# Abrasive Process and Broaching

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## UNIT IV ABRASIVE PROCESSES AND GEAR CUTTING

- Abrasive processes: grinding wheel – specifications and selection,
- Types of grinding process

  Cylindrical grinding,

  Surface grinding,

  Centreless grinding –

  Honing, lapping, super finishing, polishing and buffing,

  Abrasive jet machining –

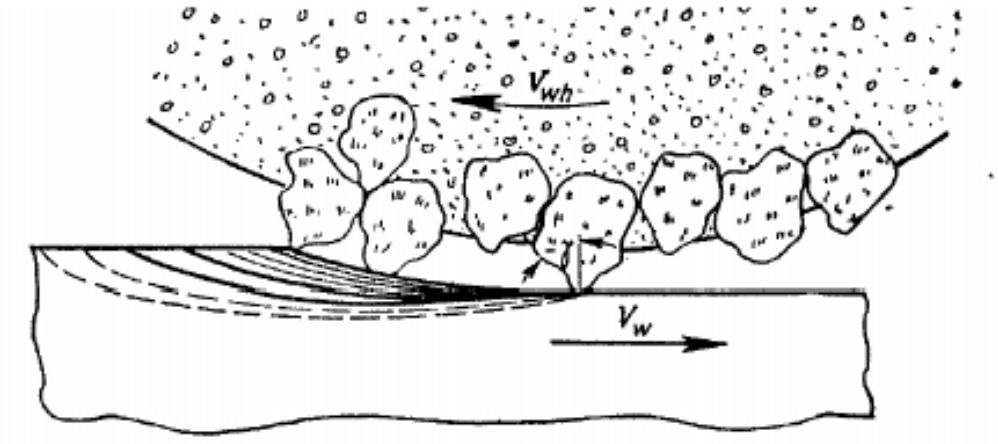
  Gear cutting, forming, generation, shaping, hobbing.

**Grinding** is the most common form of abrasive machining.

It is a material cutting process which engages an abrasive tool whose cutting elements are grains of abrasive material known as grit.

These grits are characterized by sharp cutting points, high hot hardness, chemical stability and wear resistance.

The grits are held together by a suitable bonding material to give shape of an abrasive tool.




*Cutting action of abrasive grains*

## Major advantages and applications of grinding

### Advantages

- ✓ dimensional accuracy
- ✓ good surface finish
- ✓ good form and locational accuracy
- ✓ applicable to both hardened and unhardened material

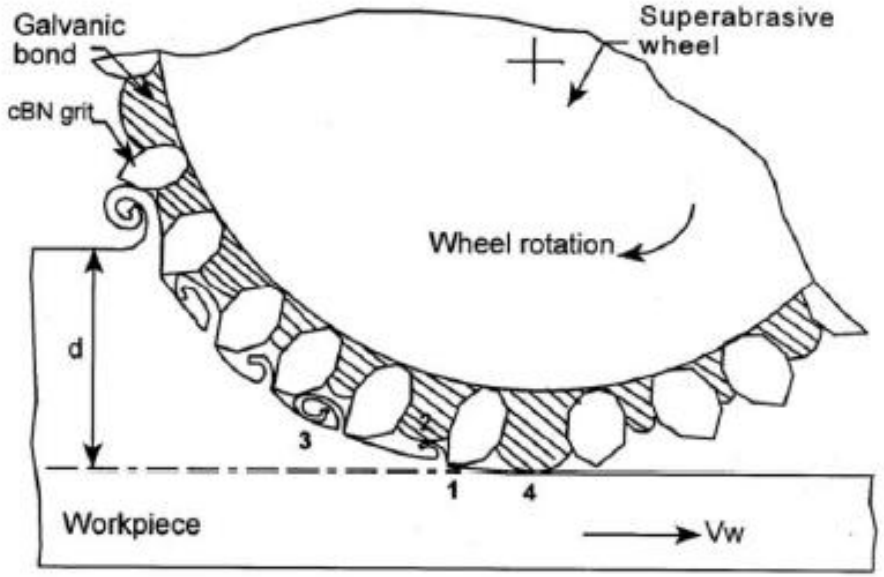
### Applications

- ✓ descsurface finishing
- ✓ slitting and parting
- ✓ aling, deburring
- ✓ stock removal (abrasive milling) finishing of flat as well as cylindrical surface •
- ✓ grinding of tools and cutters and resharpening of the same

# Grinding wheel and workpiece interaction

1. grit-workpiece (forming chip)
2. chip-bond
3. chip-work piece
4. bond-work piece

} undesirably increase the total grinding force and power requirement.




*Grinding wheel and workpiece interaction*

- 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 and silicon carbide wheels while diamond and cBN (cubic boron nitride) wheels fall in the category of superabrasive wheel.

## Specification of grinding wheel

A grinding wheel requires two types of specification

(a) Geometrical specification

(b) Compositional specification

## (a) Geometrical specification

This is decided by the type of grinding machine and the grinding operation to be performed in the workpiece.

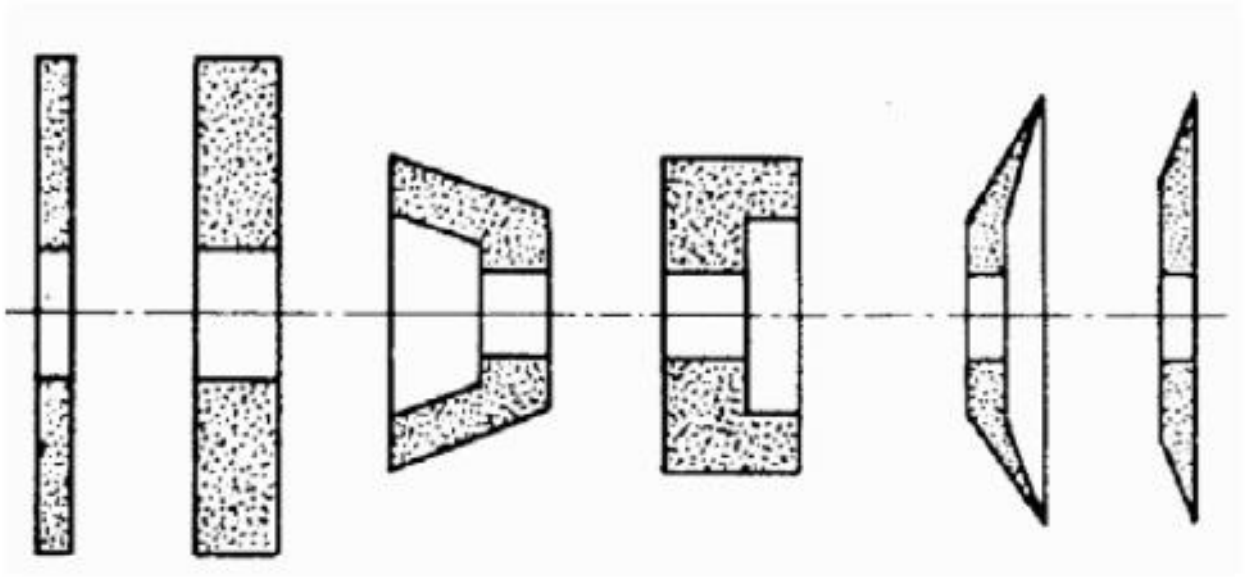
This specification mainly includes wheel diameter, width and depth of rim and the bore diameter.

