GOVERNMENT POLYTECHNIC, SIRSA

BRANCH: MECHANICAL ENGINEERING

SUBJECT: WORKSHOP TECHNOLOGY - III

SEMESTER: 5th

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CHAPTER 1

MILLING

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.

1.1 WORKING PRINCIPLE AND SPECIFICATION OF MILLING MACHINE

1.1.1 WORKING PRINCIPLE

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

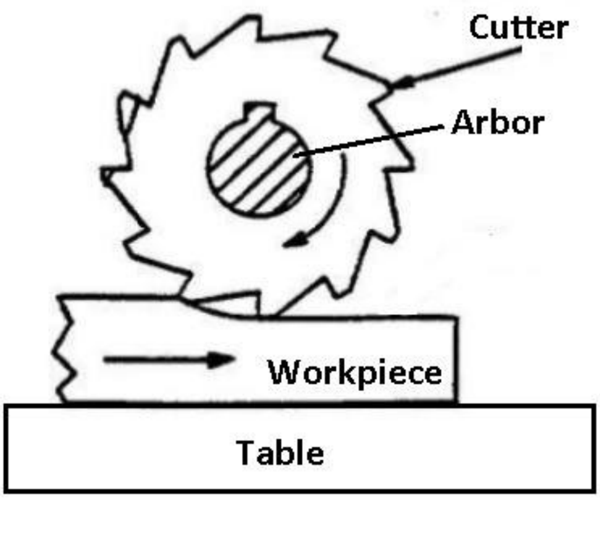

Fig.1.1 Principle of a milling machine

1.1.2 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.

1.2 CLASSIFICATION, BRIEF DESCRIPTION AND APPLICATIONS OF MILLING MACHINES

1.2.1 CLASSIFICATION AND DESCRIPTION

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 work piece to remove material from the work piece as shown in fig.1.2.

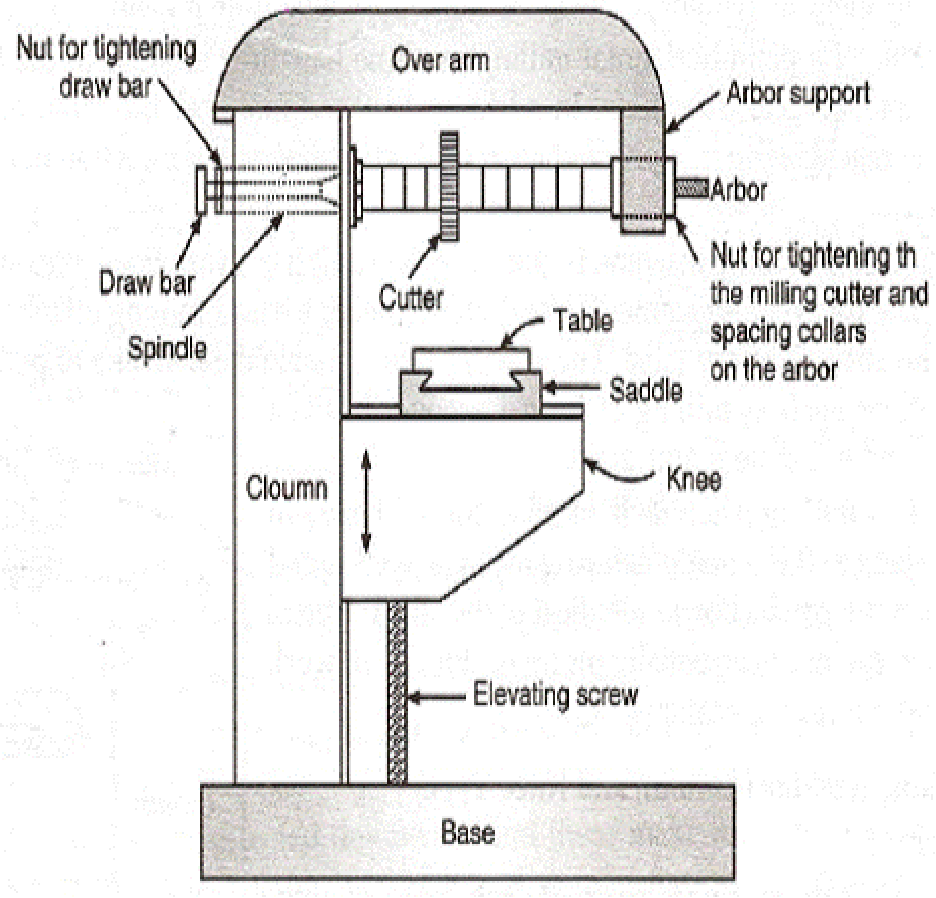

Fig. 1.2 Horizontal Milling Machine

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 general 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 work piece as shown in fig. 1.3.

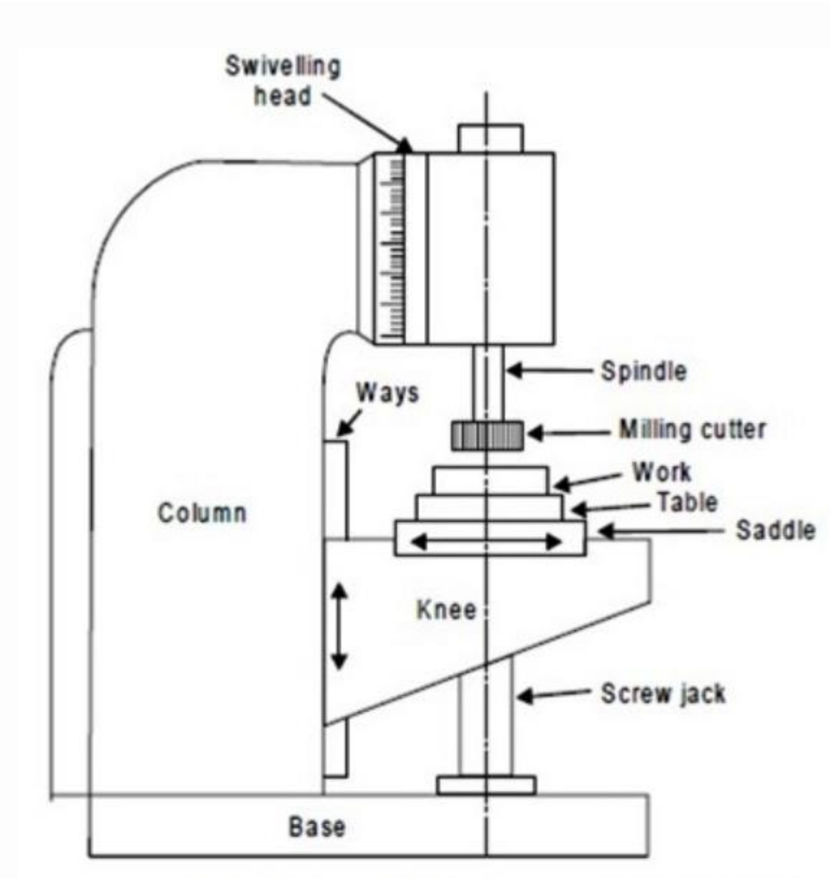

Fig. 1.3 Vertical Milling Machine

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

(c) Universal milling machine: The universal milling machine is similar 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.

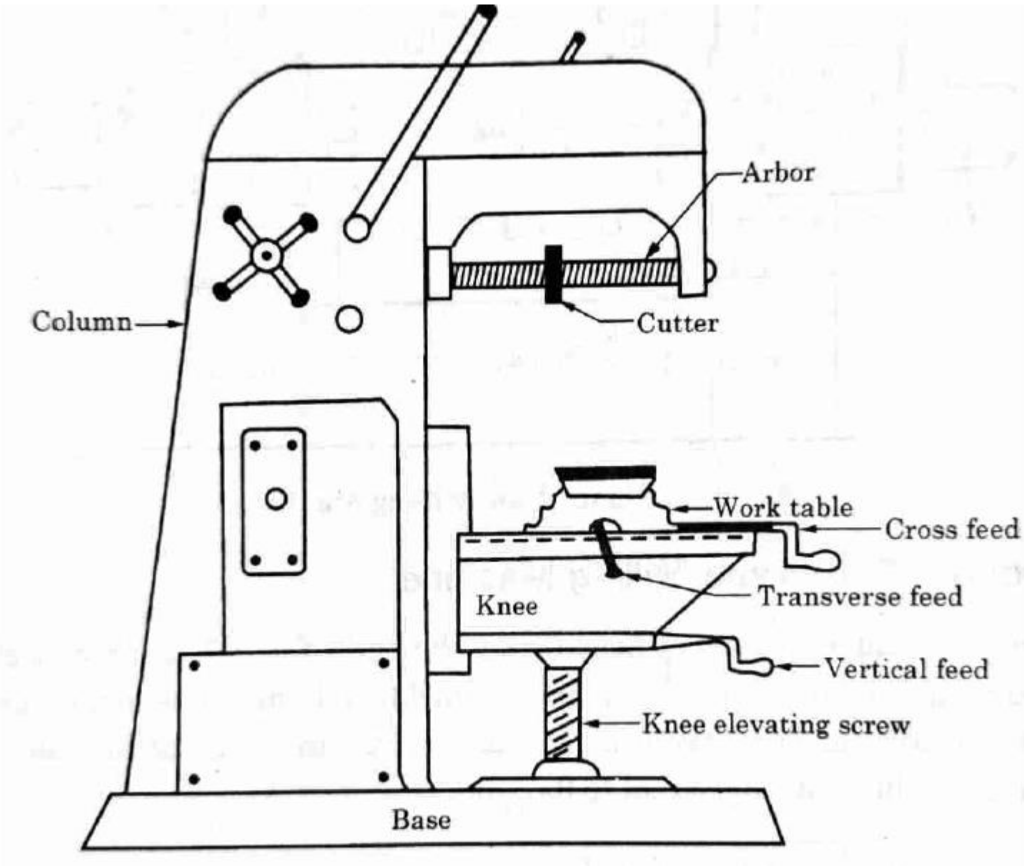

Fig. 1.4 Universal Milling Machine

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 consists of two spindles, 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 swiveled up to 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. These cutters in the machines can perform the facing operations simultaneously which is a great function.

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 move 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.

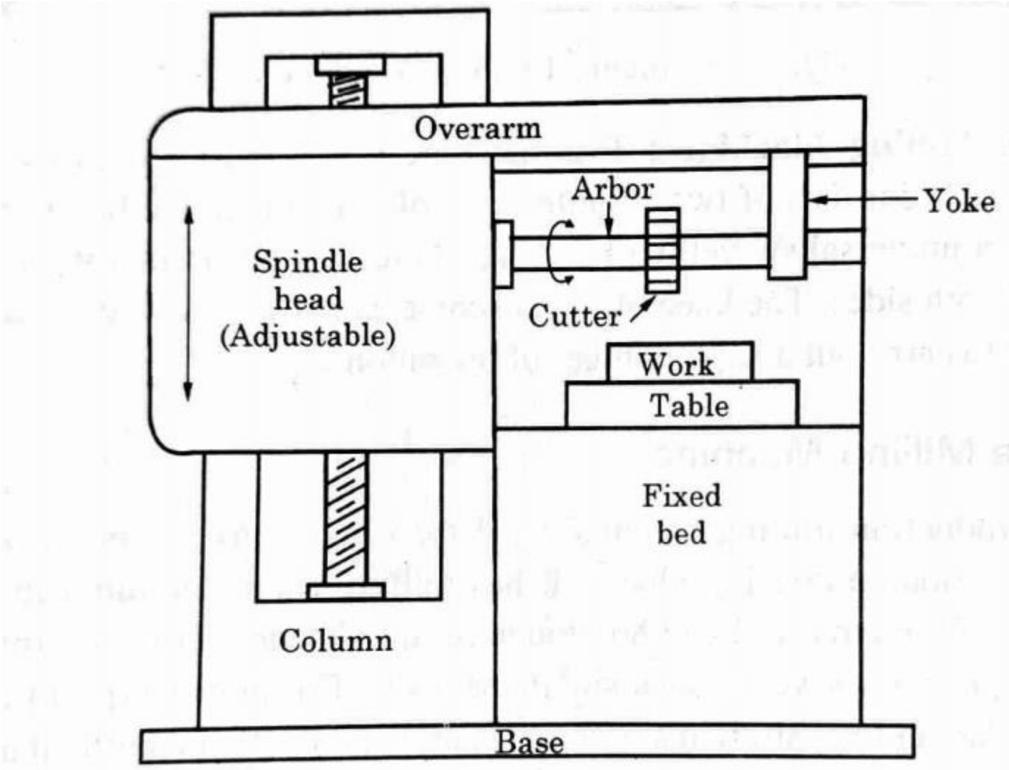

Fig. 1.5 Bed Type Milling Machine

(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.

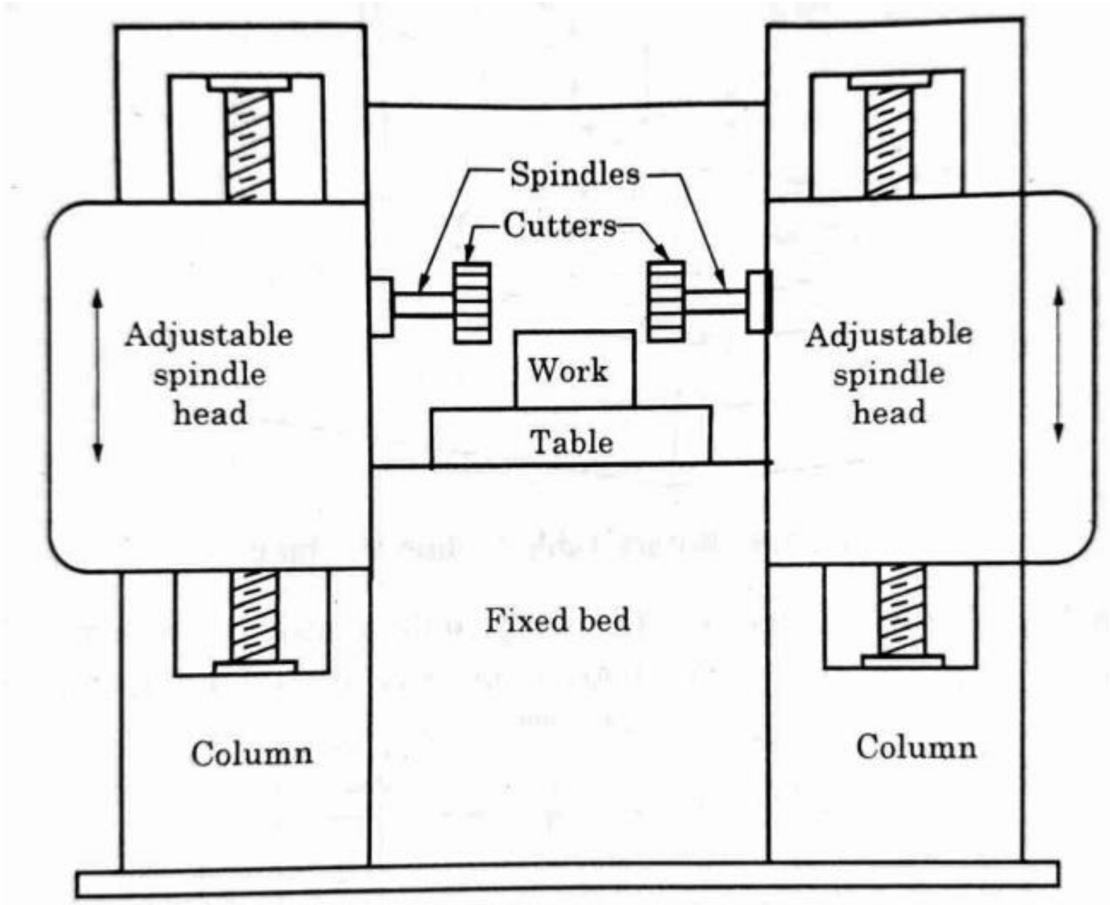

Fig. 1.6 Duplex Milling Machine

(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 work piece, and the rest of the cutters finishing the surface. The operator can load and unload the work pieces continuously while the machine is working, and that is the most significant advantage of the rotary table milling machine.

