5.1 FINISHING PROCESSES

Finishing is an abrasive process utilizing either a bonded abrasive or loose abrasive for improving surface finish, reduce irregularities and waviness.

5.2 Theory of grinding

ABRASIVE PROCESSES: GRINDING

Grinding is the most common form of abrasive machining. The art of grinding goes back many centuries. Over 5000 years ago the Egyptians abraded and polished building stones to hairline fits for the pyramids. Grinding is a metal cutting process which engages an abrasive tool whose cutting elements are grains of abrasive material known as grit. These grits are characterized by sharp cutting points, high hot hardness, wear resistance and chemical stability. The grits are held together by a suitable bonding material to give shape of an abrasive tool. Simply it is a metal removal process in which the metal is removed with the help of rotating grinding wheel. Fig. 4.1 illustrates the cutting action of abrasive grits of disc type grinding wheel similar to cutting action of teeth of the cutter in slab milling.

Applications of grinding

- To remove small amount of metal from work pieces and finish then to close tolerances. To obtain a better surface finish.
- To machine hard surfaces that cannot be machined by high-speed steels. Grinding of tools and cutters and resharpening of the same.
- Grinding of threads.
- Stock removal (abrasive milling) finishing of flat as well as cylindrical surface. Slitting and parting.
- Descaling and deburring.

Advantages of grinding

- Dimensional accuracy and good surface finish. Good form and locational accuracy.
- Applicable to both hardened and unhardened material.

GRINDING WHEELS

Grinding wheel consists of hard abrasive grains called grits, which perform the cutting or material removal, held in the weak bonding matrix. A grinding wheel commonly identified by the type of the abrasive material used. The conventional wheels include Aluminium Oxide (Al_2O_3) and Silicon Carbide (SiC) wheels while diamond and CBN (Cubic Boron Nitride) wheels fall in the category of super abrasive wheel. Thus, it forms a multi-edge cutter.

Grinding wheel and work piece interaction

The bulk grinding wheel-work piece interaction as illustrated in Fig. 4.2 can be divided into the following:

1. Grit-work piece (forming chip).
2. Chip-bond.
3. Chip-work piece.
4. Bond-work piece.

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Exceptthegrit-workpieceinteractionwhichisexpectedtoproducechip,theremainingthree undesirably increases the total grinding force and power requirement. Therefore, efforts should always be made to maximize grit-work piece interaction leading to chip formation and to minimize the rest for best utilization of the available power.

5.3 Reconditioning & Truing of grinding wheel

Truing is the act of regenerating the required geometry on the grinding wheel, whether the geometry is a special form or flat profile. Therefore, truing produces the macro-geometry of the grinding wheel.

Truing is also required on a new conventional wheel to ensure concentricity with specific mounting system. In practice the effective macro-geometry of a grinding wheel is of vital importance and accuracy of the finished work piece is directly related to effective wheel geometry.

Truing tools

There are four major types of truing tools:

Steel cutter: These are used to roughly true coarse grit conventional abrasive wheel to ensure freeness of cut. Steel or carbide crash roll: It is used to crush-true the profile on vitrified bond grinding wheel. Vitrified abrasive stick and wheel: It is used for off hand truing of conventional abrasive wheel. These are used for truing resin bonded super abrasive wheel.

Diamond truing tool:

Single point diamond truing tools. [shown in Fig. 4.5]

Multi stone diamond truing tools. [shown in Fig. 4.6]

Impregnated diamond truing tools. [shown in Fig. 4.7]

Rotary powered diamond truing wheels. [shown in Fig. 4.8] Surface set truing wheels.

Impregnated truing wheels.

Electroplated truing tools.

Diamond form truing blocks. [shown in Fig. 4.9]

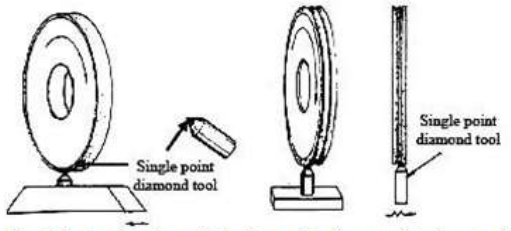
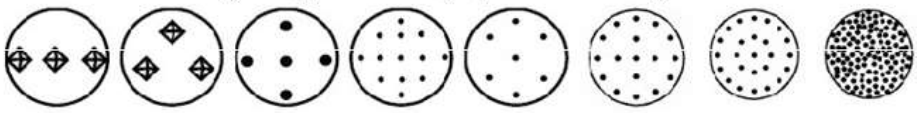


Fig. 4.5 Application of single point diamond truing tool



Distribution of diamond	Diamond weight (carat)	Distribution of diamond	Diamond weight (carat)
(i) 1 layer - 3 stone	10	(v) 5 layer - 7 stone	50
(ii) 2 layer - 3 stone	10	(vi) 5 layer - 17 stone	10
(iii) 3 layer - 5 stone	10	(vii) 5 layer - 25 stone	250
(iv) 5 layer - 13 stone	25	(viii) throughout	50

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5.3.1 Dressing of grinding wheel

Dressing is the conditioning of the wheel surface which ensures that grit cutting edges are exposed from the bond and thus able to penetrate into the work piece material. Also, in dressing attempts are made to splinter the abrasive grains to make them sharp and free cutting and also to remove any residue left by material being ground. Dressing therefore produces micro-geometry. The structure of micro-geometry of grinding wheel determines its cutting ability with a wheel of given composition. Dressing can substantially influence the condition of the grinding tool.

Truing and dressing are commonly combined into one operation for conventional abrasive grinding wheels, but are usually two distinctly separate operation for super abrasive wheel.

Dressing of super abrasive wheel

Dressing of the super abrasive wheel is commonly done with soft conventional abrasive vitrified stick, which relieves the bond without affecting the super abrasive grits. However, modern technique like electrochemical dressing has been successfully used in metal bonded super abrasive wheel. The wheel acts like an anode while a cathode plate is placed in front of the wheel working surface to allow electrochemical dissolution.

Electro discharge dressing is another alternative route for dressing metal bonded super abrasive wheel. In this case a dielectric medium is used in place of an electrolyte. Touch-dressing, a new concept differs from conventional dressing in that bond material is not relieved. In contrast the dressing depth is precisely controlled in micron level to obtain better uniformity of grit height resulting in improvement of work piece surface finish.

5.4 Classification of grinding machines

Conventional grinding machines can be broadly classified as:

a. Surface grinding machine
b. Cylindrical grinding machine
c. Internal grinding machine
d. Tool and cutter grinding machine

5.4.1 Surface grinding machine:

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

- Horizontal spindle and reciprocating table
- Vertical spindle and reciprocating table
- Horizontal spindle and rotary table
- Vertical spindle and rotary table

5.4.2 Horizontal spindle reciprocating table grinder

Figure 29.1 illustrates this machine with various motions required for grinding action. A disc type grinding wheel performs the grinding action with its peripheral surface. Both traverse and plunge grinding can be carried out in this machine as shown in Fig. 29.2

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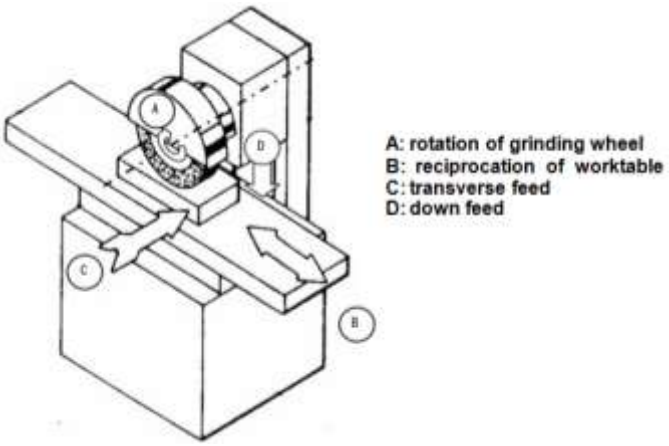


