CHAPTER 7

GRINDING

7.1 INTRODUCTION

Grinding operation is a method of machining workpieces by the use of a rotary abrasive tool, called "Grinding Wheel". Such wheels are made of fine grains of abrasive materials held together by a bonding material, called a 'bond'. Each individual and irregularly shaped grain acts as a cutting element (a single point cutting tool).

Definition

Grinding processes are chip-making metal cutting process, just like drilling, turning and milling. However, grinding processes remove very small chips (called swarf) in very large numbers by the cutting action of many small individual abrasive grains. These abrasive grains are formed into a grinding wheel that is rotated against the workpiece at high speed. Each sharp edge of a grain cuts a small chip of material from the workpiece.

In addition the chip making aspects of grinding (similar to milling) with an infinite number of cutting edges. Dimensional accuracy is in the order of 0.000025 mm.

Grinding is used for the following purpose:

i) Machining materials which are too hard for other machining processes such as tool and die steels and hardened steel material.

ii) Close dimensional accuracy of the order of 0.3 to 0.5 μm and,

iii) High degree of surface smoothness such $R_a = 0.15$ to 1.25 μm.

7.1.1 Basic kinds of Grinding

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

1. Rough Grinding

Rough grinding is a commonly used removing excess material from castings, forgings and weldments or as a method for removing or snagging thinfins, sharp corners, burrs or other unwanted projections from various shapes of workpieces. Where the work is held in the operator's hand. The work is pressed against the hard wheel or vice-versa. The accuracy and surface finish obtained are of secondary importance.

Snagging is done where a considerable amount of metal is removed without regard to the accuracy of the finished surface. For example: grinding are trimming the surface left by sprues and risers on castings, cracks, scales and imperfections on alloy steel billets.

2. Precision Grinding

This is the principal of cutting material that are too hard to be machined by other conventional tool or for producing surfaces on parts to higher dimensional accuracy and finer surface finish as compared to other manufacturing methods. Since cutting edges of the grits are extremely thin it is possible to remove much smaller chips and refine surfaces to a much greater accuracy of finish and dimension than with other machining methods.

Grinding, in accordance the type of surface to be ground as classified as:

i) External cylindrical grinding
ii) Internal surface grinding
iii) Surface grinding
iv) Form grinding

The above first three basic kinds of precision grinding as shown in figure.

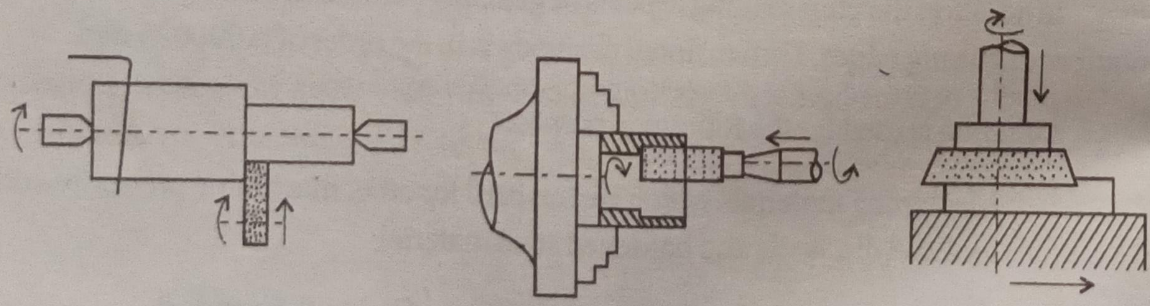


Figure 7.1 Basic Kinds of Precision Grinding

i) External cylindrical grinding

External cylindrical grinding process a straight or tapered surface on a workpiece. The workpieces must be rotated about its own axis between centres as it passes lengthwise across the face of a revolving grinding wheel.

ii) Internal cylindrical grinding

Internal Cylindrical grinding produces internal cylindrical holes and tapers. The workpieces are chucked and precisely rotated about their own axis. The grinding wheel or in the case of small bore holes, the cylinder wheels rotates against the sense of rotation of the workpiece.

iii) Surface grinding

Surface grinding produces flat surface. The work may be ground by either the periphery or by the end face of the grinding wheel. The workpiece is reciprocated at a constant speed below or on the end face of the grinding wheel.

iv) Form grinding

Form grinding is done with specially shaped grinding wheels that grind the formed surfaces as in the grinding gear teeth, threads, splined shaft, holes and spheres etc.

7.2 TYPES OF GRINDING MACHINES

Metal working machines in which the cutting of metal is performed by abrasive action is known as grinding machines. Grinding machines can be classified in different ways.

According to the quality of surface finish, may be classified as:

1. Rough Grinding or non-precision grinding
2. Precision Grinding or finish grinding

Rough Grinders

Rough grinders are those grinding machines whose chief work is the removal of stock without any reference to the accuracy of the results. This class of grinders includes the following types:

i) Floor stand and bench grinders.

ii) Portable and flexible shaft grinders.

iii) Swing frame grinders.

iv) Abrasive belt grinders.

Precision Grinders

Precision grinders are those that finish parts to a very accurate dimensions.

According to the type of surface generated or workdone they may be classified as follows:

1. Cylindrical Grinding are mainly classified into three types:

i) Plain cylindrical grinder

ii) Universal cylindrical grinder

iii) Centreless grinder

2. Internal Grinders

(a) Chucking internal grinders

i) Plain internal grinders

ii) Universal internal grinders

(b) Planetory internal grinders

(c) Centreless internal grinders

3. Surface Grinders

According to the table movement,

(a) Reciprocating table type

i) Horizontal Spindle type

ii) Vertical Spindle type

(b) Rotating table type (According to the direction of spindles wheel)

i) Horizontal Spindle type

ii) Vertical Spindle type

4. Tool and Cutter Grinders

i) Universal grinders

ii) Special grinders

5. Special Grinding machines and single purpose grinders are

i) Roll grinders

ii) Cam Shaft grinders

iii) Disc grinders

iv) Crank shaft grinders

v) Piston grinders

vi) Thread grinders

vii) Tool post grinders

viii) Way grinders (or) Form grinders

xi) Gear teeth grinders

7.3 ROUGH GRINDERS

7.3.1 Floor Stand Grinder

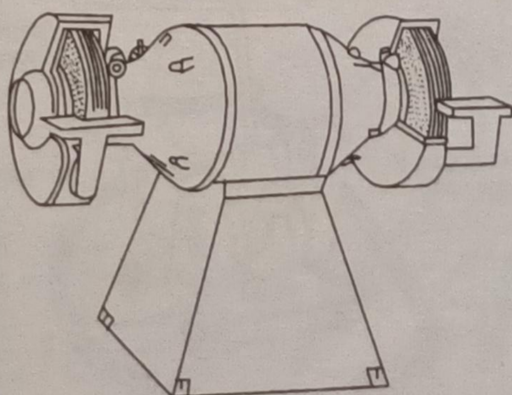


Figure 7.2 Floor Stand Grinder

A floor grinder consists of an electric motor mounted on a suitable base. The motor consists of a rotor shaft extending from each side, with a grinding wheel mounted on each end as shown in figure (7.2). Floor grinders used for heavy duty work consists of a wheel shaft mounted on heavy duty bearings. They are used for sharpening tools, tool bits, boring tools, drills etc.

One side wheel of a floor grinder consists of coarse grains while the other consists of fine grains. A coarse grained wheel is used for rough grinding, snagging or heavy work. A fine grained wheel is used for grinding cutting tools.

7.3.2 Bench / Pedastal Grinder

It is similar to floor grinder except for the size. It is fitted on the bench. These machines are used for grinding of tools and miscellaneous parts. Polishing wheels may be run on these grinders.

7.3.3 Portable and Flexible Shaft grinder

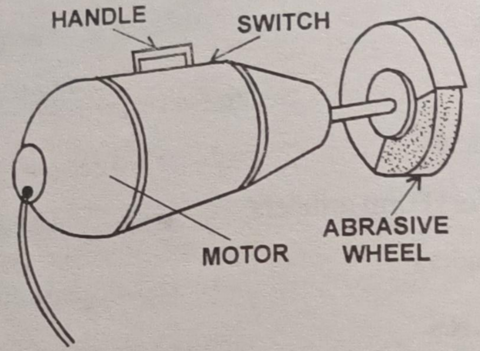


Figure 7.3(a) Portable and Flexible Shaft grinder

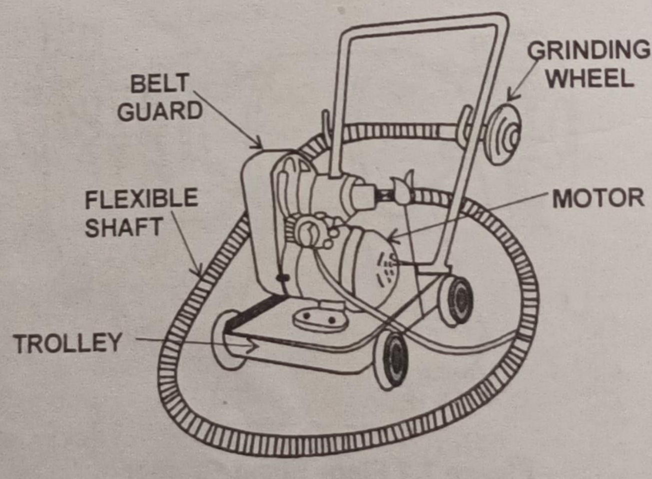


Figure 7.3(b) A trolley mounted flexible shaft grinder

A portable grinder as shown in figure 7.3(a) resembles a portable electric drill in shape. It consists of a small electric motor fitted in the casing at one end. The grinding wheel is mounted at the other end. These are used for finish castings, welded joints in a structural work etc.,

Flexible grinder similar to portable type. This has grinding wheel as the end of a long flexible shaft driven by a motor on a relatively stationary stand. It can be easily moved about and may be used to the advantage in removing comparatively small amount of stock from the widely separated areas.

7.3.4 Swing frame grinder

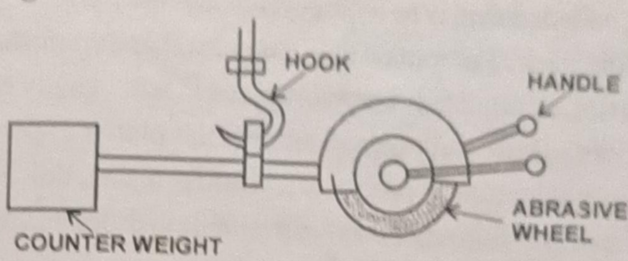
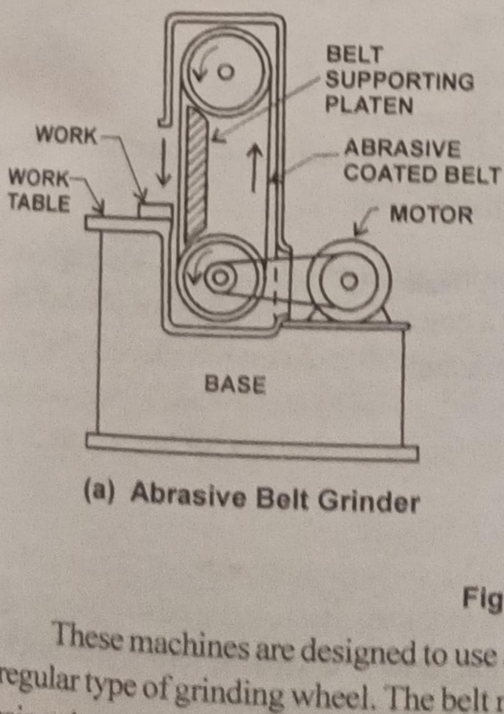


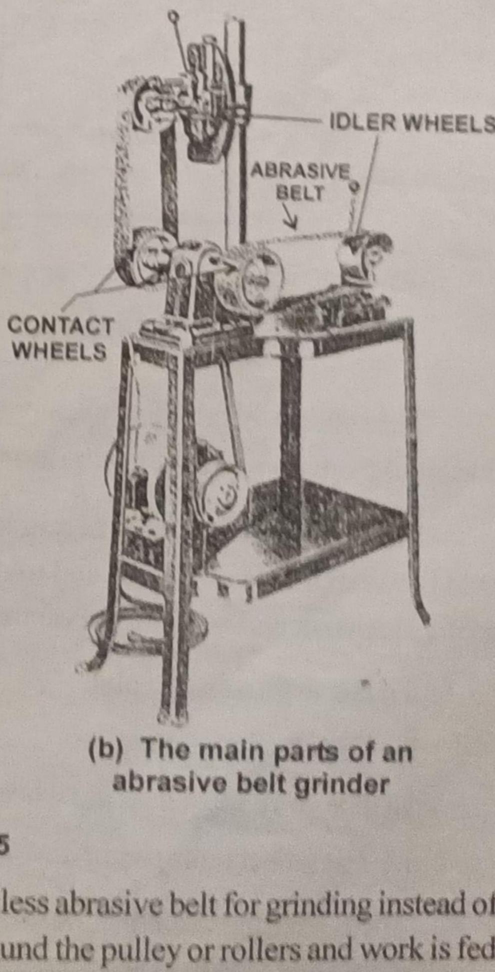
Figure 7.4 Swing frame grinder

It is used to remove material from the objects which are heavy and inconvenient to handle. It has a horizontal frame 2 to 4 meters long, suspended at the centre of gravity and having a grinding wheel on one end. The operator guides the frame and applies the wheel to the job. This is used for snagging casting which are too heavy and large.

7.3.5 Abrasive belt grinder



(a) Abrasive Belt Grinder



(b) The main parts of an abrasive belt grinder

Figure 7.5

These machines are designed to use an endless abrasive belt for grinding instead of a regular type of grinding wheel. The belt runs round the pulley or rollers and work is fed against the revolving abrasive coated belt. One of the roller (driver) revolves at high speed.

A heavy metal plate, called platen, is so incorporated that the smooth underside of the belt runs in contact with the same. This platen may carry the shape conforming to the shape of an object or may be flat, as required. The workpiece is fed, usually manually, on to the open abrasive side of the belt and pressed against the platen to perform the grinding operation. With proper selection of proper grade and grit size, this process can be used both for rough and finish grinding machines are available in different varieties like wet-belt, dry belt, combination machines etc.

7.4 PRECISION GRINDERS

7.4.1 Cylindrical grinders

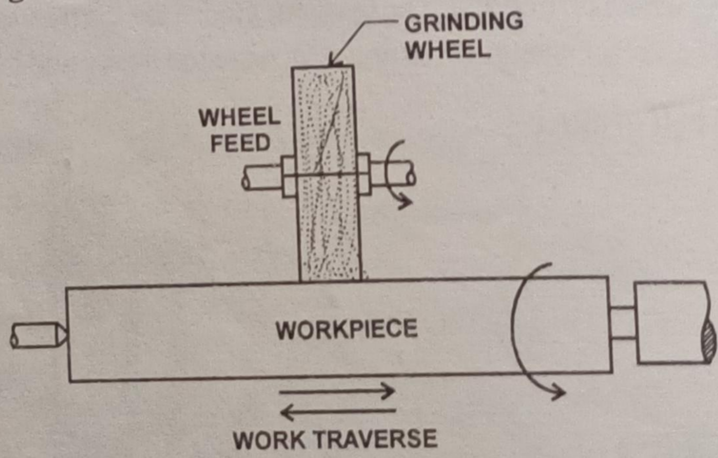


Figure 7.6 Cylindrical grinder

The cylindrical grinding machines, surface grinding machines and internal grinding machines comes under precision grinding machines catergory.