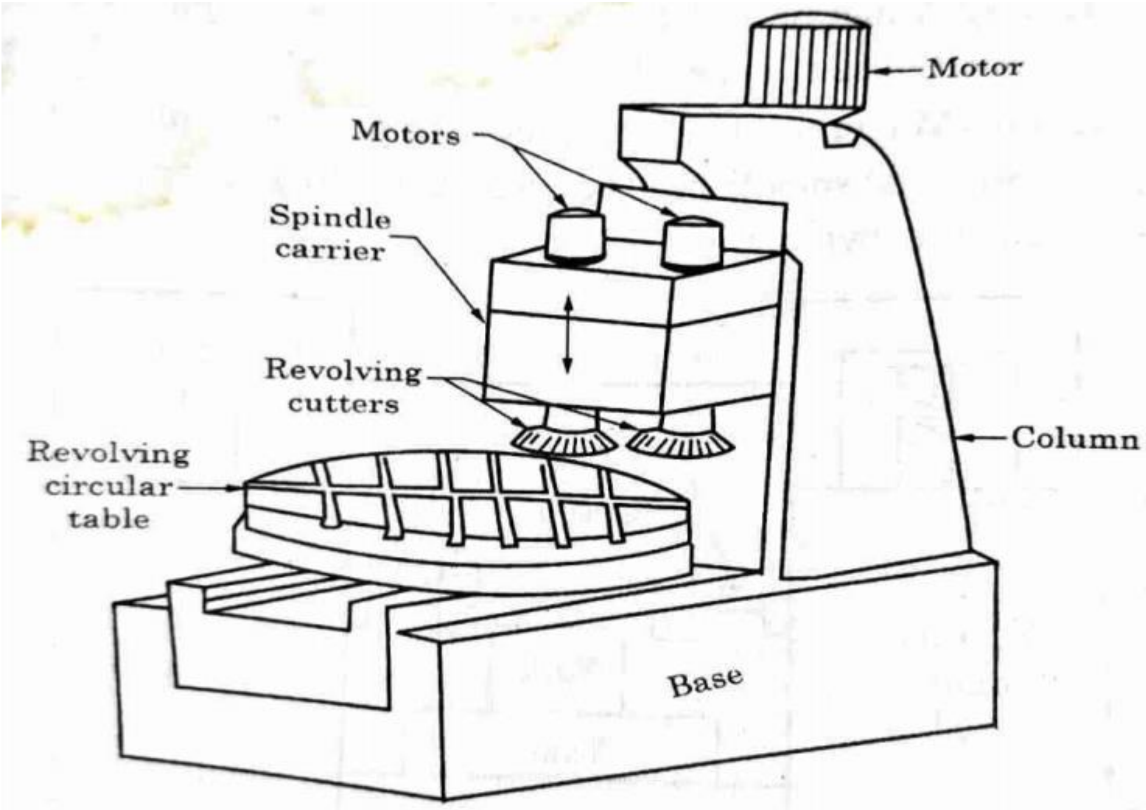

Fig. 1.7 Rotary Type Milling Machine

(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 work piece and is called a drum, which can only rotate horizontally. To remove the metal, you need to place the work piece 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 work piece 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.

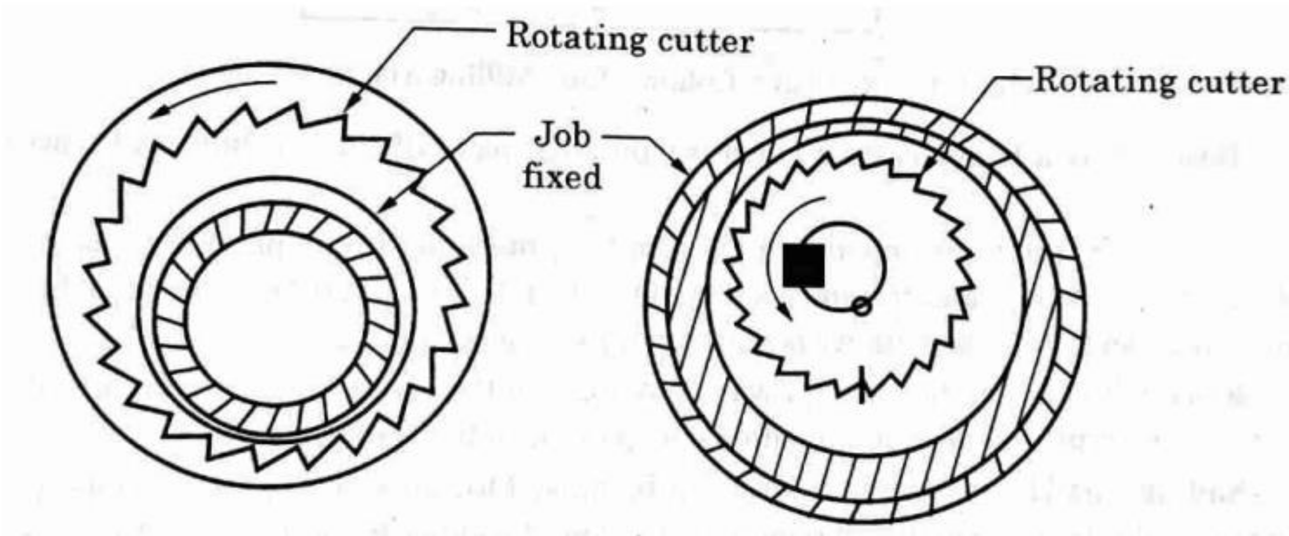

Fig. 1.8 Planetary Milling Machine

1.2.2 APPLICATIONS OF MILLING MACHINES

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 work piece. The spindle can be fed up and down with a quill feed lever on the head.
- The bed can also by feed 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.

1.3 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 guide ways provided at the front face of the column.

Principle parts: The principle parts of knee and column type milling machine are shown in fig. 1.9.

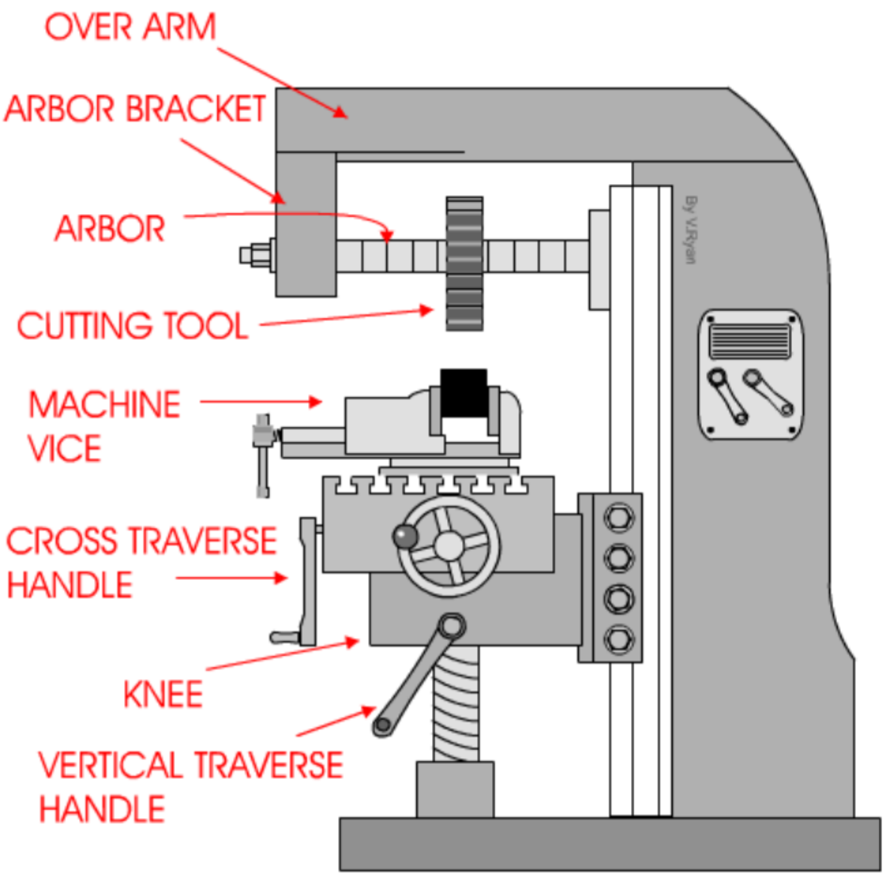

Fig.1.9 Knee and column type milling machine

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.

1.4 MILLING MACHINES ACCESSORIES AND ATTACHMENTS

1. Arbor: Arbor is cutter holding device. An arbor usually made with the taper shank for proper alignment with spindle having taper hole to at its nose. The cutter having a bore at the center is mounted and keyed to arbor.

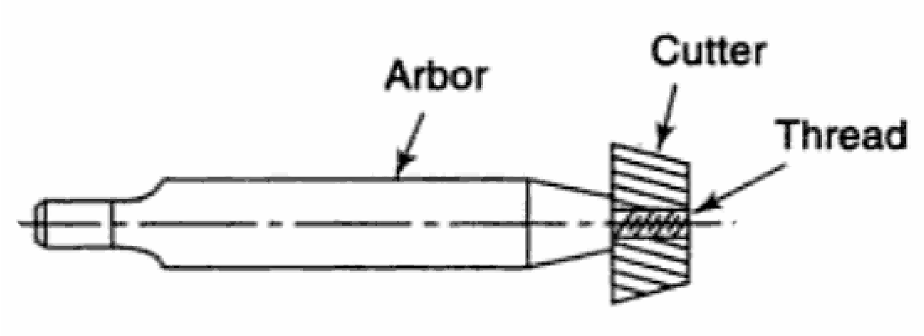

Fig.1.10 Arbor

2. Adaptors: An adaptor is like a collet used on milling machine having standardized spindle end. Cutters having shanks usually mounted on adaptors.

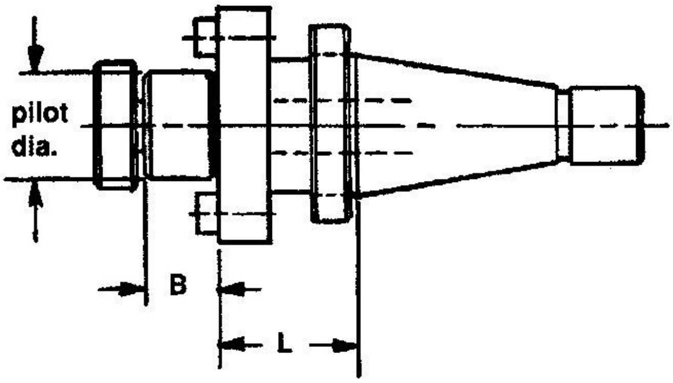

Fig.1.11 Adaptor

3. Collets: A collet is an accurate time saving cutter holding device on milling machines. The most commonly used collet is the spring type collet.

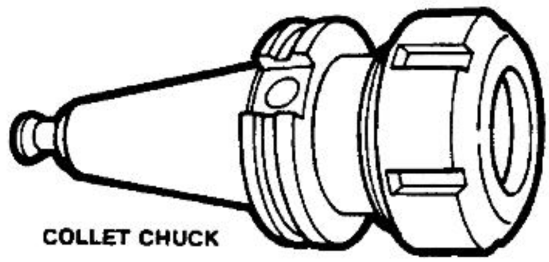

Fig.1.12 Collet

4. Vices: Vices are the most common devices used for holding work on milling machine table due to their quick loading and unloading arrangement.

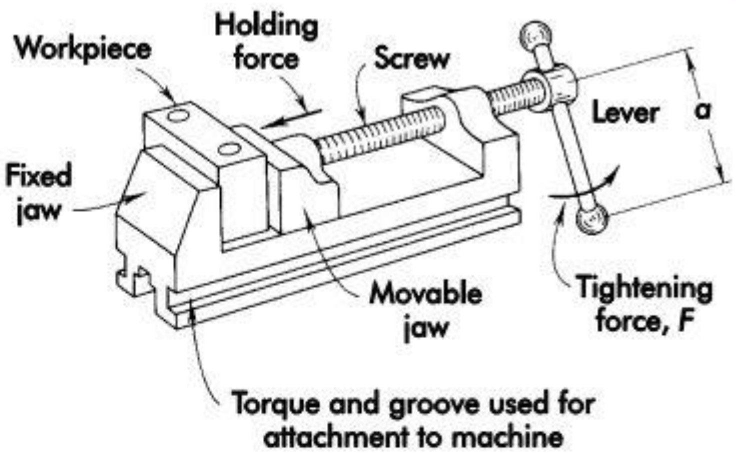

Fig.1.13 Vice

5. Circular table: It is mounted on the machine table used for producing circular surfaces after centralizations for milling circular surfaces.

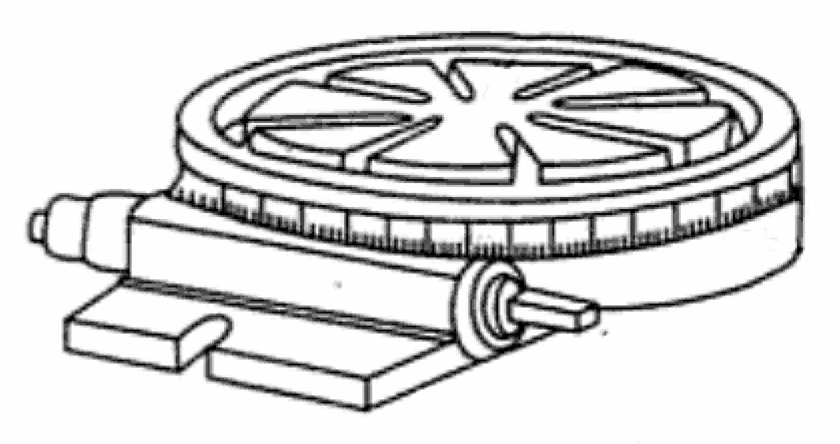

Fig.1.14 Circular Table

6. Indexing head and tail stock: It is used to divide the periphery of circular work piece. It is most common arrangement used in workshops. This is used for holding and dividing the circumference of component for grooving, gear cutting, fluting etc.

7. Vertical milling attachment: It is an attachment used for converting a horizontal milling machine into a vertical milling machine. By orienting the cutting spindle axis from the horizontal to vertical position.

8. Rotary table: It is used for variety of circular milling operations such as segment outlines, splines slotting, segmental milling and dies making jobs.

1.5 MILLING METHODS

Based upon the directions of movement of the milling cutter and the feeding directions of the work piece, 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 1.15. 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.

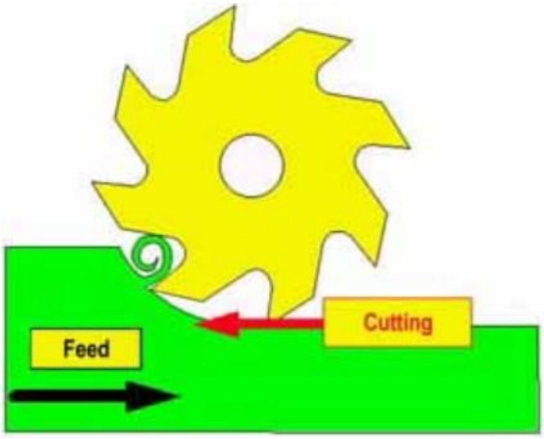

Fig.1.15 up Milling

2. Climb Milling (Down Milling):

In down cut milling, the cutter rotates in the same direction as the table feed as illustrated in figure 1.16. 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 work piece.