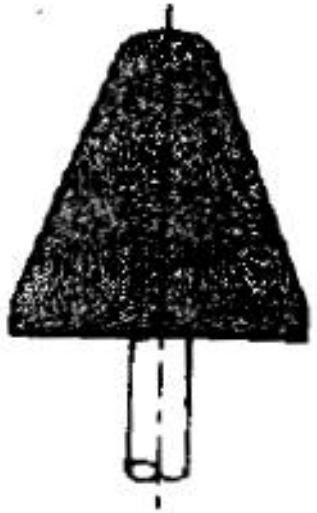
The wheel diameter, for example can be as high as 400mm in high efficiency grinding or as small as less than 1mm in internal grinding.

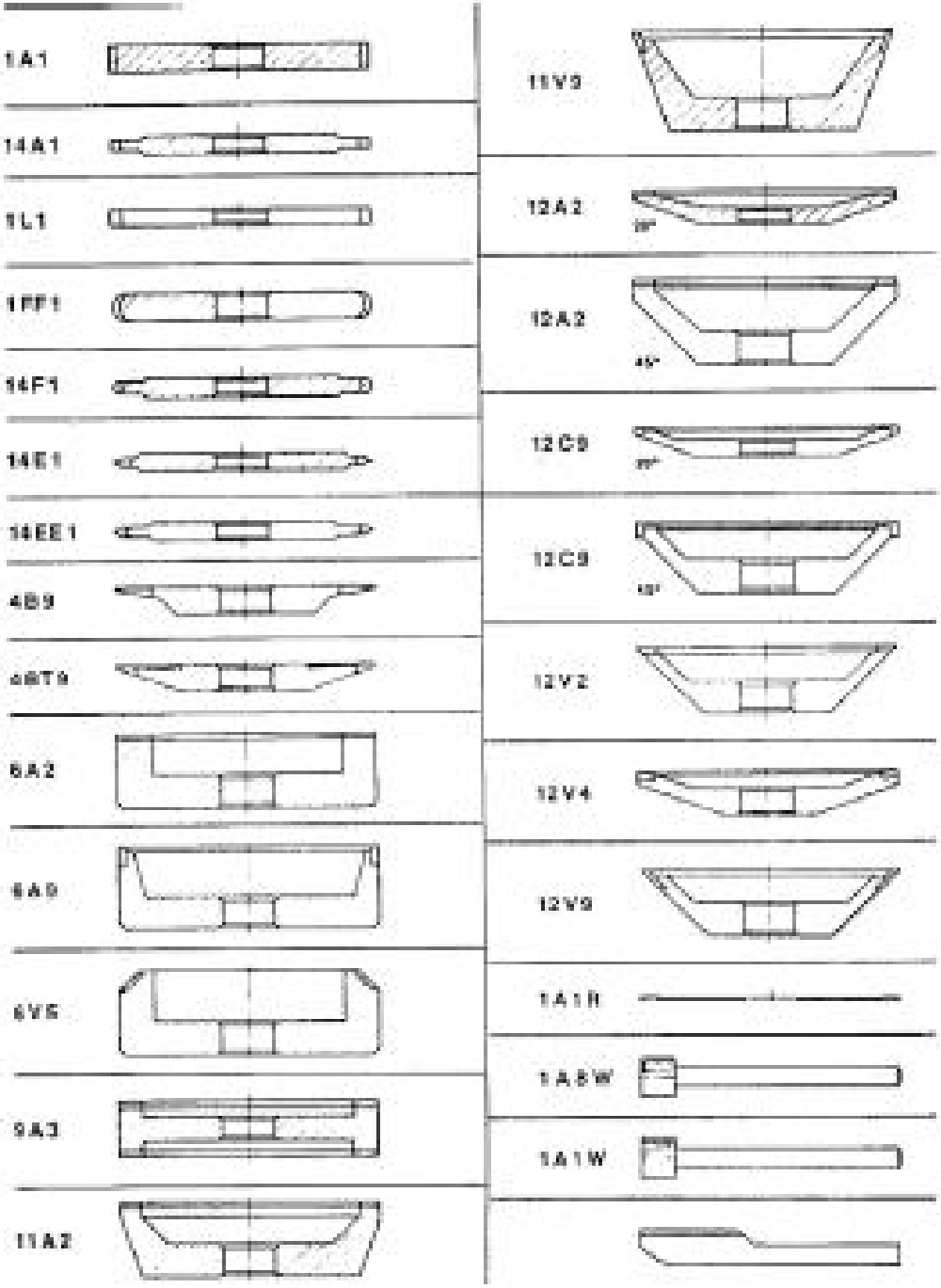
Similarly, width of the wheel may be less than an mm in dicing and slicing applications.

Standard wheel configurations for conventional and superabrasive grinding wheels are shown in Fig..

*Standard wheel configuration for conventional grinding wheels*






1A1
14A1
1L1
1FF1
14F1
14E1
14EE1
4B9
4BT9
6A2
6A9
6V6
9A3
11A2
11V3
12A2
45°
12A2
45°
12C9
22°
12C9
15°
12V2
12V4
12V9
1A1R
1A8W
1A1W

## Compositional specifications

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 structure 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.