Fig.29.1: Horizontal spindle reciprocating table surface grinder

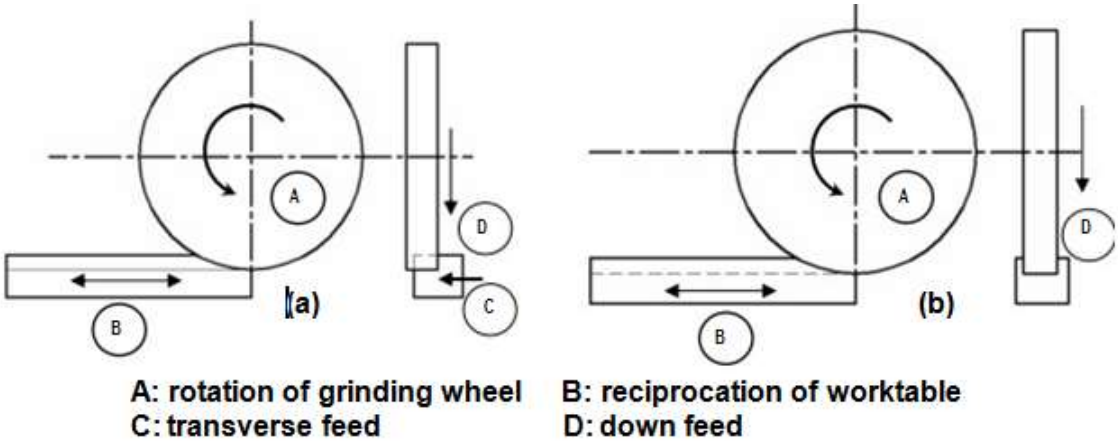


Fig. 29.2 Surface grinding (a) traverse grinding (b) plunge grinding

5.4.3 Vertical spindle reciprocating table grinder

This grinding machine with all working motions is shown in Fig. 29.3. The grinding operation is similar to that of face milling on a vertical milling machine. In this machine a cup shaped wheel grinds the workpiece over its full width using end face of the wheel as shown in Fig. 29.4. This brings more grits in action at the same time and consequently a higher material removal rate may be attained than for grinding with a peripheral wheel.

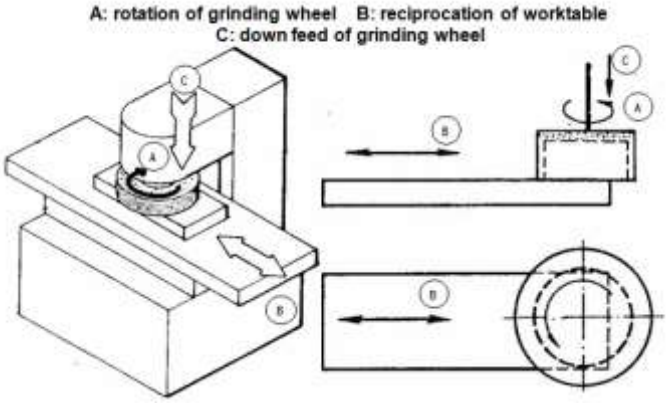


Fig. 29.3 Vertical spindle reciprocating table surface grinder

Fig. 29.4 Surface grinding in Vertical spindle reciprocating table surface grinder

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5.4.4 Horizontal spindle rotary table grinder

Surface grinding in this machine is shown in Fig.29.5. In principle the operation is same as that for facing on the lathe. This machine has a limitation in accommodation of workpiece and therefore does not have wide spread use. However, by swivelling the worktable, concave or convex or tapered surface can be produced on individual part as illustrated in Fig. 29.6

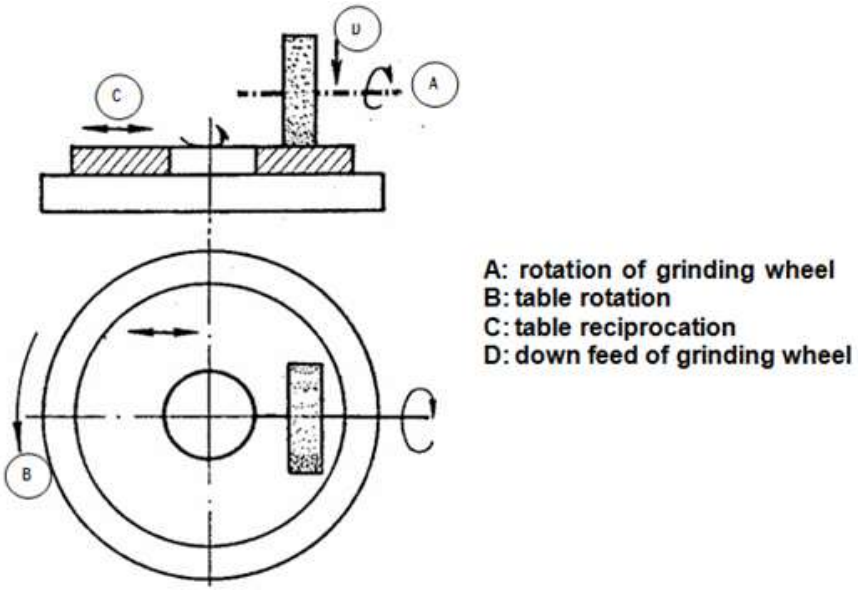


Fig. 29.5 Surface grinding in Horizontal spindle rotary table surface grinder

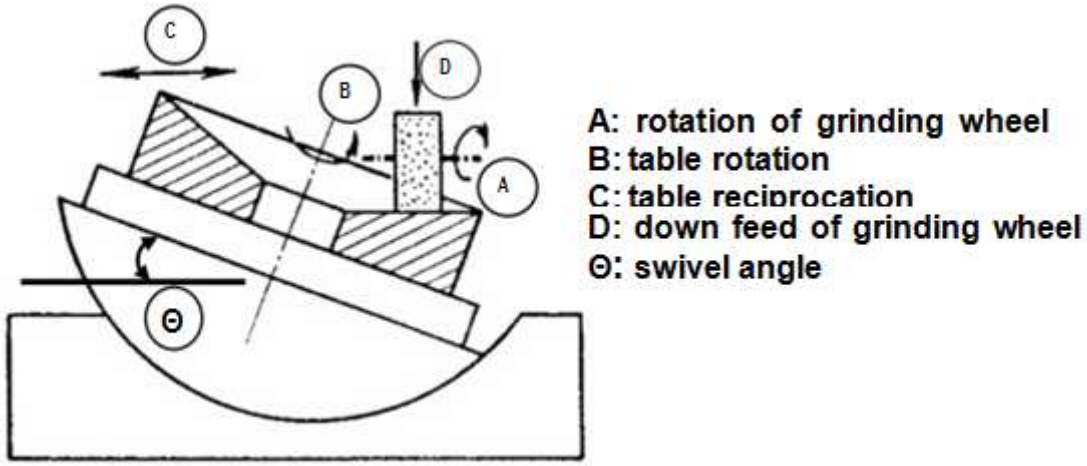
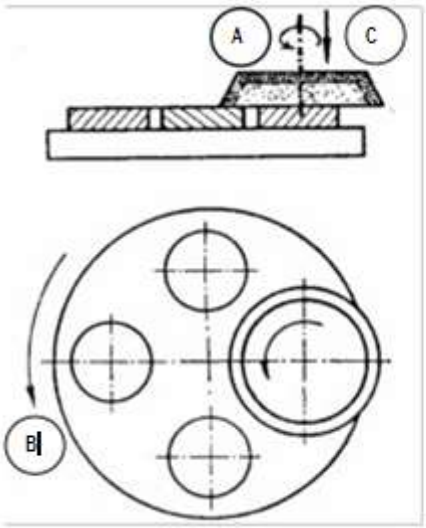


Fig. 29.6 Grinding of a tapered surface in horizontal spindle rotary table surface grinder

5.4.5 Vertical spindle rotary table grinder

The principle of grinding in this machine is shown in Fig. 29.7. The machine is mostly suitable for small workpieces in large quantities. This primarily production type machine often uses two or more grinding heads thus enabling both roughing and finishing in one rotation of the work table.



A: rotation of grinding wheel
B: work table rotation
C: down feed of grinding wheel

Fig. 29.7 Surface grinding in vertical spindle rotary table surface grinder

5.4.6 Creep feed grinding machine:

This machine enables single pass grinding of a surface with a larger downfeed but slower table speed than that adopted for multi-pass conventional surface grinding. This machine is characterised by high stiffness, high spindle power, recirculating ball screw drive for table movement and adequate supply of grinding fluid. A further development in this field is the creep feed grinding centre which carries more than one wheel with provision of automatic wheel changing. A number of operations can be performed on the workpiece. It is implied that such machines, in the view of their size and complexity, are automated through CNC.

5.4.7 High efficiency deep grinding machine:

The concept of single pass deep grinding at a table speed much higher than what is possible in a creep feed grinder has been technically realized in this machine. This has been made possible mainly through significant increase of wheel speed in this new generation grinding machine.

5.5 Cylindrical grinding machine

This machine is used to produce external cylindrical surface. The surfaces may be straight, tapered, steps or profiled. Broadly there are three different types of cylindrical grinding machine as follows:

1. Plain centre type cylindrical grinder
2. Universal cylindrical surface grinder
3. Centre less cylindrical surface grinder

5.5.1 Plain centre type cylindrical grinder

Figure 29.8 illustrates schematically this machine and various motions required for grinding action. The machine is similar to a centre lathe in many respects. The workpiece is held between head stock and tailstock centres. A disc type grinding wheel performs the grinding action with its peripheral surface. Both traverse and plunge grinding can be carried out in this machine as shown in Fig.29.9.

