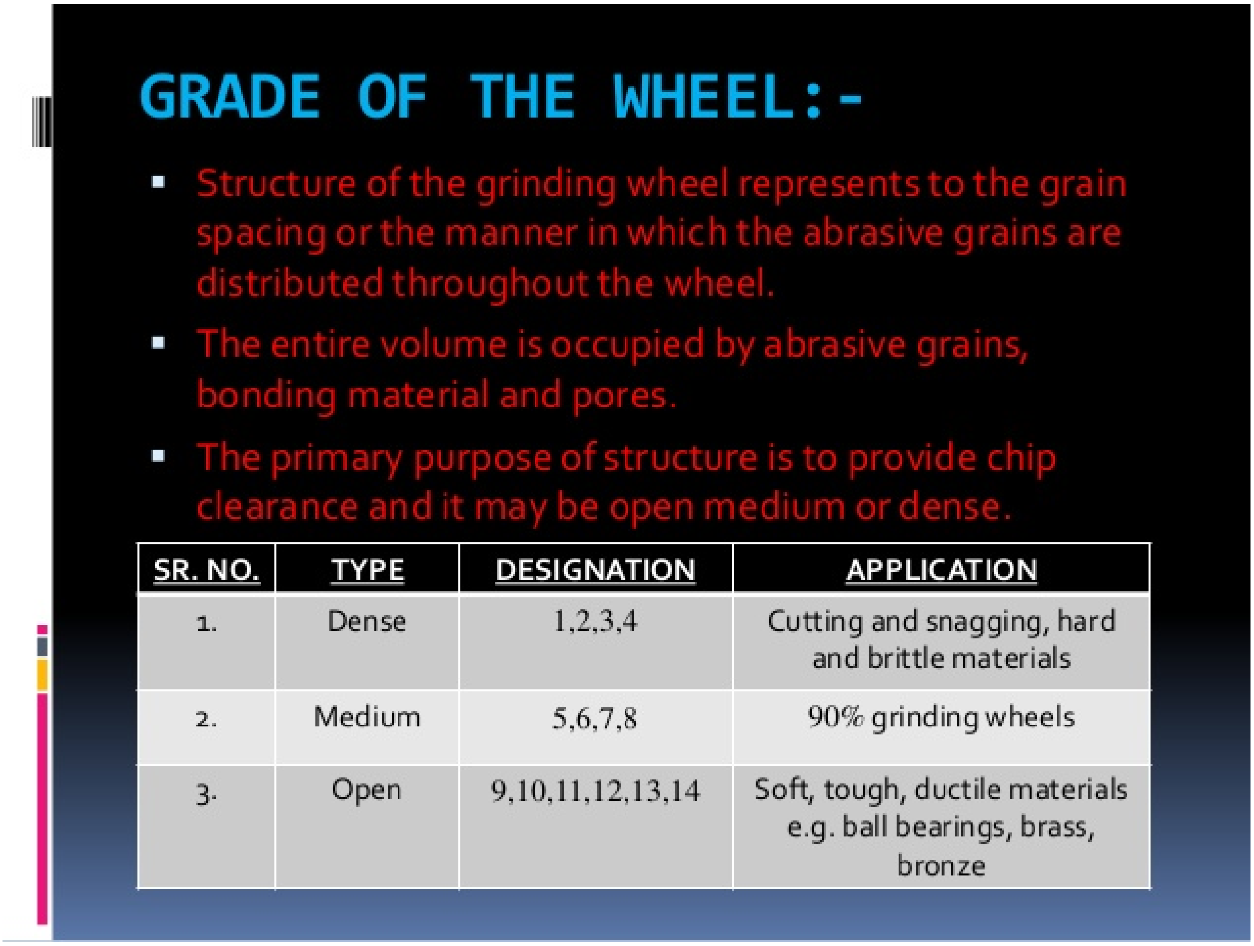
Size of the Abrasive Grain

Coarse	Medium	Fine	Very Fine
8	30	70	220
10	36	80	240
12	46	90	280
14	54	100	320
16	60	120	400
20	-	150	500
24	-	180	600

3. Grade



4. Structure

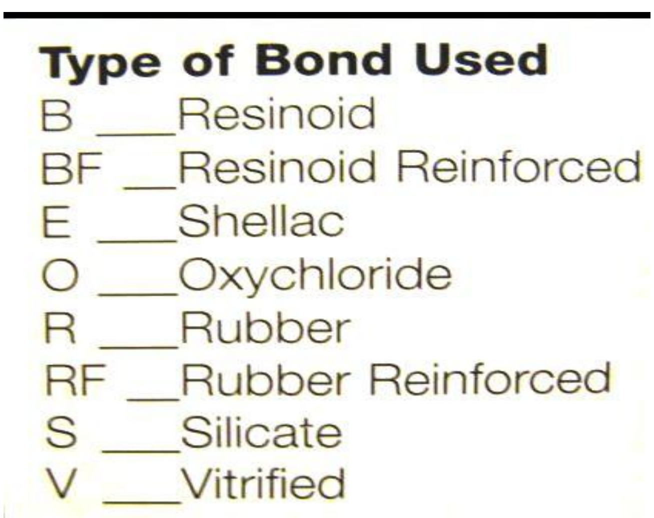


GRADE OF THE WHEEL:-

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

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

5. Types of Bond

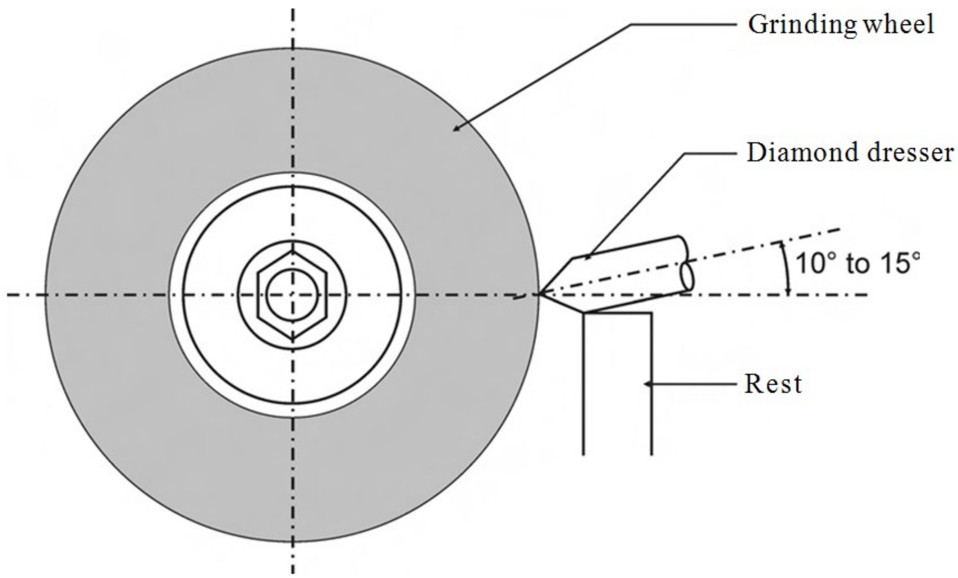


Type of Bond Used

B ___Resinoid
BF __Resinoid Reinforced
E ___Shellac
O ___Oxychloride
R ___Rubber
RF __Rubber Reinforced
S ___Silicate
V ___Vitrified

DRESSING OF A GRINDING WHEEL

When the sharpness of grinding wheel becomes dull because of glazing and loading, dulled grains and chips are removed (crushed or fallen) with a proper dressing tool to make sharp cutting edges and simultaneously, make recesses for chips by properly extruding to grain cutting edge.