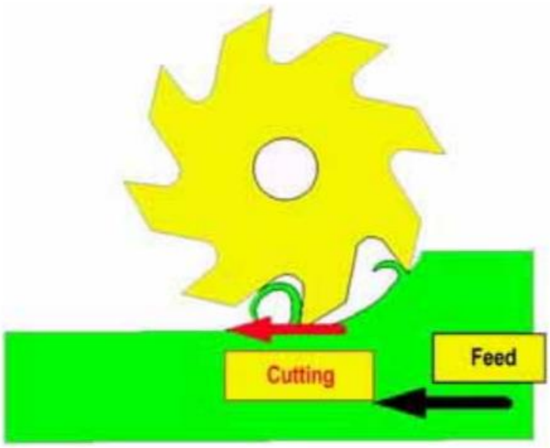

Fig.1.16 Down Milling

1.6 DIFFERENT MILLING CUTTERS AND WORK MENDRELS

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

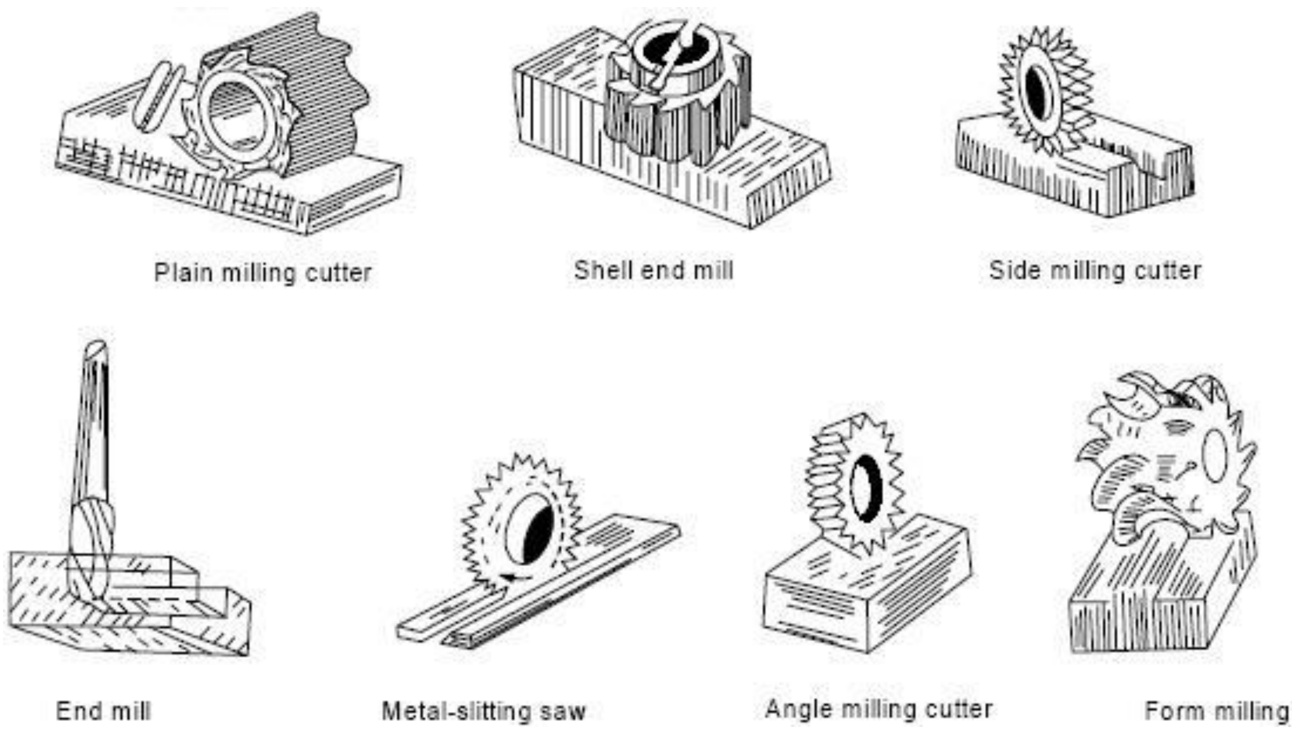

Fig.1.17 Milling Cutters

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.

1.7 WORK HOLDING DEVICES

A work piece 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 work pieces 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 spherical 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 work pieces to the plate, and also of the plate to the worktable.
- Angle plates also may be used to hold the work piece square to the table during marking-out operations.

Fig.1.18 Angle Plate

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.

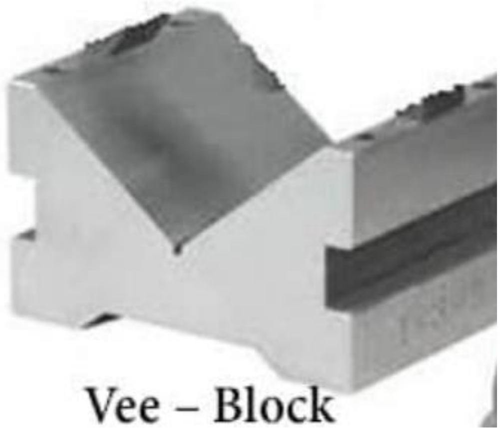

Fig.1.19 V block

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 work pieces of irregular shape special jaws are sometimes used.

Fig.1.20 Plain Vice

(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 work piece.

Fig.1.21 Universal Vice

5. Dividing Head:

Dividing head or indexing head used to hold the work piece 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.

1.8 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 work piece 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.

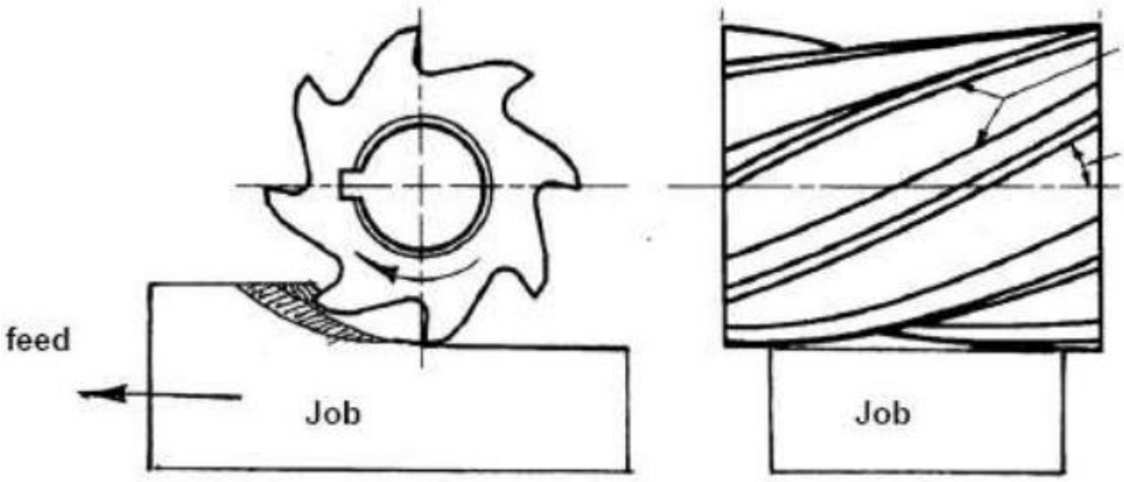

Fig.1.22 Face Milling

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 work piece. 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.

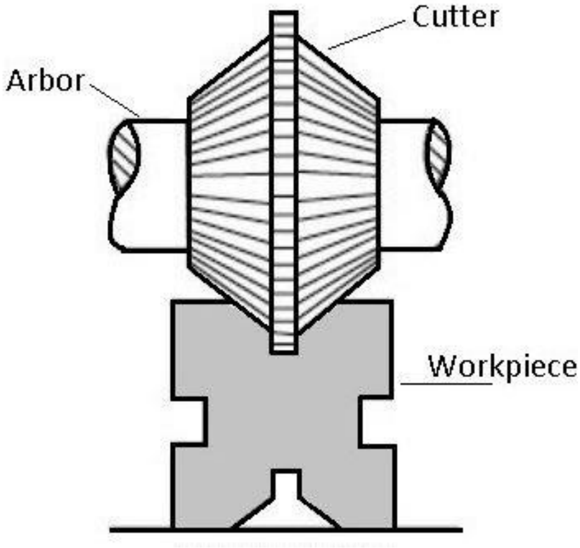

Fig.1.23 Angular Milling

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 work pieces. This operation is accomplished by using convex, concave, and corner rounding milling cutters ground to the desired circle diameter.

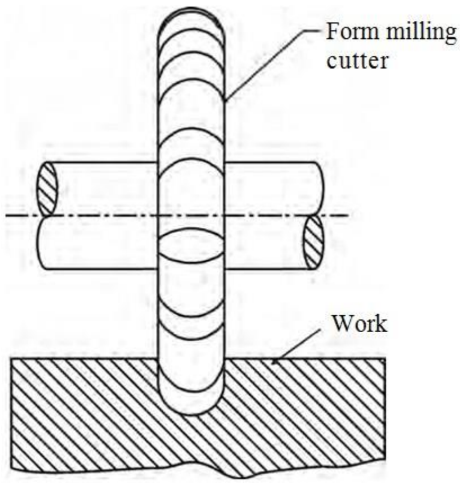

Fig.1.24 Form Milling

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 work piece. 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 work piece.

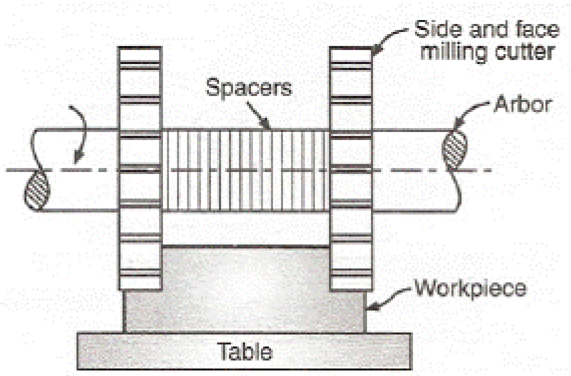

Fig.1.25 Form Milling

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.

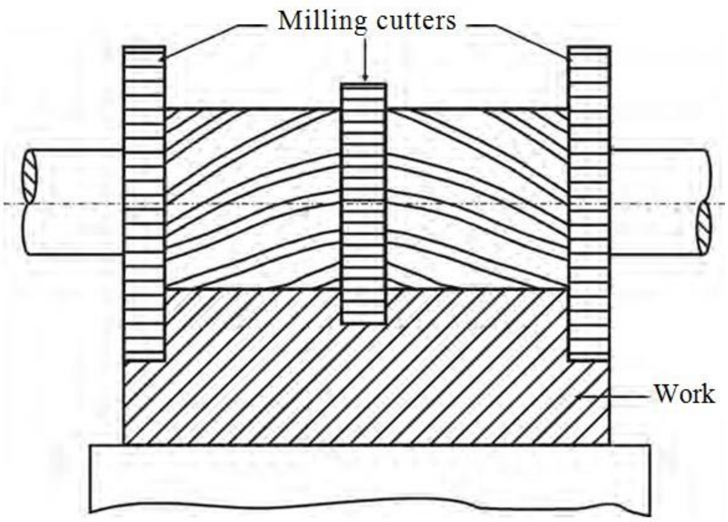

Fig.1.26 Gang Milling

1.9 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 work piece 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

1.10 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 quantities.

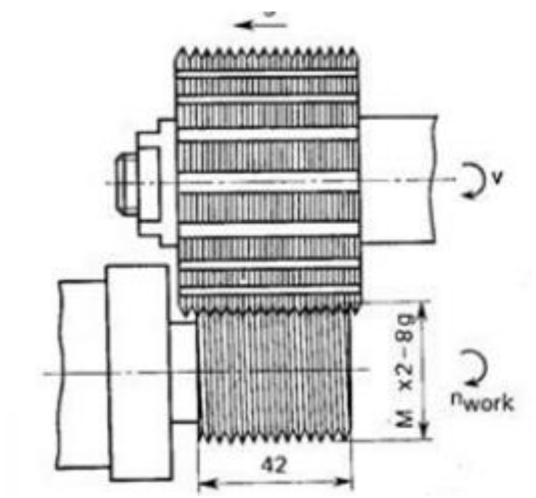

Fig.1.27 Thread Milling

CHAPTER 2

GEAR MANUFACTURING AND FINISHING PROCESS

2.1 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 work piece 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 work piece and the other with the hob. The angle between the hob's spindle (axis) and the work piece 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 work piece until the correct tooth depth is obtained. Finally the hob is fed through the work piece 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.

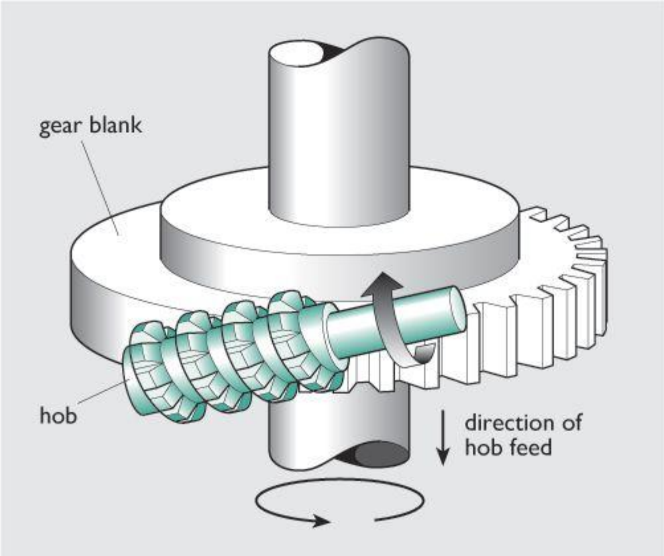

Fig 2.1 Gear Hobbing

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 work piece 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 characterized 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 mean the blank is mounted vertically. Horizontal hobbing machines are usually used for cutting longer work pieces; i.e. cutting splines on the end of a shaft.

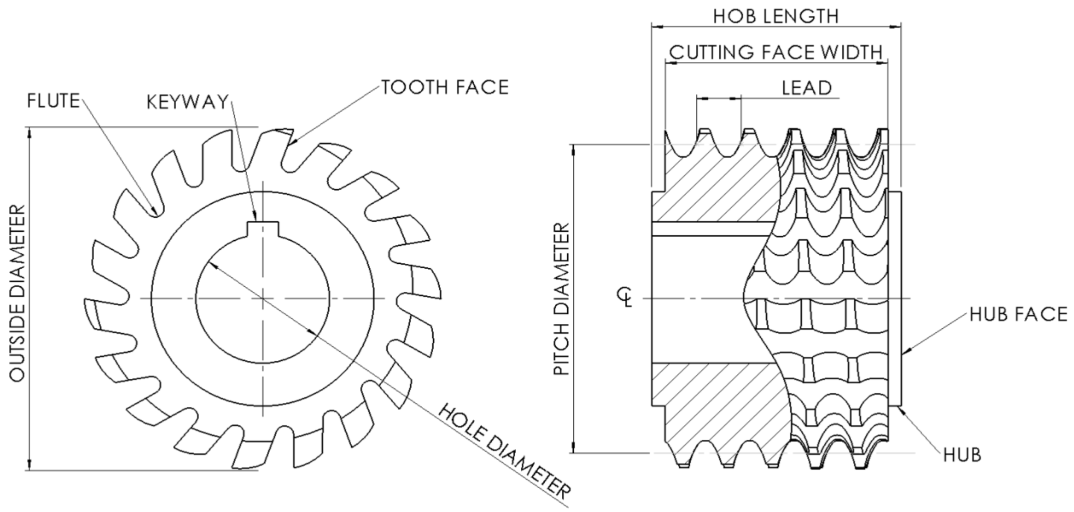

Fig.2.2 Gear Hobbing

2.2 GEAR SHAPING

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

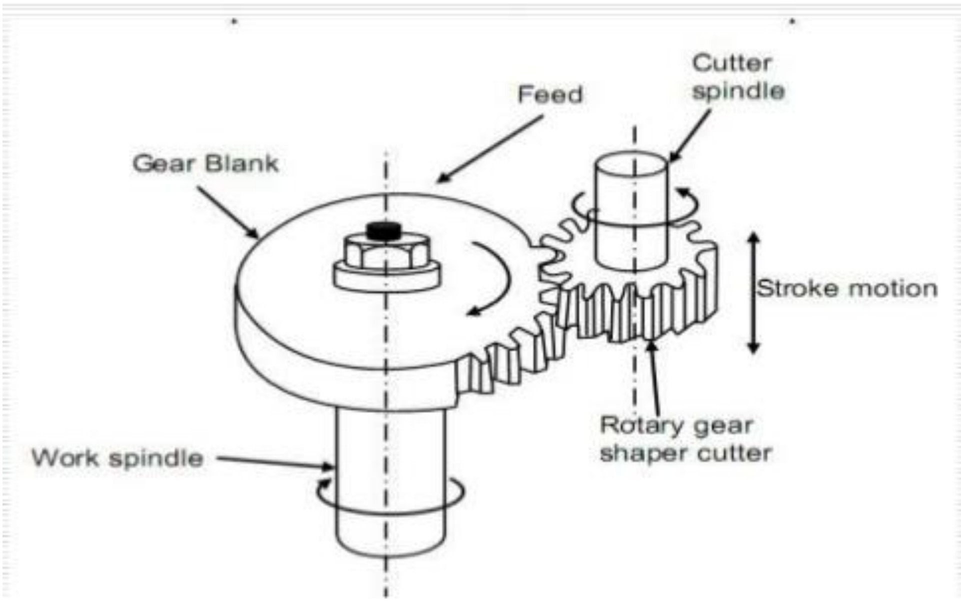

Fig. 2.3 Gear Shaping

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.