## 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. In case of silicon carbide 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 designated number may be as high as 600.
- ✓ The letter 'K' denotes the hardness of the wheel, which means the amount of force required to pull out a single bonded abrasive grit by bond fracture. 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 codes for other bond materials used in conventional abrasive wheels are B (resinoid), BF (resinoid reinforced), E(shellac), O(oxychloride), R(rubber), RF (rubber reinforced), S(silicate)
- ✓ The number '05' is a wheel manufacturer's identifier

## Marking system for superabrasive grinding wheel

- ✓ Marking system for superabrasive 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 superabrasive used.
- ✓ The letter 'D' denotes that the type of abrasive is diamond. In case of 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 superabrasive grit. The two number designation of grit size along with corresponding designation in micron is given in table 28.1.
- ✓ 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/$cm^3$. 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 superabrasive wheels are resin, vitrified or metal bond, which make a composite structure with the grit material. However, another type of superabrasive wheel with both diamond and cBN is also manufactured where a single layer of superabrasive grits are bonded on a metal perform by a galvanic metal layer or a brazed metal layer as illustrated in Fig.

## Selection of grinding wheels

Selection of grinding wheel means selection of composition of the grinding wheel and this depends upon the following factors:

- ✓ Physical and chemical characteristics of the work material
- ✓ Grinding conditions
- ✓ Type of grinding (stock removal grinding or form finish grinding)

# Grinding wheel selection factors

- **Constant factors**

1. Materials to be ground
2. Amount of stock to be removed
3. Area of contact
4. Type of grinding machine

- **Variable factors**

1. Wheel speed
2. Work speed
3. Condition of the machine
4. Personal factor

# Type of abrasives

## Aluminium oxide

**Pure $Al_2O_3$ grit with defect structure -** fine tool grinding operation, and heat sensitive operations on hard, ferrous materials.

**Regular or brown aluminium oxide (doped with $TiO_2$)** - 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 - 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

## Silicon carbide

Silicon carbide is harder than alumina but less tough.

Silicon carbide is also inferior to $Al_2O_3$ 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.

## 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.

## cBN (cubic boron nitride)

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

## Grit size

- The grain size affects material removal rate and the surface quality of workpiece in grinding.
- **Large grit-** big grinding capacity, rough workpiece surface
- **Fine grit-** small grinding capacity, smooth workpiece surface

# Bond

- Vitrified bond
- Resin bond
- Shellac bond
- Oxychloride bond
- Rubber bond
- Metal bond
- Electroplated bond
- Brazed bond

## Vitrified bond

- 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.

## Resin bond

- 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.
- Fiberglass reinforced resin bond is used with cut off wheels which requires added strength under high speed operation.

## Shellac bond

- 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

- It is less common type bond, but still can be used in disc grinding operation.
- It is used under dry condition.

## Rubber bond

- 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.

## Metal bond

- Metal bond is extensively used with superabrasive 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.

## 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 superabrasive 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

# Truing and Dressing

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 workpiece is directly related to effective wheel geometry.

# Truing tool cutter

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.

Vitrified abrasive stick and wheel:

It is used for off hand truing of conventional abrasive wheel. These are used for truing resin bonded superabrasive wheel.

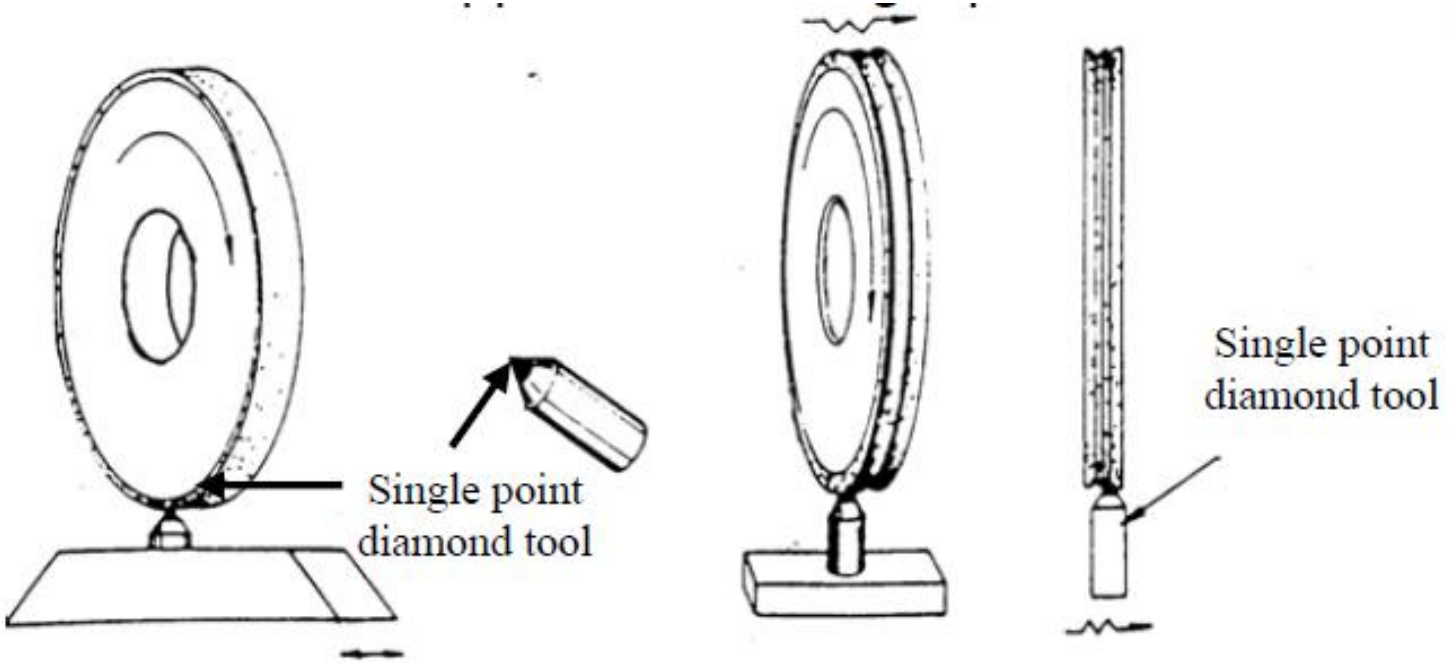
Steel or carbide crash roll

It is used to crush-true the profile on vitrified bond grinding wheel.