Dressing of a Grinding Wheel (Diamond Dresser Method)

Types of Dressing Tools

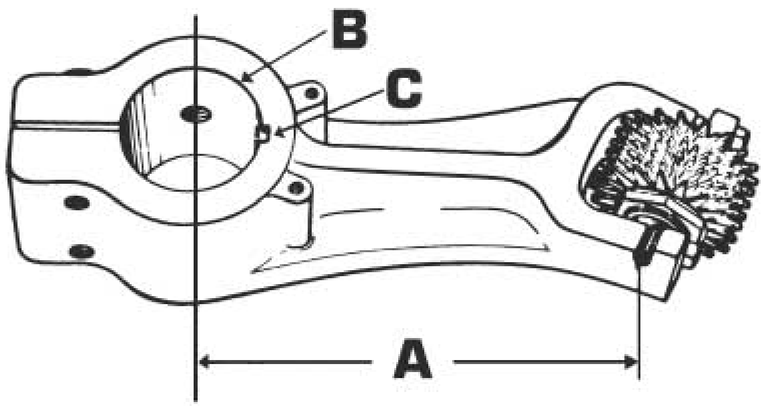
1 Wheel Dresser

2 Abrasive Stick Dresser

3 Abrasive Wheel Dresser

Wheel Dresser

A long handled tool with a row of free running, hardened and serrated, wavy discs or star-shaped cutters running at right angles to the handle. These are presented to the grinding wheel as it is turned off and slows down. Force is applied to the face of the slowing wheel with the result that the hardened discs match speed with the face of the wheel allowing the fingers or undulating surface of the dresser, to knock the abrasive grains out.



Abrasive Stick Dresser

CRATEX rubber-bonded silicon carbide dressing stick for grinding wheels is ideal tool for truing, dressing and shaping different types of grinding wheels including CRATEX rubberized abrasive wheels. It is a perfect solution to keep your grinding wheel flat, sharp, clean and running smoothly!

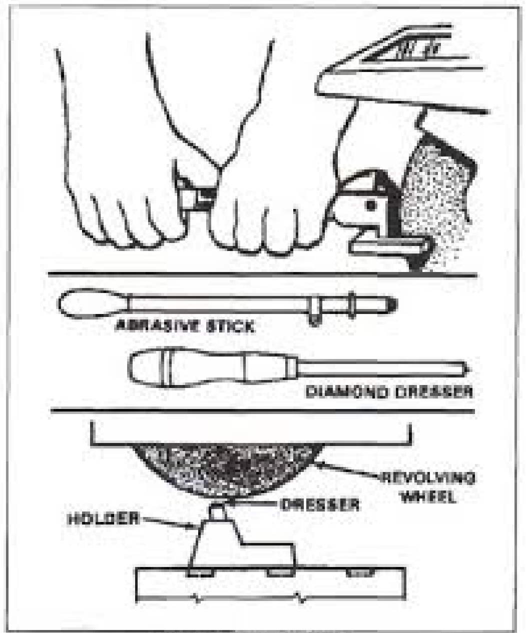
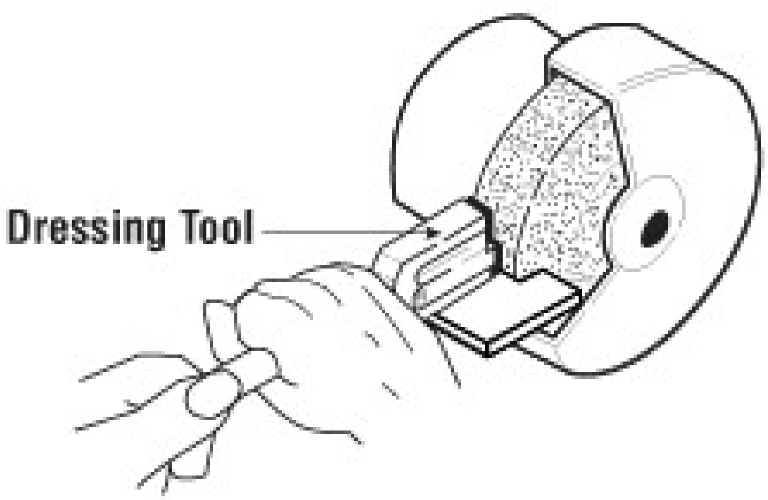


Figure 5-13. Dressing tools.

Abrasive Wheel Dresser

A grinding wheel is a wheel composed of an abrasive compound and used for various grinding (abrasive cutting) and abrasive machining operations.



DRESSING

If the grinding wheels are loaded or gone out of shape, they can be corrected by dressing or truing of the wheels. Dressing is the process of breaking away the glazed surface so that sharp particles are again presented to the work. The common types of wheel dressers known as "Star" -dressers or diamond tool dressers are used for this purpose.