The principal of cylindrical grinder is illustrated in figure (7.6). In this workpiece is held between the dead centres and rotated by a dog and driver on the face plate. There are four movements in cylindrical centre type grinding.

i) The work must revolve

ii) The wheel must revolve

iii) The work must pass the wheel

iv) The wheel must pass the work

These grinding machines are used for grinding plain cylindrical parts, although they can also the used for grinding contoured cylinders, tapers, shoulders etc.

In cylindrical grinding, two types of grinding operations are done

i) Traverse grinding ii) Plunge grinding

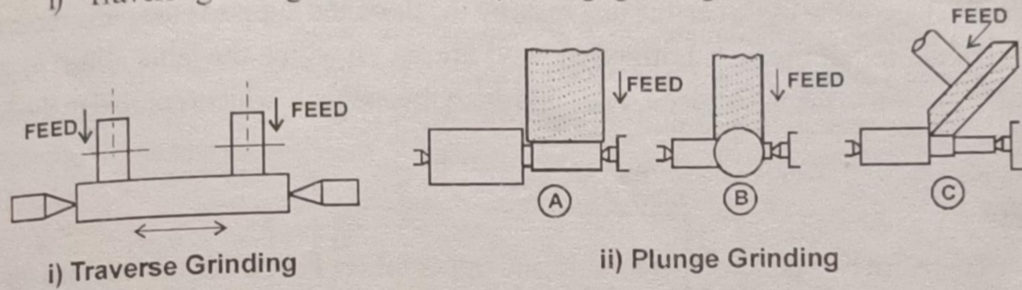


Figure 7.7 Types of Cylindrical Grinding

Traverse Grinding

In this work is reciprocated as the wheel feeds to produce cylinders longer than the width of the wheel.

Plunge Grinding

In plunge grinding, the work rotates in fixed position as the wheel feeds to produce cylinders of a length equal to or shorter than the width of the wheel. The general range of work speeds for cylindrical grinding is from 20 to 30 mpm (surface speed in meter per minute). Plunge grinding requires very low speed.

7.4.1.1 Plain centre type grinders

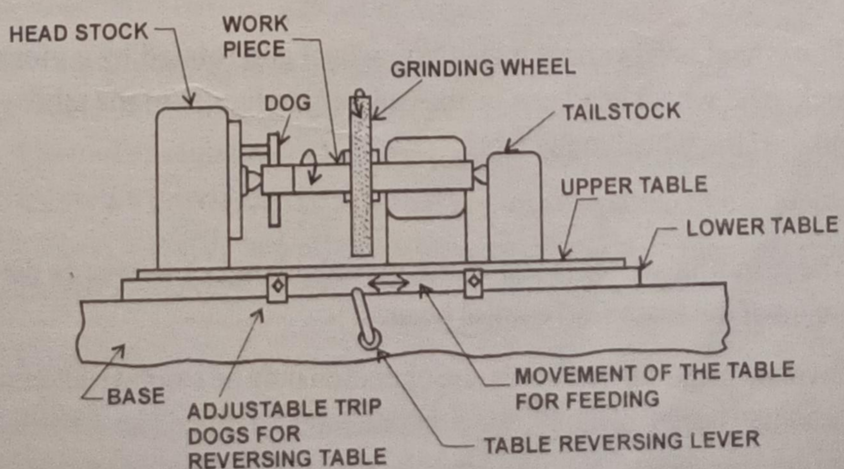


Figure 7.8 Plain Centre type grinder

In a plain centre type grinding machine and cylindrical grinding machine are shown in figure. It consists of the various parts.

Base

The base is the main casting that rests on the floor and supports the parts mounted on it. On the top of the base horizontal ways are set on which the table slides to give traverse motion to the work piece. The table drive mechanism is incorporated in the base itself.

Tables

There are two tables - lower table and upper table. The lower table slides on the ways of the bed and provides traverse of the work past the grinding wheel. It can be moved by hand or power within the limits. Headstock and tailstock are mounted on the upper table. The upper table can be swivelled upto 10° relative to the main table traverse.

Head Stock

The headstock supports the workpiece by means of a dead centre and drives it by means of a dog or it may hold and drive the work piece in a chuck. The workpiece is rotated by separate motor housed in the head stock

Tail Stock

The tail stock can be adjusted and clamped to accommodate different lengths of work pieces. It moves in end out, manually or hydraulically.

Wheel Head

The wheel head carries a grinding wheel and rotated by a motor housed in the headstock. The wheel head can be moved perpendicular to the table ways by hand or power to feed the wheel to the work.

Cross Feed

The grinding wheel is fed to the work by hand or power as determined by the engagement of the cross feed control lever.

On plain grinding machines, the operation may be stopped automatically when the work piece has been finished to size. In one method is used an automatic type gauging attachment to measure the work piece and stop the operation at the proper time.

7.4.1.2 Universal centre type grinders

Universal grinders are widely used is tool room for grinding tools etc., the features of this machine are similar to those of plain grinders, but in addition it is provided with swivelling headstock and swivelling wheel head.

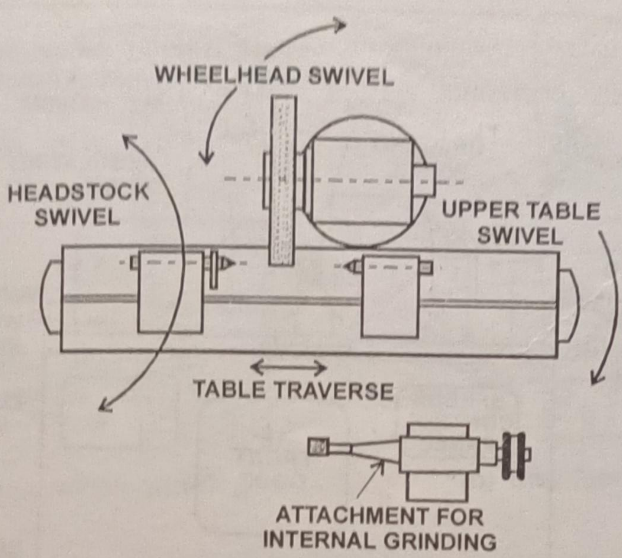


Figure 7.9 Universal Centre Type grinder

A universal machine has the following additional features:

1. Its headstock can be made to carry a live or dead spindle, as desired, the former being needed when the work is held in a chuck.
2. The head can itself be swivelled in a horizontal plane.
3. Its wheel head can be raised or lowered and can also be swivelled to ± 90° to grind tapered surfaces having large taper angles.

All these factors contribute towards the greater versatality of these grinders. All the modern universal type cylindrical grinders carry hydraulic drive for wheel head approach and feed, table traverse and elimination of back lash in the feed screw nut. Most of the modern universal grinders are provided with necessary extra equipment like work rest to support slender work, wheel truing device, arbor for balancing the wheel, internal grinding spindle and a three jaw self-centering chuck etc.

7.4.1.3 Centreless grinders

Centreless grinding is a method of grinding exterior cylindrical, tapered and formed surfaces on workpieces that are not held and rotated on centres. The principal elements of an external centreless grinder shown in figure 7.10 are the grinding wheel, regulating wheel or back up wheel and the work rest. Both wheels are rotated same direction. The work rest is located between the wheels. The work is placed upon the work rest, and the latter, together with the regulating wheel, is fed forward, forcing the work against the grinding wheel.

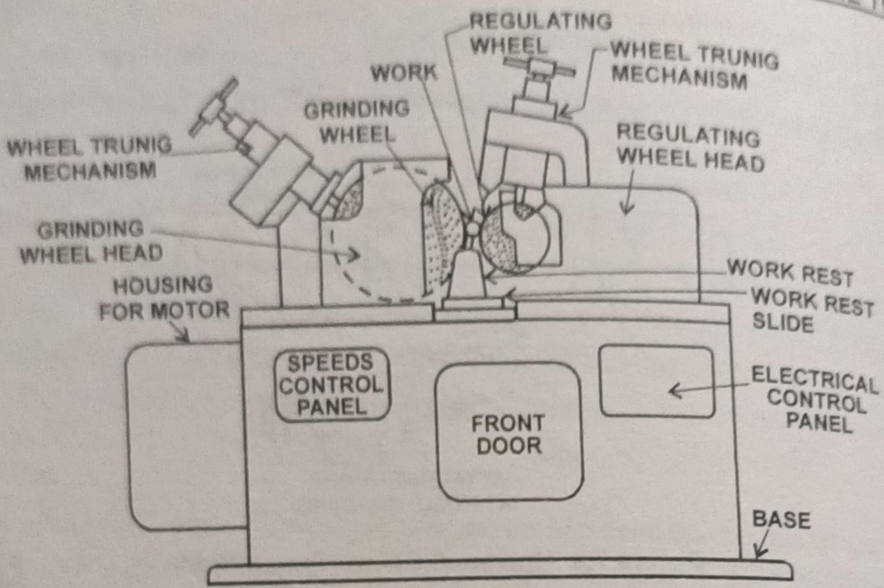


Figure 7.10 Centreless grinder

The axial movement of the work past the grinding wheel is obtained by tilting the regulating wheel at a slight angle from horizontal. An angular adjustment of 0 to 8 or 10 degrees is provided in the machine for this purpose. The actual feed (s) can calculated by the formula.

$$S \text{ or } f = \pi d n \sin \alpha$$

where S = feed in mm per minute

n = revolution / min

d = diameter of regulating wheel in mm

α = angle of inclination of regulating wheel

Methods of Centreless grinding

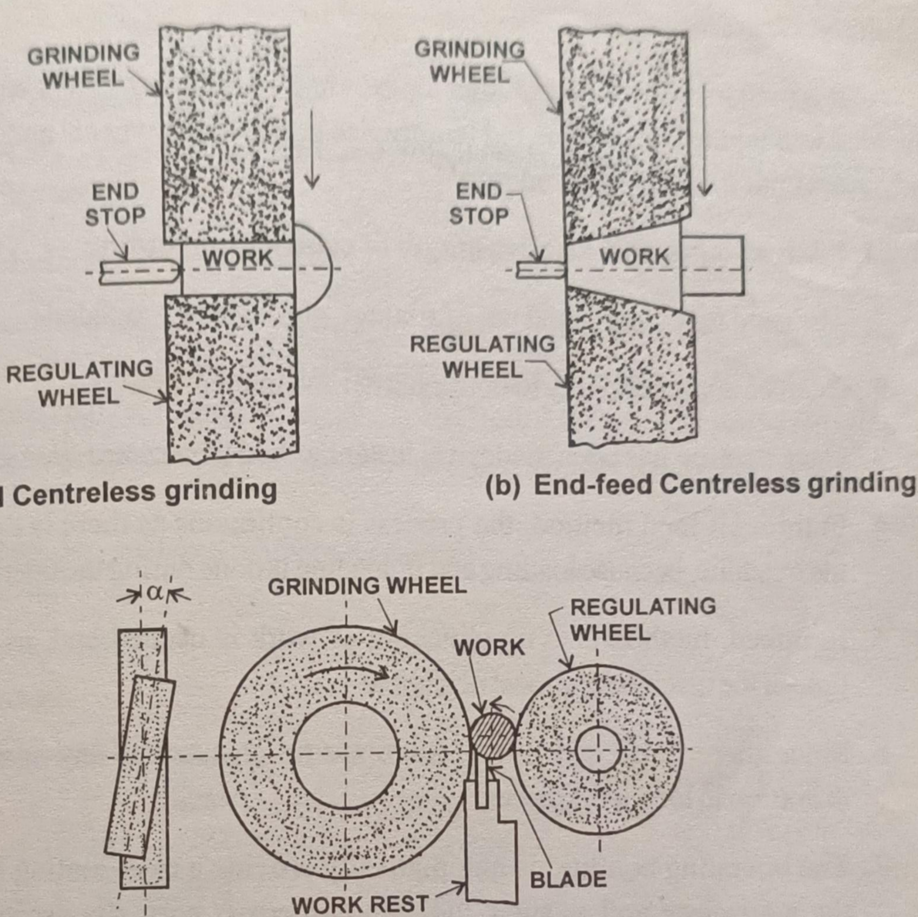
Basically there are three different methods by which centreless grinding can be done on different types of jobs. The common methods used for feeding the work are:

i) Through feed

ii) In feed

iii) End feed

these are illustrated in figures 7.11 (a), (b), (c)



(c) Through feed Centreless grinding

Figure 7.11 Methods of Centreless Grinding

Through Feed

In through feed, the enters from one side of the machine and comes out from the other side with guides at the both ends. This method is used when there are no shoulders or other forms to interfere with the passage of the work. It is useful for grinding long, slender shafts or bars.

The layer of metal removed by the grinding wheel in one pass reduces the diameter of the workpiece by 0.02 to 0.3 mm

Infeed Grinding

It is similar to plunge or form grinding, the regulating wheel is drawn back so that workpieces may be placed on the work rest blade. Then it is moved into feed the work against the grinding wheel. This method is useful to grind shoulders, and formed surfaces.

Endfeed Grinding

It is used to produce taper, either the grinding wheel or regulating wheel or both are formed to a taper. The work is fed lengthwise between the wheels and is ground as it advances until it reaches the end stop.

7.4.1.4 Advantages and disadvantages of centreless grinding

1. The need for centring and use of fixtures, etc., is totally avoided.
2. It can be applied equally to both external and internal grinding.
3. Once a set-up has been made, it is faster method than centre-type grinding.
4. In through-feed method, the process is continuous as there is no idle time for the machine, because loading and unloading is done during the operation itself.
5. In infeed, method also no chucking of work is needed and, as such, the idle time of the machine is almost negligible.
6. Since there is no end thrust, there are no chances of any springy action or distortion in long workpieces.
7. The operating conditions automatically provide a true floating type centre for the workpiece and as such, the common errors normally associated with the centres and centre holes are automatically eliminated.
8. The workpiece is supported rigidly during the operation and can be subjected to heavy cuts, resulting in a rapid and more economical grinding.
9. Since the need for marking and making centre holes is totally eliminated and a smaller grinding allowance is needed, the grinding time is considerably reduced.
10. Large grinding wheels are used and errors due to wheel wear are reduced. So the requirement of wheel adjustment is minimum.
11. A very little maintenance is needed for the machine.
12. Very highly skilled operators are not needed for operating centreless grinders.
13. Direct adjustment for sizes can be made, resulting in a higher accuracy.
14. A fairly wide range of components can be ground.

Disadvantages

1. Work having multiple diameters is not easily handed.
2. In hollow work, there is no certainly that the outside diameter will be concentric with the inside diameter.

7.4.2 Internal grinders

Internal grinders are used to finish straight, tapered or formed holes to the correct size, shape and finish. The depth of cut depends upon the diameter of the hole being ground may vary from 0.02 to 0.05mm in roughing and from 0.002 to 0.01 mm in finishing operations. Most internal grinders are horizontal, although there are relatively few vertical ones in use.