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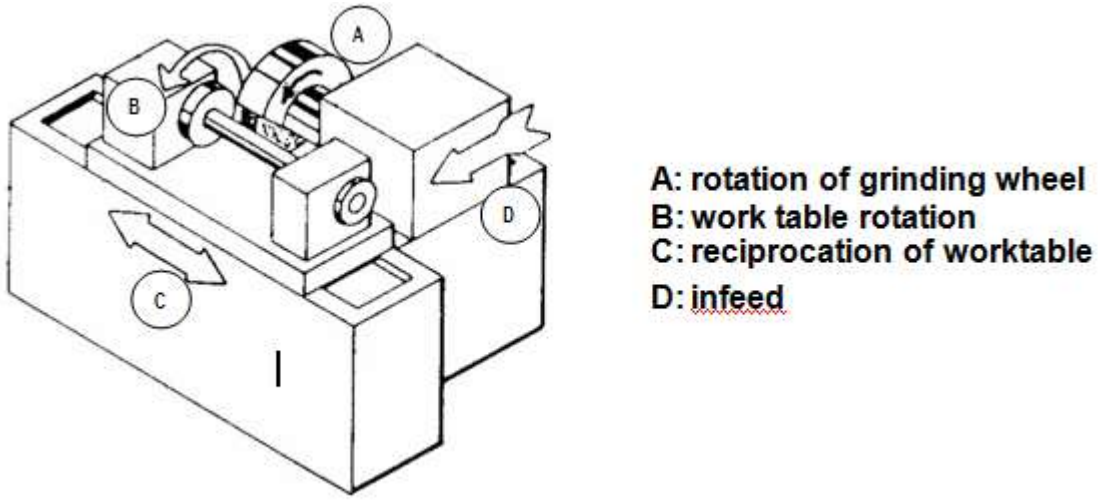


Fig. 29.8 Plain centre type cylindrical grinder

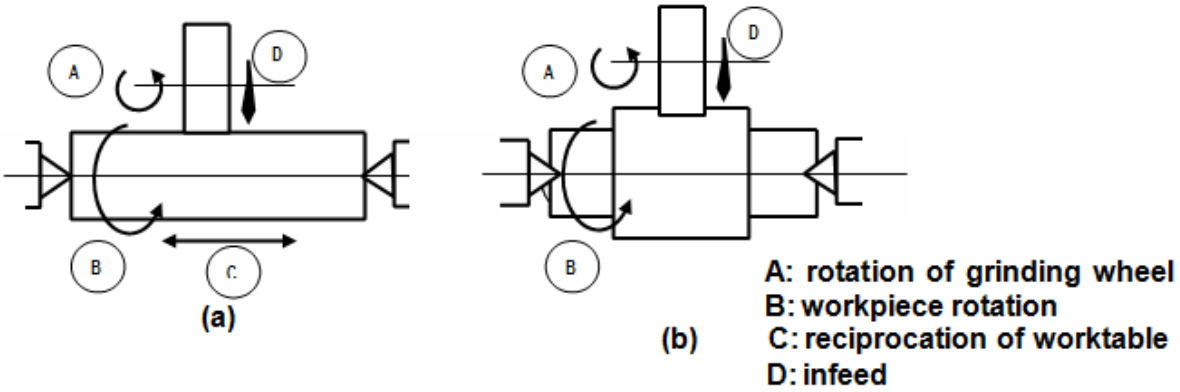


Fig. 29.9 cylindrical (a) traverse grinding and (b) plunge grinding

5.5.2 Universal cylindrical surface grinder

Universal cylindrical grinder is similar to a plain cylindrical one except that it is more versatile. In addition to small worktable swivel, this machine provides large swivel of head stock, wheel head slide and wheel head mount on the wheel head slide.

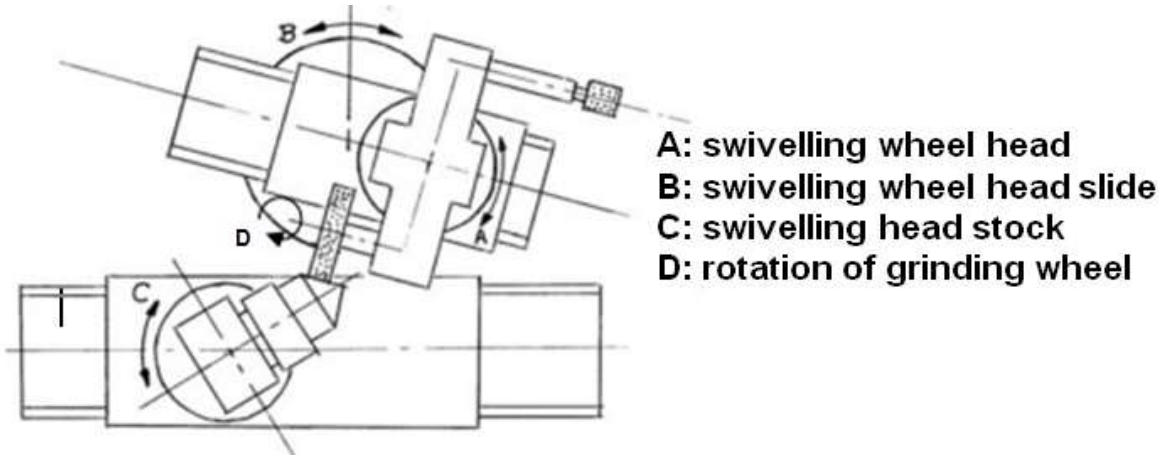


Fig. 29.10 important features of universal cylindrical grinding machine

This allows grinding of any taper on the workpiece. Universal grinder is also equipped with an additional head for internal grinding. Schematic illustration of important features of this machine is shown in Fig.29.10.

5.5.3 External centreless grinder

This grinding machine is a production machine in which outside diameter of the workpiece is ground. The workpiece is not held between centres but by a work support blade. It is rotated by means of a regulating wheel and ground by the grinding wheel.

In through-feed centreless grinding, the regulating wheel revolving at a much lower surface speed than grinding wheel controls the rotation and longitudinal motion of the workpiece. The regulating wheel is kept slightly inclined to the axis of the grinding wheel and the workpiece is fed longitudinally as shown in Fig. 29.14.

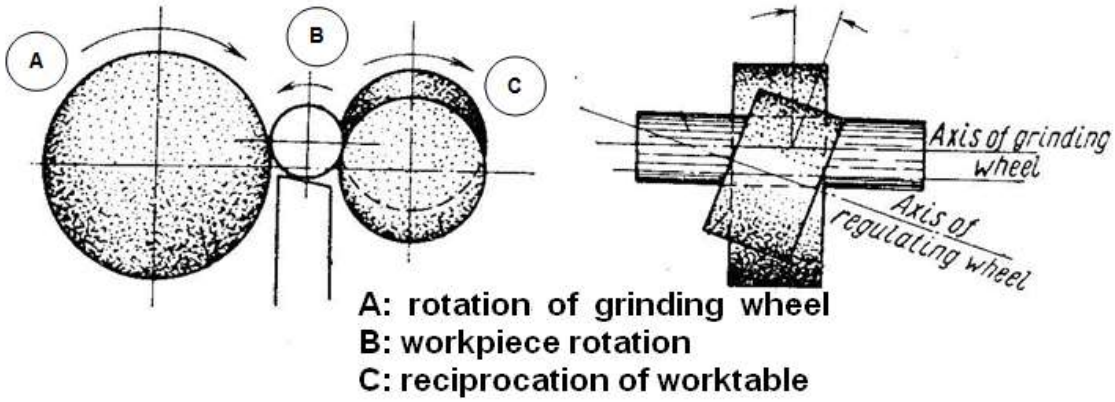


Fig.29.14: Centreless through feed grinding

Parts with variable diameter can be ground by centreless in feed grinding as shown in Fig. 29.15(a). The operation is similar to plunge grinding with cylindrical grinder. End feed grinding shown in Fig. 29.15 (b) is used for workpiece with tapered surface.