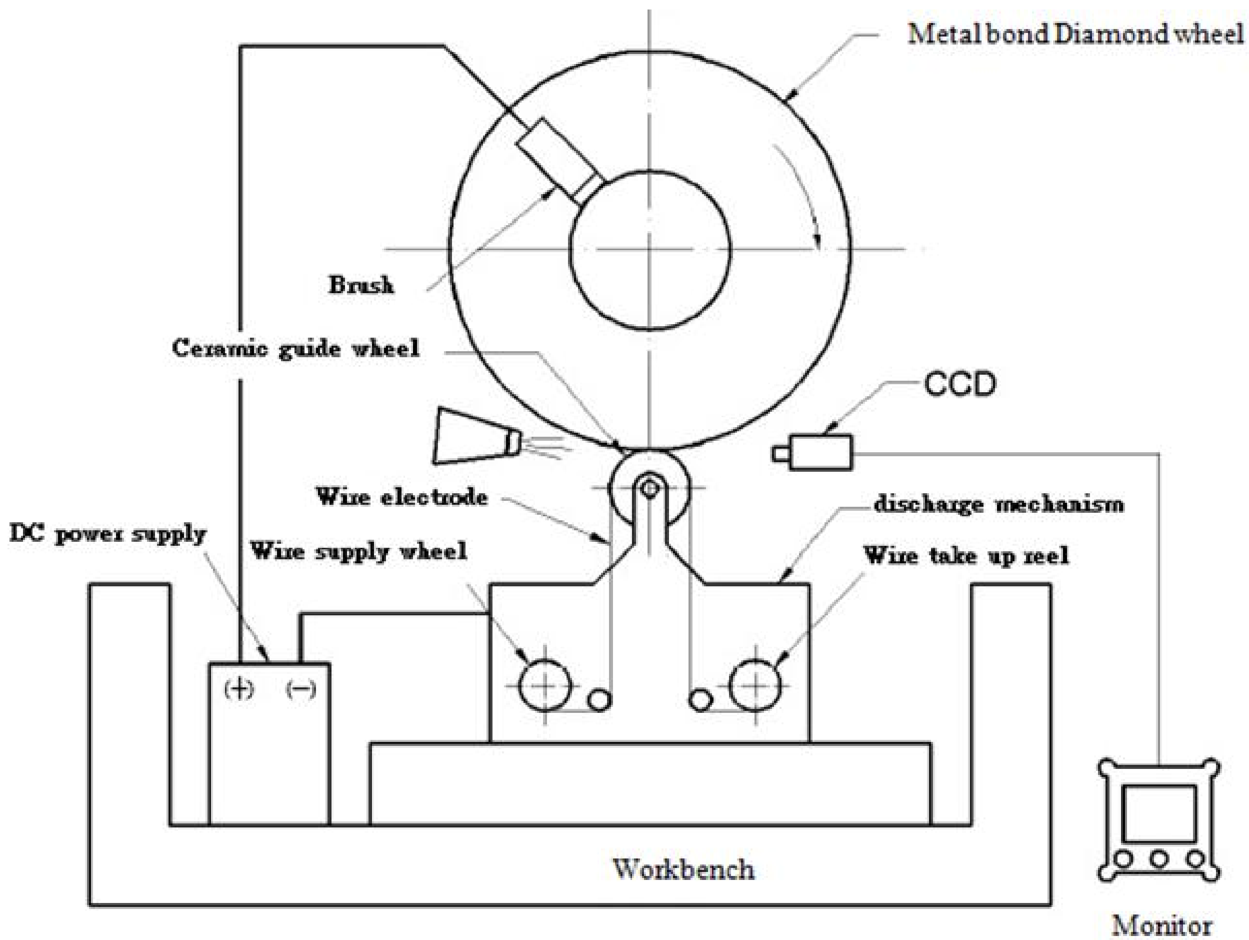
A star dresser consists of a number of hardened steel wheels on its periphery. The dresser is held against the face of the revolving wheel and moved across the face to dress the wheel surface. This type of dresser is used particularly for coarse and rough grinding wheels.

For precision and high finish grinding, small industrial diamonds known as 'bort' are used. The diamonds are mounted in a holder. The diamond should be kept pointed down at an angle of 15° and a good amount of coolant is applied while dressing. Very light cuts only may be taken with diamond tools.

TRUING

The grinding wheel becomes worn from its original shape because of breaking away of the abrasive and bond. Sometimes the shape of the wheel is required to be changed for form grinding. For these purposes the shape of the wheel is corrected by means of diamond tool dressers. This is done to make the wheel true and concentric with the bore or to change the face contour of the wheel. This is known as truing of grinding wheels.

Diamond tool dressers are set on the wheels at 15° and moved across with a feed rate of less than 0.02mm. A good amount of coolant is applied during truing.

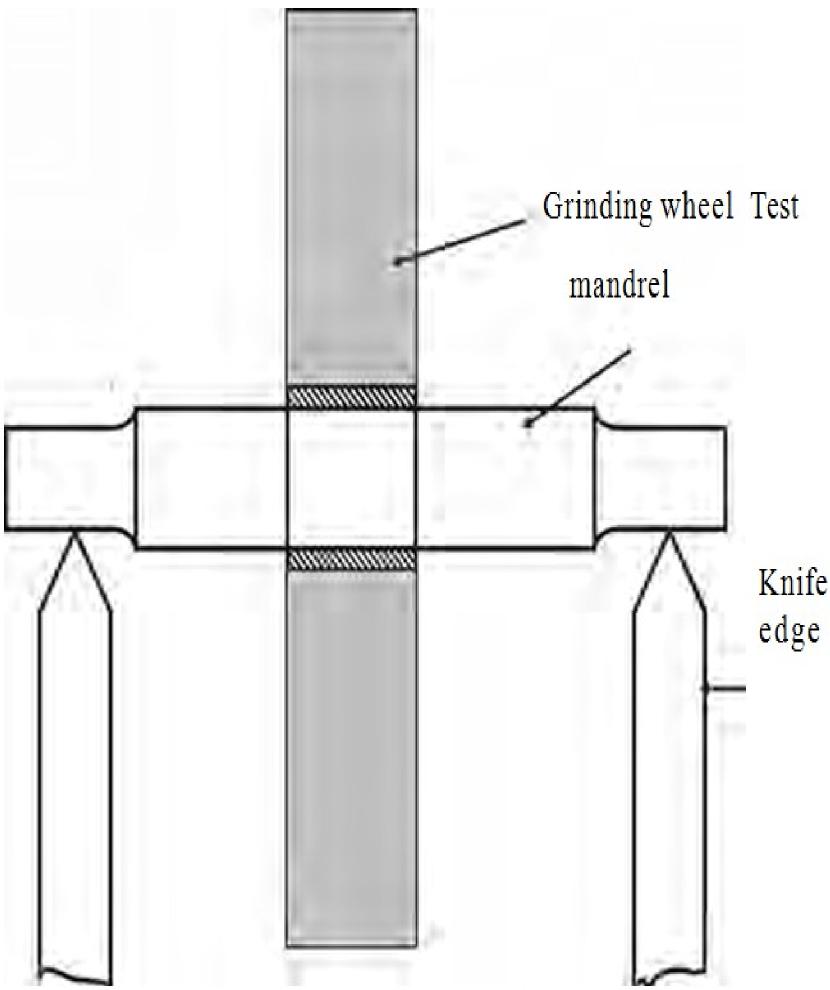


BALANCING OF GRINDING WHEEL

The regular and proper dressing of the grinding wheel is important to both reestablish a precise geometry and to create optimal grinding wheel topography. As the balance state changes constantly due to dressing, wear and profiling, the balancing of grinding wheels is essential in spite of dressing them.

Grinding wheels rotate at high speeds. The density and weight should be evenly distributed throughout the body of the wheel. If it is not so, the wheel will not rotate with correct balance.