2.3 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 work piece 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: Super finishing, also known as micromachining, micro finishing, and short-stroke honing, is a metalworking process that improves surface finish and work piece 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 work piece

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.

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.

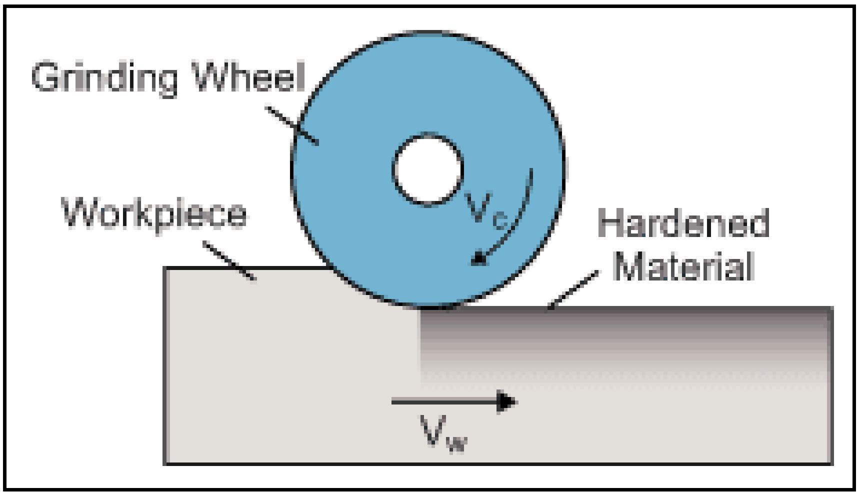

Fig.3.1 Grinding action

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

3.1 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.

3.2 VARIOUS ELEMENTS OF GRINDING WHEEL

1. 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.

2. 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

3. 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.

4. 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.

5. 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

3.3. COMMON WHEEL SHAPE, TYPES OF GRINDING WHEELS AND SPECIFICATION OF GRINDING WHEEL

3.3.1 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

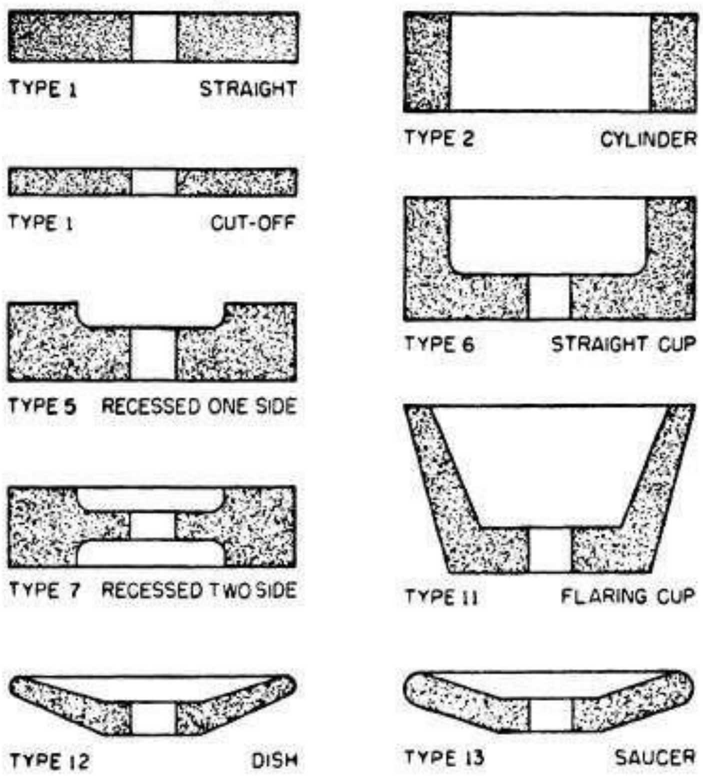

Fig.3.2 Standard grinding wheel shapes

3.3.2 TYPES OF GRINDING WHEELS

1. Built up Wheels

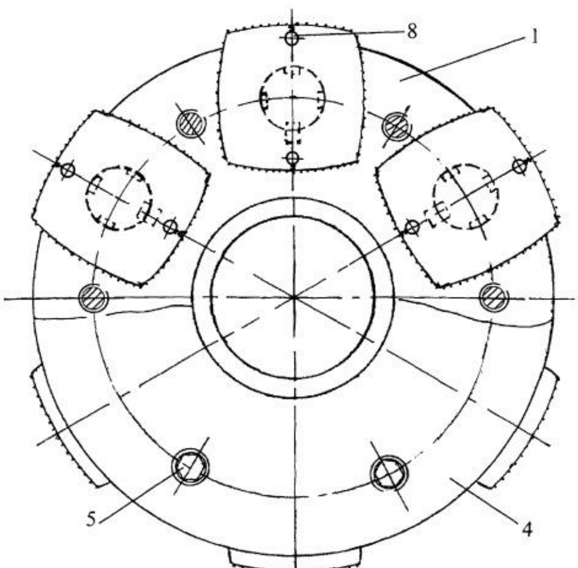

Fig.3.2 Built up Wheel

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.

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.

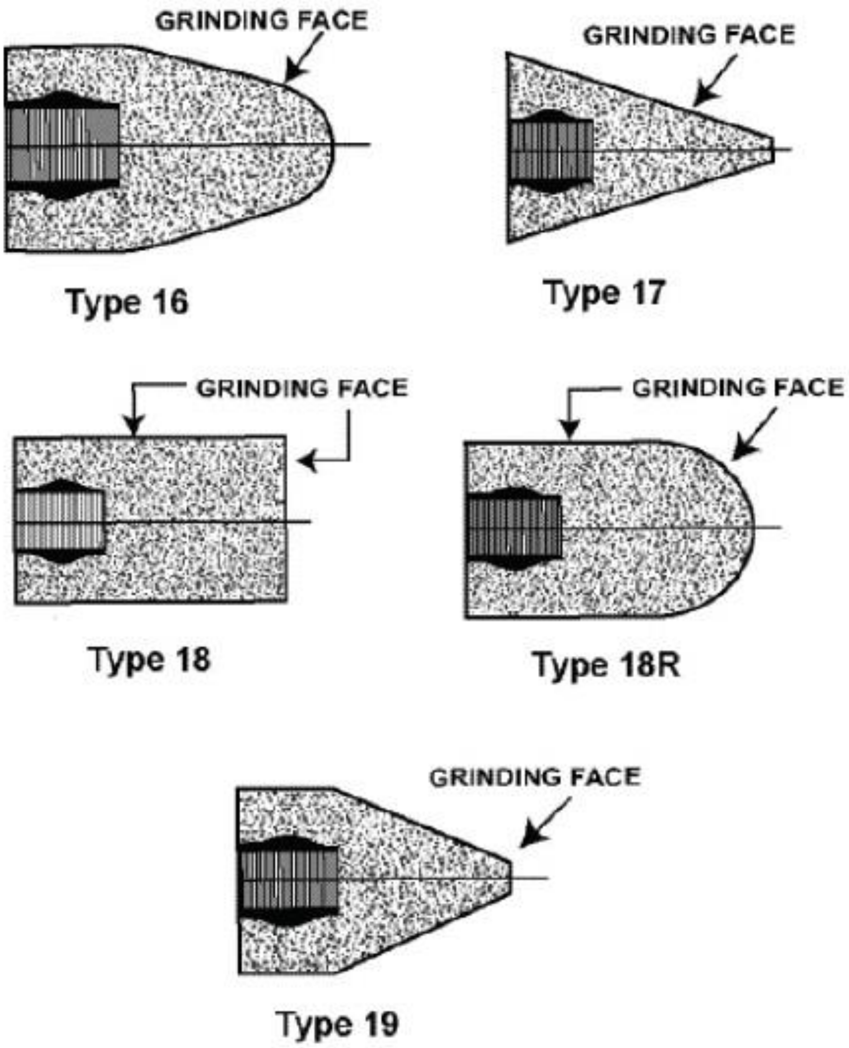

Fig.3.3 Cone and Plug shape wheel

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.

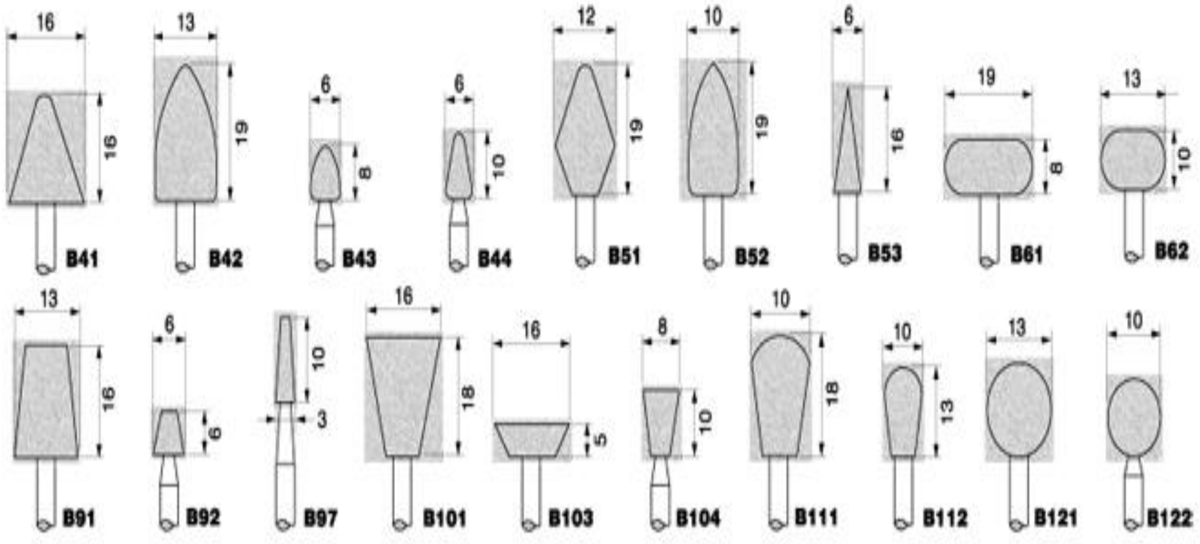

Fig.3.4 Mounted wheels

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.

Fig.3.5 Diamond wheel

3.3.3 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

Grain Size	Grit Number
Coarse Grain	8,10,12,14,16,24
Medium Grain	30,36,46,54,60
Fine Grain	80,100,120,150,180
Very Fine Grain	220,240,280,320,400,500,600

3. Grade

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

4. Structure

1 - 8	Dense structure
9 – 15	Open Structure

5. Types of Bond

Vitrified	V
Resinoid	B
Rubber	R
Silicate	S

3.4 TRUING, DRESSING, BALANCING AND MOUNTING OF GRINDING WHEEL

3.4.1 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.

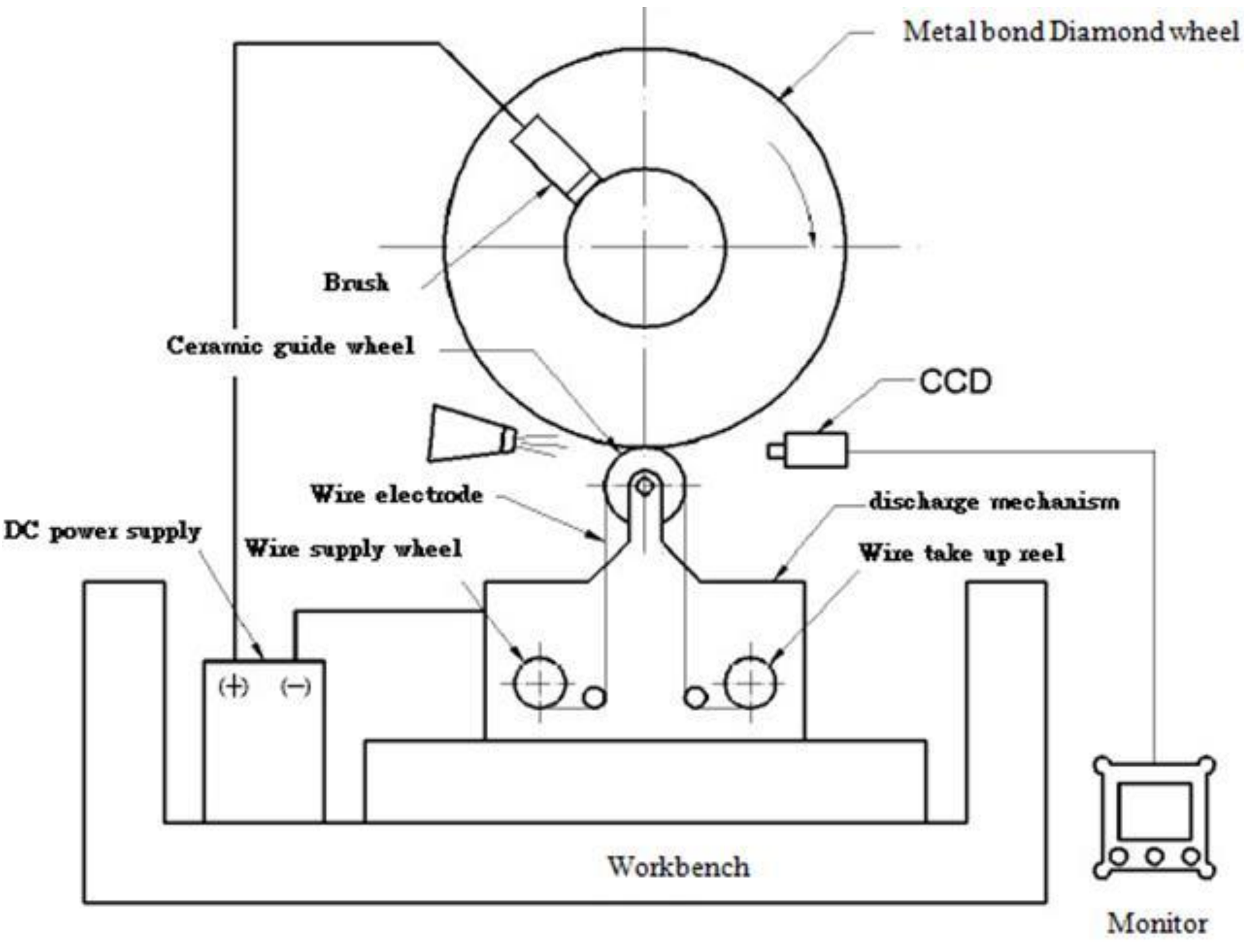

Fig.3.6 Truing

3.4.2 DRESSING

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.