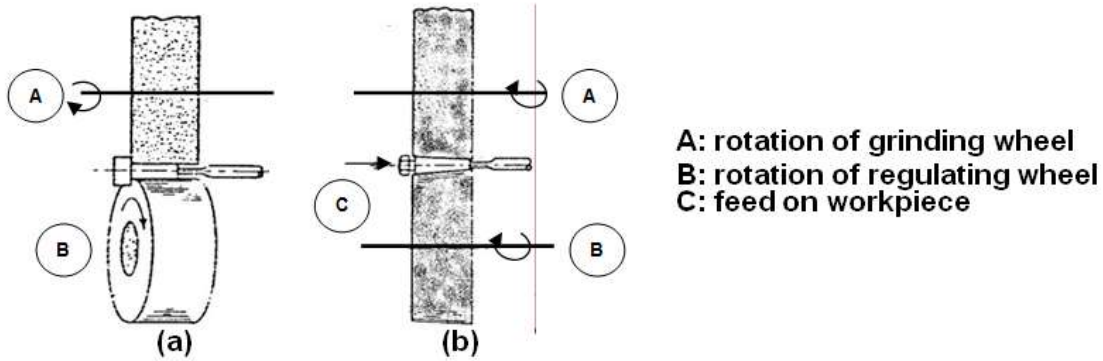


Fig. 29.15 Centreless (a) infeed and (b) end feed grinding

The grinding wheel or the regulating wheel or both require to be correctly profiled to get the required taper on the workpiece.

5.5.4 Centreless internal grinder

This machine is used for grinding cylindrical and tapered holes in cylindrical parts (e.g. cylindrical liners, various bushings etc). The workpiece is rotated between supporting roll, pressure roll and regulating wheel and is ground by the grinding wheel as illustrated in Fig. 29.19

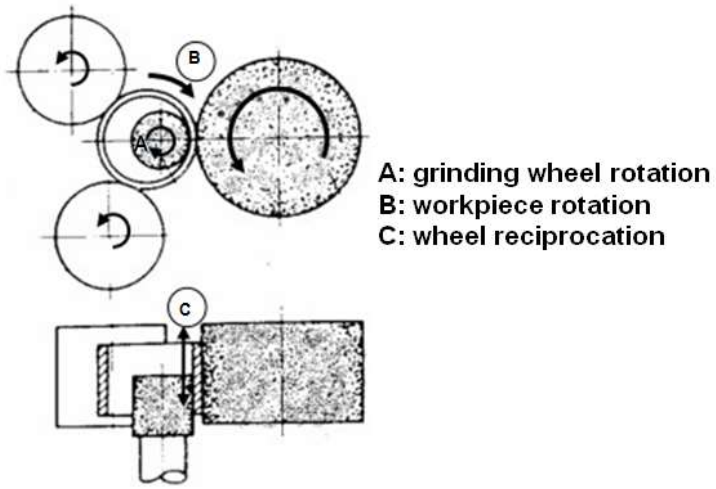


Fig. 29.19 Internal centreless grinding

5.6 Tool and cutter grinding machines

5.7 Different types of abrasives, bonds

5.7.1 Types of abrasives

Abrasives may be classified into two types:

1. Natural abrasives
    a. Emery (50 - 60 % crystalline Al_2O_3 + Iron Oxide),
    b. Sandstone or Solid Quartz,
    c. Corundum (75 - 90 % crystalline Al_2O_3 + Iron Oxide) and
    d. Diamond.
2. Artificial abrasives
    a. Aluminium Oxide(Al2O3),
    b. Silicon Carbide(SiC),
    c. Artificial diamond,
    d. Boron Carbide and
    e. Cubic Boron Nitride (CBN).

The abrasives that are generally used are

1. Aluminum Oxide. (Al_2O_3)
2. Silicon Carbide. (SiC)
3. Diamond.
4. Cubic Boron Nitride. (CBN)

1. Aluminium oxide (Al_2O_3):

Aluminium oxide may have variation in properties arising out of differences in chemical composition and structure associated with the manufacturing process. Pure Al_2O_3 grit with defect structure like voids leads to unusually sharp free cutting action with low strength and is advantageous in fine tool grinding operation, and heat sensitive operations on hard, ferrous materials. Regular or brown aluminium oxide (doped with TiO_2) possesses lower hardness and higher toughness than the white Al_2O_3 and is recommended heavy duty grinding to semi finishing. Al_2O_3 alloyed with chromium oxide (<3%) is pink in colour. Monocrystalline Al_2O_3 grits make a balance between hardness and toughness and are efficient in medium pressure heat sensitive operation on ferrous materials.

Microcrystalline Al_2O_3 grits of enhanced toughness are practically suitable for stock removal grinding. Al_2O_3 alloyed with zirconia also makes extremely tough grit mostly suitably for high pressure, high material removal grinding on ferrous material and are not recommended for precision grinding. Microcrystalline sintered Al_2O_3 grit is the latest development particularly known for its toughness and self sharpening characteristics. Trade names: Alundum, Aloxide, corundum, emery, etc.

2. Silicon carbide (SiC)

Silicon carbide is harder than alumina but less tough. Silicon carbide is also inferior to Al2O3 because of its chemical reactivity with iron and steel. Black carbide containing at least 95% SiC is less hard but tougher than green SiC and is efficient for grinding soft nonferrous materials. Green silicon carbide contains at least 97% SiC. It is harder than black variety and is used for grinding cemented carbide. Trade names: Carborundum, Crystolon, Electrolon, etc.

3. Diamond

Diamond grit is best suited for grinding cemented carbides, glass, sapphire, stone, granite, marble, concrete, oxide, non-oxide ceramic, fiber reinforced plastics, ferrite, graphite. Natural diamond grit is characterized by its random shape, very sharp cutting edge and free cutting action and is exclusively used in metallic, electroplated and brazed bond.

Monocrystalline diamond grits are known for their strength and designed for particularly demanding application. These are also used in metallic, galvanic and brazed bond. Polycrystalline diamond grits are more friable than monocrystalline one and found to be most suitable for grinding of cemented carbide with low pressure. These grits are used in resin bond.

4. Cubic Boron Nitride (CBN)

Diamond though hardest is not suitable for grinding ferrous materials because of its reactivity. In contrast, CBN the second hardest material, because of its chemical stability is the abrasive material of choice for efficient grinding of HSS, alloy steels, HSTR alloys.

Presently CBN grits are available as monocrystalline type with medium strength and blocky monocrystals with much higher strength. Medium strength crystals are more friable and used in resin bond for those applications where grinding force is not so high. High strength crystals are used with vitrified, electroplated or brazed bond where large grinding force is expected.

Microcrystalline CBN is known for its highest toughness and auto sharpening character and found to be best candidate for HEDG and abrasive milling. It can be used in all types of bond.

5.7.2 Bonds

It is an adhesive substance which holds the abrasive grains together to form the grinding wheel. Types of bonds - Bonds are classified into two types:

1. Organic - Resinoid, Rubber, Shellac & Oxychloride
2. Non – Organic - Metallic, Vitrified & Silicate

Vitrified bond (V)

Vitrified bond is suitable for high stock removal even at dry condition. It can also be safely used in wet grinding. It can not be used where mechanical impact or thermal variations are like to occur. This bond is also not recommended for very high speed grinding because of possible breakage of the bond under centrifugal force.

Rubber bond (R)

Its principal use is in thin wheels for wet cut-off operation. Rubber bond was once popular for finish grinding on bearings and cutting tools.

Silicate bond (S)

Silicate wheels are made by mixing abrasive grains with silicate of soda. The mixture is moulded in a mould and dried for several hours. After drying, the moulded material is kept in a furnace at about 260^0 C for 20 to 80 hours. Silicate bonded wheels are light grey in colour. These wheels are having a fairly high tensile strength.

Metal bond (M)

Metal bond is extensively used with super abrasive wheels. Extremely high toughness of metal bonded wheels makes these very effective in those applications where form accuracy as well as large stock removal is desired.

Shellac bond (E)

Shellac bonded grinding wheels are relatively strong but not rigid. At one time this bond was used for flexible cut off wheels. At present use of shellac bond is limited to grinding wheels engaged in fine finish of rolls.

Oxychloride bond (O)

It is less common type bond, but still can be used in disc grinding operation. It is used under dry condition. It is produced by mixing abrasive grains with oxide and chloride of magnesium.

Resinoid bond (B)

Conventional abrasive resin bonded wheels are widely used for heavy duty grinding because of their ability to withstand shock load. This bond is also known for its vibration absorbing characteristics and finds its use with diamond and CBN in grinding of cemented carbide and steel respectively.

Resin bond is not recommended with alkaline grinding fluid for a possible chemical attack leading to bond weakening. Fiber glass reinforced resin bond is used with cut off wheels which requires added strength under high speed operation.

Electroplated bond

This bond allows large (30-40%) crystal exposure above the bond without need of any truing or dressing. This bond is specially used for making small diameter wheel, form wheel and thin super abrasive wheels. Presently it is the only bond for making wheels for abrasive milling and ultra-high speed grinding.

Brazed bond

This is relatively a recent development, allows crystal exposure as high 60-80%. In addition grit spacing can be precisely controlled. This bond is particularly suitable for very high material removal either with diamond or CBN wheel. The bond strength is much greater than provided by electroplated bond. This bond is expected to replace electroplated bond in many applications.