The grinding wheels are balanced by mounting them on test mandrels. The wheel along with the mandrel is rolled on knife edges to test the balance and corrected.

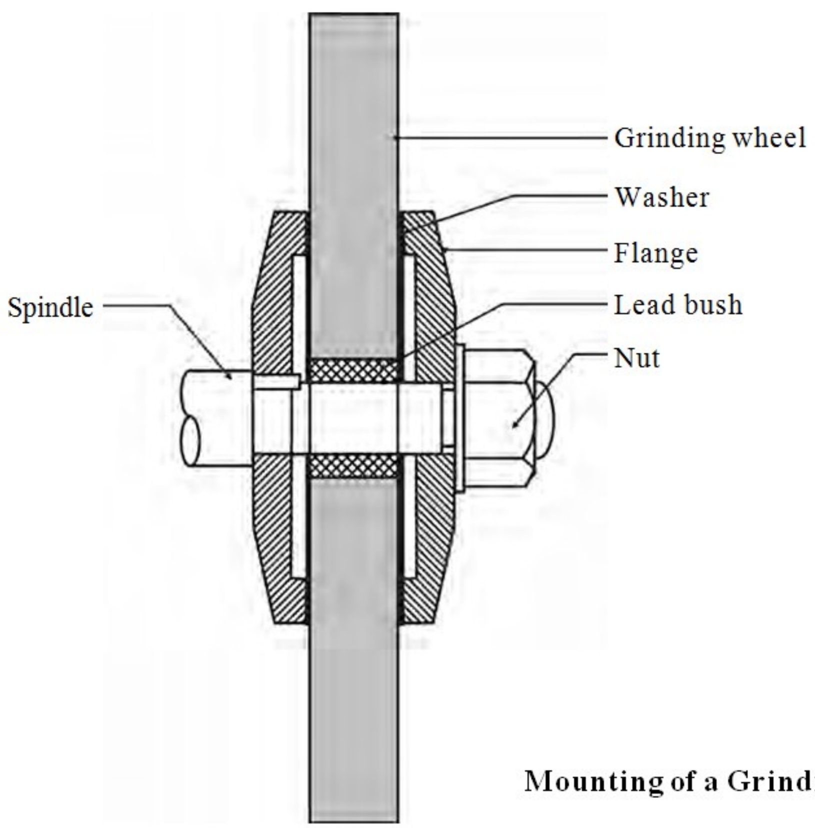


Balancing of Grinding Wheel

MOUNTING OF GRINDING WHEEL

Great care must be taken in mounting the grinding wheels on the spindle because of high cutting speeds. The following points are important in connection with mounting of grinding wheel.

1. All wheels should be inspected before mounting to make sure that they have not been the wheel is put on an arbor and is subjected to slight hammer blows. A clear, ringing, vibrating sound must be heard.
2. The wheel should not be forced on and they should have an easy fit on the spindle.
3. The hole of grinding wheel is mostly lined with the lead liner bushes should not project beyond the side of wheels.



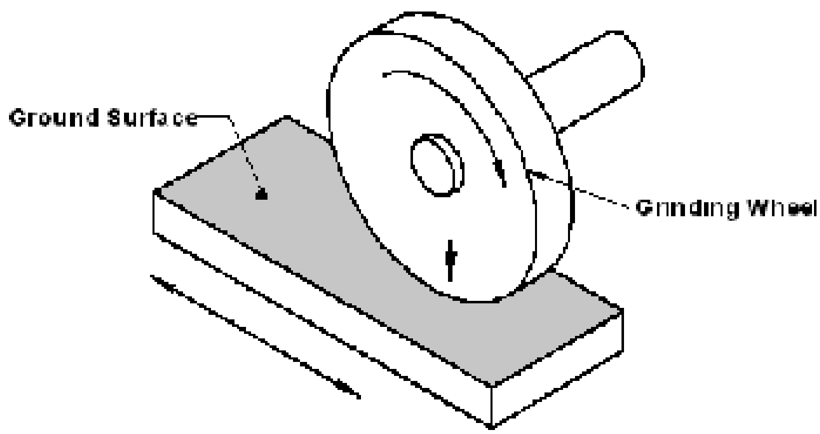
Mounting of a Grinding Wheel

4. There must be a flange on each side of the flange must be large enough to hold the wheel properly, at least the flange diameter must be equal to the half of the grinding wheel diameter. Both the flanges should be of same diameter.
5. The sides of the wheel and the flanges should be Flanges contact the wheel only with the annular clamping area.
6. Washers of compressible materials such as cardboard, leather, rubber, not over 1.5 mm thick should be fitted between the wheel and its flanges. The diameter of washers may be normally equal to the diameter of the flanges.
7. The inner flange should be keyed to the spindle, whereas the outer flange should have an easy sliding fit on the spindle so that it can adjust itself tightly to give a uniform bearing on the wheel and the compressible washers.
8. The nut should be tightened to hold the wheel firmly. Undue tightness is unnecessary and undesirable as excessive clamping strain is liable to damage the wheel.
9. The wheel guard should be placed and tightened before the machine is started.
10. After mounting the wheel, the machine is The grinding wheel should be allowed to idle for a period of about 10 to 15 minutes. Grinding wheels must be dressed and trued before any work can be started.

METHODS OF GRINDING:

Surface Grinding

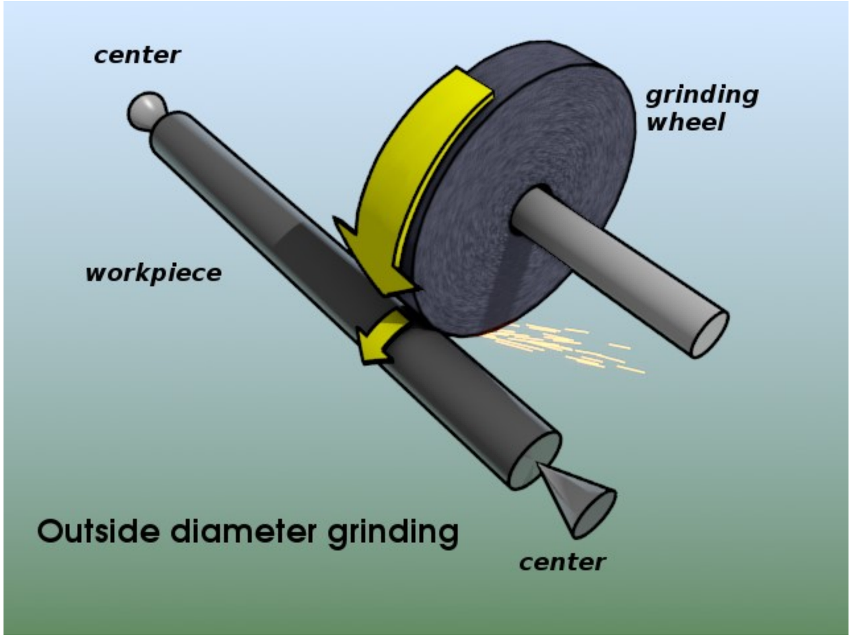
Surface grinding is used to produce a smooth finish on flat surfaces. It is a widely used abrasive machining process in which a spinning wheel covered in rough particles (grinding wheel) cuts chips of metallic or nonmetallic substance from a workpiece, making a face of it flat or smooth.