There are three general types of internal grinders

1. Chucking
2. Planetary and
3. Centreless

Chucking type internal Grinders

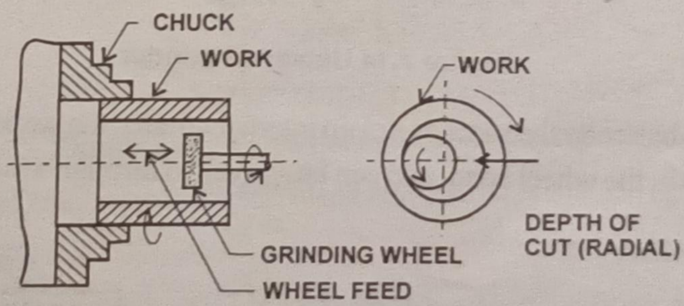


Figure 7.12 Chucking type internal grinders

In this, the work piece is chucked and rotated about its own axis to bring all the parts of the bore or other surfaces to be ground in contact with the grinding wheel. The grinding wheel is rotated at the same time reciprocated back and forth through the length of the hole as shown in figure (7.12).

In another type, known as internal and face grinder, the grinder has two wheels side by side mounted on a horizontal overhead bar. One has a small wheel to grind a hole, and the other has a large wheel for facing in the same set up and squaring with the hole. Internal grinders of chucking type may be classified as plain and universal grinders.

Plain Internal Grinder

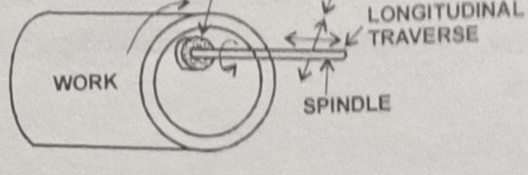


Figure 7.13 Plain internal grinder

The work head can be swivelled to grind a straight hole tapers upto 45° included angle. The wheel head is moved into and away from the hole and can be cross fed into the work.

Universal Grinder

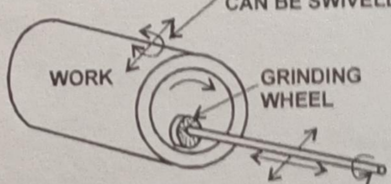


Figure 7.14 Universal grinder

Which is basically the same as a plain internal grinder, the workhead is mounted on a cross-slide as in the wheel head, and can be swivelled through a 90° angle.

Planetory grinders

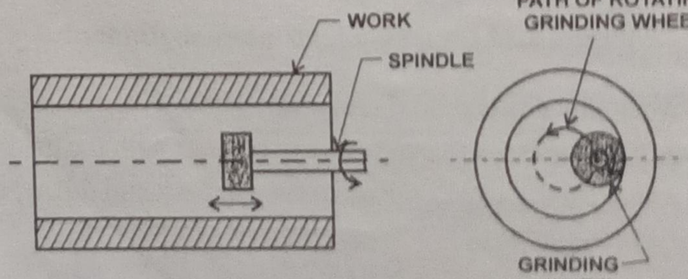


Figure 7.15 Planetory grinder

In a planetory grinder the work piece is mounted on the reciprocating table is not revealed [work remain stationary]. Instead, the grinding wheel is given rotary and planetory motion to grind cylindrical holes. Planetory grinding is usually limited to large and backward workpieces that cannot be conveniently rotated by a chuck. Since in this operation, the moition of the grinding wheel is in the form of planet and hence it is called planetory grinding.

7.4.3 Surface Grinders

Surface grinders are mainly used to grind flat and plane surfaces. They are also used to grind irregular, curved, tapered and other formed surfaces. Machine guide ways, piston rings, valves, dies, surface plates, etc., are some of the parts which are finished by surface grinding.

7.4.3.1 Horizontal spindle - reciprocating table surface grinder

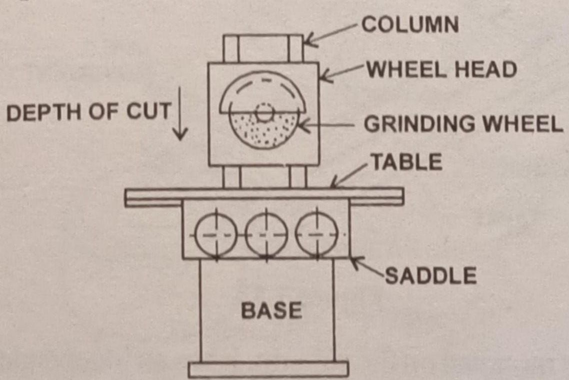


Figure 7.16 Horizontal spindle surface grinder

This type of machine has the following main parts:

Base:

The base is a rectangular box like casting. It houses the driving mechanism inside. It has a vertical column mounted at the back. The base has machined horizontal guideways at the top. The guide ways are perpendicular to the column.

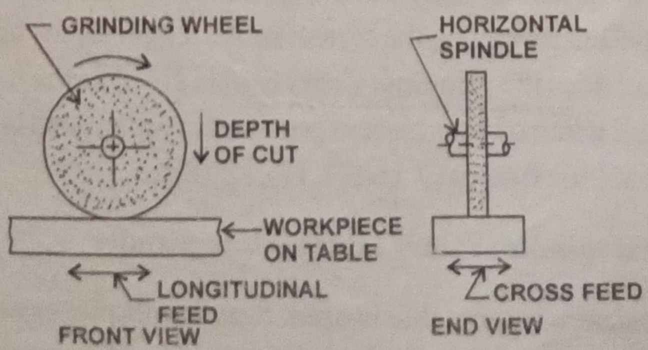


Figure 7.17

Table and Saddle

The saddle is mounted over the base. It can move along with guide ways on the base perpendicular to the column. This gives cross feed to the work.

The table slides on the horizontal guides on the saddle. This movement is parallel to the face of the column. This gives the longitudinal feed to the work. There are T-Slots on the top of the table for clamping workpiece or fixtures.

Wheel Head

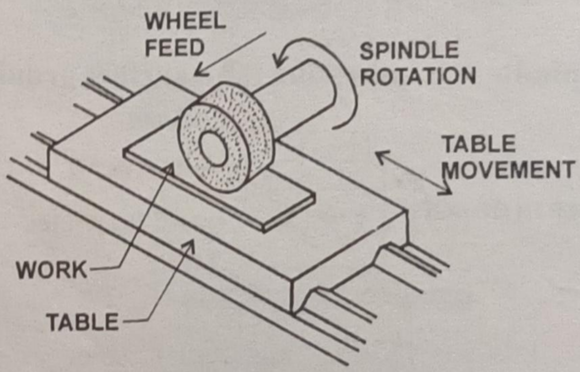


Figure 7.18

The wheel head is mounted on the column. It has an independent motor for driving the wheel. The wheel head can slide up and down along the vertical guide ways of the column. This vertical adjustment of the wheel head is done manually.

This is to accommodate the workpiece of different heights and to give depth of cut.

Operation

The workpiece clamped on the table reciprocates under the rotating grinding wheel. The workpiece may be held by means of a magnetic chuck or fixture. Trip dogs at the side of the table are adjusted for getting the correct stroke length for the table. The periphery of the grinding wheel does the grinding. Cross feed is given to the workpiece after every stroke. After the full width of workpiece is ground, the wheel head is lowered downwards to give depth of cut.(See figures (7.16), (7.17), (7.18)).

7.4.3.2 Horizontal spindle - rotary table surface grinder

In this machine, a rotary table is used. Small workpieces are clamped over the table. The table rotates with the workpiece. The wheel head reciprocates slowly about its axis.

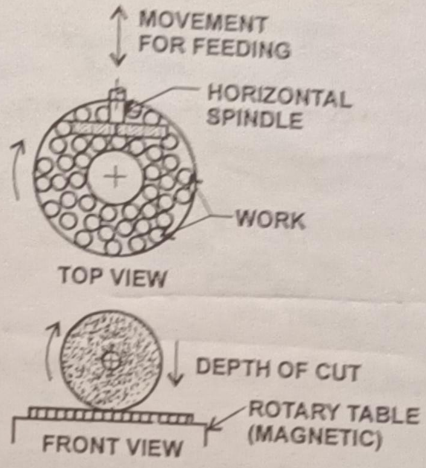


Figure 7.19

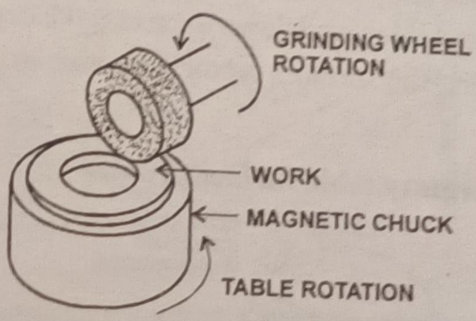


Figure 7.20 Horizontal rotary table surface grinder

This movement gives the cross feed to cover all the workpieces on the table. The wheel head is lowered to give the required depth of cut. The periphery of the grinding wheel takes the cut. This machine is used for small and medium size works. (See figures 7.19 and 7.20.)

7.4.3.3 Vertical spindle reciprocating table surface grinder

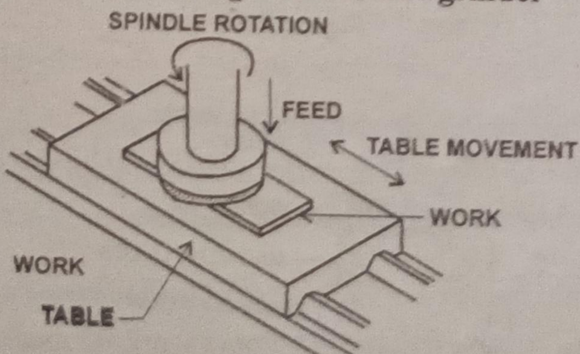


Figure 7.21

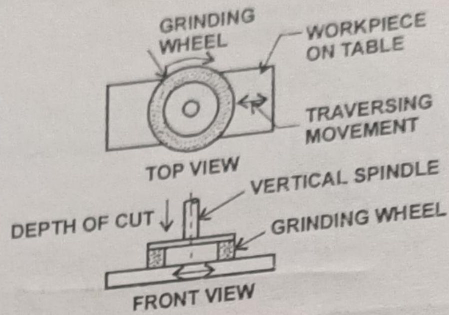


Figure 7.22 Vertical spindle reciprocating table surface grinder

The workpiece is clamped on the reciprocating work table using a magnetic chuck or fixture. The grinding wheel rotates about a vertical axis. A cup type grinding wheel is used. The longitudinal and cross feeds are given through the table. The face or side of the grinding wheel cuts the metal. The wheel head is lowered down for giving the depth of cut. This grinding machine is used for grinding flat surfaces on medium size works. See figures (7.21) and (7.22).

7.4.3.4 Vertical spindle - rotary table surface grinder

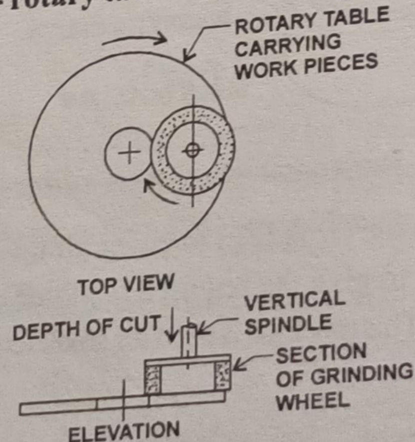


Figure 7.23

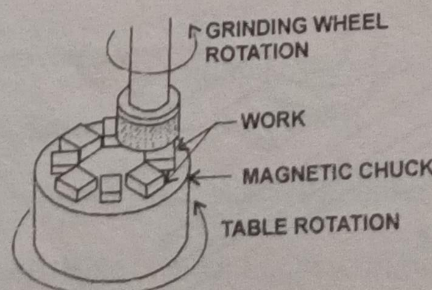
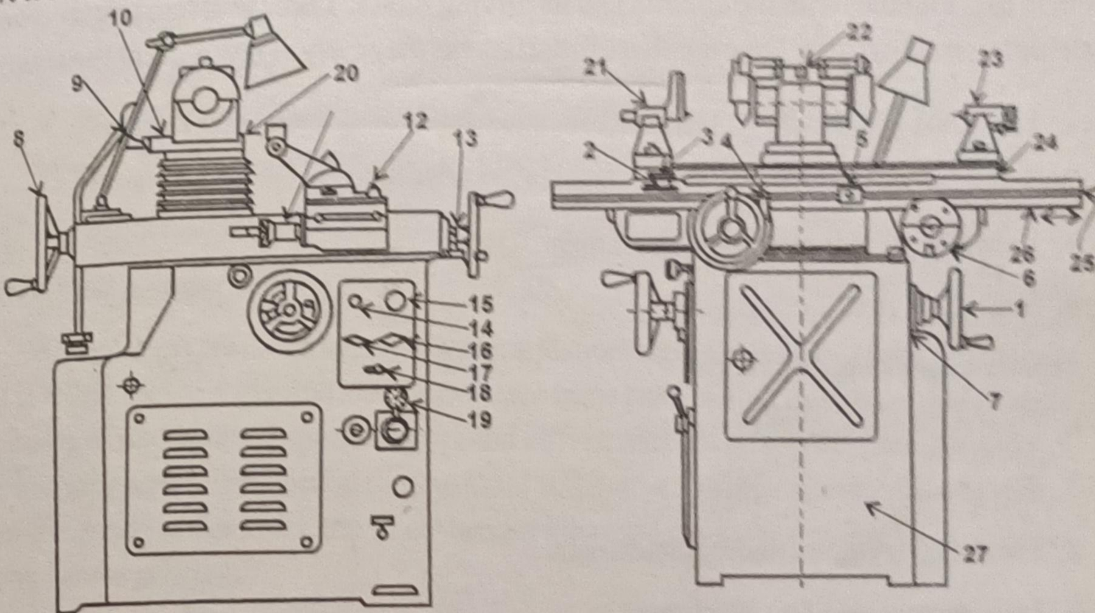


Figure 7.24 Vertical spindle - rotary table surface grinder

The grinding machine is used for grinding large quantity of small workpiece. The small workpiece are held on the rotary table. The rotary table rotates with the workpieces. The vertical spindle carries a cup type wheel. The grinding wheel is lowered for giving depth of cut. See figures (7.23) and (7.24).

7.4.4 Tool and Cutter Grinders



1. Hand wheels for elevating the wheel head, 2. Fine table swivel screw, 3. Pin for engaging table swivel screw, 4. Table travel adjustment dogs, 5. Knob for engagement of slow table traverse, 6. Crank handle for slow longitudinal table traverse, 7. Main line switch, 8. Table cross traverse handwheel, 9. Wheel head swivel lever, 10. Wheel head clamping lever, 11. Table longitudinal traverse handle, 12. Table locking nut, 13. Dial clamp, 14. 'Spindle Start' push-button, 15. 'Spindle Stop' Push-button, 16. 'Dust Exhaust' switch, 17. Work light switch, 18. 'Attachment' switch, 19. Drum switch handle, 20. Elevating Column, 21. Work Head, 22. Wheel head, 23. Tail Stock, 24. Upper table, 25. Lower table, 26. Table, 27. Base.