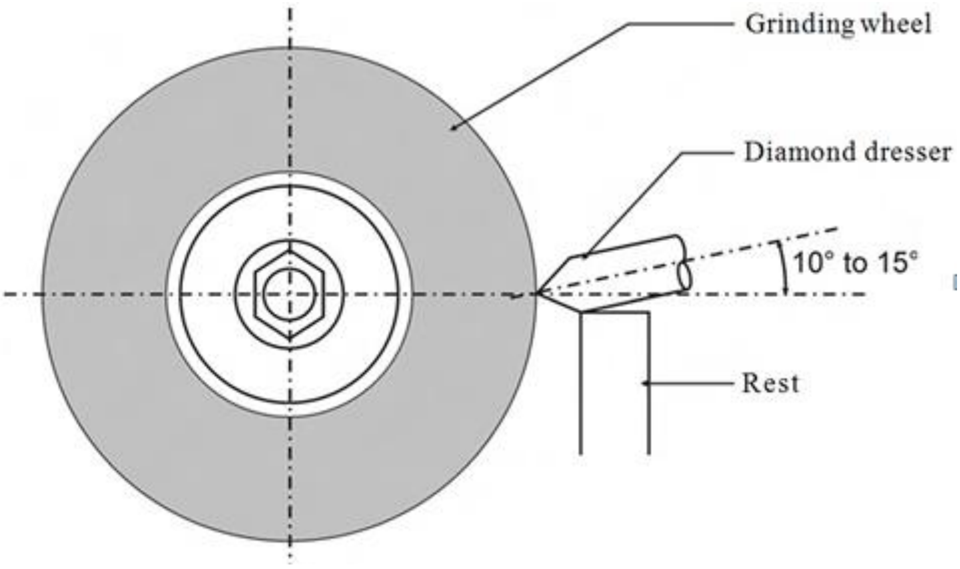

Fig.3.7 Dressing of a grinding wheel

Types of Dressing Tools

1 Wheel Dresser

2 Abrasive Stick Dresser

3 Abrasive Wheel Dresser

1. 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.

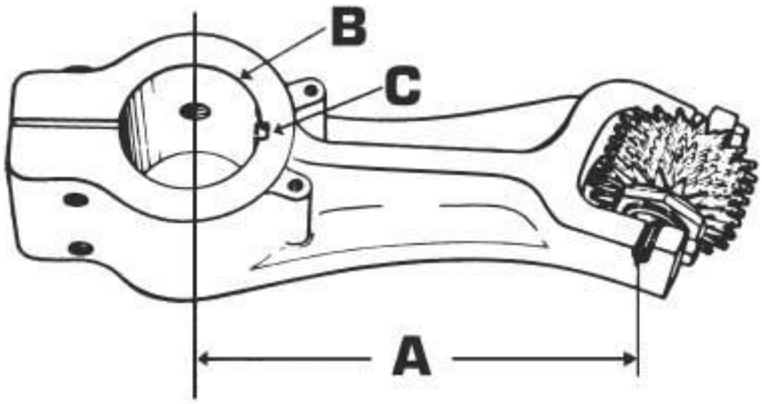

Fig.3.8 Wheel Dresser

2. 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!

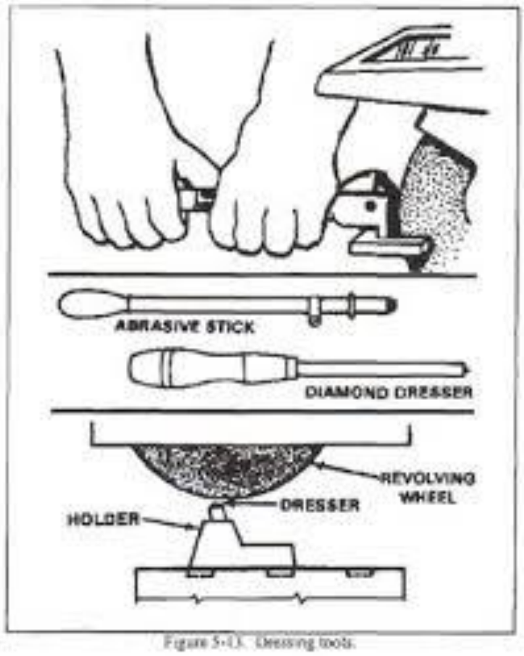

Figure 5-13. Dressing tools.

Fig.3.9 Abrasive stick dresser

3. 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.

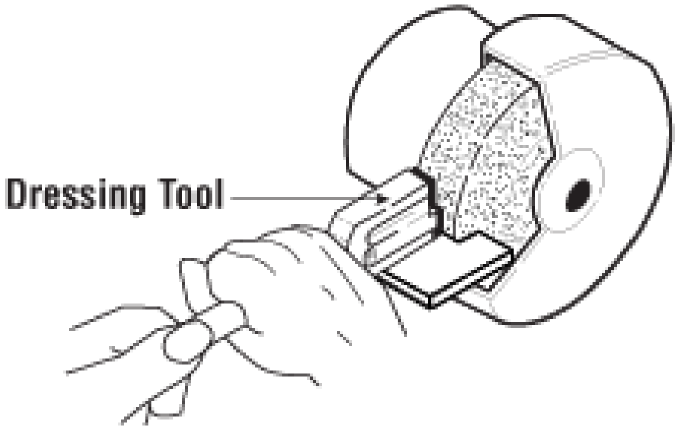

Fig.3.10 Abrasive wheel dresser

3.4.3 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.

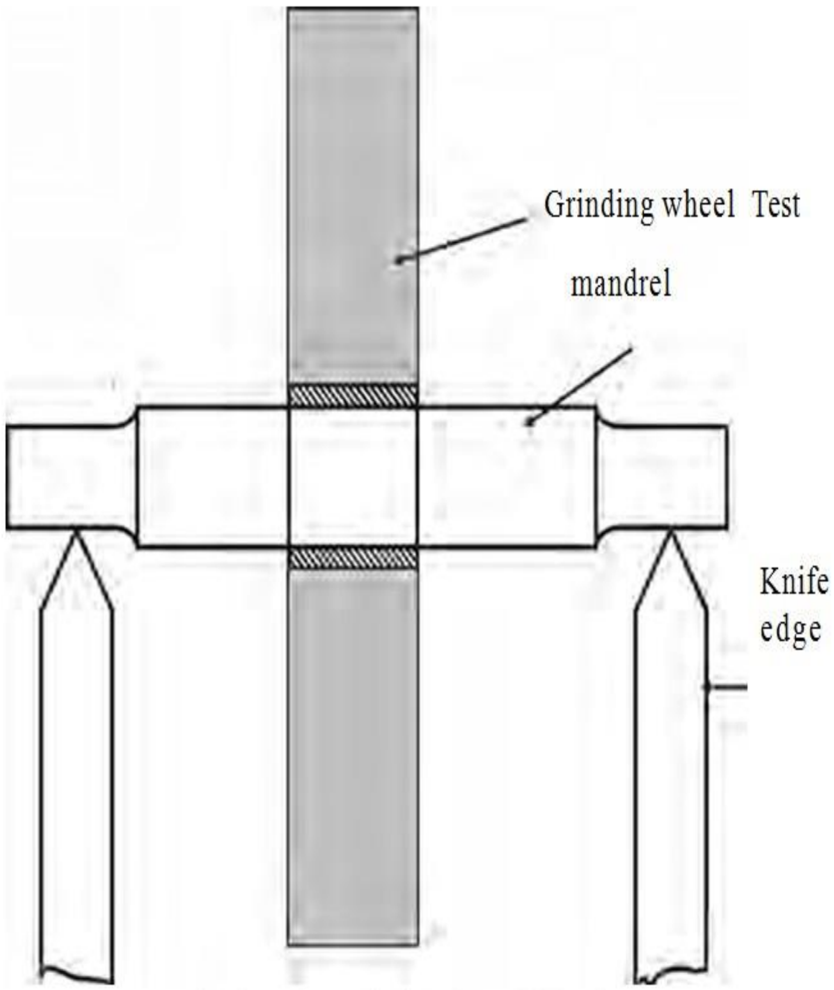

Fig.3.11 Balancing of a grinding wheel

3.4.4 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.

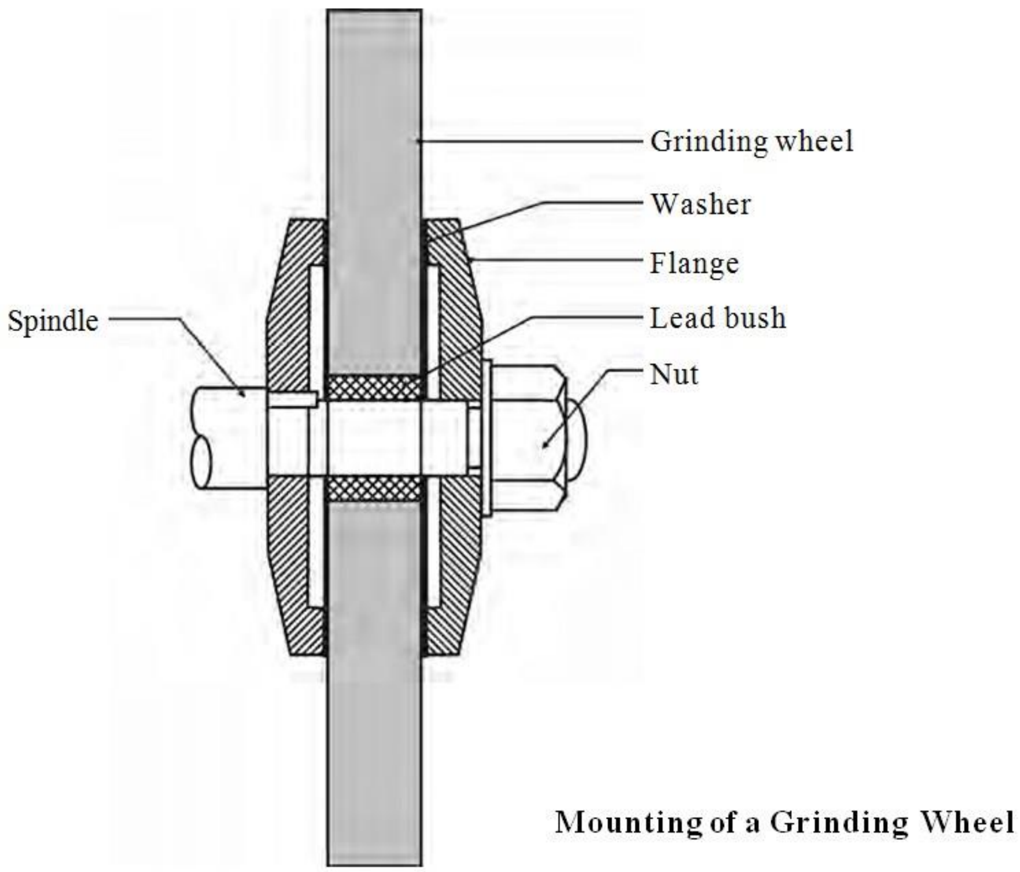

Fig.3.12 Mounting of a grinding wheel

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.

3.5 GRINDING METHODS

1. 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.

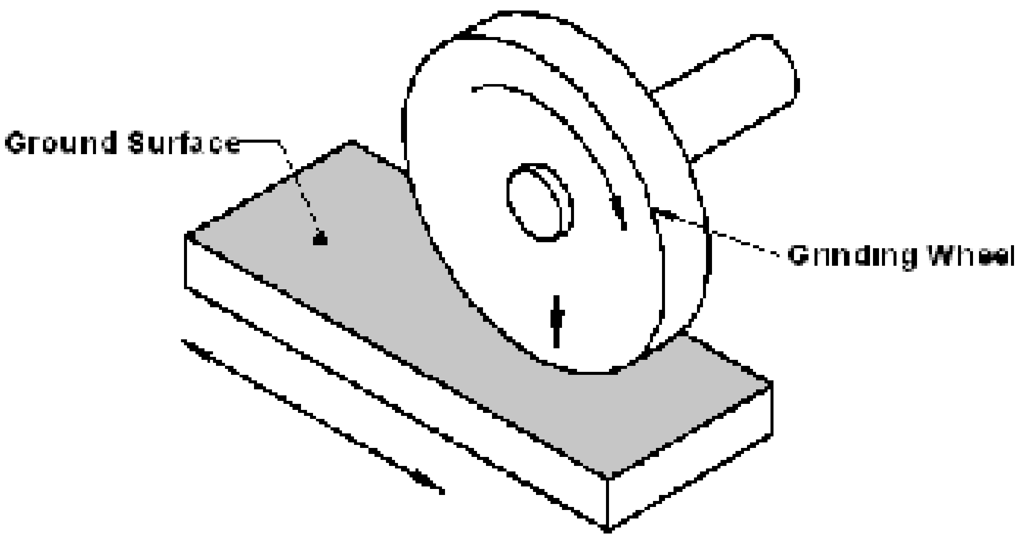

Fig.3.13 Surface Grinding

2. 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.

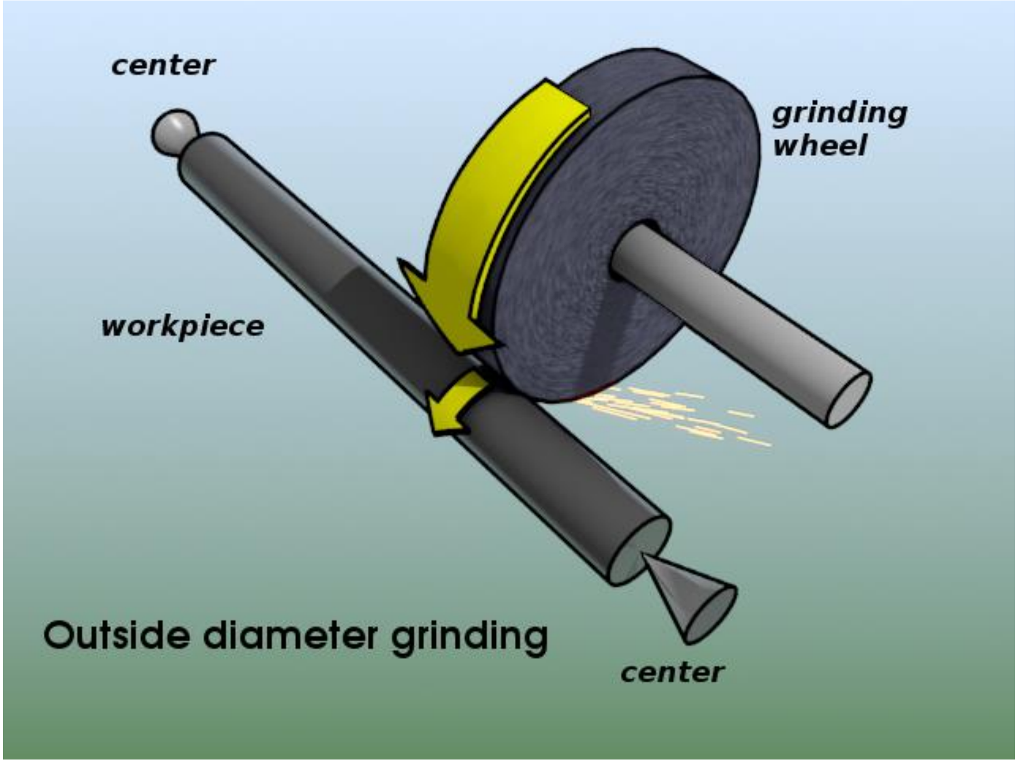

Fig.3.14 Cylindrical grinding

3. 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.