Cylindrical Grinding

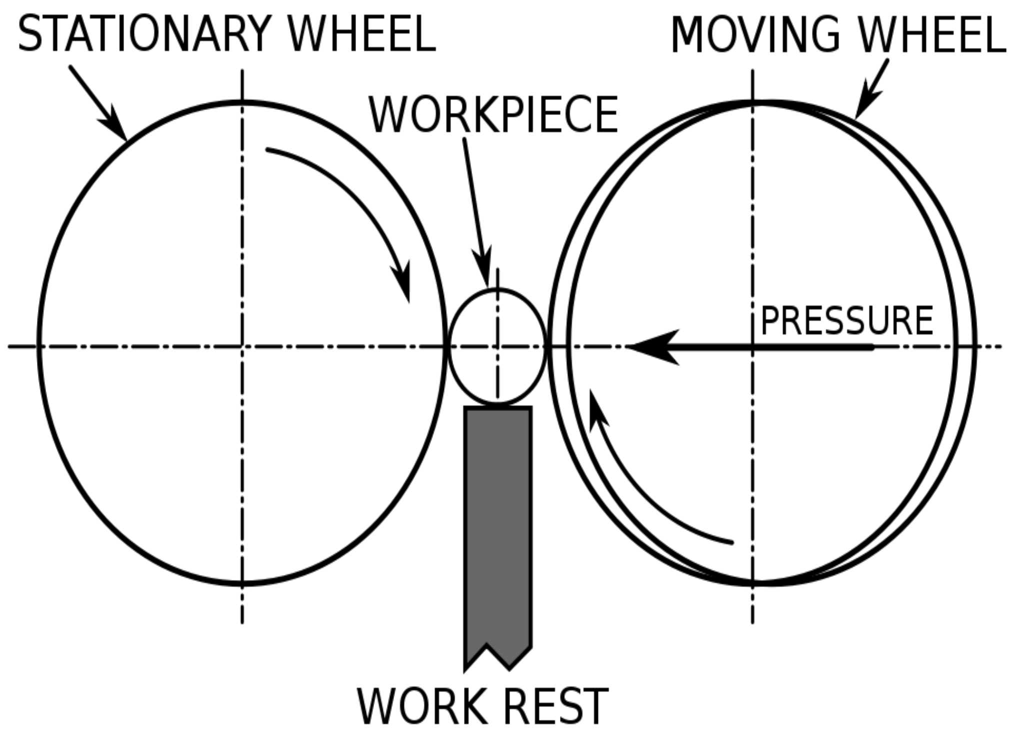
Cylindrical Grinder Operation provides a detailed overview of the steps needed to perform the various types of operations possible on a cylindrical grinder. Operations performed on the cylindrical grinder include plunge, traverse, center-type, chucking-type, ID, profile, and taper grinding. Different steps and considerations must be taken in order to perform each type of operation; including setting the grinding variables and using the appropriate machine components and controls.

In order to perform successful cylindrical grinding operations, operators must have a solid foundational knowledge of proper grinding methods. This class provides the practical steps and considerations for cylindrical grinding various workpieces from start to finish, which gives operators an understanding of grinding before ever turning on the machine.



Centre less Grinding

Centre less Grinding is a form of grinding where there is no collet or pair of centers holding the object in place. Instead, there is a regulating wheel positioned on the opposite side of the object to the grinding wheel.



A work rest keeps the object at the appropriate height but has no bearing on its rotary speed. The work blade is angled slightly towards the regulating wheel, with the workpiece centerline above the centerlines of the regulating and grinding wheel; this means that high spots do not tend to generate corresponding opposite low spots, and hence the roundness of parts can be improved. Centerless grinding is much easier to combine with automatic loading procedures than centered grinding; through feed grinding, where the regulating wheel is held at a slight angle to the part so that there is a force feeding the part through the grinder, is particularly efficient.

GRINDING MACHINE:

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

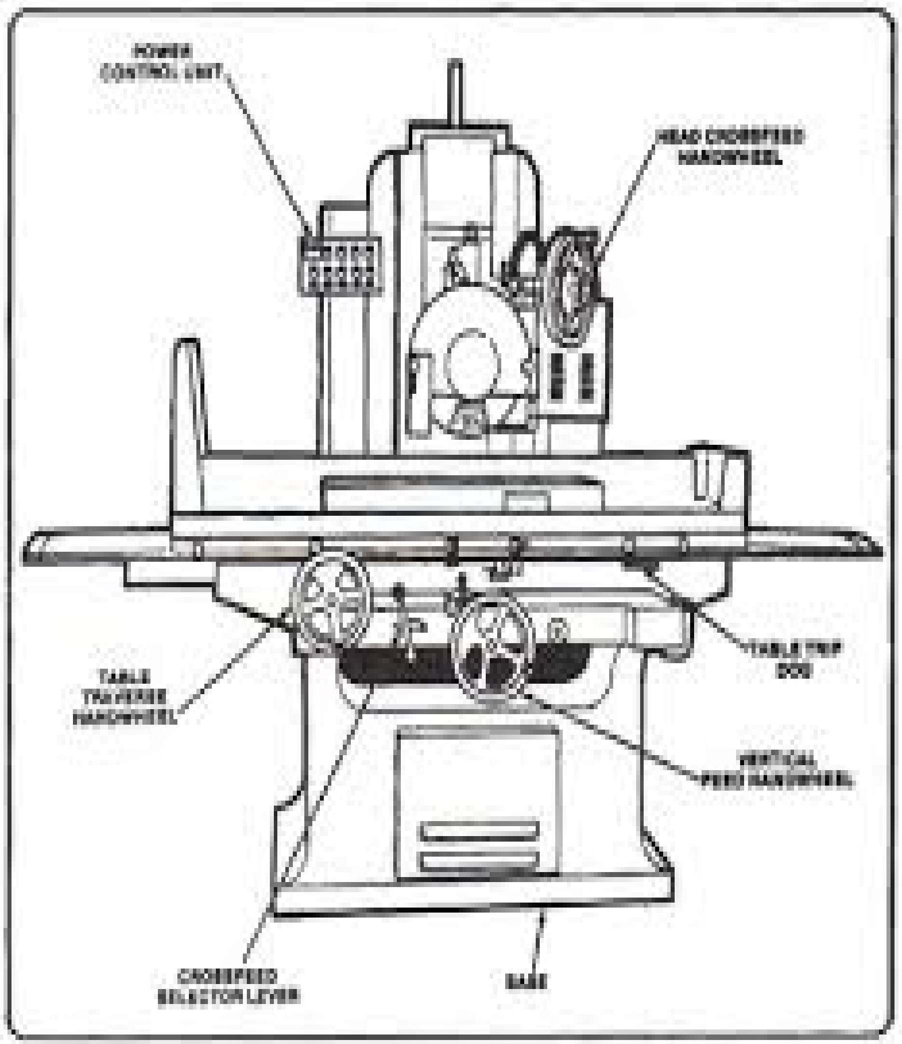
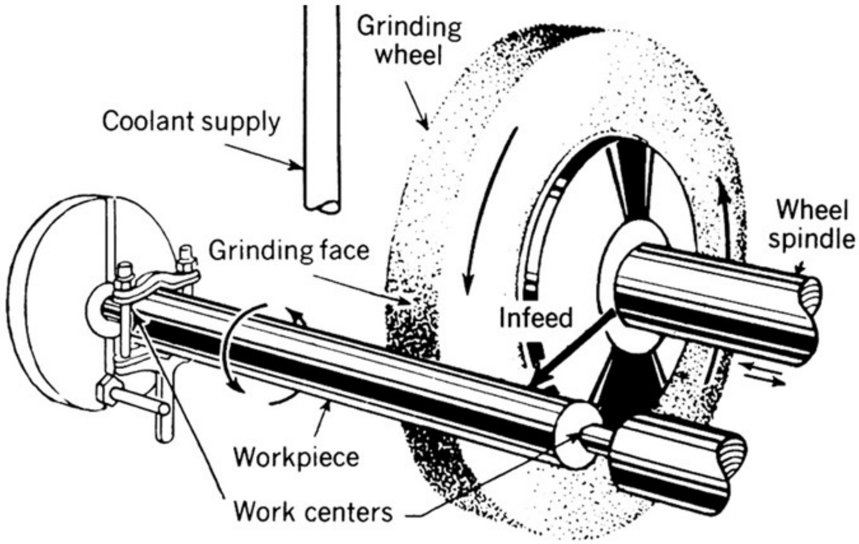