Figure 7.25 Universal tool and Cutter grinder

These machines are primarily intended for tool room work for grinding cylindrical and tapered multitooth cutting tools like milling cutters, hobs, drills, reamers, taps, broaches, gear shaper cutters, etc.,

They are also capable of doing light cylindrical, surface and internal grinding operations. They are made in various different designs. The most versatile and widely used form is, however, a **Universal tool and Cutter grinder,** shown in figure (7.25).

It carries a workhead and a tail stock on an upper table, which is mounted on a lower table on which the former can be swivelled to grind the tapered tools. The lower table travels longitudinally on the ways provided on a saddle under it. The saddle travels in a cross direction. The saddle and table travels are usually controlled by hand. The wheel head is rigidly mounted on a elevating column and consists of a housing carrying a wheel spindle, which runs in two bearings. Both ends of the spindle are tapered to receive the clamping sleeves. Carrying the grinding wheels. The wheel head can be swivelled about a vertical axis together with the column and its driving motor. These grinders largely owe their high versatility to the large number of attachments they carry. A few main of these are:

1. Universal workhead.
2. Wheel dressing device.
3. External cylindrical grinding attachment.
4. Swivelling vice.
5. Internal grinding attachment.
6. Core drill grinding attachment.
7. Tap grinding attachment.
8. Face milling cutter grinding attachment.
9. Long reamer grinding attachment.
10. Form cutters grinding attachment.
11. Universal tooth rest.
12. Gear shaper cutters grinding attachment.
13. Hob grinding attachment.
14. Twist drills grinding attachment.

Other **tool grinders** include the profile or contour grinder and monoset tool and cutter grinder. The former is used to reproduce a template form on a flat or round cutter. The later is mainly used in grinding spiral fluted cutters and twist drills. Another too grinder, known as Carbide tool grinder, is used for grinding various angles on single point tools, mainly carbide tipped tools.

7.4.5 Special grinding machines

Many grinding machines are produced to do highly speciliazed work. Some common types of these machines are the following:

1. Roll grinders
2. Cam Shaft grinders
3. Disc grinders
4. Crank shaft grinders
5. Piston grinders
6. Thread grinders
7. Tool post grinders
8. Way grinders (or) Form grinders
9. Gear teeth grinders

7.4.5.1. Roll grinders

Roll grinders are much larger, heavier, and more rigid than plain cylidrical grinders. Roll grinders are used to grind and to resurface large steel rolling mill rolls used in basic processing of steel or aluminium and strip, and differ from conventional cylindrical grinders only in their greater than normal dimensional and load-carrying capacity. In most of the larger roll grinding machines, the wheel head is traversed along the rotating workpieces to accomplish the grinding.

7.4.5.2. Cam grinders or Cam shaft grinders

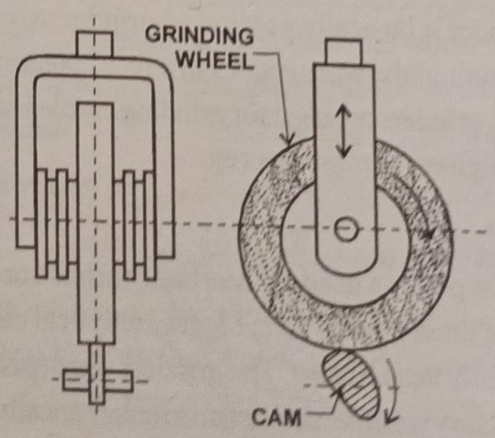


Figure 7.26 Cam grinders

These machines are basically cylindrical grinding machines with additional feeding and withdrawal mechanisms for the workpiece. It consists of a separate base that carries the headstock and tailstock. The complete unit can oscillate about a centre below the workpieces. Before carrying out the operation a small template is mounted on the headstock.

A hardened steel roller in conjuction with a template actuates the movement of the whole unit to produce the desired shape. Modern cam shaft grinders are provided with automatic feed mechanisms for rapid production. The grinding wheel is continuously in contact with the cam surface during operation. The camshaft has simultaneous rotary and oscillation motion, as well as an axial motion, to obtain a fine surface finish.

7.4.5.3 Disc grinders

Disc grinders finish flat surfaces and remove stock rapidly by grinding with the sides of disc wheels. the disc grinders produces only ordinary tolerance but at high rates of production.

There are three standard types of disc-grinding machines:

1. Single horizontal spindle
2. Single vertical spindle
3. Double horizontal spindle.

The first two are most commonly used for repetitive work by hand operation or with simple fixture. The third is widely used for production operations where parallel surface are ground simultaneously.

7.4.5.4 Crank shaft grinders

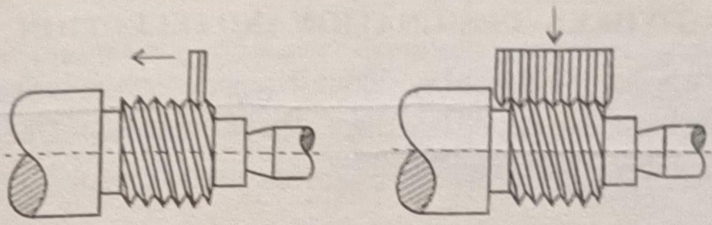
A crank shaft grinder is basically a cylinders grinder using the principal of plunge grinding. In plundge grinding, the work rotates in a fixed position and the wheel is fed to produce cylinders. These grinders are used for grinding crankshaft of automobile engines, aircraft engines, diesel engines, compressors etc.

7.4.5.5 Piston grinders

A large majority of pistons used in internal combustion engines are not of true cylindrical shape. Most of these pistons carry slightly elliptical outer surface At times, the outer surface may be slightly tapared also. The grinders used (piston grinders) in grinding of these pistons, therefore, carry suitable mechanism to automatically regulate and synchronise the inward and outward movements of the revolving piston and the cutter feed in such a way that the rigid type of outer surface is ground on the piston together with the taper if, desired.

7.4.5.6 Thread Grinders

Thread grinding is basically a generating process, in which the desired thread profile is generated on a solid cylindrical object through grinding. The machines used in this process



(a) Single Wheel Grinding (b) Plunge cut grinding

Figure 7.27 Thread grinding

operate on the principle of cylindrical grinders. These machines carry a lead screw which is connected to the head stock, much in the same way as in a centre lathe, in order to establish a definite ratio between the speed of rotation of the work and the longitudinal traverse of the grinding wheel. Thus the grinding wheel, which is given the shape of the thread profile on its face, follows helix angle is provided to the grinding wheel by tilting its spindle to the required angle. But the above process holds good with a single grinding wheel only as shown in figure 7.27(a).

7.4.5.7 Tool post grinders

These grinders form an important attachment for a centre lathe. That is why they are known as lathe grinders or lathe grinding attachment.

7.4.5.8 Way grinders or form grinders

These are large, heavy single-purpose machines intended principally to grind the various surface of the ways and beds of machines. The wheel is cup, ring or segmented, mounted on a vertical spindle which can be usually tilted at an angle. All sorts of angles may be produced on this machine.

7.4.5.9 Gear teeth grinding

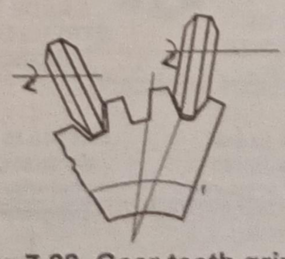


Figure 7.28 Gear teeth grinding

The teeth of gears are ground on gear grinding machines either by the generating process or by a forming process in which wheels are used. In formed wheel grinding of gears, figure (7.28), the contour of the wheel is trued by a special fixture so that it coincides with the profile of the tooth spaced on the gear. The adjacent flanks of two teeth ground simultaneously.

7.5 GRINDING WHEEL - DESIGNATION AND SELECTION

Grinding wheels are produced by mixing the appropriate grain size of the abrasive with the required bond and pressed into shape. The characteristic of the grinding wheel depend upon a number of variables.

★ *SELECTION AND IDENTIFICATION OF GRINDING WHEELS*

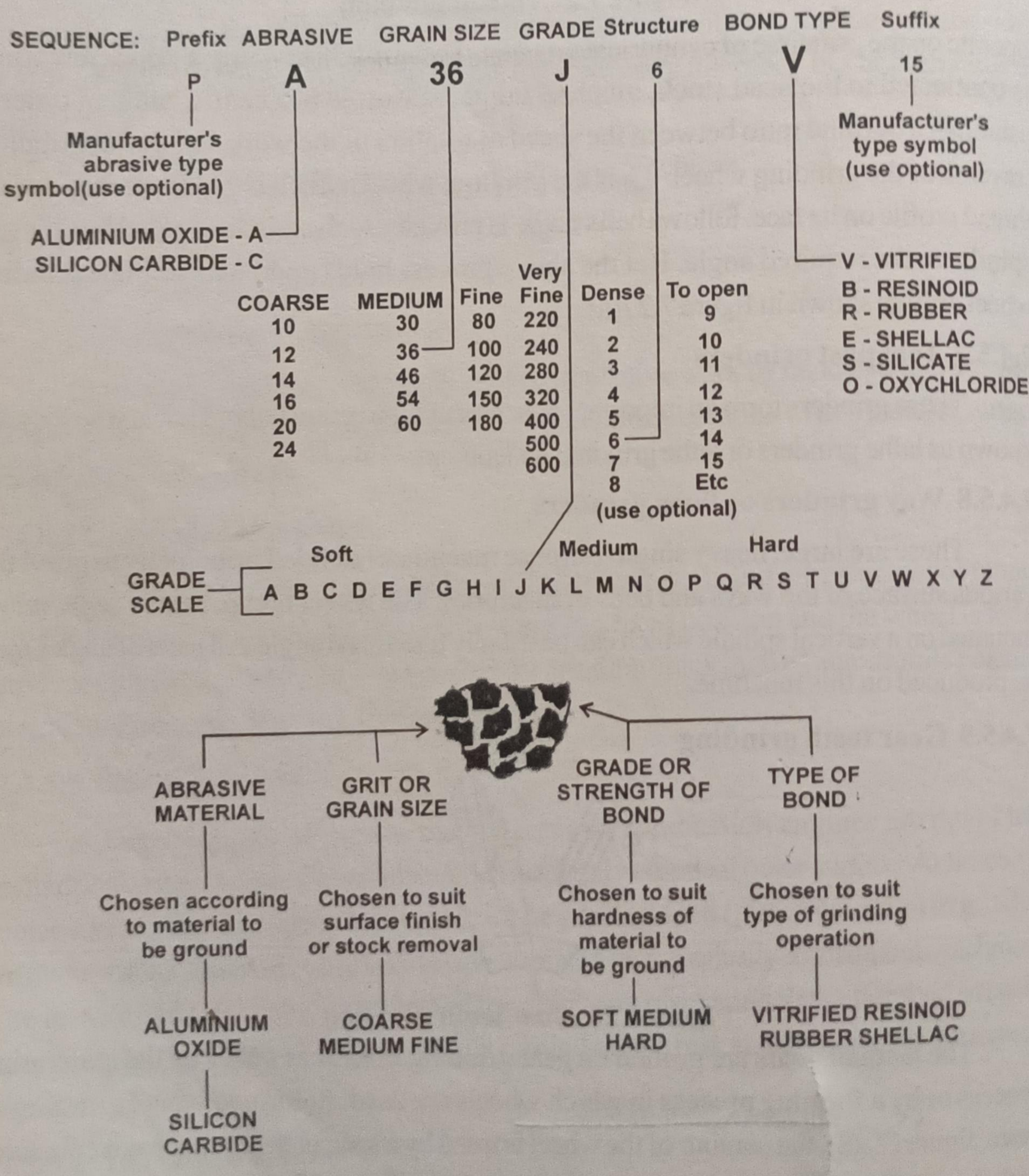


Figure 7.29 Standard marking system for grinding wheel

Selecting a grinding wheel is much like selecting any other cutting tool. Many of the same factors apply, such as size and shape. However, in grinding wheels, additional factors influence the selection process: types of abrasives, grit, grade, structure and bond. Identification of grinding wheels and to assist you in selecting the one that best fits your needs.

7.6 TYPES OF ABRASIVES

These are hard materials with adequate toughness which act as cutting edges for a sufficiently long time. They also have the ability to fracture into small pieces when the force increases, which is termed as friability. This property gives the abrasive the necessary self sharpening capability or An abrasive is a hard material. It can be used to cut or wear away other materials. When fractured the abrasive forms sharp cutting edges. Abrasive may be classified into two types:

(1) Natural abrasives (2) Artificial abrasives or manufactured.

7.6.1 Natural abrasives

These abrasives are naturally available in the earth . They have more impurities. So for most of the purpose the natural abrasives are not used.

Various natural abrasives

(i) Sand Stone or solid quartz.

(ii) Emery: It contains 55 to 65 percent alumina plus iron oxide.

(iii) Diamond

(iv) Garner

(v) Corundum: It contains 75 to 95 percent aluminium oxide plus impurities.

7.6.2 Artificial Abrasives

In artificial abrasives, we can easily control the quality. These abrasives are mostly used for making grinding wheel.

The abrasives that are generally used are:

(i) Aluminium oxide (Al_2O_3)

(ii) Silicon oxide (SiC)

(iii) Ceramic aluminium oxide.

Super Abrasives

(i) Diamond

(ii) Cubic boron nitride (CBN)

Super abrasive wheels specifications

It consists of types of abrasive grain size grade concentration, depth of coating any type of bond. The concentration value usually 30 to 175.

Artificial: Artificial or manufactured abrasives chiefly (a) silicon carbide and (b) aluminium oxide.

Silicon Carbide (SiC):

Abrasive is manufactured from 56 parts of silicon sand, 34 parts of powdered coke, 2 parts of salt and 12 parts of saw dust in a long. Rectangualar electric furnance of the resistance type that is built up of loose brick. Sand furnishes silicon, coke furnishes carbon, saw dust makes the change porous, salt helps to fuse it, and gases may escape through the open joints in the brick work. the abrasives wheels are denoted by "S".

There are two types of silicon carbides abrasives: green grit which contains at least 97 percent silicon carbide, and black grit which contains atleast 95 percent silicon carbide. This form is harder but weaken than the latter.

Silicon Carbide:

Silicon carbide follows the diamond in order of hardness, but it is not a tough as aluminium oxide. It is used for grinding materials of low tensile strength such as cemented carbides, stones and ceramic materials, grey cast iron, brass, bronze, copper, aluminium, vulcanized rubber, etc., The names of the manufactures, manufacturing silicon carbide grinding wheels and the trade names are given below.

Figure 7.30 Large grains of silicon carbide

Manufacturer	Trade name	Manufacturer	Trade name
The carborundum Co.	Carborundum	Macklin Co.	Silicon carbide
The Norton Co.	Cryptolon	Abrasive Co.	Electron

Fused aluminium oxide: Al_2O_3 also known as corundum or emergy. Fused aluminium oxide is the most widely used abrasive in manufacturing.

Trade name as Aluminium and Aloxite. The higher the level purity, the more friable (less tough) the grit becomes. The pure grades are very often white in colour and are used mainly on hardened steels. The grinding of hard steel causes a fairly rapid breakdown of the grinding of the individual grains to expose new sharp edges. A sharp wheels cuts easily. with less heat being produced. Less pure aluminium oxide usually is grey in apperance. It has a tougher grain structure that resists fracturing, and it is better for applications such as off hand grinding on a pedesdal grinder. For extremly harsh application. Such as snagging in foundries, a crystalline combination of aluminium and zirconium oxide has been developed that results in a very tough abrasives.