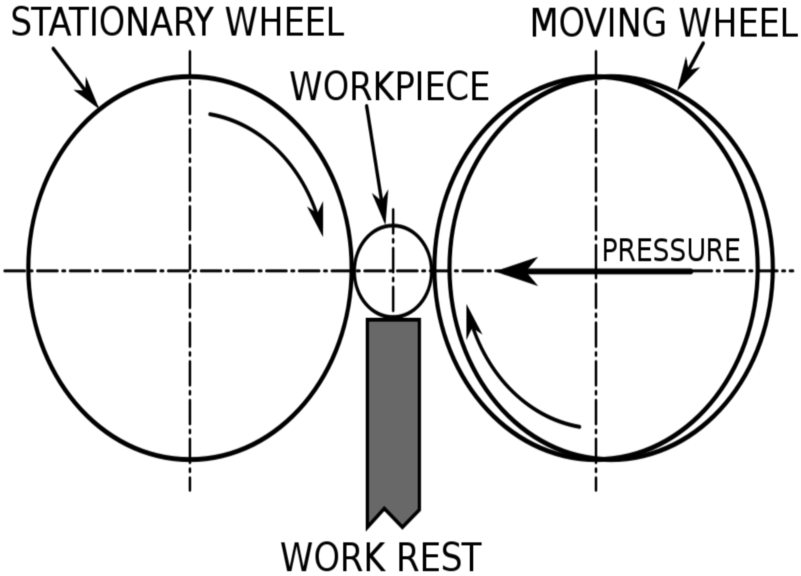

Fig.3.15 Centerless grinding

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.

3.6 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 work piece via shear deformation.

1. 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.

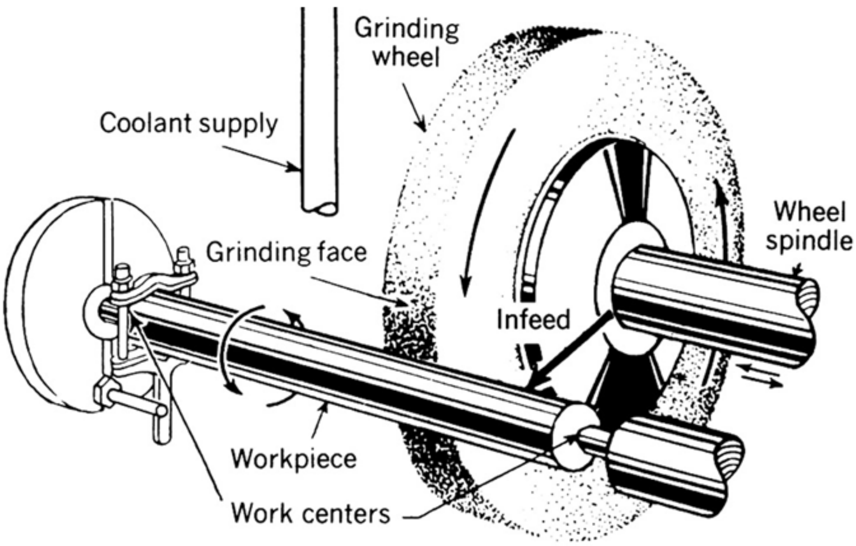

Fig.3.16 Cylindrical Grinding Machine

2. Centreless Grinding Machine

Centreless grinding is a machining process that uses abrasive cutting to remove material from a workpiece. Centreless grinding is an 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 work piece is not mechanically constrained during centreless grinding. Therefore the parts to be ground on a centreless grinder do not need center holes, drivers or work head fixtures at the ends. Instead, the work piece is supported in the grinding machine on its own outer diameter by a work blade 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.

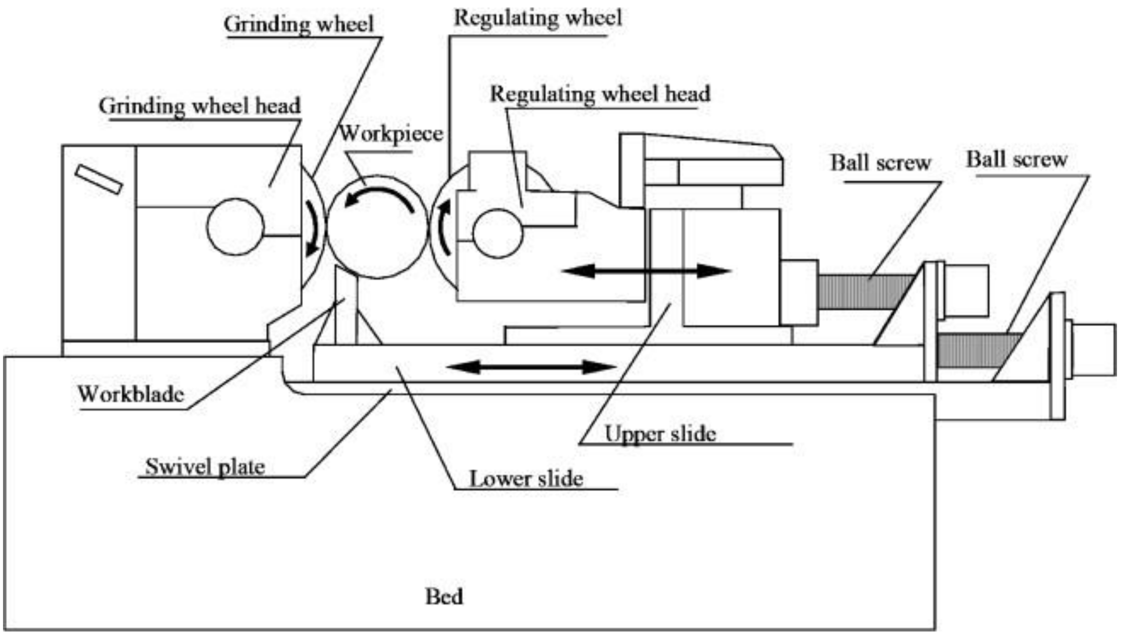

Fig.3.17 Centerless Grinding Machine

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.

3. Tool and Cutter Grinder

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

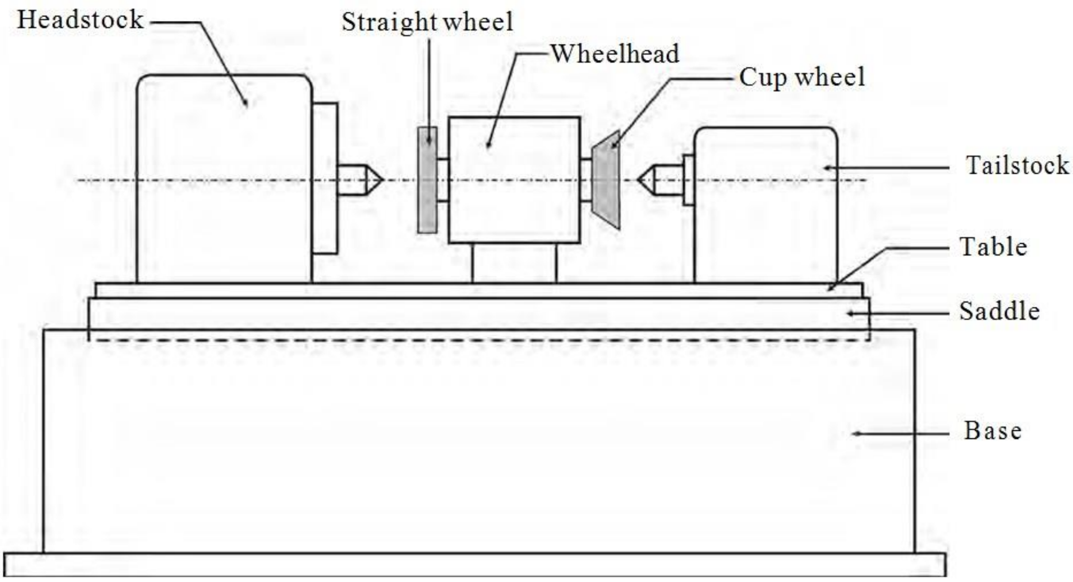

Fig.3.18 Tool and Grinder Machine

4. SURFACE GRINDING MACHINE

This machine may be similar to a milling machine used mainly to grind flat surface. However, some types of surface grinders are also capable of producing contour surface with formed grinding wheel. Basically there are four different types of surface grinding machines characterized by the movement of their tables and the orientation of grinding wheel spindles as follows:

1. Horizontal spindle and reciprocating table
2. Vertical spindle and reciprocating table
3. Horizontal spindle and rotary table
4. Vertical spindle and rotary table

1. Horizontal spindle and reciprocating table

A disc type grinding wheel performs the grinding action with its peripheral surface. Both traverse and plunge grinding can be carried out in this machine.

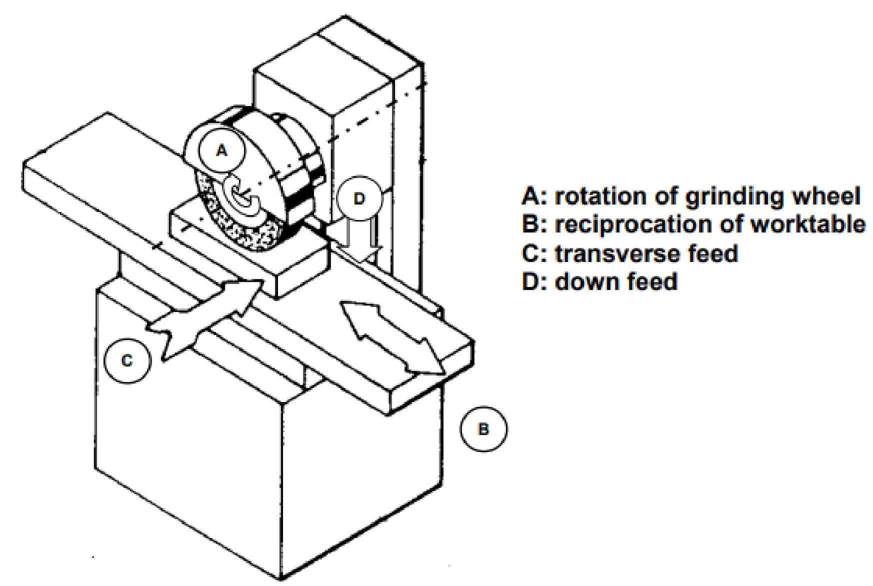

Fig.3.19 Horizontal spindle and reciprocating table

2. Vertical spindle and reciprocating table

This grinding machine with all working motions. The grinding operation is similar to that of face milling on a vertical milling machine. In this machine a cup shaped wheel grinds the work piece over its full width using end face of the wheel.

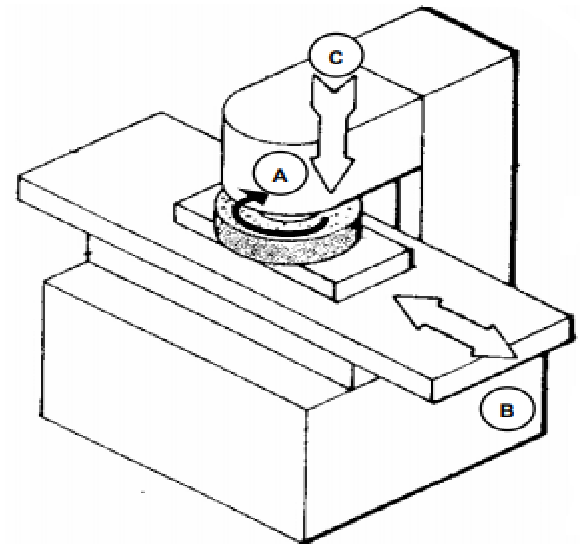

Fig.3.20 Vertical spindle and reciprocating table

5. INTERNAL GRINDING MACHINE

This machine is used to produce internal cylindrical surface. The surface may be straight, tapered, grooved or profiled. Internal grinding machine is employed for finishing an accurate hole in a hardened part and also, when it is possible to apply other methods of finishing an accurate hole. Depending upon the shape of the work piece two grinding methods have been used:

1. Grinding of work piece which can rotate.
2. Grinding of work piece which cannot rotate.

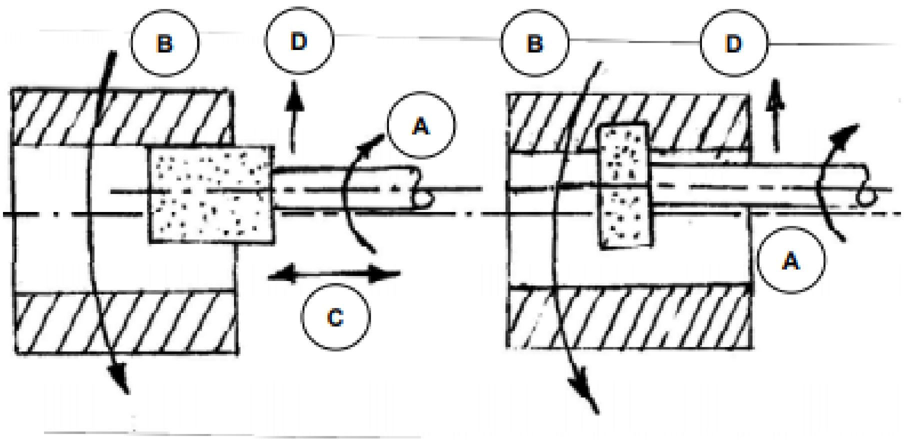

Fig.3.21 Internal Grinding Machine

3.7 SELECTION OF GRINDING WHEEL

1. 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.

2. 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.

3. 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.

4. 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.

5. **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.

6. **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.

3.8 THREAD GRINDING

This process is employed as a finishing/forming operation on a number of screw threads. It is used in the following manners:

1. Single wheel grinding method: This used is utilized for blanks of larger lengths. In this method, a thin disc type grinding wheel is used and threads are finished in single pass of grinding wheel.

2. Plunge cut grinding method: This used is utilized for blanks of smaller lengths. The length of grinding wheel is larger than that of the thread to be ground.

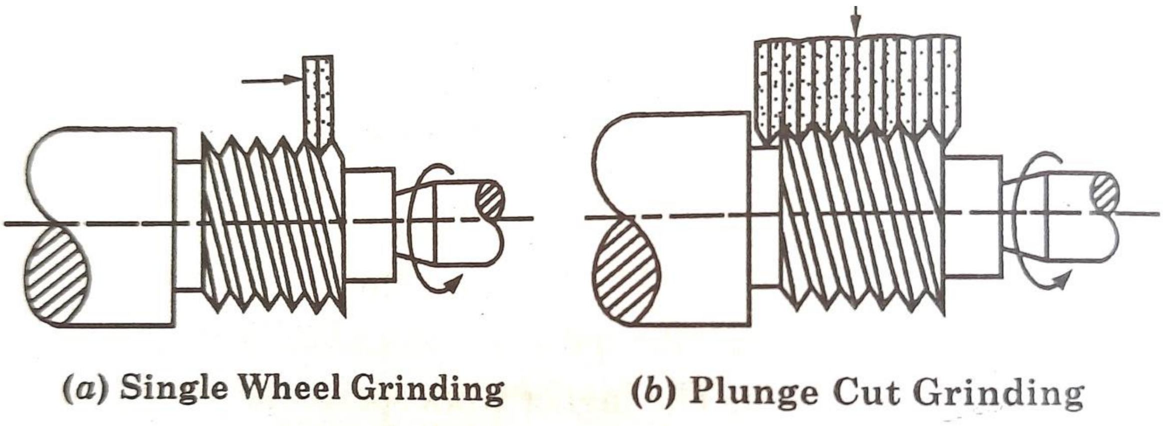

Fig.3.22 Thread Grinding

CHAPTER 4

4.1ULTRASONIC MACHINING (USM)

4.1.1. Introduction

The term ‘ultra-sonic’ is used to describe vibrational waves having a frequency above hearing range of normal ear i.e. beyond 18 kHz. This includes a wide range a wide range of frequencies and wave lengths. Ultrasonic machining may be defined as the process of material removal by repetitive impacts of abrasive particles of an abrasive slurry vibrating at an ultrasonic frequency between the tool and the work piece.