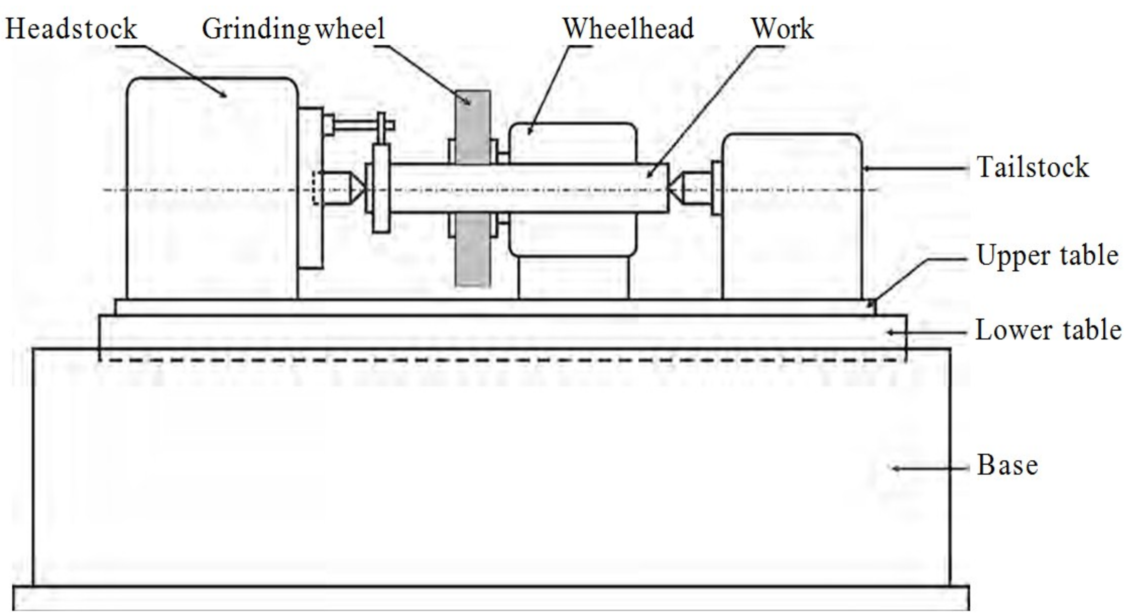
Figure 1-4. Reciprocating surface grinding machine.

Cylindrical Grinding Machine

The cylindrical grinder is a type of grinding machine used to shape the outside of an object. The cylindrical grinder can work on a variety of shapes; however the object must have a central axis of rotation. This includes but is not limited to such shapes as a cylinder, an ellipse, a cam, or a crankshaft.



