

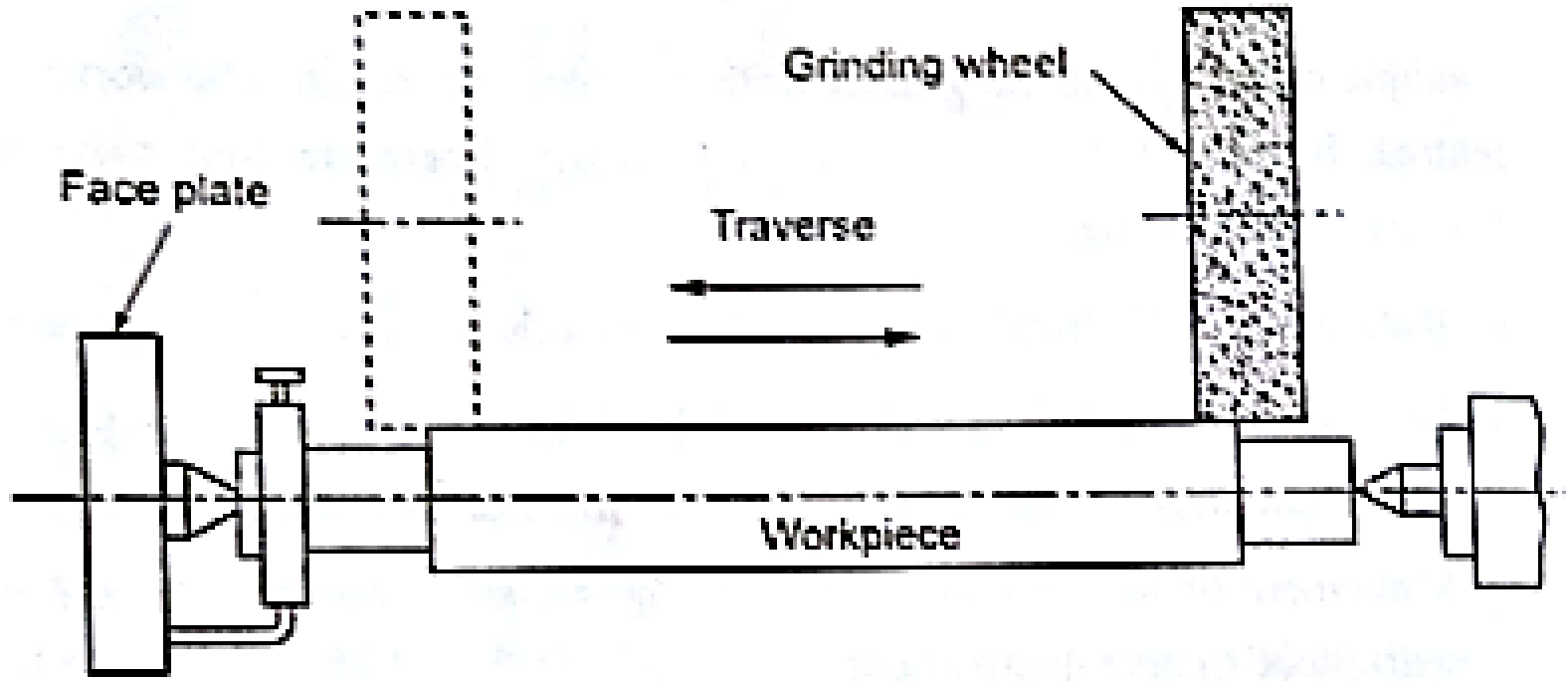
GRINDING

- Abrasive process
- Metal is removed with the help of **ROTATING GRINDING WHEEL**
- Wheels are made of fine grains of abrasive materials held together by a bonding material called a **BOND**