Diamond truing tool:

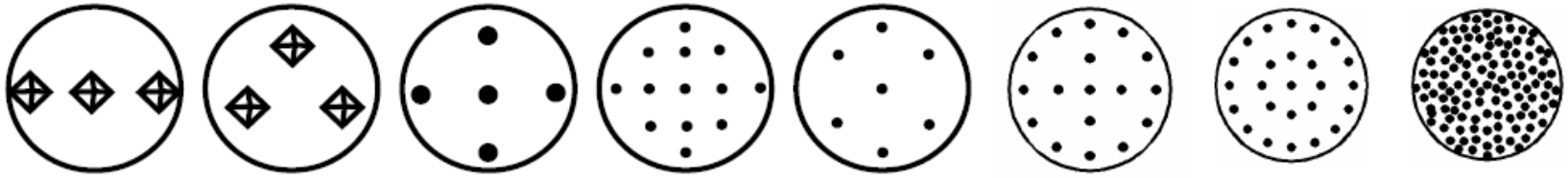
*Single point diamond truing tools*

The single point diamond truing tools for straight face truing are made by setting a high quality single crystal into a usually cylindrical shank of a specific diameter and length by brazing or casting around the diamond. During solidification contraction of the bonding metal is more than diamond and latter is held mechanically as result of contraction of metal around it. Some application of single point diamond truing tool is



*Multi stone diamond truing tool*

In this case the truing tool consists of a number of small but whole diamonds, some or all of which contact the abrasive wheel at the same time. The diamond particles are surface set with a metal binder and it is possible to make such tool with one layer or multilayer configuration. Normal range of diamond used in this tool is from as small as about 0.02 carat to as large as of 0.5 carat. These tools are suitable for heavy and rough truing operation. Distribution pattern of diamond in this tool shown



(i) (ii) (iii) (iv) (v) (vi) (vii) (viii)

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

# Dressing

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 workpiece 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 determine 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 superabrasive wheel.

Dressing of superabrasive wheel

Dressing of the superabrasive wheel is commonly done with soft conventional abrasive vitrified stick, which relieves the bond without affecting the superabrasive grits.

However, modern technique like electrochemical dressing has been successfully used in metal bonded superabrasive wheel. The wheel acts like an anode while a cathode plate is placed in front of the wheel working surface to allow electrochemical dissolution.

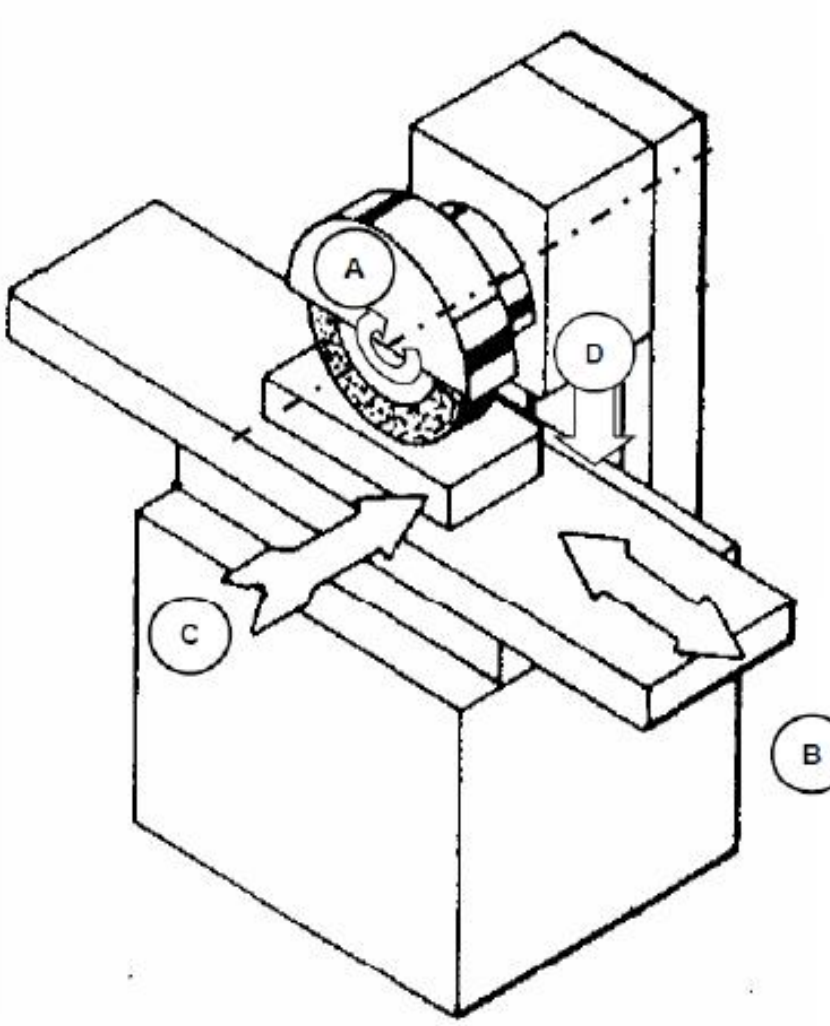
# Classification of grinding machines

- Surface grinding machine
- Cylindrical grinding machine
- Internal grinding machine
- Tool and cutter grinding machine

# Surface grinding machine

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

# Horizontal spindle and reciprocating table




A: rotation of grinding wheel
B: reciprocation of worktable
C: transverse feed
D: down feed

A: rotation of grinding wheel B: reciprocation of worktable
C: down feed of grinding wheel

