UNIT 6:

Grinding machines: Types of abrasives, bonding process, classification, constructional features (cylindrical and surface grinding), Selection of grinding wheel.

6 Hrs

Instructional Objectives:

At the end of this lesson the students would be able to

- Understand basic principle of grinding.
- Recognize purpose and application of grinding.
- Understand cause of development of force during grinding.
- Understand variation of grinding characteristics with grinding conditions.
- Illustrate various methods of wheel conditioning.

Grinding:

- 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.

Fig. 6.1 illustrates the cutting action of abrasive grits of disc type grinding wheel similar to cutting action of teeth of the cutter in slab milling.
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

- Surface finishing
- Slitting and parting
- Descaling, deburring
- Stock removal (abrasive milling) finishing of flat as well as cylindrical surface
- Grinding of tools and cutters and resharpening of the same.

Conventionally grinding is characterized as low material removal process capable of providing both high accuracy and high finish. However, advent of advanced grinding machines and grinding wheels has elevated the status of grinding to abrasive machining where high accuracy and surface finish as well as high material removal rate can be achieved even on an unhardened material. This is illustrated in Fig. 6.2.
Grinding wheel and workpiece interaction:

The bulk grinding wheel-workpiece interaction as illustrated in figure 6.3 can be divided into the following:

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

Except the grit-workpiece interaction which is expected to produce chip, the remaining three undesirably increase the total grinding force and power requirement. Therefore, efforts should always be made to maximize grit-workpiece interaction leading to chip formation and to minimise the rest for best utilisation of the available power.

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

Fig. 6.2 Elevation of the status of Grinding to Abrasive Machining
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.6.4 and 6.5.
(b) Compositional specifications:

Specification of a grinding wheel ordinarily means compositional specification. Conventional abrasive grinding wheels are specified encompassing the following parameters.

1. The type of grit material
2. The grit size
3. The bond strength of the wheel, commonly known as wheel hardness
4. The structure of the wheel denoting the porosity i.e. the amount of inter grit spacing
5. The type of bond material
6. Other than these parameters, the wheel manufacturer may add their own identification code prefixing or suffixing (or both) the standard code.
Fig. 6.5: Standard wheel configuration for superabrasive wheel
Marking system for conventional grinding wheel:

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

\[ 51 \quad A \quad 60 \quad K \quad 5 \quad V \quad 05, \quad \text{where} \]

- 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

\[ R \quad D \quad 120 \quad N \quad 100 \quad M \quad 4, \quad \text{where} \]

- 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.
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 $4.4 \text{ carats/cm}^3$. 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.6.6.

**Fig.6.6** Schematic diagrams for the relative comparison of brazed type and galvanically bonded single layer cBN grinding wheel

**Selection of grinding wheels:**

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

1) Physical and chemical characteristics of the work material
2) Grinding conditions
3) Type of grinding (stock removal grinding or form finish grinding)
Type of abrasives:

Aluminium oxide:

- Aluminium oxide may have variation in properties arising out of differences in chemical composition and structure associated with the manufacturing process.

- Pure $\text{Al}_2\text{O}_3$ 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 $\text{TiO}_2$) possesses lower hardness and higher toughness than the white $\text{Al}_2\text{O}_3$ and is recommended heavy duty grinding to semi finishing.

- $\text{Al}_2\text{O}_3$ alloyed with chromium oxide (<3%) is pink in colour.

- Monocrystalline $\text{Al}_2\text{O}_3$ grits make a balance between hardness and toughness and are efficient in medium pressure heat sensitive operation on ferrous materials.

- Microcrystalline $\text{Al}_2\text{O}_3$ grits of enhanced toughness are practically suitable for stock removal grinding. $\text{Al}_2\text{O}_3$ 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 $\text{Al}_2\text{O}_3$ grit is the latest development particularly known for its toughness and self sharpening characteristics.

Silicon carbide:

- Silicon carbide is harder than alumina but less tough. Silicon carbide is also inferior to $\text{Al}_2\text{O}_3$ 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.

- 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.

**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

**Grade:**

- The worn out grit must pull out from the bond and make room for fresh sharp grit in order to avoid excessive rise of grinding force and temperature.

- Therefore, a soft grade should be chosen for grinding hard material.

- On the other hand, during grinding of low strength soft material grit does not wear out so quickly. Therefore, the grit can be held with strong bond so that premature grit dislodgement can be avoided.
Structure / concentration:

- The structure should be open for grinding wheels engaged in high material removal to provide chip accommodation space.
- The space between the grits also serves as pocket for holding grinding fluid.
- On the other hand dense structured wheels are used for longer wheel life, for holding precision forms and profiles.

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.

Oxycarbide 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 applications.