5.8 Specification and selection of a grinding wheel

Specification of a grinding wheel ordinarily means compositional specification. Conventional abrasive grinding wheels are specified encompassing the following parameters.
The type of grit material.
The grit size.
The bond strength of the wheel, commonly known as wheel hardness.
The structures of the wheel denoting the porosity i.e. the amount of inter grit spacing. The type of bond material.
Other than these parameters, the wheel manufacturer may add their own identification code prefixing or suffixing (or both) the standard code.

13.21. SELECTION OF GRINDING WHEELS

Selection of a proper grinding wheel is a vital necessity to obtain the best results in grinding work. A wheel may be required to perform various different functions like quick removal of stock material, give a high class surface finish, maintain close dimensional tolerances and a single wheel will fail to meet all the requirements. It is necessary, therefore, that proper grain size, bond, grade, strength, shape and size of the wheel should be selected to meet the specific requirements of a job. The factors upon which the above selection will depend are as follows :

1. Properties of the material to be machined, *i.e.*, its hardness, toughness, strength, etc.
2. Quality of surface finish required.
3. Grinding allowance provided on the workpiece, *i.e.*, the amount of stock to be removed.
4. Dimensional accuracy required.
5. Method of grinding, *i.e.*, wet or dry.
6. Rigidity, size and type of machine.
7. Relative sizes of wheel and job.
8. Type of grinding to be done.
9. Speed and feed of the wheel.

The Indian Standard Institution (*see* IS : 1249-1958) has recommended the use of the following grinding wheels for different materials and operations.

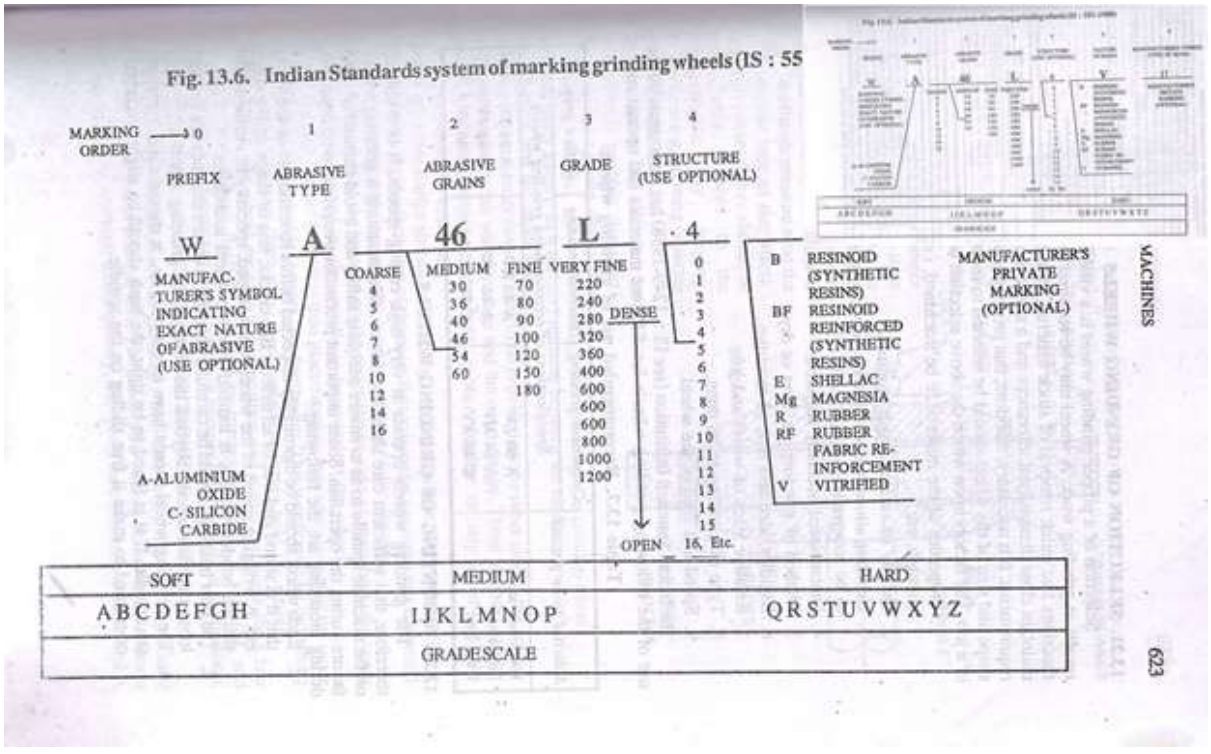


Fig. 13.6. Indian Standards system of marking grinding wheels (IS : 55

Marking system for conventional grinding wheel

The standard marking system for conventional abrasive wheel can be as follows:

51 A 60 K 5 V 05

where

The number '51' is manufacturer's identification number indicating exact kind of abrasive used. The letter 'A' denotes that the type of abrasive is Aluminium Oxide (Al2O3). In case of Silicon Carbide (SiC) the letter 'C' is used.

The number '60' specifies the average grit size in inch mesh. For a very large size grit this number may be as small as 6 where as for a very fine grit the number may be as high as 600.

The letter 'K' denotes the hardness of the wheel. The letter symbol can range between 'A' and 'Z', 'A' denoting the softest grade and 'Z' denoting the hardest one.

The number '5' denotes the structure or porosity of the wheel. This number can assume any value between 1 to 20, '1' indicating high porosity and '20' indicating low porosity.

The letter code 'V' means that the bond material used is vitrified.

The number '05' is a wheel manufacturer's identifier.

Marking system for super abrasive grinding wheel

Marking system for super abrasive grinding wheel is somewhat different as illustrated below:

R D 120 N 100 M 4

where

The letter 'R' is manufacture's code indicating the exact type of super abrasive used.

The letter 'D' denotes that the type of abrasive is Diamond. In case of Cubic Boron Nitride (CBN) the letter 'B' is used.

The number '120' specifies the average grain size in inch mesh. However, a two number designation (e.g. 120/140) is utilized for controlling the size of super abrasive grit.

Like conventional abrasive wheel, the letter 'N' denotes the hardness of the wheel. However, resin and metal bonded wheels are produced with almost no porosity and effective grade of the wheel is obtained by modifying the bond formulation.

The number '100' is known as concentration number indicating the amount of abrasive contained in the wheel. The number '100' corresponds to an abrasive content of 4.4 carats/cm3. For diamond grit, '100' concentration is 25% by volume. For CBN the corresponding volumetric concentration is 24%.

The letter 'M' denotes that the type of bond is metallic. The other types of bonds used in super abrasive wheels are resin, vitrified or metal bond, which make a composite structure with the grit material. However, another type of super abrasive wheel with both diamond and CBN is also manufactured where a single layer of super abrasive grits are bonded on a metal perform by a galvanic metal layer or a brazed metal layer

Indian standard marking system

W A 36 K 5 R 17

Where

W - Manufacture's symbol indicating exact kind of abrasive, (optional use).

A - Abrasive type: A for Al2O3, C for SiC, D for Diamond.

36 - Grain size.

K - Grade.

5 - Structure.

R - Bond type.

17 - Private marking to identify the wheel, (optional use).

5.9 Lapping operations

Lapping is regarded as the oldest method of obtaining a fine finish. Lapping is basically an abrasive process in which loose abrasives function as cutting points finding momentary support from the laps. Figure schematically represents the lapping process. Material removal in lapping usually ranges from .003 to .03 mm but many reach 0.08 to 0.1mm in certain cases.

Characteristics of lapping process:

Use of loose abrasive between lap and the workpiece

Usually lap and workpiece are not positively driven but are guided in contact with each other

Relative motion between the lap and the work should change continuously so that path of the abrasive grains of the lap is not repeated on the workpiece.

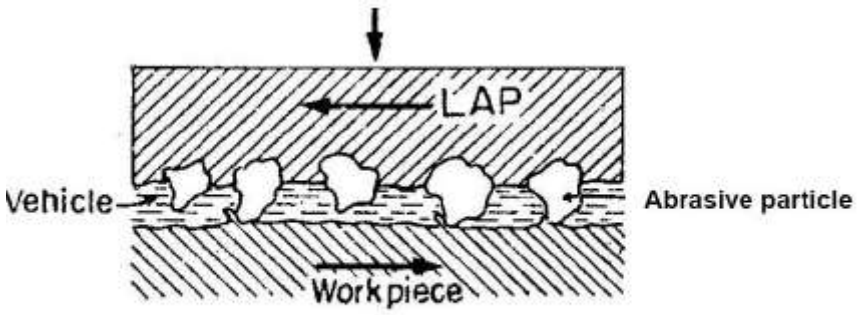


Fig. 30.1 *Scheme of lapping process*

Cast iron is the mostly used lap material. However, soft steel, copper, brass, hardwood as well as hardened steel and glass are also used.