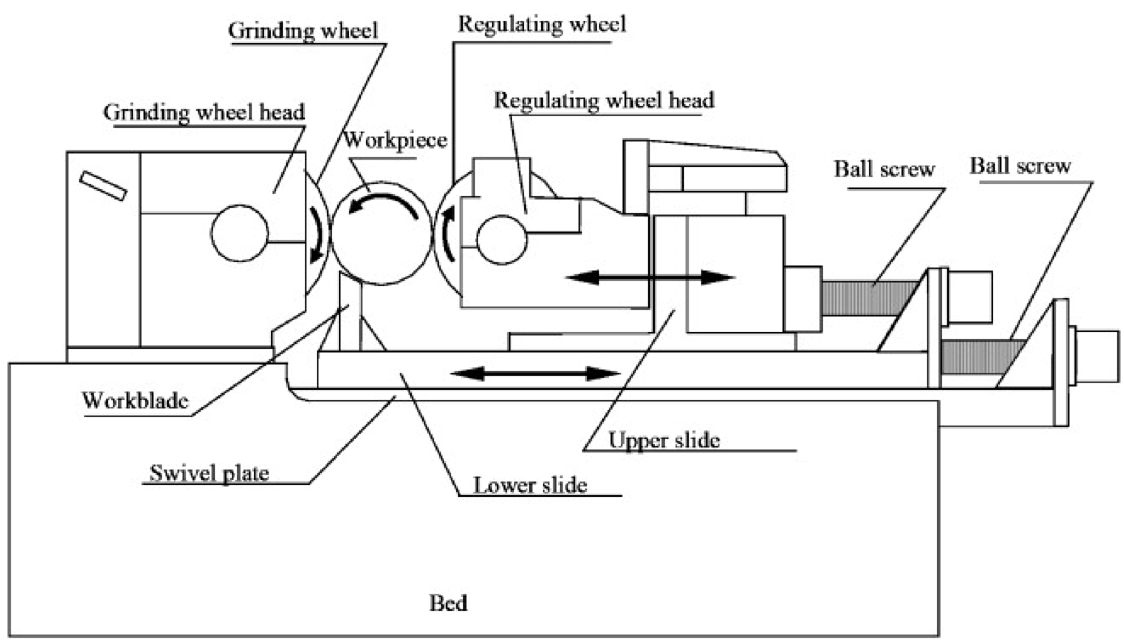
Plain Cylindrical Grinding Machine



Cylindrical Grinding Machine

CentrelessGrinding Machine

Centerless grinding is a machining process that uses abrasive cutting to remove material from a workpiece.centreless (centerless) grinding is an OD (outer diameter) grinding process. In difference from other cylindrical processes, where the work piece is held in the grinding machine, while grinding between centers, the workpiece is not mechanically constrained during centreless (centerless) grinding. Therefore the parts to be ground on a centreless (centerless) grinder do not need center holes, drivers or workhead fixtures at the ends. Instead, the workpiece is supported in the grinding machine on its own outer diameter by a workblade and by the regulating wheel. The work piece is rotating between a high speed grinding wheel and a slower speed regulating wheel with a smaller diameter.



The blade of the grinding machine is usually positioned in a way that the center of the work piece is higher than the virtual line between the centers of the regulating wheel and the grinding wheel. Also the blade is designed with an angle in order to ensure that the work piece is fixed between the blade and the regulating wheel. The regulating wheel consists of soft material like rubber and can contain some hard grain material to achieve good traction between work piece and regulating wheel.

Tool and Cutter Grinder

A tool and cutter grinder is used to sharpen millingcutters and tool bits along with a host of other cuttingtools. It is an extremely versatile machine used to perform a variety of grinding operations: surface, cylindrical, or complex shapes.

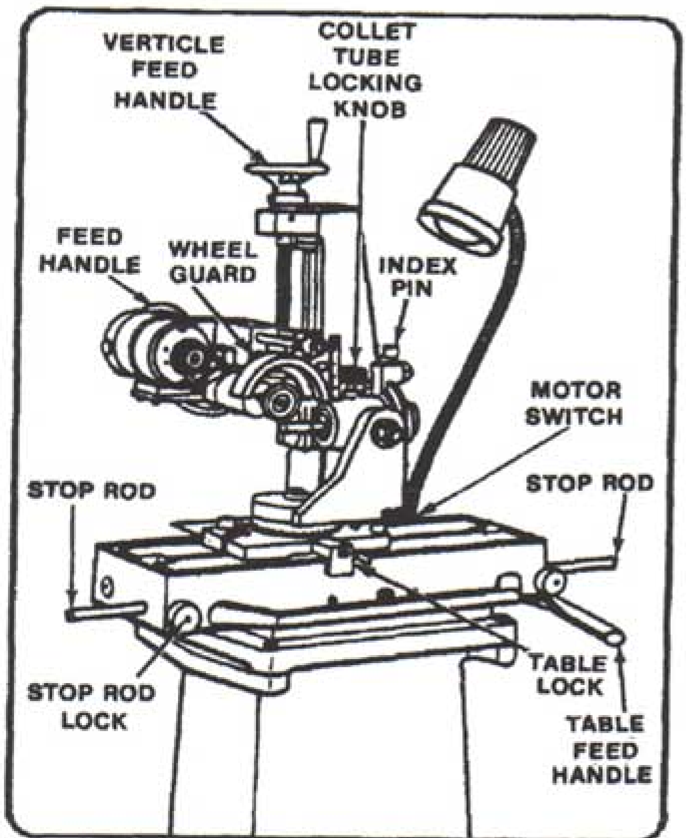


Figure 5-4. Bench-type tool and cutter grinder.

SELECTION OF GRINDING WHEEL:

Size and shape

Nine standard grinding wheel shapes have been established by the Grinding Wheel Manufacturers' Association. These are shown in Fig. 1. The dimensional sizes have also been standardized.

Although these standard shapes represent the group most used in grinding operations, there are many special shapes which are used less frequently or in highly specialized grinding operations.

Abrasive

There are two main types of abrasive.

- Silicon carbide: This is very sharp and extremely hard, but its use as an abrasive is limited to some extent by its brittleness. Silicon carbide should be used in the grinding of low tensile strength materials such as grey cast-iron, chilled iron, bronze, aluminium, copper, brass and non-metallic materials. A special form of silicon carbide, green in colour, is used to grind carbide-tipped tools.
- Aluminium oxide: This is slightly softer than silicon carbide but is much tougher. It should be used in the grinding of high tensile-strength materials such as alloy steel, annealed malleable iron and strong bronzes. There is also another form of aluminium oxide which is white in colour as opposed to the normal brown variety. This white alumina tends to fracture more readily than the regular (brown) aluminium oxide, and more and sharper cutting edges are therefore presented to the work. Grinding wheels of white alumina should be selected when grinding hardened tool steels or for use in general tool room grinding.

Grit size

In general, coarse grit wheels are used for fast removal of material. Fine grit wheels are used where finish is considered important. Coarse wheels may be used for soft materials, but a fine grit should generally be used for hard and brittle materials.

Bond

The bond material holds the abrasive particles in the form of a wheel. When these particles become blunt or break down completely, the bond material releases the blunt grains and thereby exposes new, sharp particles to continue the work. This action occurs because of the increase in grinding pressures resulting from the particles of grit becoming dull. The four principal bond types are vitrified, shellac, resinoid and rubber.

Grade

Grade is a measure of "holding power" for the abrasive grains, which determines the degree of hardness or softness of a grinding wheel. Most manufacturers indicate the grade of wheel by a letter. Although standards vary since grade is not an exact value, the grade letters generally increase in hardness from E to Z. The selection of correct wheel grade for specific grinding applications is discussed later in this article, but hard wheels are usually recommended for soft materials and soft wheels for hard materials.

Structure

This refers to the spacing of the grit or grains and indicates the number of cutting edges per unit area of wheel face.

The structure to use depends mainly on the physical properties of the material to be ground and the type of finish required. Soft, ductile materials require greater chip clearance and, therefore, a wide spacing of the grit. A fine finish requires a wheel with a close spacing of the abrasive particles.

Grinding wheel function

For rapid removal of material where finish is of little importance, such as a fettling operation, a coarse-grained, open structure is desirable. Finish depends largely on the size of grit used in the wheel, but on precision grinders on which proper diamond truing and dressing devices are available, it is possible to obtain a fine finish without sacrificing production, which usually occurs when fine wheels are used.

The greater the area of contact between wheel and work, the softer the wheel for a given job, e.g. surface grinding with the periphery of a wheel, where the area of contact approximates a line, needs a harder and finer wheel than surface grinding with a cup or cylinder, where the area of contact is comparatively large. The more rigid the machine and the better its condition, the softer the wheel for the job.