Truing and dressing of grinding wheel:

Truing:
- 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 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.

- **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.

- **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 illustrated in Fig. 6.7

![Application of single point diamond truing tool](image)

**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 in Fig.6.8

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<table>
<thead>
<tr>
<th>Distribution of diamond</th>
<th>Diamond weight</th>
<th>Distribution of diamond</th>
<th>Diamond weight</th>
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<tbody>
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<td>(i) 1 layer-3 stone</td>
<td>10</td>
<td>(v) 5 layer-17 stone</td>
<td>50</td>
</tr>
<tr>
<td>(ii) 2 layer-3 stone</td>
<td>10</td>
<td>(vi) 5 layer-7 stone</td>
<td>10</td>
</tr>
<tr>
<td>(iii) 3 layer-5 stone</td>
<td>10</td>
<td>(vii) 5 layer-25 stone</td>
<td>250</td>
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<tr>
<td>(iv) 5 layer-13 stone</td>
<td>25</td>
<td>(viii) throughout</td>
<td>50</td>
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</tbody>
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**Fig 6.8** Diamond distribution pattern of diamond particles in multi-stone diamond

**Impregnated diamond truing tools:**

- This wheel truing tool consists of crushed and graded diamond powder mixed with metal powder and sintered.

- The diamond particles are not individually set in a pattern but are distributed evenly throughout the matrix in the same way that an abrasive wheel consists of abrasive grains and bonding agent.

- The size of diamond particles may vary from 80-600 microns.

- By using considerably smaller diamond grit and smaller diamond section it is possible to true sharp edge and fine grit grinding wheel.

- The use of crushed diamond product ensures that there are always many sharp points in use at the same time and these tools are mainly used in fine grinding, profile grinding, thread grinding, cylindrical grinding and tool grinding.

- Truing action of an impregnated diamond tool is shown schematically in Fig 6.9.
Rotary powered diamond truing wheels:

- Rotary powered truing devices (Fig.6.10) are the most widely recommended truing tool in long run mass production and are not ideally suited for those wheels with large diameters (greater than 200 mm).
- They can be pneumatic, hydraulic or electrically powered.
- Rotary powered truing device can be used in cross axis and parallel axis mode.
- Basically there are three types of truing wheels

![Diagram of rotary powered truing wheel in cross-axis and parallel-axis modes](image)

**Fig. 6.10** Rotary power truing wheel being used in (a) cross-axis (b) parallel-axis
1. **Surface set truing wheels:**

Here the diamond particles are set by hand in predetermined pattern. A sintered metal bond is used in this case. These truing wheels are designed for high production automated operations.

2. **Impregnated truing wheels:**

In this case impregnated diamond particles are distributed in a random pattern to various depths in a metal matrix. This type of roll finds its best applications (i.e. groove grinding) where excess wheel surfaces must be dressed of.

3. **Electroplated truing tool:**

In this truing wheel diamond particles are bonded to the wheel surface with galvanically deposited metal layer. Main advantage of this technique is that no mould is necessary to fabricate the diamond truing wheel unlike that of surface set or impregnated truing wheels.

**Diamond form truing blocks:**

Diamond form truing block can be either diamond impregnated metal bond or electroplated, as shown in Fig.6.11. Brazed type diamond truing block has also come as an alternative to electroplated one. They can be as simple as flat piece of metal plated with diamond to true a straight faced wheel or contain an intricate form to shape the grinding wheel to design profile. Truing block can eliminate the use of self propelled truing wheels and are used almost exclusively for horizontal spindle surface grinder to generate specific form.

![Diamond form truing block to true](image)

**Fig. 6.11** Diamond form truing block to true (a) a straight faced wheel (b) a form wheel
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.

Note: 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 superabrasive wheel:

• Dressing of the super-abrasive 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.

• Electro discharge dressing is another alternative route for dressing metal bonded superabrasive 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 workpiece surface finish.
Grinding Machines:

- Grinding Machines are also regarded as machine tools. A distinguishing feature of grinding machines is the rotating abrasive tool.

- Grinding machine is employed to obtain high accuracy along with very high class of surface finish on the workpiece.

- However, advent of new generation of grinding wheels and grinding machines, characterised by their rigidity, power and speed enables one to go for high efficiency deep grinding (often called as abrasive milling) of not only hardened material but also ductile materials.

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

(a) **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 characterised 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
Horizontal spindle reciprocating table grinder:

Figure 6.12 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. 6.13.