While aluminim oxide works well on steel, it can work poorly on cast iron. This appears to be a mater of the aluminium oxide being some what soluable in cast iron at the high temperature of grinding. The wheel dulls quickly, apparently from the sharp edges being disolved away into a solid solution with the iron, suitable for grinding tool steel, HSS on.

Cubic boron nitride(CBN):

Figure 7.31 Cubic boron nitride

Cubic boron nitride(CBN) is next in hardness only to diamond (knoop hardness 4700 kg/mm^2). It is not a natural material but produced in the laboratory using a high temperature / high pressure process similar to the making of artificial diamond. CBN is less reactive with materials like hardened steels, hard chill cast iron, and nickel base and cobalt base super alloys. This is very expensive, 10 to 20 times that of a conventional abrasive such as Al_2O_3. CBN-Combination of Boron and Nitrogen.

Diamond: Diamond is the hardest (Knoop-hardness - 8000 kg/mm^2) material that can be used as a cutting tool material. It has a very high chemical resistance capacity along with a low coefficient of thermal expansion. Synthetic diamonds are mainly used for truing and dressing other grinding wheels, for sharpening carbide tools, and for processing glass, ceramics and stone.

Ceramic aluminium oxide: Ceramic aluminium oxide is produced by a process similar to growing crystals in a supersaturated solution. This method permits engineering the crystal shape for specific purpose. Wheels made of pure ceramic aluminium oxide as the abrasive component are suitable for rough grinding but are unsuitable for precision grinding. By combining ceramic aluminium oxide with fused aluminium oxide, a wheel can be produced that has a combination of sharpness, agrasive cutting action, form retention and resultant long life between dressings, resulting is a three to five fold improvement in grinding ratio over straight fused aluminium oxide grinding wheels.

A recent development by the norton company has combined ceramic aluminium oxide (seeded gel abrasives) with CBN. The grinding performance is three to five times that of conventional abrasives. This combination is sometime referred to in the literature as "hybrid" super abrasive grinding wheel.

7.7 SIZE AND SHAPE OF WHEELS

The standard coding system uses number 1 to 28 to indicate wheel size and shape. Grinding wheels are made in different shapes and size. Suitable grinding wheel may be selected according to the types of grinding machines and classes of work. The shape and size of various grinding wheels have been standardised. You should be familar with five of the most common types:

Type 1 - Straight Wheel (Figure 7.32)

Type 2 - Cylinder wheel (Figure 7.33)

Type 6 - Straight-cup wheel (Figure 7.34)

Type 11 - Flaring-cup wheel (Figure 7.35) with grinding faces on both face and wall.

Type 12 - Shallow disk wheel (Figure 7.36)

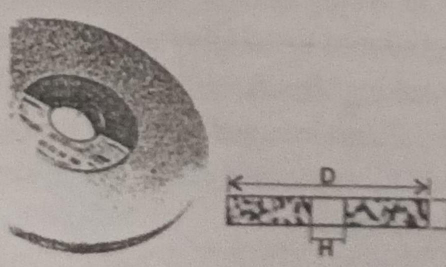


Figure 7.32 Straight or type 1 wheel, whose grinding face is the poriphery. Usually comes with the grinding fact at right angles to the sides, in what is sometimes called an "A" face.

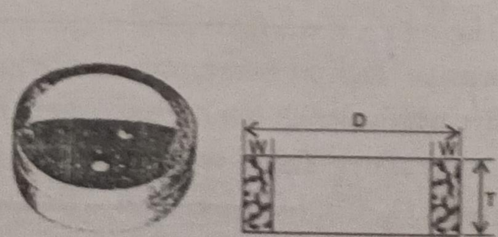


Figure 7.33 Cylinder or type 2 wheel, whose grinding face is the rim or wall end of the wheel. Has three dimensions: diameter, thickness and wall thickness

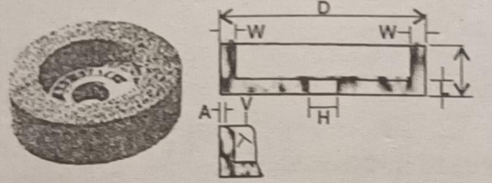


Figure 7.34 Straight-cup or type 6 wheel, whose grinding face is the flat rim or wall end of the cup.

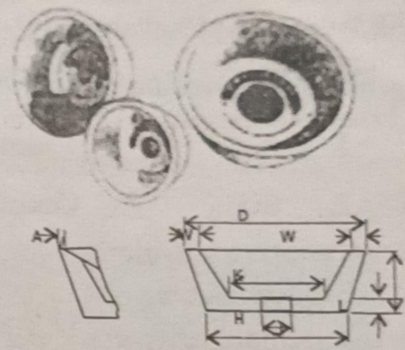


Figure 7.35 Flaring-cup or type 11 wheel, whose grinding face is also the flat rim or wall of the cup. Note that the wall of the cup is tapered.

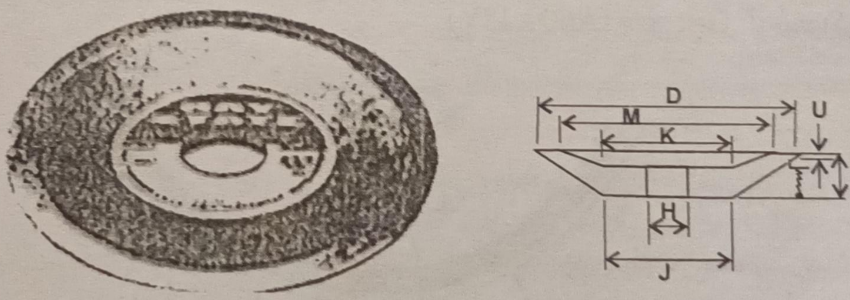


Figure 7.36 Dish or type 12 wheel, similar to type 11, but with a narrow, straight peripheral grinding face in addition to the wall grinding face. This is the only wheel of those shown that is considered safe for both peripheral and wall (or rim) grinding.

7.7.1 Standard marking system of grinding wheels

A standard wheel making system (Figure 7.37) is used for the purpose of identifying five factors (IS 551 – 1654) is grinding wheel (or) size selection.

1. Type of abrasives
2. Grit size
3. Grade of hardness
4. Structure
5. Bond type
6. Manufacturer's record (use is optional)

These factors are indicated on the grinding wheel blotter by a numeric and letter identification code for example, a wheel maked. A60 – J8V

First Symbol: Type of abrasive.

Five major abrasives are in common use:

1. A - Fused aluminium oxide.
2. SG - Ceramic aluminim oxide
3. C - Silicon carbide
4. D - Diamond
5. MD or SD - Manufactured or synthetic diamond
6. B - Cubic boron nitride.

Second Symbol: Grit size (A60 – J8V)

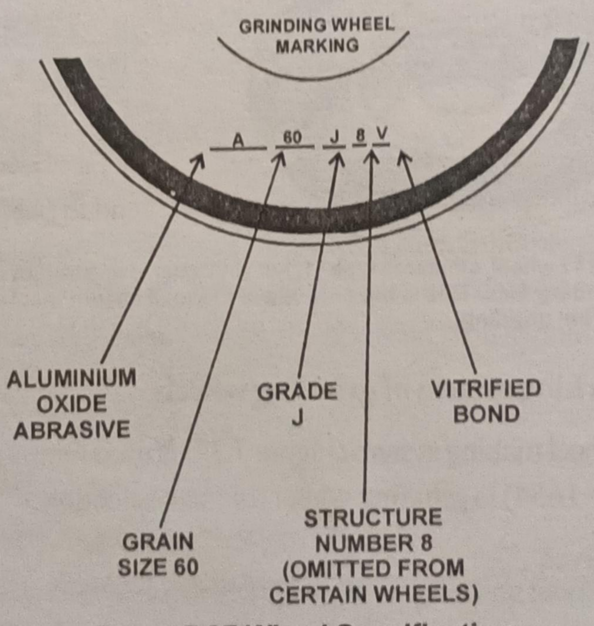


Figure 7.37 Wheel Specification

Grit refers to the size of the abrasive grains, grit size ranges from 4 to 8 (coarse) upto 500 or higher (fine). Grit numbering is derived from the screen openings used to sort the abrasive grains after manufacturer. The following approximate scale can be used to determine grit.

4	36	46	100	120	240	500
← Coarse →			← Medium →		← Fine →	

Selection of grit depends on the amount of stock to be removed and the surface finish requirements. Usually, coarse grits are used for fast stock removal and on soft ductile materials. Fine grit is used for hard brittle materials. General usage calls for wheel grits ranging from 46 to 100.

Third Symbol: Grade of hardness (A60 – J8V)

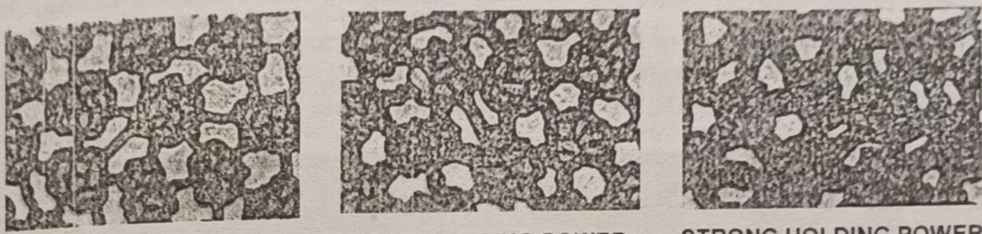


Figure 7.38 Three sketches illustrating (from top down) a soft, a medium, and a hard wheel. This is the grade of the wheel. The white areas are voids with nothing but air; the black lines are the bond and the others are the abrasive grain. The harder the wheel, the greater the proportion of bond and, usually, the smaller the voids.

Grade of hardness (figure 7.38) is a measure of the bond strength of the grinding wheel. The bond material holds the abrasive grains together in the wheel. The stronger the bond, the harder the wheel. Precision grinding wheels tend to be softer grades because it is necessary to have dull abrasive grains pull from the wheel as soon as they become dull.

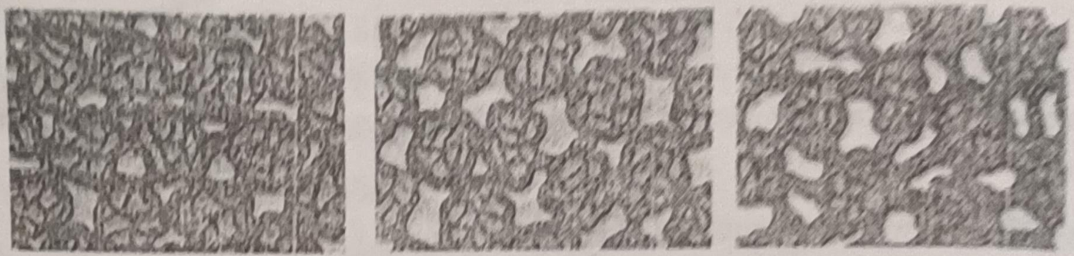
This will expose new sharp grains to the workpiece. If this does not happens the wheel will become glazed will dull abrasive. Cutting efficiency and surface finish will be poor. Later alphabet letters indicate harder grades. For example, F to G would be soft, where as R to Z are very hard.

Fourth Symbol: Structure (A60 – J8V)

Structure or the spacing of the abrasive grains in the wheel (figure 7.39) is indicated by the number 1 (dense) to 15 (open). Structure provides chip clearance so that chips may be thrown from the wheel by centrifical force or washed out by the grinding fluid. If this does not happen, the widest becomes loaded with workpiece particles (figure 7.40) and must be dressed.

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

★ The structure is denoted when the spacing is wide, the structure is called open structure. Grinding wheels are used for soft, tough and ductile materials. Also used for heavy cuts.



Dense Spacing Medium Spacing Open Spacing

Figure 7.39 Three similar sketches showing structure. From the top down, dense, medium and open structure or grain spacing. The properties of bond, grain and voids in all three sketches are about the same.

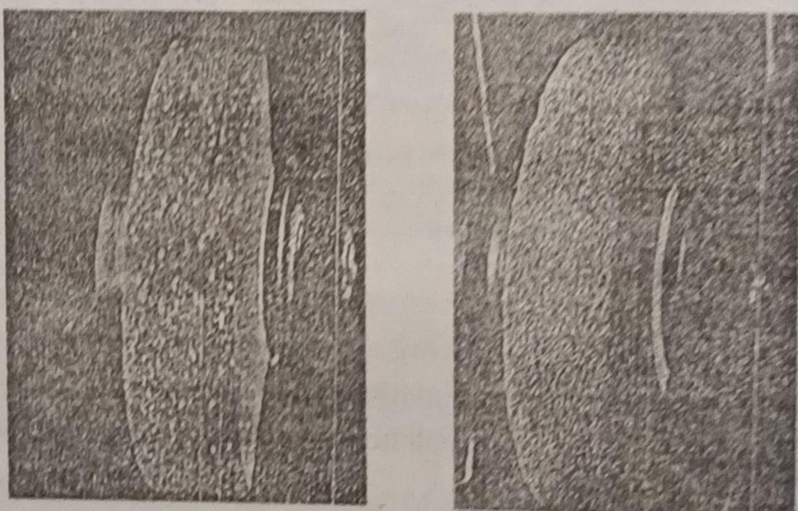


Figure 7.40 The wheel at the top is called loaded with bits of metal embedded in its grinding face. It is in appropriate to do off-hand grinding of soft metals like aluminum on a pedestal grinder. The same wheel, below has been dressed to remove the loading

★ When spacing is close, the structure is called dense structure. Used for hard and brittle material. Also used for finishing cuts.

Fifth Symbol: Bond (A60 – J8V)

Bond is identified by letter according to the following:

V - Vertified
B - Resinoid or Bokelite bond
R - Rubber
E - Shellac
M - Metal
S - Silicate bond
O - Oxychloride bond

7.7.1.1 Bonds

A bond is an adhesive material. It holds the abrasive grains together to form the grinding wheel. The bonds which are used during the manufacture of grinding wheel.

In machine shop, vitrified bonds are the most common. Vitrified wheels are used mostly for precision grinding. Vitrified super abrasive grinding wheels are becoming more common. (Clay and abrasive when heating clay turns and forms porcelin) Resinoid bond wheels are typically used in rough-grinding operations where some flexibility is needed. Such as "Snagging" of casting in a foundry. With high wheel speeds and heavy stock removal. Resinoid bonds are also used with super abrasives for carbide grinding on tool and cutter grinders. Abrasive grains as mixed in the synthetic resin. The mixture is rolled to derived shape and backed or temperature 210 to 256°C for few hours.

Rubber: is the usual bonding material for regulating wheel on centreless grinders. Manufactured by mixing grains with pure rubber and sulphur, sulphur act relationship angle less heat resistant wheel thick 125mm.

Shellac Bond or Elastic bond: In this process the abrasive grains are coated with shellac. The mixing is heated to give uniform mixing. Then it is rolled in headed moulds. The mixture is finally baked for few hours at temperature of about 200°C. This process gives considerable elasticity to the wheel. Shellac still finds some limited use in the finish grinding of surface like camshaft, although belded superfinishing methods are used more frequently for this task.