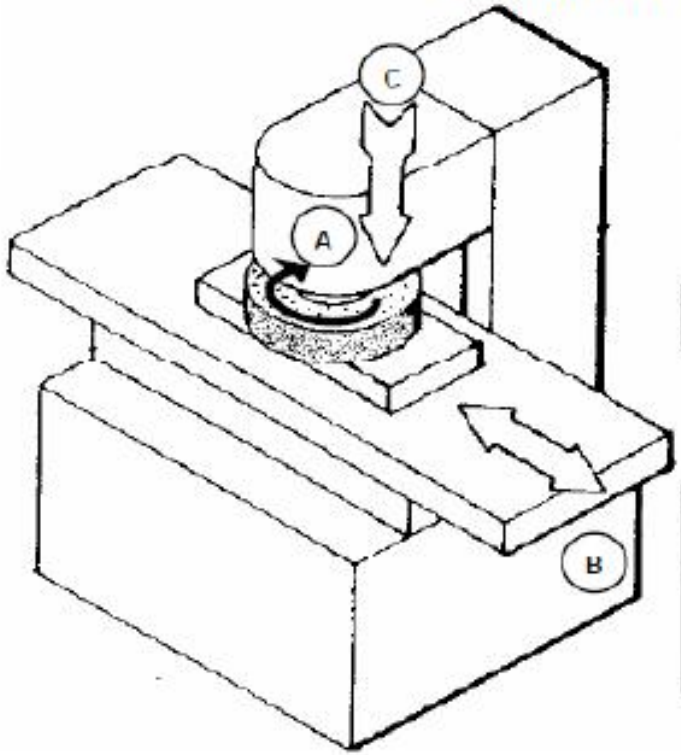



*Fig. 29.3 Vertical spindle reciprocating table surface grinder*

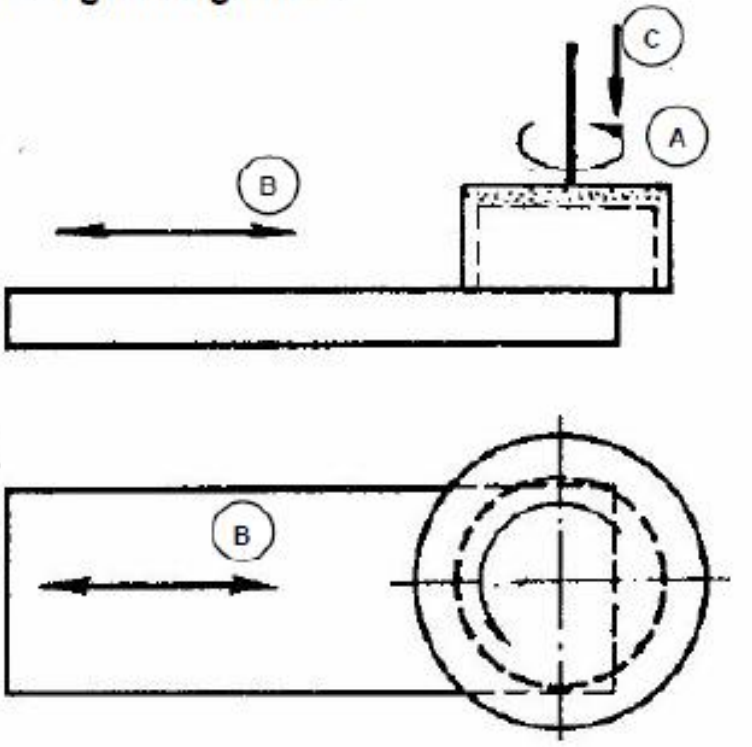
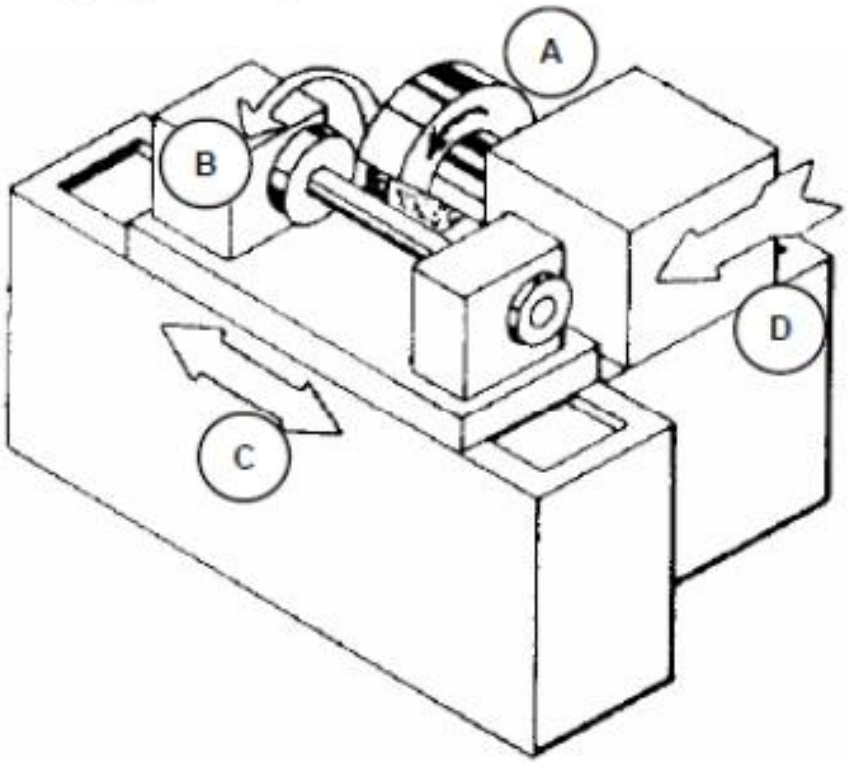



*Fig. 29.4 Surface grinding in Vertical spindle reciprocating table surface grinder*

## Cylindrical grinding machine

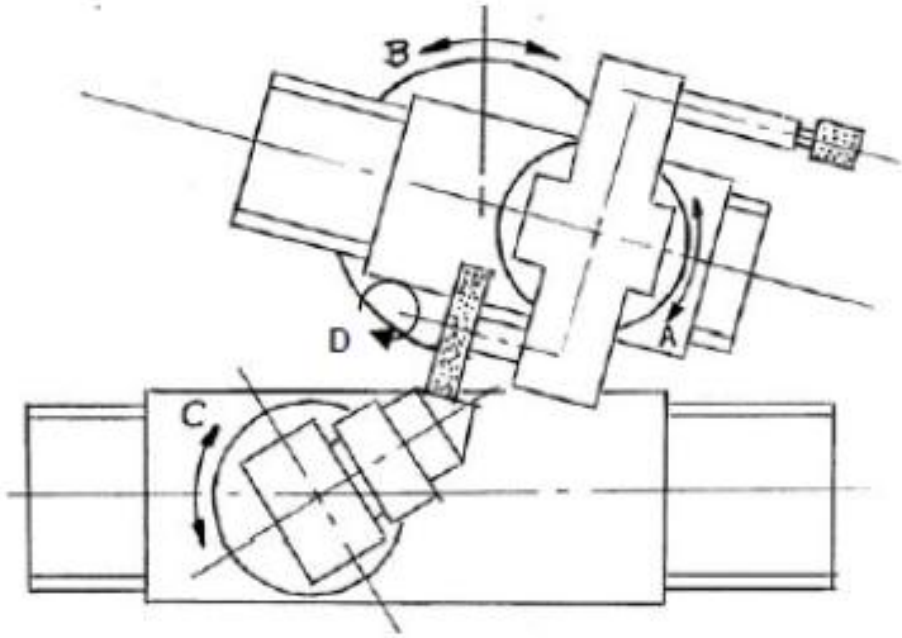
1. Plain centre type cylindrical grinder
2. Universal cylindrical surface grinder
3. Centreless cylindrical surface grinder