Abrasives of lapping:

Al_2O_3 and SiC, grain size 5~100µm

Cr_2O_3, grain size 1~2 µm

Diamond, grain size 0.5~5 V

Vehicle materials for lapping

Machine oil

Rape oil

grease

Technical parameters affecting lapping processes are:

Unit pressure

The grain size of abrasive

Concentration of abrasive in the vehicle

Lapping speed

Lapping is performed either manually or by machine. Hand lapping is done with abrasive powder as lapping medium, whereas machine lapping is done either with abrasive powder or with bonded abrasive wheel.

Hand lapping

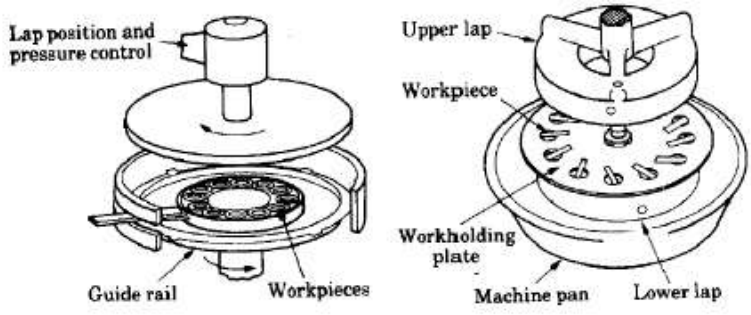
Hand lapping of flat surface is carried out by rubbing the component over accurately finished flat surface of master lap usually made of a thick soft close-grained cast iron block. Abrading action is accomplished by very fine abrasive powder held in a vehicle. Manual lapping requires high personal skill because the lapping pressure and speed have to be controlled manually.

Laps in the form of ring made of closed grain cast iron are used for manual lapping of external cylindrical surface. The bore of the ring is very close to size of the workpiece however, precision adjustment in size is possible with the use of a set screw as illustrated in Fig. To increase range of working, a single holder with interchangeable ring laps can also be used. Ring lapping is recommended for finishing plug gauges and machine spindles requiring high precision. External threads can be also lapped following this technique. In this case the lap is in the form of a bush having internal thread.

Solid or adjustable laps, which are ground straight and round, are used for lapping holes. For manual lapping, the lap is made to rotate either in a lathe or honing machine, while the workpiece is reciprocated over it by hand. Large size laps are made of cast iron, while those of small size are made of steel or brass. This process finds extensive use in finishing ring gauges.

Lapping Machine

Machine lapping is meant for economic lapping of batch qualities. In machine lapping, where high accuracy is demanded, metal laps and abrasive powder held in suitable vehicles are used. Bonded abrasives in the form wheel are chosen for commercial lapping. Machine lapping can also employ abrasive paper or abrasive cloth as the lapping medium. Production lapping of both flat and cylindrical surfaces is illustrated in Fig. In this case cast iron plate with loose abrasive carried in a vehicle can be used. Alternatively, bonded abrasive plates may also be used. Centre less roll lapping uses two cast iron rolls, one of which serves as the lapping roller twice in diameter than the other one known as the regulating roller. During lapping the abrasive compound is applied to the rolls rotating in the same direction while the workpiece is fed across the rolls. This process is suitable for lapping a single piece at a time and mostly used for lapping plug gauges, measuring wires and similar straight or tapered cylindrical parts.



Production lapping on (a) flat surface (b) cylindrical surface

The bonded abrasive lapping wheel as well as the regulating wheel is much wider than those used in centreless grinding. This technique is used to produce high roundness accuracy and fine finish, the workpiece requires multi-pass lapping each with progressively finer lapping wheel. This is a high production operation and suitable for small amount of rectification on shape of workpiece.

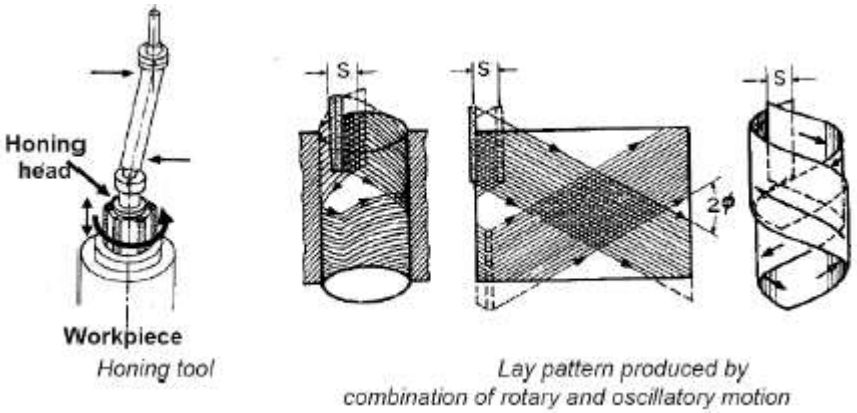
Therefore, parts are to be pre-ground to obtain substantial straightness and roundness. The process finds use in lapping piston rings, shafts and bearing races.

Machines used for lapping internal cylindrical surfaces resemble honing machines used with power stroke. These machines in addition to the rotation of the lap also provide reciprocation to the workpiece or to the lap. The lap made usually of cast iron either solid or adjustable type can be conveniently used.

5.10 Honing operations

Honing is a finishing process, in which a tool called hone carries out a combined rotary and reciprocating motion while the workpiece does not perform any working motion. Most honing is done on internal cylindrical surface, such as automobile cylindrical walls. The honing stones are held against the workpiece with controlled light pressure. The honing head is not guided externally but, instead, floats in the hole, being guided by the work surface. It is desired that

1. Honing stones should not leave the work surface
2. Stroke length must cover the entire work length.



Honing tool

Lay pattern produced by combination of rotary and oscillatory motion

The honing stones are given a complex motion so as to prevent every single grit from repeating its path over the work surface. The critical process parameters are:

1. Rotation speed
2. Oscillation speed
3. Length of the stroke
4. Honing stick pressure

With conventional abrasive honing stick, several strokes are necessary to obtain the desired finish on the work piece. However, with introduction of high performance diamond and CBN grits it is now possible to perform the honing operation in just one complete stroke.

5.11 Broaching operations

5.11.1 Basic principles of broaching

Broaching is a machining process for removal of a layer of material of desired width and depth usually in one stroke by a slender rod or bar type cutter having a series of cutting edges with gradually increased protrusion as indicated in Fig. 4.51 (b). In shaping, attaining full depth requires a number of strokes to remove the material in thin layers step-by-step by gradually infeeding the single point tool as illustrated in Fig. 4.51 (a). Whereas, broaching enables remove the whole material in one stroke only by the gradually rising teeth of the cutter called broach. The amount of tooth rise between the successive teeth of the broach is equivalent to the infeed given in shaping.

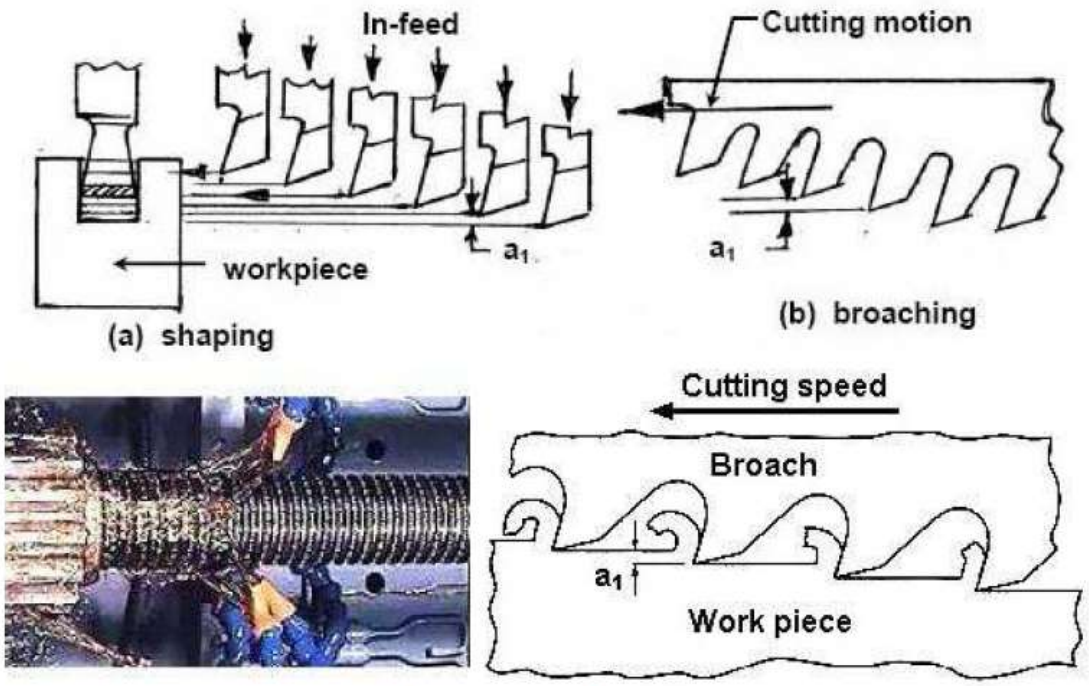


Fig. 4.51 Basic principle of broaching

Machining by broaching is preferably used for making straight through holes of various forms and sizes of section, internal and external through straight or helical slots or grooves, external surfaces of different shapes, teeth of external and internal splines and small spur gears etc. Fig. 4.52 schematically shows how a through hole is enlarged and finished by broaching