Metal: Bonded diamond wheels are also used for grinding hard non-metallics such as ceramics and some. Bonds also alter wheel speeds.

Silicate bond: These wheels are manufactured by mixing abrasive grains with sodium silicate. The mixer is moulded in a mould and dried for several hours. Finally the moulded shapes are paked at a temperature of 270°C for 20 to 80 hours. Silicate wheels are water proof. The process is rapid. These wheels are suitable for grinding cutters, blades etc., due to less heat generation. But these wheels are not suitable for common grinding process because the wheels wear quickly.

Oxy chloride bond: Abrasive grains are mixed with oxide and chloride of magnesium. This type of wheel ensures a cool cutting action. So grinding is done dry. The mixing of bond and abrasive is performed similar to the vitrified bonded wheel. These bonds are used in making wheels for use in disc-grinding operation. The bond ensures of cool cutting action.

Other factors in wheel selection:

Variable factors:

1. Composition of the Workpiece material
2. Cutting fluid.
3. Material hardness
4. Work finish

Fixed factors:

1. H.P of the machine
2. Severity of the grinding
3. Area of grinding contour
4. Wheel speed
5. Fluid.

7.7.2 Selection of a grinding wheel

The selection of a grinding wheel is based on the following factors:

1. Size and shape of wheel.
2. Kind of abrasive
3. Grain size of abrasive particles
4. Grade of bond
5. Structure
6. Kind of bond material
7. Functioning of grinding wheel.
8. Other factors : Wheel speed, Work speed, Materials

7.7.2.1 Size and shape of wheel

The principle dimensions of a grinding wheel are the outside diameter "D", bore "d" and the width "T'. Straight wheels are available with an outside diameters from 3 to 100 mm and width 6 to 200 mm.

Wheel Shapes:

1. Plain or straight disc wheel.
2. Straight cone side recess.
3. Straight (Both side Reserves)
4. Tapered
5. Straight cup wheel.
6. Saucer wheel
7. Disk wheel
8. Flaring cup wheel

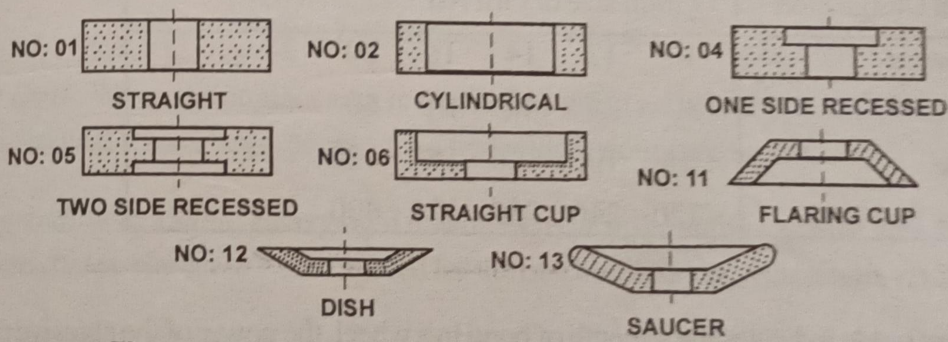


Figure 7.41 Wheel Shape and Size (Shape and Name)

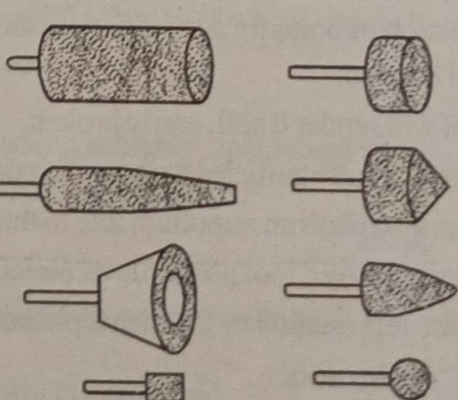


Figure 7.42 Examples of mounted abrasives wheels and points

7.7.2.2 Grain or Grit

The form grain or grit denotes the approxiate size of the abrasive particles and gives an idea of the coarse ness or finess of the grinding wheel. A grinding wheel may the abrasive particles of same size or different sizes. The former is known as as straight wheel and the latter compound wheel. The choice of grain size or grit depends upon many factors, viz Quality of finish required, amount of stock material to be removed and physical properties of the material to be ground. The coarser grit will remove the stock at a faster rate and finer finish will always require a finer grit.

Coarse grit wheels are most suitable for grinding soft and ductile material whereas hard and brittle material are best ground with finer grit wheels.

The grain size or grit of an abrasive is denoted by a number representing the number of meshes per inch of the screen through which the grains of crushed abrasive are passed for grading. The standard numbers representing different grain size are given in table (1).

Table (1) Standard grain sizes for grinding wheels:

Grit Designation	Grain size or Grit No
Coarse	10 12 14 16 20 24
Medium	30 36 46 54 60
Fine	80 100 120 150 180
Very fine	220 240 280 320 400 500 600

7.7.2.3 Grade

The term grade indicates the strength of bond in a wheel, the power of the abrasive particles to hold together and resist disintegration under the cutting pressure.

- Higher the proportion of bond for a specified quantitive of abrasives particles harder wheel will be used.
- Lower proportion will render it soft, easily broken.
- Hard wheel will retain these particles for a much longer period.
- Machine condition also plays an important role in this selection.
- Harder wheels are employed tool post grinder on lathes.

Different wheel grades are represented by English alphabets from A to Z. 'A' being the softest and 'Z' the hardest.

7.7.2.3.1 Different grade of grinding wheels

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

7.7.2.4 Structure

This term denotes the spacing between the abrasive grains or in other words the density of the wheel. High proportion - open structure lower proportion will lead to a closer structure.

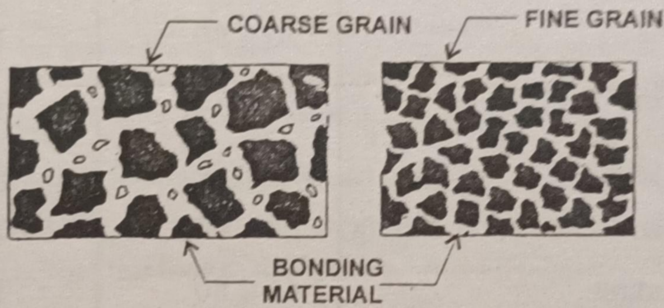


Figure 7.43 Structure of wheels

Contact area: When the contact area is small, fine grain and close spacing are useful. When the contact area is large, coarse grain and wide spacing are useful.

Type of grinding machine: Heavy rigid machines require the softer grade of wheel than the light machines. Harder of wheel is used for the machines, giving vibrations.

7.7.2.5 Variable / Other factors

Work Speed: If the work speed is higher, hard wheel should be selected. If the workspeed is lower, soft wheel is selected.

Wheel Speed: If the wheel speed is higher, soft wheel should be selected. If the wheel speed is lower, hard wheel should be selected.

Condition of the grinding machine: Condition of the grinding machine means whether the grinding is done in wet condition or dry condition.

In wet conditions - hard wheel is selected.

In dry conditions - soft wheel is selected.

Personal Factor: A skilled worker is permitted to handle both soft and hard grinding wheel. But an unskilled worker should not permitted to handle soft wheels, because he is likely to break them.

7.8 RECOMMENDATION FOR SELECTION OF GRINDING WHEELS AS PER I.S. 1249

Class of Work	Grit No	Grade
1. Fetting, snagging	12 – 30	Q – T
2. Tool grinding	30 – 80	M – Q
3. Offhand grinding	14 – 80	Q – S
4. Cylindrical grinding	36 – 120	J – N
5. Centreless and Cranksoft grinding	46 – 80	J – N
6. Internal grinding	46 – 80	I – M
7. Surface grinding	20 – 36	G – K

Types of grinding	Surface speed in m/min
1. Cylindrical	1500 – 2000
2. Surface	1200 – 1500
3. Internal	600 – 1800
4. Tool and cutter	1500 – 2000
5. Centreless	1500 – 1800

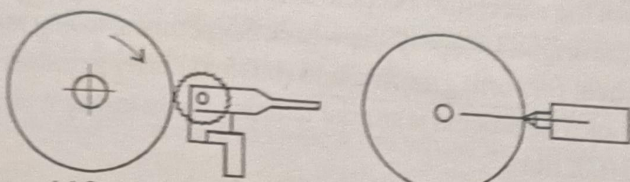
7.9 RECONDITIONING OF GRINDING WHEEL

7.9.1 Dressing

It is defined as an act of improving the cutting action. This can be done by removing the glazed surface on the wheel. This is done by various types of dressers namely,

1. Star dressing tool.
2. Round (or) Square stick.
3. Diamond dressing tool.
4. Crush dressing fixtures.

1. **Star dressing tool**



(a) Star Dressing Tool (b) Abrasive Stick

Figure 7.44 Dressing a grinding wheel

A common type of star-dresses is shown in figure 7.44(a). It consists of a number of hardened steel wheel with points on their periphery. It is held against the face of the grinding wheel. It is moved across the face to dress the whole surface.

2. **Round abrasive stick**

This type of dressing tool consists of a steel tube filled with a bonded abrasive. The end of the tube is held against the wheel and move across the face. (See figure 7.44(b))

3. **Diamond Dressing Tool**

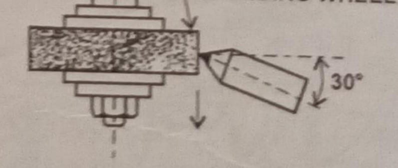


Figure 7.45 Diamond dressing tool

These dressers are used for dense coarse-grain abrasive wheels. For precision and high finish grinding, diamond is used to dress the wheel. While dressing is done with diamond tip tool, coolant should be used. The industrial diamond is mounted in a holder. The diamond should be kept pointed. Since the point only can be used for cutting. The tool is held at 5° to 15° to horizontal as shown in figure (7.45). The tool is pressed against the revolving wheel. It is moved cross-wise to cover the entire width of wheel.

Truing

The original face of the wheel may become irregular. Hence it loses its original shape. Truing is done to bring the original shape of the wheel. Sometimes, truing is done to change the face shape of the wheel for form grinding and tool and cutter grinder. Truing is done with a diamond truing tool. The process is similar to dressing. In truing with a diamond, the feed should not exceed 0.02mm.

Now a days, form truing is done by a crushing roll. The crushing roll is made of hard steel to the required shape. It is forced against the revolving wheel crush the corresponding shape. The crushing roll may be power drive or it may be rotated by the friction of wheel.

Crush dressing

It is also known as crush forming. It is a method of truing the grinding wheel and producing a desired contour an its periphery. In this method a roll made of a hard metal, like H.S.S. is machined to the desired shape held in suitable bracker and pressed in to the slowly revolving grinding wheel. With its result, a reverse contour of the roll is formed on the periphery of the wheel. Wheels causing vitrified bond are most suitable for crush dressing. Silicate bonded wheels are also sometime used but are not favoured much shellac rubber and resin bonded wheels are not suitable. Best results are obtained with Al_2O_3, SiC with vitrified bond also gives good results.

7.9.2 Balancing of grinding wheel

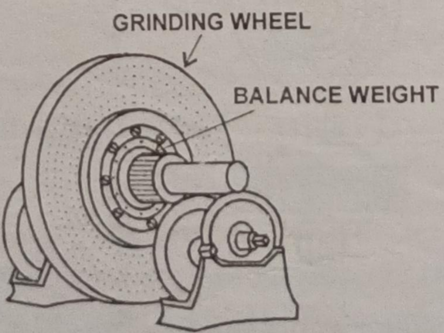


Figure 7.46 Balancing of Grinding wheel

If the centre of gravity of a grinding wheel and its axis of rotation coincide, the grinding wheel is said to be balanced. Since the grinding wheel speeds are high, straight out of balance condition may give use to large forces. This may results in execessive vibrations. Poor surface finish, and faster wheel break down and may even dangerous to the operator.

Therefore, particular attention should be given to the balancing of the wheel.

The commonly used procedure for the balancing of grinding wheels is to use a balancing bench. The following steps are involved in this process.

(a) Thoroughly clean and inspect the wheel for cracks.

(b) Place the balancing stand on the flat surface and align it horizontally with an accurate level.

(c) Place the grinding wheel on the balancing stand figure (7.46).

(d) Set the wheel in any arbitary position. Balanced wheel set in any position. If the wheel is not properly balanced, the heavier part will move downwards.

(e) Now bring the wheel to static position by moving the balance weights.

7.9.3 Mounting of Grinding Wheels

The grinding wheel rotate at high speeds. If they are not properly mounted on the spindle it is dangerous to the operator. Before mounting, all grinding wheels should be inspected by ringing test. On light taping with a metal bar a good wheel gives a ringing sound. A cracked wheel gives a dull sound.

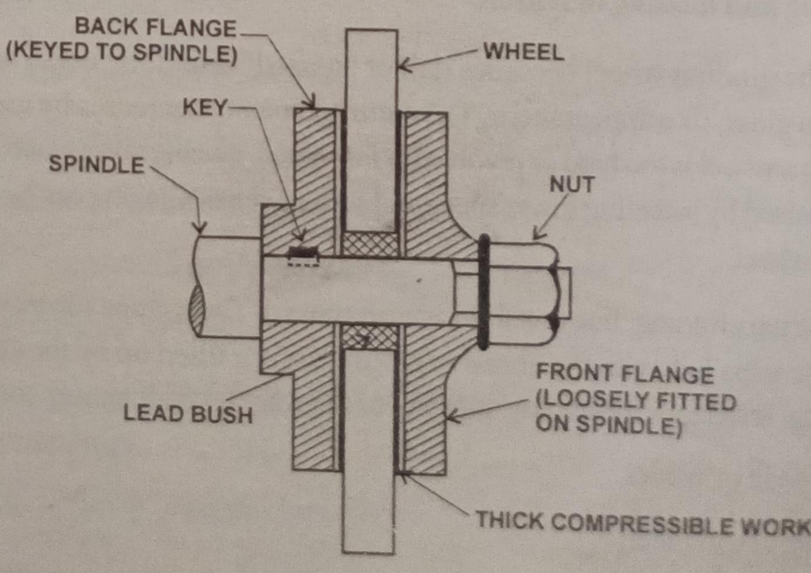


Figure 7.47 Mounting grinding wheels (fresh)

While mounting the wheels, the following point are considered

1. The abrasive wheels should have a sliding fit on the spindle. The wheel should not be forced on spindle.
2. A linear lead bush is used in the bore of the wheel. The bush should not project beyond the wheel face.
3. Flanges of equal diameter are fitted at both sides of the wheel. The flange diameter must be at least equal to half of the wheel diameter.
4. The side of the wheel and the flange should be perfectly flat.
5. Flanges should have clearances only on their faces.
6. The inner fixed flange is keyed to the spindle, the outer flange has a sliding fit with the spindle.
7. Thick compressive washers are placed on both sides between the wheel faces and the flanges. This helps proper gripping of flanges on the wheel.
8. The nut should be tightened firmly enough to hold the wheel.
9. Wheel should be placed in position before starting the grinder.