*Plain centre type cylindrical grinder*




**A: rotation of grinding wheel**
**B: work table rotation**
**C: reciprocation of worktable**
**D: infeed**

# Universal cylindrical surface grinder

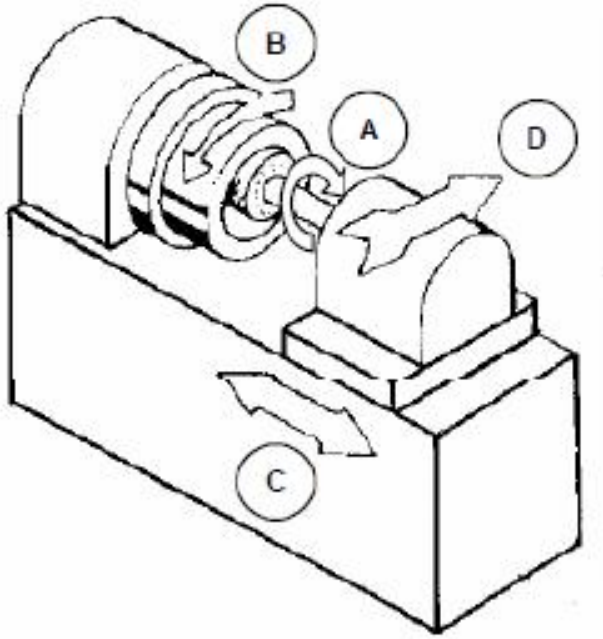


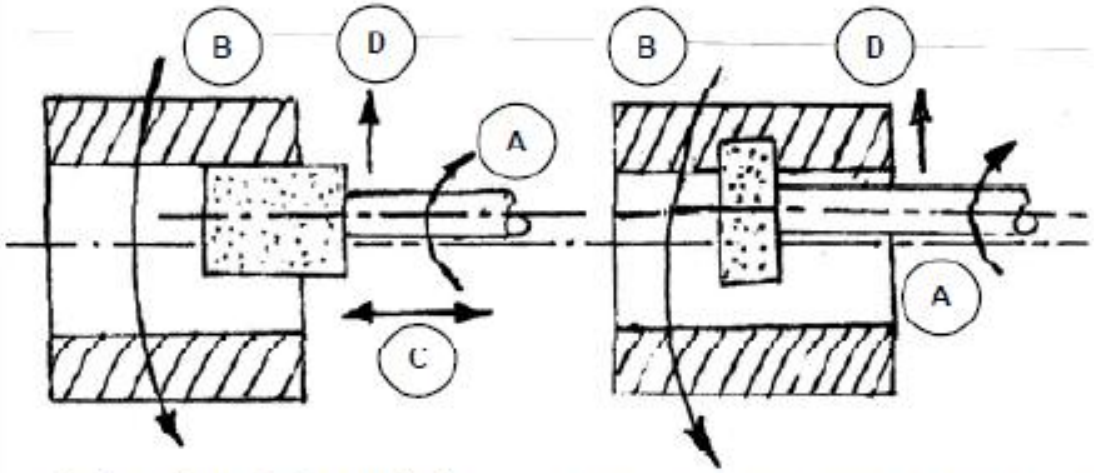

A: swivelling wheel head
B: swivelling wheel head slide
C: swivelling head stock
D: rotation of grinding wheel

# Internal grinding machine

- Chucking type internal grinder
- Planetary internal grinder
- Centreless internal grinder