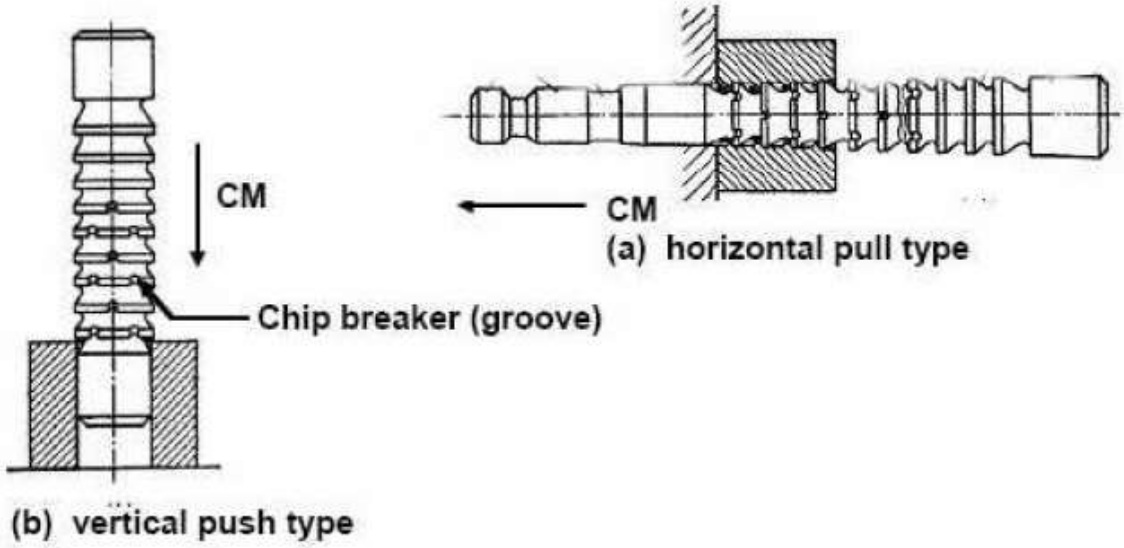


Fig. 4.52 Schematic views of finishing hole by broaching

The cutting tool is called a broach, and the machine tool is called a broaching machine. The shape of the machined surface is determined by the contour of the cutting edges on the broach, particularly the shape of final cutting teeth. Broaching is a highly productive method of machining. Advantages include good surface finish, close tolerances, and the variety of possible machined surface shapes, some of them can be produced only by broaching. Owing to the complicated geometry of the broach, tooling is expensive. Broaching is a typical mass production operation.

Productivity improvement to ten times or even more be not uncommon, as the metal removal rate by broaching is vastly greater. Roughing, semi finishing and finishing of the component is done just in one pass by broaching, and this pass is generally accomplished in seconds.

Broaching can be used for machining of various integrate shapes which can not be otherwise machined with other operations. Some of the typical examples of shapes produced by internal broaching are shown in Fig. 4.53.

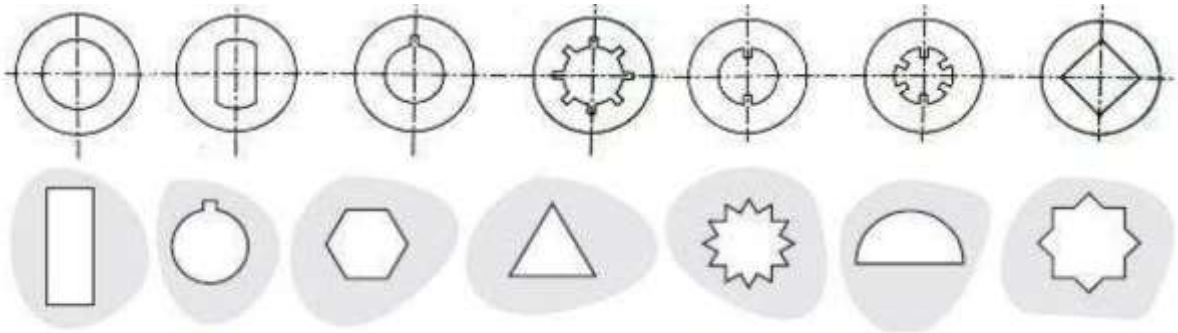


Fig. 4.53 Typical examples of shapes produced by internal broaching

4.20.2 Different types of broaches and their applications

Broaching is getting more and more widely used, wherever feasible, for high productivity as well as product quality. Various types of broaches have been developed and are used for wide range of applications. Broaches can be broadly classified in several aspects such as:

Internal broaching or external broaching.

Pull type or Push type.

Ordinary cut or Progressive type.

Solid, Sectional or Modular type.

Profile sharpened or form relieved type.

Internal broaching and broaches

Internal broaching tools are used to enlarge and finish various contours in through holes

preformed by casting, forging, rolling, drilling, punching etc. Internal broaching tools are mostly pull

type but may be push type also for lighter work. Pull type internal broaching tools are generally provided

with a set of roughing teeth followed by few semi-finishing teeth and then some finishing teeth which

may also include a few burnishing teeth at the end. The wide range of internal broaching tools and their

applications include:

Through holes of different form and dimensions. [Fig. 4.54] Non-circular holes and internal slots. [Fig. 4.54]

Internal keyway and splines. [Fig. 4.54]

Teeth of straight and helical fluted internal spur gears. [Fig. 4.54]

External broaching and broaches

External surface broaching competes with milling, shaping and planing and, wherever feasible, outperforms those processes in respect of productivity and product quality. External broaching tools may be both pull and push type. Major applications of external broaching are:

Un-obstructed outside surfacing; flat, peripheral and contour surfaces. [Fig. 4.55 (a)] Grooves, slots, keyways etc. on through outer surfaces of objects. [Fig. 4.55 (a)] External splines of different forms.

Teeth of external spur gears or gear sectors as shown in Fig. 4.55 (b).

External broaching tools are often made in segments which are clamped in fixtures for operation.