7.9.4 Glazing and loading in wheels

Glazing: The ginding wheel becomes dull or "glazed" after long use. The edges of a glazed take a glass, like appearances. The cutting capacity decreases by using a glazed wheel. When a wheel is too hard or revolved at fast speed, glazing takes place. The glazing can be minimised by selecting lower speed and soften wheel. Glazing can be removed by dressing the wheel.

Loading: During grinding, fine metal chips are removed. These chips adhere to the cutting face. i.e., The gaps between the abrasive particulars are filled up by the chips. This is called loading. It reduces the cutting capacity of the wheel. Loading may occur due to

1. Slow speed of wheel.
2. Grinding of soft metal.
3. Taking very deep cut.
4. Not using proper coolant.

The loading can be minimised by increasing the speed to the wheel or by using a softer wheel. Loading can be removed by dressing the wheel.

7.9.5 Dressing and Truing of Grinding Wheel

Grinding wheel loses its efficiency due to loading and glazing. During the operation, the chips formed get entrapped in the inner granular space of abrasive particles. This is called loading of the wheel and it results in inefficient cutting operation.

When the band of the abrasive wheel is very hard, it doesn't dislodge an abrasive particle which has became blunt. This results in this process get a shinning appearance. This is known as glazing of the wheel. the ineffectiveness in the cutting action of grinding wheel by loading and glazing is removed and dressing and truing of the wheel expose the new sharp edges.

7.9.6 Work holding devices and attachments

The work holding devices and attachments cover a wide range and include the following;

1. Work holding and supporting devices.
2. Equipment for contour grinding.
3. Attachment to improve grinding results.
4. Measuring and sizing devices.

Work Holding and supporting devices:

1. Steady rest for cylindrical grinders.
2. Chucks and fixtures for other grinders.
3. Magnetic chucks used particularly on surface grinders.

Equipment for contour grinding:

They include wheel dressing and attachments using master cams and templates for cam and shape grinding.

Attachments to improve grinding results:

They include wheel reciprocating attachments for better finish, ultrasonic wheel cleaning devices and electrolytic attachments to aid in grinding extremely hard materials.

Measuring and sizing devices:

They range from simple measuring devices to continuous readings gauges which actually control the feeding of machine.

7.10 GRINDING OF VARIOUS MACHINE ELEMENTS

The primary object of grinding is to produce a finished surface and not a heavy stock removal. As such, the grinding operation is usually preceded by some other operation through which the bulk of stock is removed from the work. It is so because of the high cost of labour, tools and power required in grinding work. Thus, the value of the operation lies in the accuracy and quality of finish obtained on the product and not in the amount of strock material removed. Moreover, the time taken in removing a certain amount of stock through grinding is much more than that required for the same in other machining operations. Another important consideration is that the grinding wheels are costlier and wear out more quickly than other types of cutting tools. A specific advantage of grinding over others is that very hard metals can be machined more easily and efficiently than the other operations. Accuracy and quality of surface finish obtained by grinding is definitely much better than obtained through other machining operations.

7.11 PURPOSE OF GRINDING FLUIDS

The correct selection of grinding fluid can greatly affect the grinding process. But the correct grinding gluid, poorly applied, can in some cases be worse than none at all. All of these fluids serve a cooling function. Grinding fluids:

1. Reduce temperature in the work piece.
2. Lubricate the contact area between wheel and work piece. Thus help to prevent chips from sticking to the wheel, which aids surface finish.
3. Help the common grinding dust, which can be hazardous to the health of the operator.

7.11.1 Types of Grinding Fluids

Types of fluids

i) Water-soluble chemical types

ii) Water-soluble oil types

iii) Straight oils

i) Water - soluble chemical types

These types of fluids, called synthetic fluids, are typically mineral-oil free. They are usually transparent, which helps operator visibility. They are compounded to provide good rust control, and they are not prone to bacterial growth. They provide a high level of cooling capacity, but have less lubriating ability than the soluble or straight oils. The synthetic grinding fluids are used principally on vertical spindle grinders where excessive lubrication can cause workholding difficulties (part slippage). Synthetic grinding fluids are also used with diamond wheels to keep them cool and clean. Synthetic fluids are also important where workpiece contamination is a problem, as in some microwave and other electronic device parts. Solutions made up for these situations should use deionized water to avoid chloride salt contamination.

Semisynthetic grinding fluids have been developed to combine the benefits of synthetics and soluble oils. These contain less mineral oil in their content than soluble oils. The semisynthetics offer good lubricity and better wetting and cooling properties than soluble oils. They are also less viscous than soluble oils, hence settling is faster and filtration easier.

ii) Water - soluble oil types

Like the chemical fluids, this type uses water as a vehicle with a water soluble (or emulstions) mineral oil mixed in before use. The fluid is the common milky substance often seen in the machine shop. For grinding, this fluid is good for medium stock removal operations. One of the methods used in selecting fluids of this type is to select a heavy-duty soluble oil and use a 10 percent concentration for critical work, and greater dilution on other work.

Bacterial growth, resulting in a foul-smelling fluid, often occurs when the fluid is idle, making it necessary to add bacterial growth inhibitor. The aeration that normally occurs during daily use in often sufficient to inhibit bacterial growth.

iii) Straight Oils

Straight mineral oils are excellent for lubricating characteristics, but their heat transfer properties are not as good as those of water-based grinding fluids. Straight oils are preferred for heavy from grinding and thread grinding. When grinding superalloys using superabrasives, sulfo-chlorinated mineral oils are often used to provide extreme pressure capability. Some additives cause workpiece staining. Some producers are reformulating their products to reduce recycling problems from such additives. The use of oil precipitators and good positive ventilation of the work area is essential when straight or enhanced oils are being used.

7.12 LAPPING

Lapping is a process of chipping away material with loose abrasive grains. Extremely high accuracy of form and dimensions, as well as very good surface quality, can be obtained with this process.

7.12.1 Lapping Process

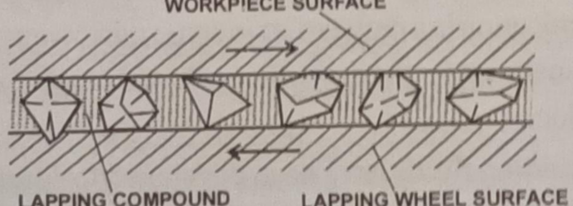


Figure 7.48 Lapping Process

The abrasive substance, consisting of silicon carbide, refined corundum, boron carbide or diamond, in grain sizes between 18 and 150 μm, is mixed with a liquid (oil, kerosine, etc.,) and the mixture is known as lapping compound or lapping paste. This lapping compound chips away material when it is introduced between the surfaces of the lapping wheel and the workpiece and the two are moved against each other with the application of light pressure. The workpiece surface is worn away more rapidly, because the abrasive grains lodge in the softer and more porous lapping wheel and act as cutting wedges against the workpiece. Another theory holds that the abrasive grains roll on the workpiece surface and cause notches on it. The material work hardens and tiny particles chip off.

7.12.2 Lapping Methods

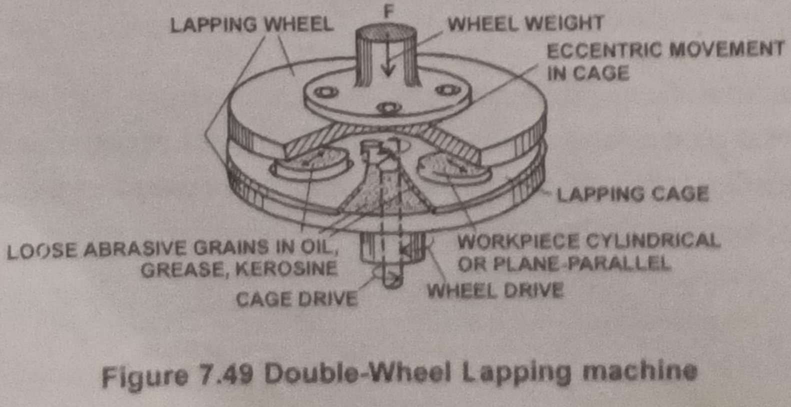


Figure 7.49 Double-Wheel Lapping machine

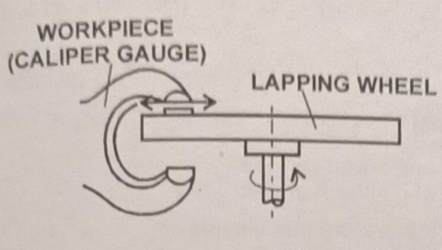


Figure 7.50 Single-Wheel Lapping

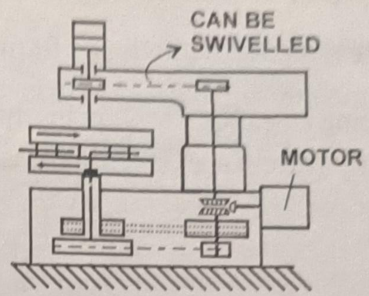


Figure 7.51 Lapping machine

Plane-parallel lapping is carried out to produce flat surfaces, by double or single-wheel lapping. In the double-wheel process (Figure 7.49, 7.50), the flat workpieces are placed in a lapping cage between two lapping wheels rotating in opposite directions. The cage imparts an additional radial movement to the workpieces, to ensure that the wheels do not leave annular grinding tracks on the surfaces.

In single-wheel lapping, the workpiece is placed on a rotating lapping wheel and moved back and forth manually in the radial direction, with the application of gentle pressure.

7.12.3 Cylindrical Lapping

Figure 7.52 External Cylindrical Lapping

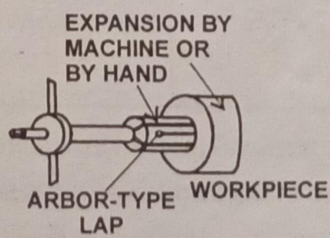


Figure 7.53 Internal Cylindrical Lapping

Outer surfaces of round or cylindrical workpiece can also be machined on *double-wheel lapping machines*. The workpieces are placed tangentially in the cage, whose eccentric movement results in great accuracy of shape.

Lapping tongs are also used to *external cylindrical lapping.* The workpiece is rotated by a drilling machine or lathe and the ring lap is pressed together manually with the tongs and moved in the axial direction.

Expanding arbor-type laps are used for *internal cylindrical lapping.* The procedure is similar to that with the lapping tongs. Lapping compound must be fed continuously in both cases.

Other lapping methods are: form lapping (for specially formed surfaces, *vibration lapping*, pressure lapping)

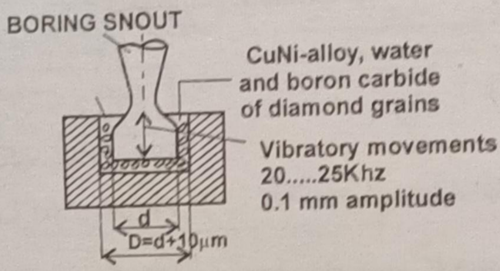


Figure 7.54 Vibration Lapping

Surface finish achieved in a lapping process:

Abrasive Used	*Grain Size*	*Surface Finish, MM*
SIL	220, 320, 400, 500 600, 800	0.75–1.00, 0.64–.75, 0.46–0.64, 0.38–0.46, 0.25–0.38, 0.13–0.25
Al_2O_3	400, 800, 900	0.08–0.13, 0.05–0.08, 0.03–0.08.

Stock removal rares with SIL are generally more compared to Al_2O_3. Corresponding Al_2O_3 gives a better surfinish for the same grain size.

- Soft non-ferrous materials require a fine grain size to produce satisfactory finish compered to steel.

- Lapping is done by changing a lap made of soft materials with abrasive particles and rubbing it over the workpiece surface with a slight pressure.

Lapping Speed:

The lapping speed is 100 – 250 m/min. The material removed depends upon the lapping speed. Higher lapping allowance require higher lapping speeds. The lapping pressure is 0 – 01 to 0.03 mpa for soft materials and 0 – 07 mpa for hard materials. Higher pressures are likely to cause scouring of the work surface. The lapping allowance depends upon the previous operation caused and the material hardness.

Example:

Work Material	*Lapping allowance, mm*
Cast Iron	0.2
Aluminum	0.1
Soft Steel	0.01–0.02
Glass	0.03

lapping can be carried out on flat surface as well as any other form such as a cylindrical surface. The lap has to match the form surface required.

7.13 HONING

Honing is a process of machining with bonded abrasive grains. It serves to improve the shape, size, accuracy and surface quality of the workpiece.

One distinguishes between long-stroke honing and short-stroke honing (superfinishing), in terms of the movement cycles. Both processes can be used for internal surfaces (holes) as well as for outer surfaces (shafts).

Long-stroke honing (honing):

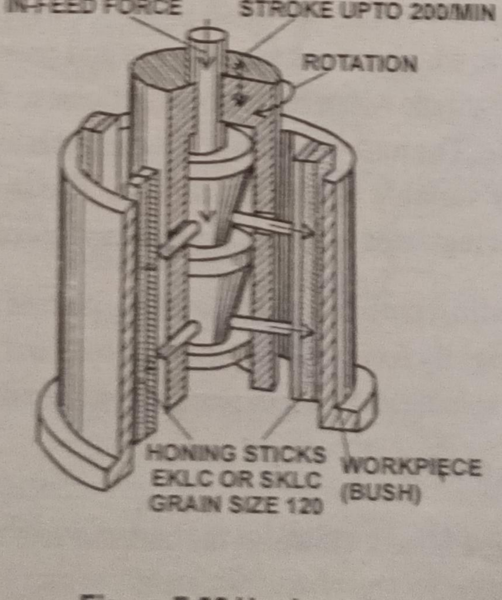


Figure 7.55 Honing tool

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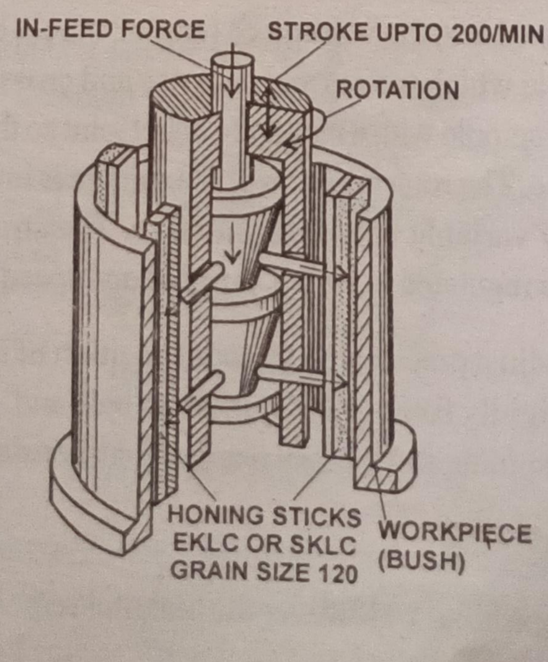

Figure 7.55 Honing tool

The ***honing tool*** has four or more honing sticks mounted in it. The tool rotates and goes through an axial stroke motion at the same time. The stroke length is set so that the tool moves upward and downward beyond the workpiece by about 1/4 of its own length. These motions combine to form a helical grinding track. This not only improves the surface quality, but also the cylindrical shape of the honed workpiece. This process does not significantly affect the roundness of holes. The honing sticks are pressed and fed against the generated surface by two cones inside the tool.