Wheel speed is another important factor influencing grit and grade selection, as a hard wheel can be made to appear soft by running it very slowly. It is usually best to run a grinding wheel at the manufacturer's recommended speed. Table 1 provides a list of grinding wheel speeds recommended by the Universal Grinding Wheel Company.

CHAPTER 4

MODERN MACHINING PROCESSES

4.1 INTRODUCTION

Ultrasonic Machining is a non-traditional process, in which abrasives contained in a slurry are driven against the work by a tool oscillating at low amplitude (25-100 microns) and high frequency (15-30 kHz).

4.1.1 PRINCIPLE

It is also known as Ultrasonic impact grinding is an operation that involves a vibrating tool fluctuating the ultrasonic frequencies above 18 KHz in order to remove the material from the work piece. The process involves abrasive slurry that runs between the tool and the work piece. Due to this, the tool and the work piece never interact with each other as shown in fig. 4.1

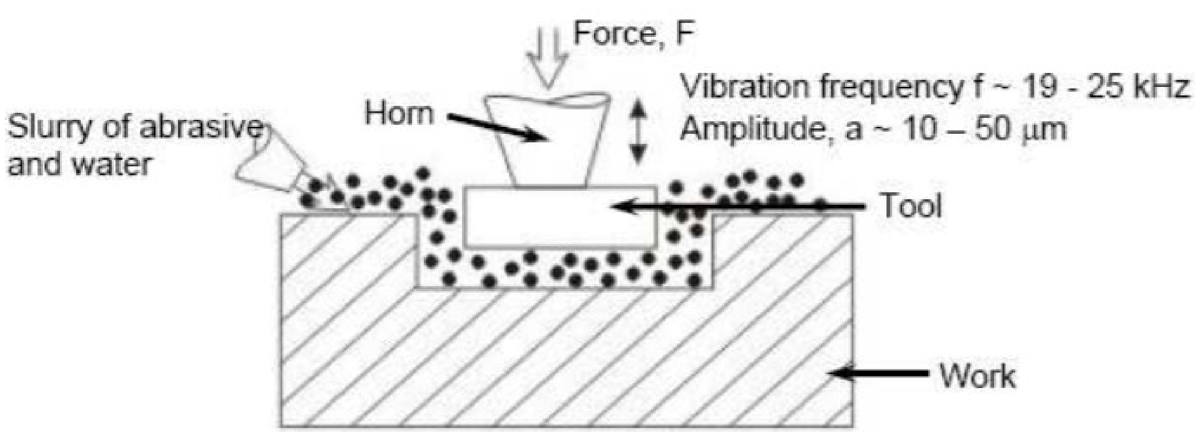


Fig. 4.1 Principle of USM

4.1.2 PROCESS

Ultrasonic machining is a mechanical type non-traditional machining process. It is employed to machine hard and brittle materials (both electrically conductive and non conductive material) having hardness usually greater than 40 HRC. The process was first developed in 1950s and was originally used for finishing EDM surfaces. In ultrasonic machining, tool of desired shape vibrates at ultrasonic frequency (19 to 25 kHz.) with an amplitude of 15-50 Microns over work piece. Generally tool is pressed down with a feed force F. Between the tool and work, machining zone is flooded with hard abrasive particles generally in the form of water based slurry. As the tool vibrates over the work piece, abrasive particles acts as indenter and indent both work and tool material . Abrasive particles , as they indent , the work material would remove the material from both tool and work piece. In Ultrasonic machining material removal is due to crack initiation, propagation and brittle fracture of material. USM is used for machining hard and brittle materials, which are poor conductors of electricity and thus cannot be processed by Electrochemical machining (ECM) or Electro discharge machining (EDM) as shown in fig .4.2.

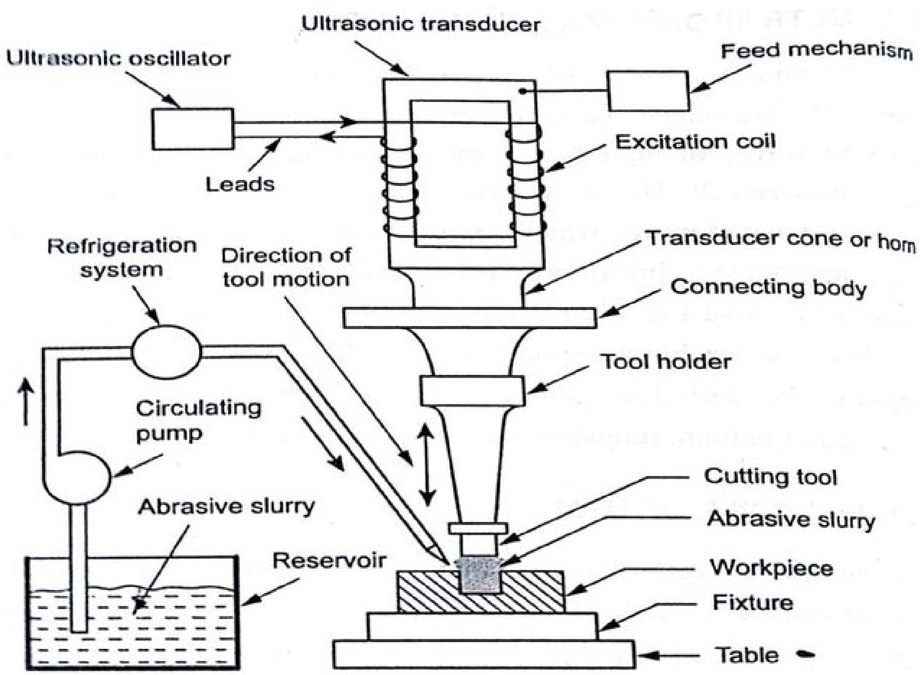


Fig. 4.2 Process of USM

The tool in USM is made to vibrate with high frequency on to the work surface in the midst of the flowing slurry. The main reason for using ultrasonic frequency is to provide better performance. Audible frequencies of required intensities would be heard as extremely loud sound and would cause fatigue and even permanent damage to the auditory apparatus.

4.1.3 ADVANTAGES

1. Machined all sorts of hard materials
2. Produces fine finished and structured results
3. Produces less heat
4. Various hole cut shapes due to vibratory motion of the tool

4.1.4 DISADVANTAGES

1. Requires a higher degree of integrity and skills
2. No certified record of radiography
3. Unnecessary large grain sizes causes defects
4. Additional repairs might be required due to spurious signs and misunderstanding of the process.

4.1.5 APPLICATIONS

1. It is used for cutting operations.
2. It is used for drilling, threading, milling etc.
3. It is used for surface finishing.
4. It is used in forming of plastics.
5. It is used for gernerating round, irregular holes and impressions.