**A**: rotation of grinding wheel
**B**: workpiece rotation
**C**: reciprocation of worktable
**D**: infeed

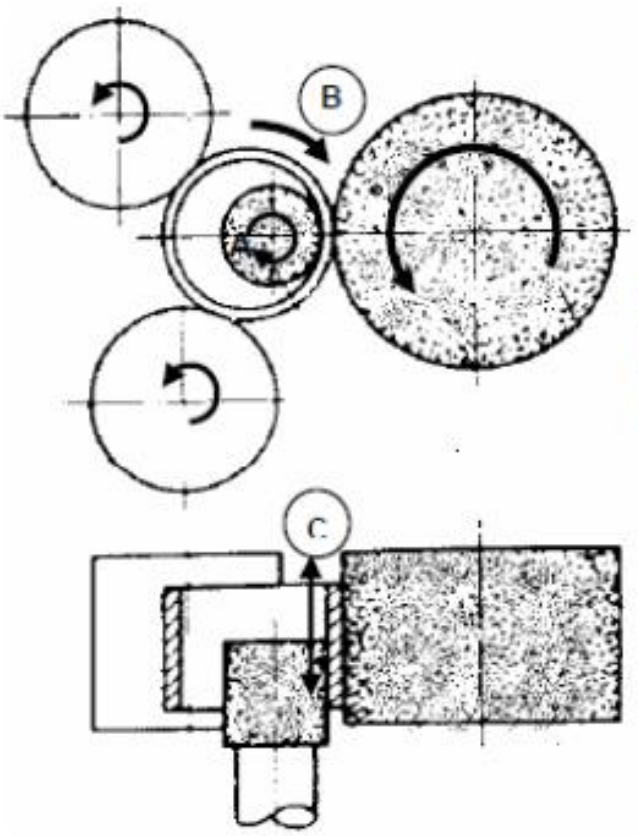



*Internal centreless grinder*

*Internal (a) traverse grinding and (b) plunge grinding*

# Internal centreless grinding

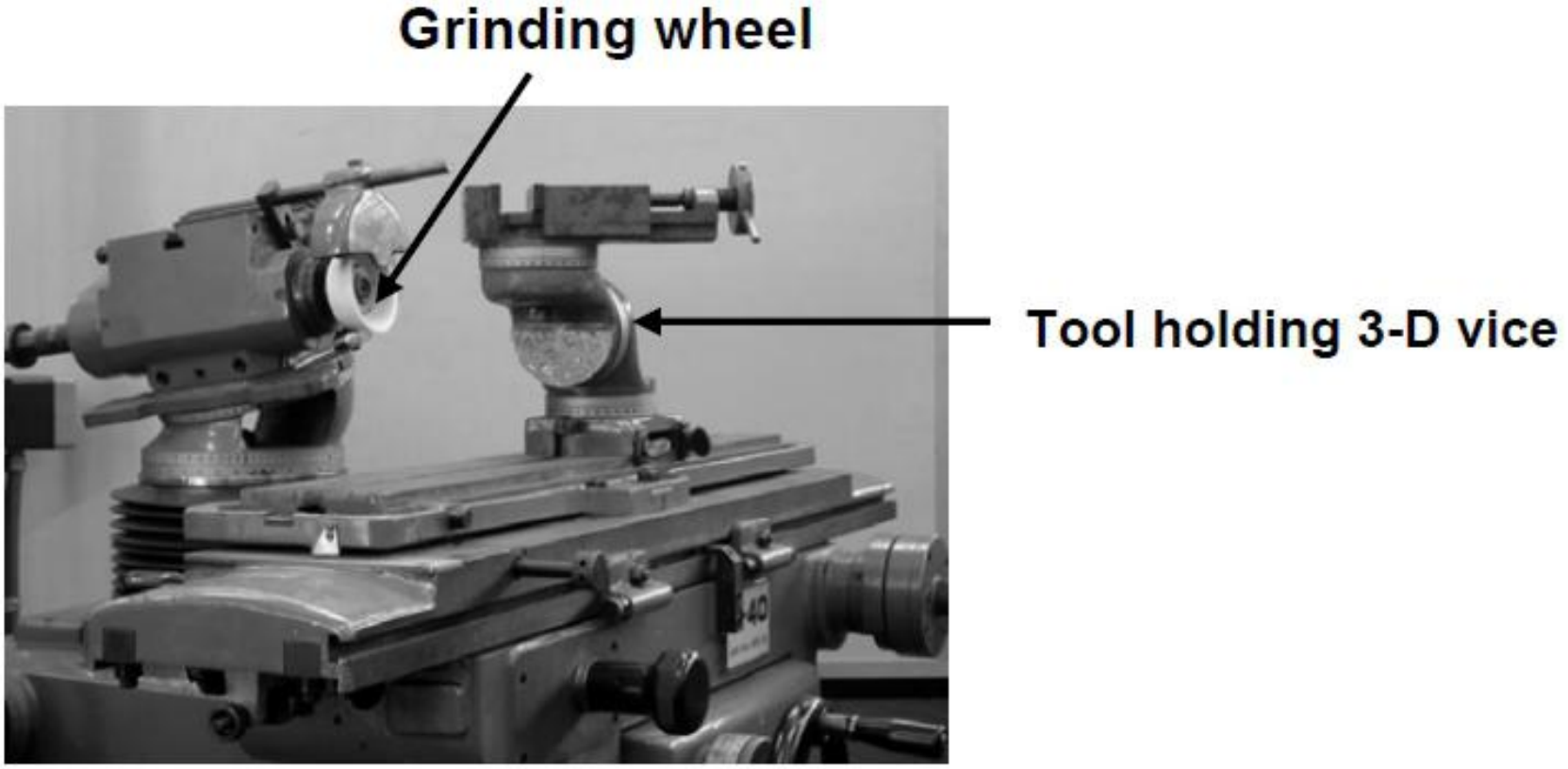



A: grinding wheel rotation
B: workpiece rotation
C: wheel reciprocation

# Tool and cutter grinder machine

- Tool grinding may be divided into two subgroups: tool manufacturing and tool re-sharpening.
- There are many types of tool and cutter grinding machine to meet these requirements.
- Simple single point tools are occasionally sharpened by hand on bench or pedestal grinder. However, tools and cutters with complex geometry like milling cutter, drills, reamers and hobs require sophisticated grinding machine commonly known as universal tool and cutter grinder.
- Present trend is to use tool and cutter grinder equipped with CNC to grind tool angles, concentricity, cutting edges and dimensional size with high precision.