The material removal during USM is due to

1. The impact of the free abrasive particles on the work surface

2. The hammering of the abrasive particles on the work surface.

3. The erosion due to cavitation.

4. The chemical action associated with the fluid used.

4.1.2 Principle of USM

A slurry of small abrasive particles is forced against the work by means of a vibrating tool. The material is removed due to action of abrasive grains which are hammered into the work surface by a tool oscillating at high frequency normal to the work surface. For this purpose, the tool oscillation frequency is in the range of 20 kHz.

The grains used are of silicon carbide, aluminium oxide, boron carbide or diamond dust. The tool is pressed against the work under a load of few kilograms of force.

Ultrasonics are produced by feeding high frequency electric current to a transducer which converts it to high frequency mechanical vibrations. The vibrations are focused on the cutting point with the help of concentrator. A brasives are supplied is the form of slurry suspended in a carrier fkuid nd tool is fed by means of static loading of the vibrator head.

Ultrasonic machining is a copying operationi.e. theshape of work produced is the mirror image of the tool itself. Thus the accuracy of

th tool itself.

4.1.3 Elements of the process

the main elements of this process are as follow:

1. Generator,

2. Transducer,

3. Concentrator,

4. Abrasive,

5. Tool.

1. Generator:

(i) Compact, reliable and easy to operate.

(ii) Controlled power output over a wide range.

(iii) Absence of higher harmonics in the output voltage.

2. Transducer: Transducer used in ultrasonic machining woks on the principle of magnetostriction. A magnetostrictive transducer is a basically a magnetized rod which has a coil wrapped around it in which a voltage in induced by tension or compression. on returning to its original position, te bar induces a voltage of opposite polarity.

therefore, the vibration of the bar at some AC frequency will induce an AC voltage of some frequency in the coil.

3. Concentrator: Tool cone (or horn) focuses the mechanical energy produced by the transducer to the workpiece in such a manner that its utilization is optimum. the main purpose of the concentrator is to increase the amplitude upto the level needed for cutting.

4. Abrasive: The shape of tool an important effect on the rate of tool penetration in ultrasonic machining. Tool with smaller contact area yields better penetration rate allowing efficient flow of abrasive underneath. the choice of tool material is also important as tool has to withstand corrosion due to the flow of abrasive and vibrations.

4.1.4: Process Parameters

Ultrasonic machining paramaters such as frequency, abrasive size, contact load, amplitude of vibrations etc. influence the rate of metal removal and surface finish. The relationship between some of the parameters and metal removal rate is shown in figs. 4.3 to 46

4.2 Advantages of Ultra Sonic Machining

The following are the advantages of ultrasonic machining:

1. Hard and brittle materials can be easily machined.

2. This machining operation is quite safe than other machining operations.

3. The workpiece produced by this method is free from stresss.

4. The operation is generally noiseless.

5. Cost of production is low.

4.3 Disadvantages of Ultra Sonic Machining

The following are the diadvantages of ultrasonic machining:

1. The cost of the equipment is high.

2. The cost of tooling is also high.

3. It is not suitable for heavy metal removal.

4. The metal removal rate is also low.

5. The size of the cavity that can be machined is limited.

4.4 Applications Ultrasonic Machining

It is used the following purpose:

1. It is used for cutting operations.

2. It is used fo drilling, threading milling, grinding etc.

3. It is used for deniststst work i.e. to drill fine holes of desired shape in teeth.

4. It is used for surface finishing.

5. It is used for forming of plastics.

4.4 ELECTRO CHEMICAL MACHINING (ECM)

4.4.1. Introduction

Electro-chemical machining is an extension of electroplating some modification, but in a reverse direction. It consists of a shaped tool or electrode, electrolyte and workpiece. The electrode acts as cathode and workpiece acts as anode. The electrolyte is pumped through the small gap which is maintained between the electrode and workpiece. A.D.C. Power supply of low voltage and high current is supplied between electrode and the workpiece by which metal removal takes place due to the ions migration toward the tool or electrode.

4.4.2 Principle of Electro-Chemical Machining

Electro-chimical machining is a new field of metal removal which has been developed on two well-known principles given by Ohm and Faraday. According to the first law of electrolysis, the amount of any substance dissolved or deposited is proportional to the quantity of electricity that is passed through the electrolyte.

According to the second law of electrlysis, the amount of any substance dissolved or deposited by the same quantity of electricity is proportional to the chemical equivalent weight the electrolyte.

Michael Faraday discovered that if two electrods are placed in a bath containing a conductive liquid and a D.C. supply is applied across them, metal can be deplated from the anode and plated on the cathod.

4.4.3 Electro-Chemical Machining Plant

An Electro-chemical machining plant consists of following elements:

1. Machine tool,

2. Electrolyte supply and filteration system,

3. Hydrogen extraction system,

4. Power supply system.

A machine tool is used for (i) Holding the work relative to the tool (ii) hold the tool in appropriate ralstion with the work-piece (iii) feed the tool at predetermined rate. A pump is used to circulate the electrolyte through the gap between the tool and the workpiece. A filter is also used for filtration. the normal electrolyte through the gap between the tool and the workpiece. A filter is also used for filtration.

4.4.4 Electro-Chemical Machining Process

Fig. 4.8 shows the schematic arrangement of ECM process. The process consists of the following steps:

1. The job to be machined is fixed in the vice, in the machining chamber

2. The tool which act as a cathode in the electrolytic cell is brought near the job with the help of press buttons provided on the control panel and table lifting arrangement for maintaining particular gap.

3. When the current is switched ON, the electrolyte (Say NaCl + H_2O) gets ionized according to the relationship given below:

As hydrogen ions reach the cathode, they combine with free electrons resulting into evaluation of H_2 gas.

Let us assume the case of machining of pure iron by this method, the reactions that would occur are as follow:

4. The tool is fed at controlled rate and when desired depth of machining has been achieved, hooter gives an indication of completion of the process.

4.4.5 Advantages of Electro-chemical Machining

Electro-chemical machining has a number of advantages. Some of these are as follow:

1. ECM has the ability to machine th ecomplex, shaped workpiece economically.

2. The surface produced by this method is free stresses.

3. There is no tool wear for normal operation of the process.

4. High surface finish of the order of 0.1 to 2 microons can be obtained.

5. The process does not produce any chips or burrs during machining.

4.4.6 Disadvantage of Electro-Chemical Machining

The following the disadvantage of electro-chemical machining:

1. Large floor space is required.

2. Power consumption is very high.

3. High capital cost.

4. Grain boundary attack may take place under certain condition.

5. Material which are non-conductors of electricity cannot be machined.

6. Minimum corner radius that can be machined is limited to about 0.2mm.

4.4.7 Applications of Electro-Chemical Machining

The following are the main applications of electro-chemical machining.

1. It can be used for various metals except non conductive metals.

2. Machining of blind holes and pockets such as in forging dies.

3. Machining of cavities and holes of irregular shapes.

4. Machining of aerospace components.

5. Drilling small deep holes such as nozzles.

4.5 ELECTRIC DISCHARGE MACHINING (EDM)

4.5.1 Introduction

This process is also known as spark erosion machining. In this process, the metal is removed due to erosion caused by rapidly recurring spark discharge between the tool and work. The concept of electric discharge machining was developed in USSR in 1943. Then onward research and development have brought this process to its present level. A dielectric fluid is also used in this process. The main aim of the process is controlled removal of material from the work piece.

4.5.2 Principle Parts of EDM Machine

The principle parts of EDM machine are as follow:

1. Dielectric-fluid and circulation system.

2. D.C. Power supply.

3. Reduction gear box.

4. Rack and pinion.

5. Base.

6. Capacitor.

The schematic arrangement of these parts is shown in fig.

4.5.3 Terminology

1. Anode: In EDM, the workpiece is made anode. The anode is connected to the terminal and it erodes at faster rate.

2. Cathode: In EDM, the tool made cathode. This is connected to the negative terminal and it erodes at slower rate than anode.

3. Dielectric Fluid: For improving the effectiveness, the workpiece and the tool are submerged in a dielectric fluid (hydrocarbon or mineral oils).

4. Spark Gap: It is the gap between the workpiece and the electrode. The spark generated effectively only for certain gap between these two (work piece and tool).

5. Gap voltage: It the voltage required at the gap to initiate at discharge or the flow of current.

6. Wear Ration: It is the ration of tool wear to the materials removal rate.

4.5.4. Principle of electric Discharge Machining

The basic principle of electric discharge machine is shown in fig In this process, when a discharge takes place between two points of the anode and cathod, which are separated by a gap called spark gap, the intense heat generated near the zone melta and evaporates the materials in the sparking zone.

4.5.5 Mechanics of Electric Discharge Machining

Fig shows the details of the electrodes surfaces. The surface may appear smooth, but irregularities and aserities are alway present as indicated. As result, the local gap various and at a given instant, it is minimum at one point (say A). The sparj is produced at point A as it has minimum gap between cathode and anode. as soon as this happens, the gap between the electrodes at A increases and the next location of the shortest gap is somewhere eles (say (B).

4.5.6 Electric Discharge Machining Process

1. The workpiece is help in a fixture at proper position.

2. Then workpiece is placed i the operational chamber.

3. The spark gap usually varies from 0.005 mm to 0.05 mm.

4. The melted particles of the metal are then carried away by the dielectric fluid.

5. After achieving the required surface, the process is stopped.

6. The workpiece is the taken out of the operation chamber, rinsed cleaned and dried.

4.5.7 Advantages of Electric Discharge Machining

The main advantages of electric discharge machining are as follow:

1. High degree of surface finish and accuracy can be achieved.

2. Fine holes can be easily drilled.

3. Cpmlicated shapes can be easily obtained.

4. It is a rapid process than conventional machining process.

5. Surface produced by this process can be easily polished.

6. The process can easily be automated.

7. It is a rapaid process than conventional machining process.

4.5.8 Disadvantages of Electric Discharge Machining

The main disadvantaes of elctric discharge machining are as follow:

1. This process requires high power comsumption as compared to other processes.

2. Sharp corners cannot be produced by this process.

3. Surfece cracking may take place in some materials.

4. Workepiece must be an electrical conductor for this process.

4.5.9 Application of Electric Discharge Machining

It is widely used process in engineering industries which have following applications:

1. Cutting of slots in diesel fuel injection nozzles.

2. Machining of intricate shapes, blind cavities and narrow slots.

3. This process is very useful in tool manufacturing due to the ease with which hard metals and alloys can be machined.

4. It is used for resharpening of cutting tools and broaches.

5. It is also used for trepanning of holes with straight or curved axes.

4.5.10 Metal Removal (MRR) In Electric Discharge Machining

The metal removal rate is proportional to the working current value. It is generally described as the volume of metal removed per ampere which then yields a basis for the output comarison of different machines or different electrode materials. The machining rate during roughing the steel with a graphite electrode with a 50 A generator is about 400

1. Fig shows the variation of voltage with metal removal rate. Higher the voltage, more will be the metal removal rate.

2. Pressure of dielectric fluid also affects the metal removal rate during operation. Forced circulation of fluid gives more metal removal rate as shown in fig.

3. Fig. shows the variation of metal removal rate with spark gap in which initially metal removal rate is more and after peak metal removal rate, it drops suddenly. It means that only at optimum gap, we shall get maximum metal removal rate.

4. Capacitance also affects metal removal rate. Fig shows the effect of capacitance. It is clear that higher the capacitance, higher will be the metal removal rate.

5. The effect of resistance is just opposite to the capacitance. In this case, higher the resistance, lower will be the metal removal rate and vice-versa. fig shows the effect of resistance on metal removal rate.

4.5.11 Dielectric Fluid Used Discharge Machining

The electric fluids generally used are mineral oil, white spirit, transformer oil, siliconoil or kerosene. these have the following functions:

1. It removes the eroded material from the surface of the tool and work-piece continuosly.

2. It provides the effective cooling to the system.

3. It avoids the defects on work surface after machining.

4. It maintains the suitable conditions for effective sparking.

4.5.12 Properties of Dielectric Fluid

The basic properties of an ideal dielectric fluid are as follow:

1. It should have high dielectric strength.

2. It should have low viscotity.

3. It should be free from toxic vapours.

4. It must have chemical neturality.

5. It should have good cooling capability.

4.6 LASER BEAS MACHINING (LBM)

The word LASER stands for "Light Amplification by Stimulated Emission of Radiations". In Laser beam machining, the mono-frequency stimulatedbeam of light of order 10 is focused on the surface of workpiece to remove the metal by melting and evaporation.

4.6.1 Principle Of Laser Beam Machining

The principle of Laser beam machining is that the light energy of a particlar frequency is used to stimulate the electrons in an atom to emit additional light having exactly the same characteristics of the original light source.

4.6.2 Process of Laser Beam Machining

The process Laser beam machning includes following steps as shown in fig. 4.16.

1. The work-piece is held in work holding device below the laser mechaism.

2. When the atom falls back to original energy level, an intense beam of visible light is emitted.

3. When this light is reflected back again and again, more atoms are excited and stimulated to return to ground level.

5. In, this way, laser beam machining works.

4.6.3 Advantages of Leser Beam Machining

1. No distortion of work-piece occurs.

2. Its is a non-contact process.

3. Minimum heat production rate.

4. High production rate.

5. Process can be easily automated.

6. High beam efficiency.

4.6.4 Disadvantages of Laser Beam Machining

1. High cost operation.

2. Overall efficiency is low.

3. Highly skilled workers are required.

4.6.5 Application of Laser Beam Machining

1. It is used for mocro welding and micro drilling works.

2. Drilling the hole in rubber bady bottle nipple.

3. Relief hole in pressure plugs.

4. Producing holes in aerosol spray nozzles.

5. Making holes in surgical and hypodermic needles.

4.7 PLASMA ARC MACHINING (PAM)

When a flowing gas is heated to a sufficient high temperture to become partially ionized, it is called plasma.

4.7.1. Principle and Working of Plasma Arc Machining

The principle of plasma arc machining is shown in fig. 4.17. In the plasma torch, a volume of gas such as hydrogen, nitrogen, oxygen etc. is passed through a small chamber in which a high frequency spark is maintained between tungsten electrode (cathode) and copper nozzle (anode). Both the electrodes are water cooled. The high velocity electrons produced by the spark collide with the ags molecules and produce dissociation of molecules of gas resulting in ionization of atoms. Due to this, a large amount of heat energy is generated.

4.7.2 Advantage of Plasma Arc Machining

1. It is a faster process.

2. It can be used to cut any metal.

4.7.3 Disadvantages of Plasma Arc Machining

1. Initial cost of equipment is quite high.

2. The work surface may undergo some metallurgical changes.

3. Adequate safety precautions are always required for the operator.

4.7.4 Applications of Plasma Arc Machining

1. Cutting stainless steel and aluminium alloys.

2. Turning and milling of materials which and hard and difficult to machine.

CHAPTER 5

METAL COATING PROCESSES

5.1 Metal Spraying

Metal Spraying is also known as spray metalizing. It is a process of providing a thin coating by depositing an atomized metal on the surface of the base metal. In this process, the coating metal in molten state is sprayed on the prepared surface of the base metal. The metal to be deposited may be used either in the form of the wire or powder. The surface to be metalized should be properly cleaned before metalizing to ensure perfect adhesion of the spray metal and deposition of an even and uniform layer. Following are the two common method of metal spraying.