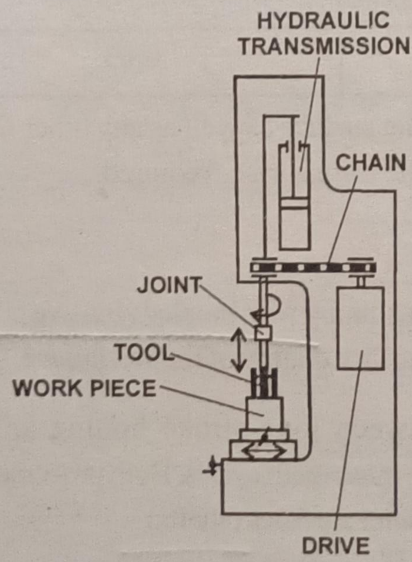

Figure 7.56 Honing machine

On the ***honing machine***, the workpiece (engine block, bush, etc.,) travels under the honing tool on a table which moves and endwise and crosswise. The honing tool is suspended in the honing spindle with a ball-and-socket joint so that it can move and adjust to the position of the hole. The rotary motion of the spindle is imparted to it by an electric motor over a steplessly variable belt or chain drive. The stroke motion is generated hydraulically, and can be regulated in length, position and speed.

Because it must adjust precisely to the axial position of the hole being honed, the honing tool cannot be rigidly fixed to the spindle. A ball-and -socket joint is therefore interposed between the spindle and the tool (cardanic suspension).

Honing conditions

All materials can be honed. However the material removal rate is affected by the hardness of the work material. The typical rates are;

Soft material – 1.15mm/min on diameter.

Hard material – 0.30mm/min on diameter.

The maximum bore size that can be conveniently honed is about 1500mm while the minimum size is 1.5mm in diameter. The honing allowance should be small to be economical. However, the amount also depends upon the previous error to be corrected.

The abrasive and the grain size to be selected depends up on the work material and the resultant finish derived.

Generally higher cutting speeds are used for metals that shear easily such as cast iron and non-famous metals. Alternatively the harder work pieces require lower cutting speeds. Also the rough surfaces that dress the honing stone mechanically allow for higher cutting speeds. Speeds should be decreased as the area of abrasive grain per unit area of bore increases. Higher cutting speeds usually result in a finer finish. However, they decrease dimensional accuracy, over heating of the work piece and dulling of the abrasive. Honing pressures applied are typically about 1.0 to 3.2 mpa.

- This method is mostly used for finishing automobile crank shaft journals.

Layer of metal 0.005 to 0.05 mm grain size 400 to 600.

7.14 SUPERFINISHING

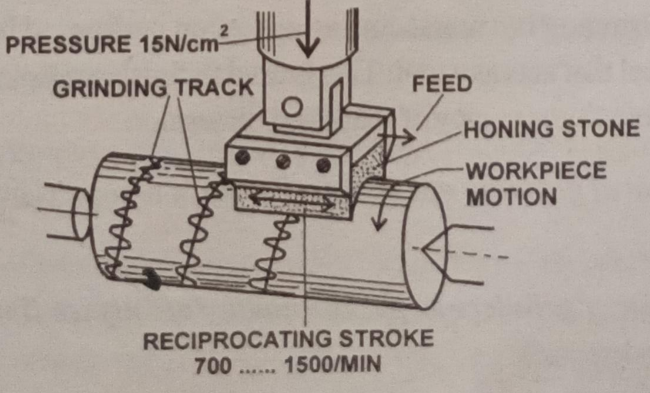

Figure 7.57 Super finishing

This process is characterised by a third movement. In addition to the rotation of the workpiece and the stroke movement of the tool (honing block), the tool also reciprocates through a distance of 1 to 5 mm at 700 to 1500 cycles per minute. The grinding track is a continuous wavy spiral. The curvauture of the honing block is matched to the workpiece diameter, so that the three fold movement improves the circularity as well as cylindrical shape of the workpiece.

In both pocesses, longer and broader honing blocks (i.e., of greater surface area) improve the shape of the workpiece. The infeed pressure is, however, reduced when the tool is of greater area, which increases production time.

Super finishing speed used are 10 to 40 m/min while the working pressure maintained is about 0.1 to 0.3 mpa. The heat generated under these conditions is appreciably small and hence there is no metallurgical alternation of the work. The finish obtained on the surface depends up on the time for which the stone is in contact with the work.

- Rotational Speed is low (2 to 20m/min)
- Longitiduinal speed range 0.1 to 0.15mm/min rest.
- Frequency 500 to 1800 strokes per minute and
- Special lubricant usually a mixture of kerosene and oil is used to obtain a high quality of surface finish.
- Special general purpose machine for super finishing.

SUMMARY

- ***Grinding:*** Grinding is a metal cutting operation performed by means of a rotating abrasive wheel that acts as a tool. This is used to finish workpiece which must have a high surface quality, accuracy of shape and dimension.
- ***Classification of grinding operations:*** Rough or non-precision grinding, precision grinding.
- ***Classification of grinders as per the quality of surface finish:*** Rough grinders, precision grinders.
- ***Grinding machine specified:*** They are specified according to the size of the largest work piece that can be mounted on the machine, which varies with each type of grinder.
- ***Basic methods of thread grinding:*** Centre type traverse grinding (axial -feed), Centre type plunge grinding (infeed or radial feed), Centreless grinding, Internal thread grinding.

- ***Non-diamond dressers:*** Non diamond dressers depends on following types of tools: Cemented carbide discs, star wheel, silicon crabide wheels. These tools are generally clamped in special holders for dressing.

- ***Kind of grinding the arc of contact:*** The arc of contact is at its maximum in internal grinding. Because the greater the arc of contact the longer the chip and more severe will be the conditions of operations of grinding wheel.

- ***Types of Grinding wheel:*** The straight or disc shaped wheel, the cup type either in straight or flating form, the disc type.

- ***Special grinding machines:*** Crankshaft grinders, piston grinders, roll grinders, cam grinders, thread grinders, way grinders, tool post grinders.

- ***Principle of grinding operations:*** Grinding of external and internal cylindrical surfaces, tapered surface grinding, formed surface grinding, gear teeths and thread grinding.

- ***Grinding wheel:*** A grinding wheel is a multi tooth cutter made of many hard particles known as abrasives which have been crushed to leave sharp edges which do the cutting.

- ***Abrasive:*** An abrasive is a substance that is used for grinding and polishing operations. It should be pure and must have uniform physical properties such as hardness, toughness and resistance to fractures.

- ***Wet grinding and dry grinding operations:*** An ordinary wet grinding machine use a coolant box,which spreads a large amount of coolant over the work wheel face and slides. Wet cutting promotes long wheel life.

- ***Bond:*** A bond is an abrasive grain together in the form of sharpening stones or grinding wheels.

- ***Types of bonds:*** Vitrified bond used for making vitrified grinding wheels, silicate bond for making silicate wheels, shellac bond for making elastic wheels, resinoid bond used for making resinoid wheels, rubber bond used for making vulcanised wheels.

- ***Grain size:*** Grain size is denoted by a number indicating the number of meshes, per linear inch (25.4 mm) of the screen through which the grains pass when they are graduated after crushing. In case grinding wheels are manufactured from special grain combination, the grinding wheel manufactures may use an additional symbol added to the standard grain size number. Example: 36 - normal standard, 36.5 - special grain combination.

- ***Factors upon the GRADE of grinding wheel depends:*** Hardness of the material being ground, the arc of contact, the wheel and work speeds, the condition of grinding machine.
- ***The grade of a wheel indicated:*** It is indicated by a letter of english alphabet. A-denoting softest, z-the hardest grade. The term soft or hard refers to the resistance a bond offers to the disruption of abrasives.
- ***Structure of the grinding wheels:*** Abrasive grians are distributed through the bond. The relative spacing is referred to as the structure and is denoted by the number of cutting edges per unit area of the wheel face as well as by the number and size of void spaces between grains.
- ***The function or purpose of a structure and the factors:*** The primary purpose of structure is the provide chip clearance and it may be open or dense. The structure of a grinding wheel depends on the: hardness of material being ground, the finish required, the nature of the grinding operation.
- ***The standard grinding wheel shapes:*** Straight wheels, tapered face straight wheel, cylinder or wheel, cup wheel, dish wheel, segmented wheels.
- ***Mounted wheels:*** Mounted wheels are small shaped wheels. (50 mm dia and below) mounted. Securely and permanently to steer spindle or mandrel by cementing or other means. Great care should be taken in using mounted wheels and points.
- ***Indian standard marking system:*** The IS marking system for grinding wheels has been prepared to establish a uniform system of marking of grinding wheels to designate their chracteristics. Each marking system consists of six symbols, denoting the following in succession: abrasive type, grain size, grade, structure, bond type, manufactured record.
- ***Balancing of grinding wheels:*** If wheels become out of balance through wear and cannot be balanced ty truing or dressing, they should be removed from the machine and discarded wheels should be tested for balance occasionally and rebalanced if necessary.
- ***Diamond wheels:*** Diamond wheels are made with three different types of bonds: Resinoid, vitrified and metallic bonds. Each has particular applications, with some overlapping in order to conserve diamonds, wheels larger than 25mm in diameter are produced with a bonded diamond layer at the cutting surface. All diamond wheels, operate at greater efficiency when used wet.

- ***Feed grinding:*** The feed (s) in cylindrical grinding is the longitudinal movement of the workpiece per revolution. It is expressed in mm/revolution of the workpiece. It is usually from 0.6 to 0.9 of the face width of wheel for rough grinding and from 0.4 to 0.6 of the face width for finished grinding.

- ***Depth of cut in grinding:*** Depth of cut (t) is the thickness of the layer of metal, removed in one pass. It is expressed in mm. It ranges between 0.005 and 0/04 mm.

- ***Truing of grinding wheels:*** This is prepartion of the grinding wheel face to produce a work within specified form, size and finish tolerance. This refers to the altering of form or shape of the wheel. It is used for: making the wheel concentric to axis, putting a shape or profile in to the face of the wheel for form grinding.

- ***Grit number of a grinding number:*** The grain or grit number of indicates the size of the abrasive grains used in making a wheel. Grain size is indicated by a number indicating the number of meshes per linear inch of the screen through which the grain when they are graded after crushing.

- ***Grade of a grinding wheel:*** Grade refers to the hardness with which the bond holds the cutting points or the abrasive grains in a place. It is denoted with letters of english alphabet. A to H - Soft (for hard materials), I to P - medium, Q to Z - Hard (used for soft materials)

- ***Structure of a grinding wheel:*** Structure of a grinding wheel is defined as the relative spacing between the abrasive grains. It is denoted by the number of cutting edges per unit area of the wheel face. The are classified as dense and open wheels: Dense: No: 1 to 8, Open - No: 9 to 15 or higher.

- ***Abrasive in grinding wheel with examples:*** An abrasive is a substance that is used for grinding and polishing operations. Abrasives Natural abrasives- Example: Sand stone, solid quartz, emery, corundum and diamond. Artificial abrasives - Example: silicon carbide, aluminium oxide.

- ***Using grinding process:*** To remove metal from the work piece in small amounts and give them good surface finish, to machine hard surfaces that cannot be machined using high-speed steel, to sharpen cutting tools, to grind threads, can be used for grinding irregular surfaces.

- ***Purpose of rough grinding:*** Rough grinding is done to remove projections like sprue pins from castings, grinding projections in forgings, finishing weldments etc. Since a large amount of metal is cut in a single operation, surface finish and accuracy are not very high.

- ***Portable grinding machine:*** It is made use of in cleaning castings, welded works, sheet metal works, rough works etc. It is handy and easy to carry.

- ***Traverse grinding:*** This method is employed when the length of the job is more than that of its width. The rotating work is fed longitudinally.

- ***Plunge grinding:*** This grinding is very useful when the width of the work piece exceeds its length. The work is given only cross feed into the grinding wheel. They find application in grinding shoulders, stepping and various contours on the work piece.

- ***Centreless grinding:*** This method is employed on workpieces that do not have centers such as pistons, tubes, valves, drills, shafts etc. This operation can be done on both external and internal surfaces. The workpiece is kept in a floating condition between the wheels and hence the name. The workpiece is placed between two wheels. One of them called the grinding wheel rotates at about 1850 rpm while the other wheel called the regulating wheel rotates at speeds varying from 33 to 130 mpm.

- ***Rolls used in centreless grinding:*** Regulating wheels, pressure rolls and supporting rolls are the once made use of in centreless grinding.

- ***Abrasive grains:*** Small abrasive materials that appear on the surface of the grinding wheel is called as abrasive grains. Abrasives are hard materials that cut or wear away other materials.

- ***Lapping:*** Lapping is a surface finishing process used for producing geometrically accurate flat, cylindrical and spherical surfaces.

- ***Types of lapping:*** Equalizing lapping, form lapping.

- ***Honing:*** An abrading process of finishing previously machine surface is called as Honing. (or) Honing was originally used only as a method for finishing and polishing. Recent engineering improvements in the honing machines, together with refinements in tooling, abrasives and honing techniques have combined to greatly increase the utilization of honing as an important production process.

- ***Super finishing:*** Super finishing process is the other name given to a micor finishing process that produces a controlled surface condition on parts which is unobtainable by any other method. Super finishing is a find honing operation. Super finishing achieved higher surface finish on components, removes marks. It also produces the ultimate is the refinement of metal surface (or) The process of obtaining a surface of very high quality is known as super finishing.

REVIEWS

1. Define grinding operation.
2. What is the difference between 'rough' grinding and 'precision' grinding?
3. Why is grinding so important in modern production?
4. Why the natural abrasives are not suitable for making grinding wheels?
5. How is aluminium oxide abrasive produced? Write its field of application.
6. How is silicon carbide abrasive produced? Write its field of application.
7. Under what conditions are diamond, boron carbide and cubic boron nitride used as abrasive materials for making grinding wheels?
8. What is meant by 'grain size' of an abrasive material?
9. Discuss the various types of bonding materials uesd for making grinding wheels?
10. Define a grinding wheel.
11. Discuss the various methods of making grinding wheels.
12. Sketch the various shapes of grinding wheels and write their fields of application.
13. What is meant by 'grade' and 'structure' of a grinding wheel?
14. What is meant by standard marking of grinding wheels?
15. How the grinding wheel is selected for a particular job?
16. What is meant by dressing and truing of grinding wheels?
17. Define "grinding ratio".
18. Sketch and explain the working of an external cylindrical grinding machine.
19. Sketch and explain the three methods of cylindrical grinding.
20. What is the difference between plain and universal cylindrical grinders'
21. Describe in detail how an internal grinder operates.
22. What are the advantages and disadvantages of centreless grinding?
23. Sketch and explain the three methods of external cylindrical centreless grinding.

24. Sketch and explain the internal centre less grinding process.

25. Sketch and explain the various methods of surface grinding.

26. How th ejobs are held during surface grinding operation?

27. Sketch and explain the following grinding processes: Form grinding, gear tooth grinding, thread grinding and cam grinding.

28. What is a tool post grinder?

29. What kind of grinding can be done on the lathe?

30. Sketch and discuss a tool and cutter grinder.

31. What are disk grinders?

32. What are coated abrasives?

33. Explain abrasive belt grinding.

34. Write the drawbacks of abrasive belt grinding.

35. Discuss the various grinding process variables.

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