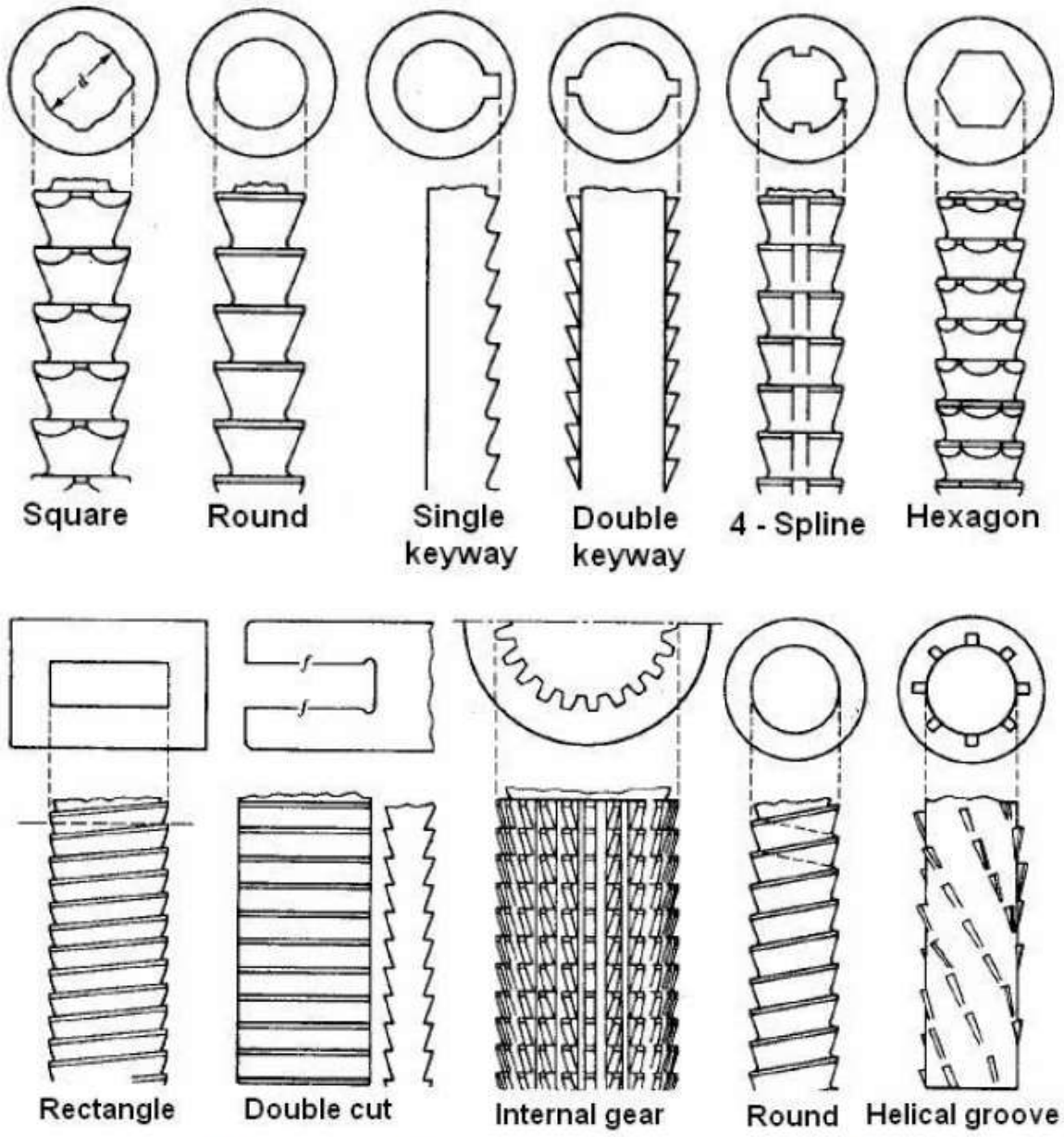


Fig. 4.54 Internal broaching – tools and applications

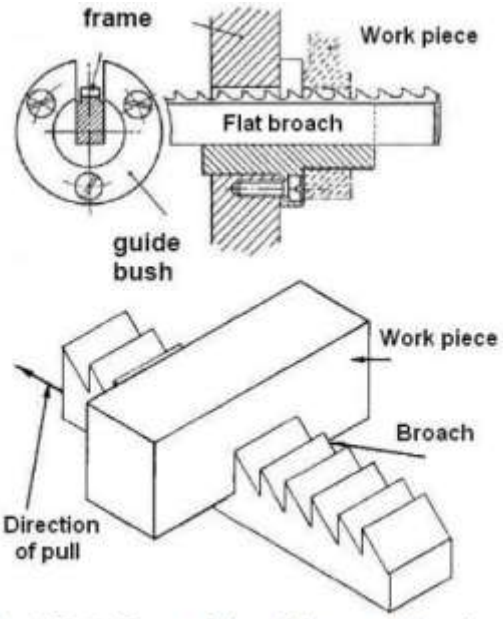


Fig. 4.55 (a) External broaching – making slot

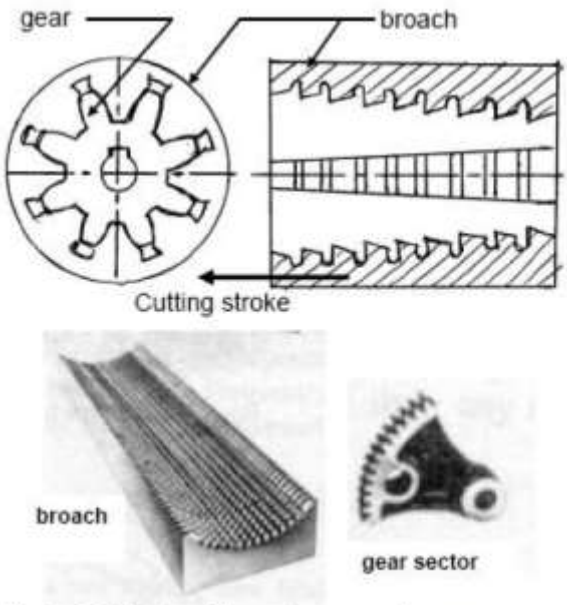


Fig 4.55 (b) Broaching of gears and gear sectors

Pull type and push type broaches

During operation a pull type broach is subjected to tensile force, which helps in maintaining alignment and prevents buckling. Pull type broaches are generally made as a long single piece and are more widely used, for internal broaching in particular. Push type broaches are essentially shorter in length (to avoid buckling) and may be made in segments. Push type broaches are generally used for external broaching, preferably, requiring light cuts and small depth of material removal.

Ordinary cut or progressive type broach

Most of the broaches fall under the category of Ordinary - cut type where the teeth increase in height or protrusion gradually from tooth to tooth along the length of the broach. By such broaches, work material is removed in thin layers over the complete form. Whereas, Progressive cut type broaches have their teeth increasing in width instead of height. Fig. 4.56 shows the working principle and configuration of such broach.

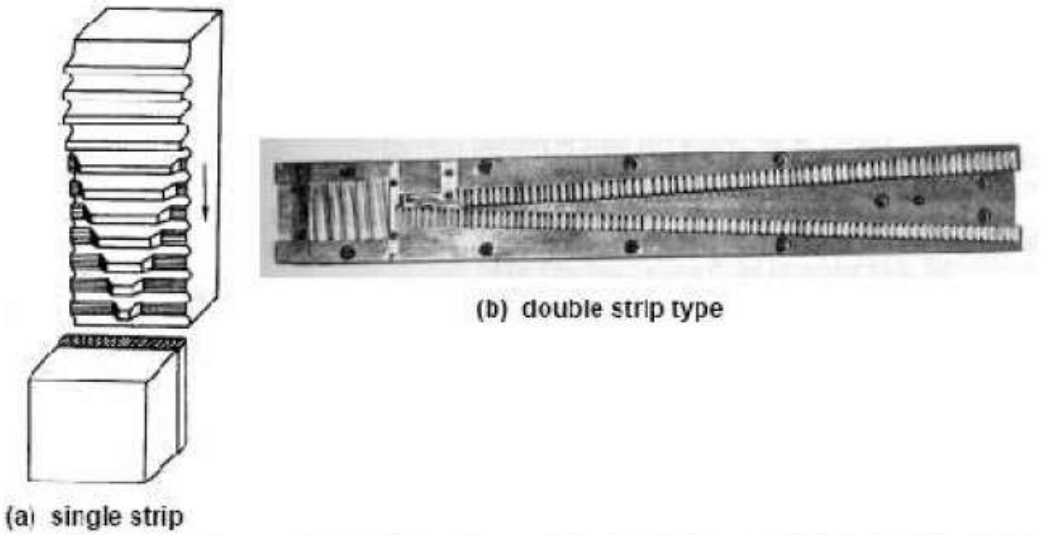


Fig. 4.56 Progressive cut type broaches: (a) single bar and (b) double bar type

Solid, Sectional and module type broaches

Broaches are mostly made in single pieces especially those used for pull type internal broaching. But some broaches called sectional broaches, are made by assembling several sections or cutter-pieces in series for convenience in manufacturing and resharpening and also for having little flexibility required by production in batches having interbatch slight job variation. External broaches are often made by combining a number of modules or segments for ease of manufacturing and handling. Fig. 4.57 typically shows solid, sectional and segmented (module) type broaches.

Profile sharpened and form relieved type broaches

Like milling cutters, broaches can also be classified as:

Profile sharpened type broaches - Such cutters have teeth of simple geometry with

same rake and clearance angles all over the cutting edge. These broaches are generally designed and used for machining flat surface(s) or circular holes.

Form relieved type broaches - These broaches, being used for non-uniform profiles

like gear teeth etc., have teeth where the cutting edge geometry is more complex and varies point

- to - point along the cutting edges. Here the job profile becomes the replica of the tool form. Such broaches are sharpened and resharpened by grinding at their rake faces unlike the profile sharpened broaches which are ground at the flank surfaces.

4.20.3 Advantages and limitations of broaching

Major advantages

Very high production rate (much higher than milling, planing, boring etc.). High dimensional and form accuracy and surface finish of the product. Roughing and finishing in single stroke of the same cutter.

Needs only one motion (cutting), so design, construction, operation and control are simpler. Extremely suitable and economic for mass production.

Since all the machining parameters are built into the broach, very little skill is required from the operator.

Any type of surface, internal or external can be generated with broaching.

Limitations

Only through holes and surfaces can be machined.

Usable only for light cuts, i.e. low chip load and unhard materials. Cutting speed cannot be high.

Defects or damages in the broach (cutting edges) severely affect product quality.

Design, manufacture and restoration of the broaches are difficult and expensive.

Separate broach has to be used when the size, shape and geometry of the job changes. Economic only when the production volume is large.

5.12 Comparison to grinding.

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