1. Wire gun method,

2. Powder metal method.

1. Wire gun method: In this method, special type of spray gun is used which carries a gas torch. This is attached with oxygen and acetylene cylinders. The schematic diagram of wire gun methods is show in fig. In this method, the wire is draw through the gun and nozzle by a pair of rollers and melted by an oxy-acetylene flame. Then a blow of compressed air is used with a high velocity to atomize the molten metal and deposit it uniformly on the prepared surface. Depending upon the required thickness of the metalized coating, many such layers are laid over one another to build up the required thickness.

Advantages of Wire Gun Method:

The followings are advantages of wire gun method:

(i) The wire is less costly than powder.

(ii) The wire can be fed into spray gun at a definite rate.

(iii) The wire gun method is more rapid and can be easily handled.

2. Powder Metal Method: This method is also known as thermosray method. In process, the coating material is used in powdered form and not in wire form. The metal powder is filled in a hopper, where it is fed through a rubber hose to the spray gun. The metal powdergets melted as it passes through the oxy-acetylene or 0xy-hydrogen gas flame. The metal is already in the atomised form, the blast of compressed air needed is just sufficient to deposit the molten metal on the surface being coated.

Advantage of Powder Metal Mthod:

The advantage of powder metal method are as follow:

(i) It can be applied to large and irregularly shaped objects.

(ii) It can be pplied to fabricated structure and there is no possibiliy of damages to the coating.

(iii) It can be applied to non-metallic objects made of glass, wood, plastic, etc.

5.2 Anodizing Coating

Anodising is an oxidation process developed for aluminium. An electrilyte of sulphuric acid, oxalic acid, chromic acid or phosphoric acid is employed with the part to be anodised which acts as anode.

The thickness of the resuliant coating depends on the type of electrolyte, temperture, current density used and time of application.

The process is generally completed in three different stages. The firet stage consists of clening and preparation of surface. The second stage consists of anodizing i.e. convertig the metal surface into an oxidised film.

5.3 Process of Anodizing Coating

1. when an electriccurrent (generally D.C.) is suplied to electrolyte, hydrogen is produced at the cathode and oxygen at the anode.

2. Oxygen instantly tries to combine with any material brought in contact with it.

Anodizing coating can also be produced on zinc and magnesium. Zinc is made the anode in a solutio of chromic acid or chromate, whereas mageium is treated electrolytically in a soluion of sodium chromate and monosodium phosphate or in sodium hydroxide containing an oxidizating agent such as potassium permanganate.

5.4 Galvanizing

Galvanizing is a commercial term used to designate a process by which a zinc coating is provided on steel by immersion in molten zinc to protect the steel from corrosion.

The application of Zinc coating to steel surface used for protection against corrosion has been in practice for many years. Galvanizing is applied only to mild steel, cast iron and steel alloys. The temperture of molten zinc is kept above 500C in this process Galvanizing improves the resistance against corrosion caused due to atmosphere and water. As zinc is anodic to iron or steel (which serves as cathod), therefore, the zinc coating also called anodic coating is obtained by electro-chemical reaction between the zinc and the iron or steel.

1. The preliminary cleaning of the metal products to be coated.

2. The regulation on the bath temperature.

For production of zinc coating on irregularly shaped articles, the process is entirely a manual operation. Articles such as bolts, nuts laundry tubes etc.

5.5 Advantage of Galvanizing:

The advantges of galvanizing are as follow:

1. It is very simple in nature.

2. It is best suitable for irregular shape products.

3. It can be obtained at low cost and in a comparatively pure state state.

4. It takes less time.

5.6 Disadvantages of Galvanizing:

The main disadvantages of galvanizing are as follow:

1. It is used for limited metal i.e. mild steel, cast iron and steel alloys.

2. As zinc gets dissolved in dilute acid to form highly toxic compound, therefore, the glavanisd utensils should not be used preparing and storing food stuffs especially acidic ones.

5.7 Application of Galvanizing:

The main applications of galvanizing are as follow:

1. It is used for roofs and wallls of buildings.

2. Structural parts.

3. Fencing material.

4. Pipes.

5. Containers.

6. Wires etc.

5.8 POWDER COATING

Powder coting is a dry coating which is applied as a free flowing dry powder. The basic difference between powder coting and conventional liquid paint is that the powder coating does not require a solvent to keep the binder and filler parts in a liquid suspension form. The powder coating is applied statically and is then cured under heat to allow it to flow and form a skin. Powder coating is used to create a hard finish which is tougher than conventional paint.

5.9 Types of Powder Coating

There are two types of powder coating:

1. Thermosetting,

2. Thermoplastic.

The thermosetting variety incorporates a cross linker into the formulation. When the powder is baked, it reacts with the other chemical groups in the powder polymer and increases the molecular weight and improves the performance properties. The thermoplastic variety does not undergo any additional reactions during the baking process.

5.10 Process of Powder Coating

The powder coating process involves the following three steps:

1. Part preparation,

2. Powder application,

3. Curing.

1. Part Preparation: Removal of soil, oil grease, metal oxide, welding scale etc. is essential prior to powder coating. It can be done by a variety of chemical and mechanical methods. The selection of the a particular method depends upon the size and material of the part to be powder-coated the type of soil to be removed and the performance requirement of the finished product.

2. Powder Application: The most common way of applying powder coating to the metal objects is to spray the powder with the help of an electrostatic gun or corona gun. The gun imparts a positive charge on the powder which is then sparyed to the object which is grounded.

3. Curing: When a thermoset powder is exposed to high temperature, it begins to melt, flow out and then chemically reacts to from a higher molecular weight polymer in a network like structure. The curing process called cross-linking requires a certain degree of temperature for a certain period of time in order to reach full curing and establish the full film properties for which the material was designed.

5.11 Advantage of powder Coating

The following the advantage of powder coating over conventional liquid coating.

1. It emits zero volatile organic compounds.

2. It can produced much thicker coating without running or sagging.

3. Its overspray can be recycled and thus it is possible to obtain 100% use of coating.

4. Powder coating production lines produce less hazardous waste than conventional liquid coating.

5. Equipment and operating cost for powder coating production lines is usually less than conventional liquid lines.

5.12 Disadvantage of powder Coating

The major disadvantage of powder coating is that thin smooth films cannot be obtained.

CHAPTER 6

METAL FINISHING PROCESSES

6.1 PURPOSES OF FINISHING SURFACES

The main purpose of finishing surfaces of metal parts are as follow:

1. To improve the functional properties of the machine parts such as wear resistance, corrosive resistance, fatigue resistance etc.

2. Top improve surface appearance of the metal parts by polishing, buffing, burnishing and tumbling.

3. To remove fins and scale from parts.

4. To remove micro finish.

5. Top make higher contact area.

6. To increase the surface life of parts.

6.2 SURFCAE ROUGHNESS

It is known to us that no surface is perfectly smooth. Even the surface produced by super finishing processes show micro irregularities when they are seen under microscope. These irregularities affect the functional qualities of mating parts and are called surface. An actual surface roughness. Thus surface roughness may be defined as fine irregularities in the surface.

1. Ideal Surface: Ideal surface may be defined as the perfect surface without any micro-irregularity.

2. Roughness Width: Roughness width may be defined as the distance between two adjacent peaks or valleys.

3. Roughness Height: Roughness height may be defined as the arithmetic mean deviation measured from the centre line. It is measured in microns.

4. Waviness : Waviness may be defined as the surface irregularity in the from waves having larger wave length.

5. Waviness Width: Waviness width may be defined as the distance between two successive wave peaks or valleys. It is measured in mm.

6. Waviness Height: Waviness height may be defined as the distance between peak and valley of the waviness curve.

6.3 HONING PROCESS

1. The work piece is clamped rigidly on the work table. Care must be taken to keep the bore exactly parallel to the axis of the hone spindle.

2. The abrasive sticks of aluminium oxide or silicon carbide are mounted on a mandrel or fixture.

3. A floating action between the work and the tool prevails so that any pressure exerted on the tool is transmitted equally on all sides.

4. The stroke and working length must finally be adjusted which the hone must follow in order to obtain a good cylindrical bore.

5. The hole to be honed is flooded with a lubricant like paraffin, hard oil mixed with kerosene, while the honing stick acts as metal removal. Lubricant is used for following two purposes:

(i) To carry away the heat.

(ii) To finish away the chips.

Both internal cylindrical and flat surface can be honed. But, the process of honing is largly applied to internal cylindrical surface only. Fig. 6.3 shows a hone and simplified representation of honing operation for a cylindrical hole.

6.4 HONE

Hone is a metal frame which holds the abrasive sticks during honing operation. It is also known as honing tool. Hones may be of two types.

1. Internal hones,

2. External hones.

1. Internal Hones: When a hone is used to finish an internal cylindrical surface, it is called internal hone. Internal honing is carried with the help of abrasive sticks which are mounted on the expanding head or hone in the holder as shown in fig. 6.4. By spring action, the stones/sticks can be fed over a predetermined distance during honing operation. The hone is connected with the spindle of machine through universal joint which allows it to align itself with the hole. This method is mostly used for finishing automobile cylinders. The desired honing pressure is also set. Hones are built in a wide range of sizes and also in different forms for through hole and blind hole honing.

2. External Hones: When a hone is used to finish an external cylindrical surface, it is called external hone. Fig . 6.5 shows the two different designs of external hones used to finish external cylindrical surface.

Honing of external surfaces can be successfully accomplished by mounting four sticks held in holders on contracting yoke. The work-piece is rotated while the sticks envelop the work-piece. Only a little pressure is applied on the sticks.

6.5 METERIAL OF HONING TOOL

The honing tool is made up of following two materials:

1. Abrasive material,

2. Bonding material.

1. Abrasive material: Aluminium oxide (Al_2O_3) Silicon carbide (SiC), diamond etc. diamod etc. are most commonly used grit particles. The grit size is 150 to 180 for roughing and 600 for finishing operations.

2. Bonding Material: In holds the grit during its cutting life, but should not be so hard that it may rub against the bore and reTARD the cutting action. The bond of abrasive is often treated with a fill of wax, sulphur, resin and other material to control the cutting action and increase the life

6.6 COOLANT USED IN HONING PROCESS

A liberal supply of coolant is necessary for honing. The coolant is used for the following two purposes:

1. To carry away the heat.

2. To flush away the chips.

For this, lard oil mixed with kerosene can be used. Sometimes, turpentine, soap and water solution are also used.

6.7 TYPES OF HONING/METHODS OF HONING

Honing is broadly into groups as follow:

1. Manual honing,

2. Machine honing.

1. Manul Honing: In this method, the motion of job or of honing tool is controlled by the operator with his hands which may be performed in either of the following two methods:

(i) The tool is rotated and job is passed back and forth over the tool.

(ii) The job is help in a fixture and tool is rotated as well as given slow back and forth quantity during the operation and it is necessary that a suitable coolant should be used in sufficient quantity during the operation. Hand honing tool and honing process.

2. Machine Honing: The honing proecess can be done on many deneral purpose machines such as lathes and drilling machines by holding the holding tool in tailstock of lathe or by mounting the tool in place of drill. In case of production work, where honing is to be done on a large scale, such machines will fail to give the desired results. In such cases,

LAPS

A lap is a solid rectangular, cylinderical or circular block of soft metal charged with abrasive powder or compound and is used for obtaining extremely accurate and finished surfaces.

TYPES OF LAPPING OPERATIONS

The lapping operations can be classified into main groups:

1. Equalising lapping,

2. Form lapping.

1. Equalising Lapping: The operation in which work and lap mutually improve their shape and surface is known as equalising lapping. e.g. gear running together with some, tappet valves seated in seats.

2. Form Lapping: As is clear from the name, it is the shape of the lap which is responsible for finishing a corresponding work surface.

MATERIALS USED IN LAPPING PROCESS

The following three materials are required for lapping process;

LAPPING PROCESS/ TYPES OF LAPPING METHOD

Lapping methods are brodly classified into groups:

1. Hand lapping,

2. Machine lapping.

1. Hand Lapping: This is carried out by the operator himself. He can hold the small workpiece in one hand by another hand, he can do the lapping. If the work piece is large and heavy, then it can be help in a fixture and he can do lapping by hand. The work is turned frequently to obtain unifrom cutting action. This method is used for lapping press work dies, dies and metallic moulds for castings etc.

Hand lapping is further sub-classified as follow:

(i) Here the lap is falt similar to a surface plate. The suitable lapping compound is spread on lapping plate. Then, for finishing of the work surface, either the lap or the work piece is help by one hand and the irregular rotary motion of the other by the second hand, enables the abrasion of the two surface in contact.

(ii) Lapping Cylinderical Work (External Lapping): An external lap for external round work piece is shown in fig 6.12. It is also known as ring lapping. The external surface of pin or shaft type work can be lapped on ordinary lathes with hand laps. The lap shown in fig 6.12 is an adjustable ring of copper, white metal (used for rough lapping) or cast iron (used for fine lapping) During the proces, the ring lap is reciprocated by hands over the work piece surface.

(iii) Lapping of Holes (Internal Lapping) This makes use of a rod like lap for lapping of holes as shown in fig 6.13. To lap cylindercal hole e.g. in a bush, the hand lapping operation can be carried out on ordinary lathe.

2. Machine Lapping: In this, either the work-piece or the lap is given the rotation by machine, while the other one is held stationary. It uses a motor driven lap and is used to obtain highly finished surface on races of ball and roller bearings, worm, gears, cam shaft, piston pins and gauges, injector pump parts, spray nozzles etc.

It consists of two circular plates (wheels), onr above the other. the workpieces which are to be lapped are placed between these two plates and loose abrasive grains with vehicle are fed.

THe parts to be lapped are confind into cages that impart rotary and gyratory motions at the same time due, to which the entire of the two plates are converted.

6.27 LAPPING MACHINES

The various lapping machine used are as follow:

1. Vertical axis lapping machine,

2. Abrasive belt lapping machine,

3. Spherical lapping machine,

4. Roller type lapping machine,

5. Centre less axis lapping machine.

6. Vertical axis lapping machine with bonded abrasive wheels as laps.

1. Vertical Axis Lapping Machine: Fig 6.15 shows a vertical axis lapping machine carrying a stationary lap and rotary lap on bottom side and in between, a work-piece is mounted for lapping. During lapping, a pressure of 0.007 to 0.02 N/mm^2 for soft materials and up to 0.07 N/mm^2 for hard materials is maintained. It is a general purpose machine used for lapping external cylindrical and flat surfaces. A column carries a swinging overarm which supports the upper lap.

In some machines, the upper lap is kept rotating, whereas in some other machines upper machines upper and lower laps rotate in opposite directions.

2. Abrasive Belt Lapping Machine: This machine is used for lapping of crankpins, crankshafts, aeroplane engine cams etc. it is a horizontal axis machine. It has a horizontal spindle. It neither uses embedded abrasive laps nor bonded wheels. It is coated with abrasive paper or cloth.

3. Spherical Lapping Machine: Fig. 6.16 shows a spherical lapping machine. It is used for spherical surface lapping and works similar to drill press. A crank

6.28. POLISHING

This is another finishing operation and superior to other method except buffing. It is used for removing scratches, tool marks, surface pits and such other defects which might have been left after working of the job on machines and with various tools. The work piece is help against the rotating polishing wheel which is made of leather or cloth glued with abrasive grains.

The primary objective of this operation is to improve surface finish only and it is, therefore, employed only where dimensional accuracy is not to be closely controlled. Polishing is an intermediate abrasing process which follows grinding and precedes buffing operation.

6.29. BUFFING

Buffing is a smoothening and brightening process on a surface by the rubbing action of fine abrasives in a lubricating binder applied intermittently to a moving wheel of wood, cotton, fabric, felt or cloth. The is an improvement over polishing. In this, material removed is almost nil.

6.30 BURNISHING

Burnishing is an operation of producing bright polished finish on the surface of metal by the rubbing action of burnishers which are made of very hard material having highly polished surface. Burnishing can remove small scratch marks from the metal surface. When burnishers are rubbed over the metal being treated with pressure, no metal is actually removed, but an action somewhat resembling to flow of metal takes place.