![Diagram of Horizontal Spindle Reciprocating Table Grinder]

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

**Fig. 6.12**: Horizontal spindle reciprocating table surface grinder

![Diagram of Surface Grinding]

**Fig. 6.13** Surface grinding (a) traverse grinding (b) plunge grinding
**Vertical spindle reciprocating table grinder:**

This grinding machine with all working motions is shown in Fig. 6.14. 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. 6.15. 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. 6.14 Vertical spindle reciprocating table surface grinder](image1)

**Fig. 6.14 Vertical spindle reciprocating table surface grinder**

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

**Fig. 6.15 Surface grinding in Vertical spindle reciprocating table surface grinder**

**Horizontal spindle rotary table grinder:**

Surface grinding in this machine is shown in Fig. 6.16. 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. 6.17

![Fig. 6.16 Horizontal spindle rotary table grinder](image2)
A: rotation of grinding wheel
B: table rotation
C: table reciprocation
D: down feed of grinding wheel

Fig. 6.16: Surface grinding in Horizontal spindle rotary table surface grinder

A: rotation of grinding wheel
B: table rotation
C: table reciprocation
D: down feed of grinding wheel
Θ: swivel angle

Fig. 6.17: Grinding of a tapered surface in horizontal spindle rotary table surface grinder
Vertical spindle rotary table grinder:

The principle of grinding in this machine is shown in Fig. 6.18. 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.

Fig. 6.18. Surface grinding in vertical spindle rotary table surface grinder

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

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.
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.

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. Centreless cylindrical surface grinder

1. Plain centre type cylindrical grinder:

Figure 6.19 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.6.20.

![Fig. 6.19: Plain centre type cylindrical grinder](image)
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.

![Diagram of universal cylindrical grinding machine features]
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. 6.21.

**Special application of cylindrical grinder:**

Principle of cylindrical grinding is being used for thread grinding with specially formed wheel that matches the thread profile. A single ribbed wheel or a multi ribbed wheel can be used as shown in Fig. 6.22.

![Fig. 6.22 Thread grinding with (a) single rib (b) multi-ribbed wheel](image)

Roll grinding is a specific case of cylindrical grinding wherein large workpieces such as shafts, spindles and rolls are ground.

Crankshaft or crank pin grinders also resemble cylindrical grinder but are engaged to grind crank pins which are eccentric from the centre line of the shaft as shown in Fig. 6.23. The eccentricity is obtained by the use of special chuck.

![Fig. 6.23 Grinding of crank pin](image)
Cam and camshaft grinders are essentially subsets of cylindrical grinding machine dedicated to finish various profiles on disc cams and cam shafts. The desired contour on the workpiece is generated by varying the distance between wheel and workpiece axes. The cradle carrying the head stock and tail stock is provided with rocking motion derived from the rotation of a master cam that rotates in synchronisation with the workpiece. Newer machines however, use CNC in place of master cam to generate cam on the workpiece.

**External centreless grinder:**

This grinding machine is a production machine in which out side 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. 6.24.

![Fig. 6.24 Centreless through feed grinding](image)

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

Parts with variable diameter can be ground by Centreless infeed grinding as shown in Fig. 6.25 (a). The operation is similar to plunge grinding with cylindrical grinder.

End feed grinding shown in Fig. 6.25 (b) is used for workpiece with tapered surface.
A: rotation of grinding wheel  
B: rotation of regulating wheel  
C: feed on workpiece

Fig. 6.25 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.

**Tool post grinder:**

A self powered grinding wheel is mounted on the tool post or compound rest to provide the grinding action in a lathe. Rotation to the workpiece is provided by the lathe spindle. The lathe carriage is used to reciprocate the wheel head.

**Internal grinding machine:**

This machine is used to produce internal cylindrical surface. The surface may be straight, tapered, grooved or profiled.

Broadly there are three different types of internal grinding machine as follows:

1. Chucking type internal grinder
2. Planetary internal grinder
3. Centreless internal grinder

**Chucking type internal grinder:**

Figure 6.26 illustrates schematically this machine and various motions required for grinding action. The workpiece is usually mounted in a chuck. A magnetic face plate can also be used. A small grinding wheel performs the necessary grinding with its peripheral surface. Both transverse and plunge grinding can be carried out in this machine as shown in Fig. 6.27.
Fig. 6.26 Internal Centreless grinding

Fig. 6.27 Internal (a) traverse grinding and (b) plunge grinding

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

**Planetary internal grinder:**

Planetary internal grinder is used where the workpiece is of irregular shape and cannot be rotated conveniently as shown in Fig. 6.28. In this machine the workpiece does not rotate. Instead, the grinding wheel orbits the axis of the hole in the workpiece.

Fig. 6.28 Internal grinding in planetary grinder
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. 6.29.

![Internal centreless grinding](image)

**Fig. 6.29** 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 resharpening. 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.
Fig. 6.30 Pictorial view of a tool and cutter grinder