# Pictorial view of a tool and cutter grinder



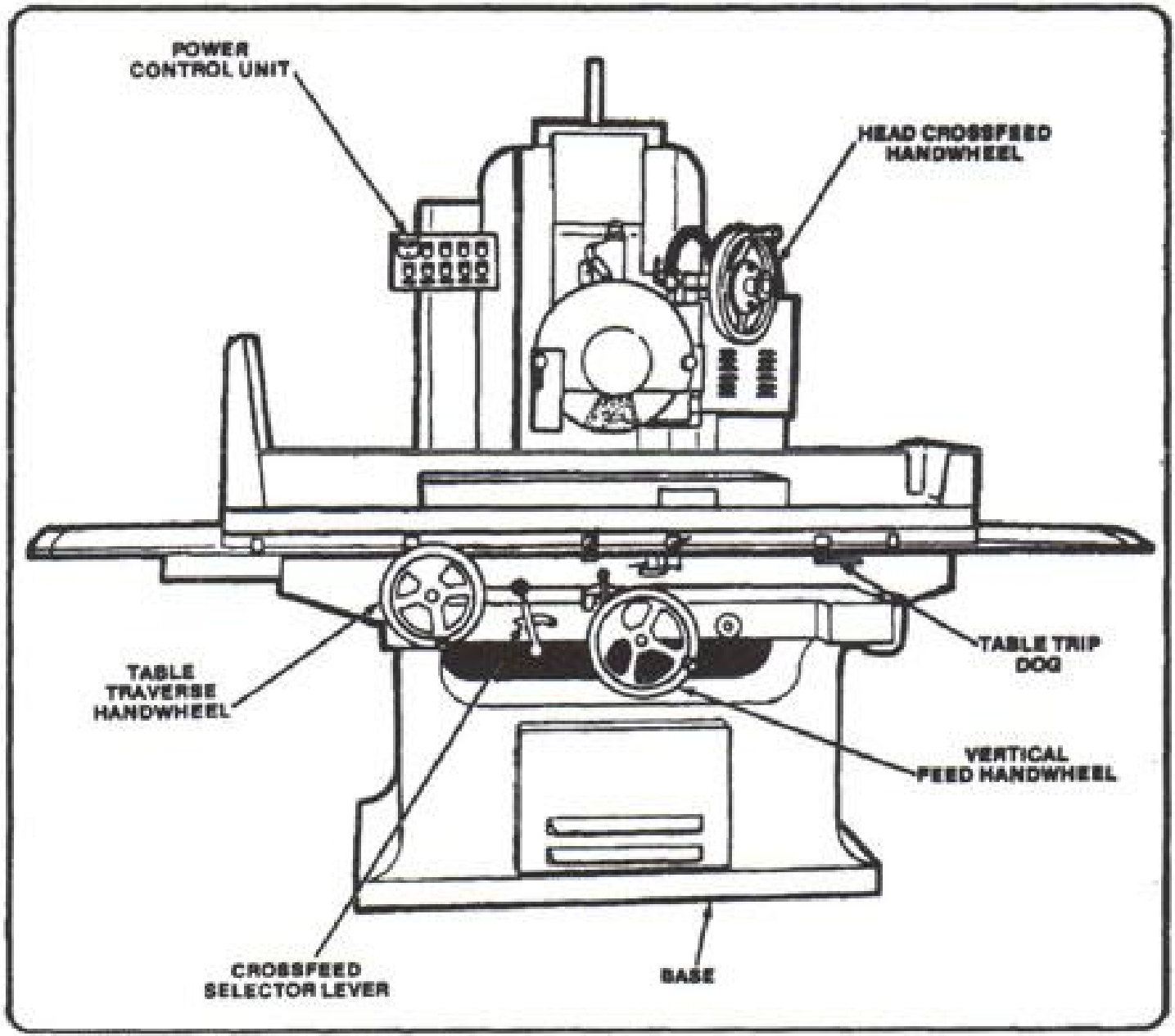
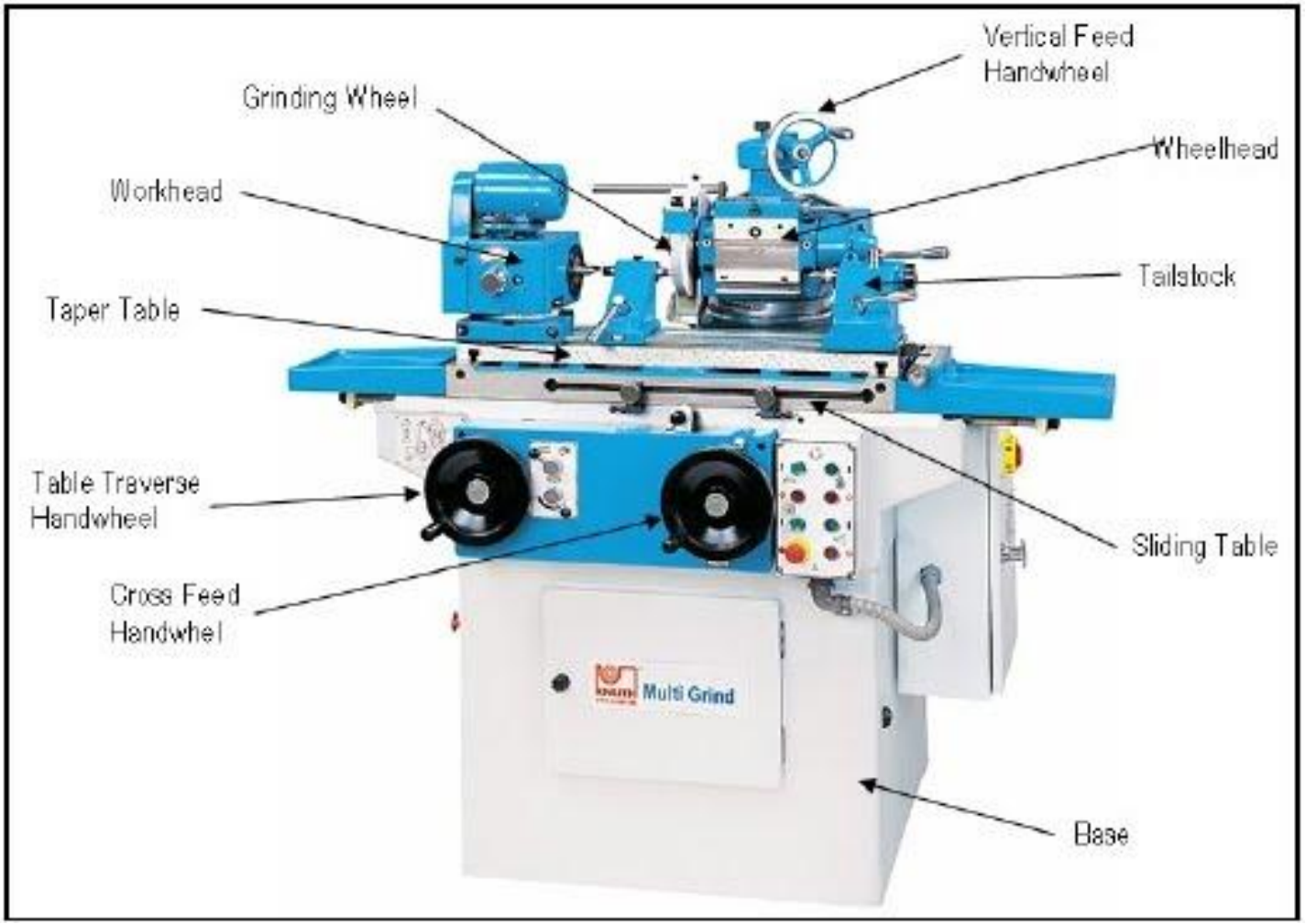



Figure 5-6. Reciprocating surface grinding machine.


Vertical Feed
Handwheel
Grinding Wheel
Wheelhead
Workhead
Tailstock
Taper Table
Table Traverse
Handwheel
Sliding Table
Cross Feed
Handwhel
Multi Grind
Base