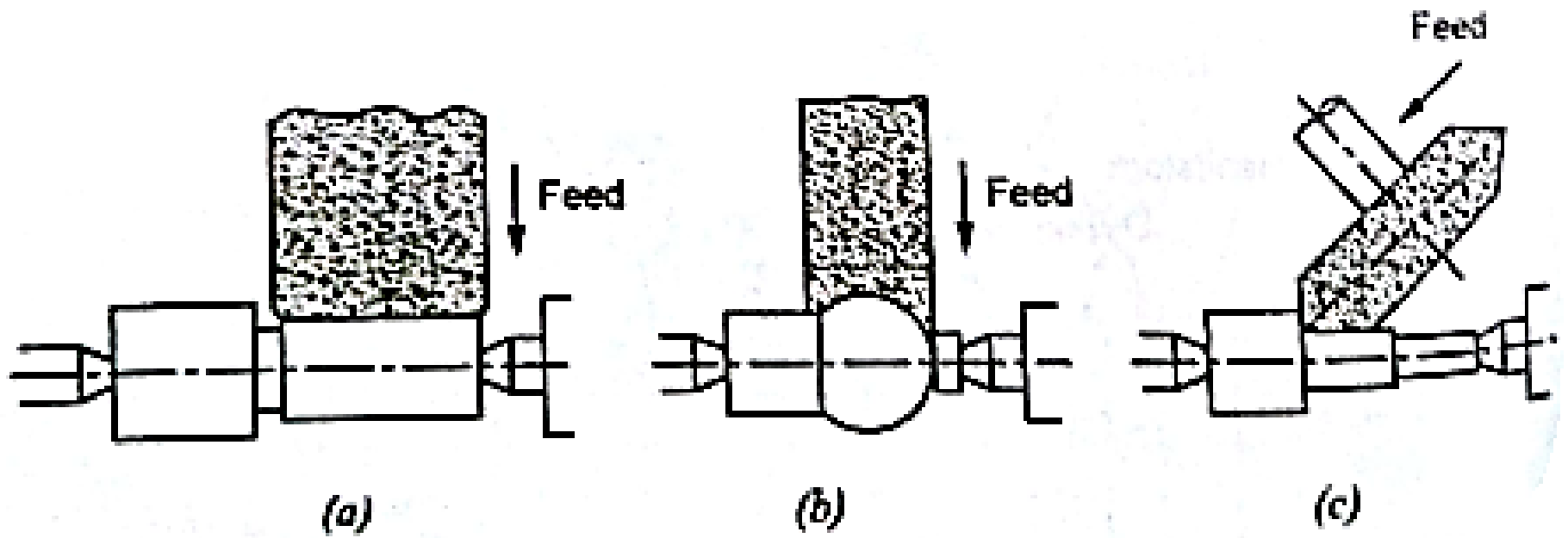


Types of operations performed in cylindrical grinding

1. TRAVERSE GRINDING
2. PLUNGE GRINDING



Traverse grinding

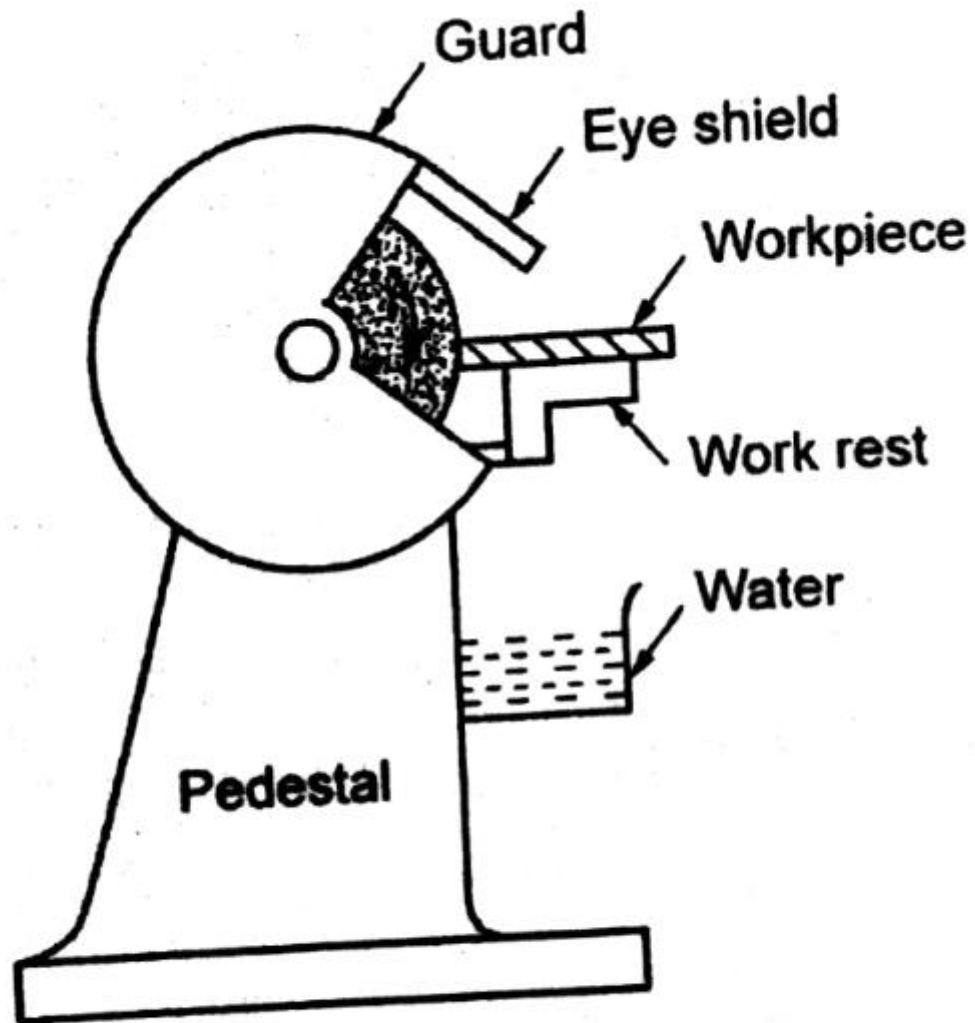


Plunge grinding

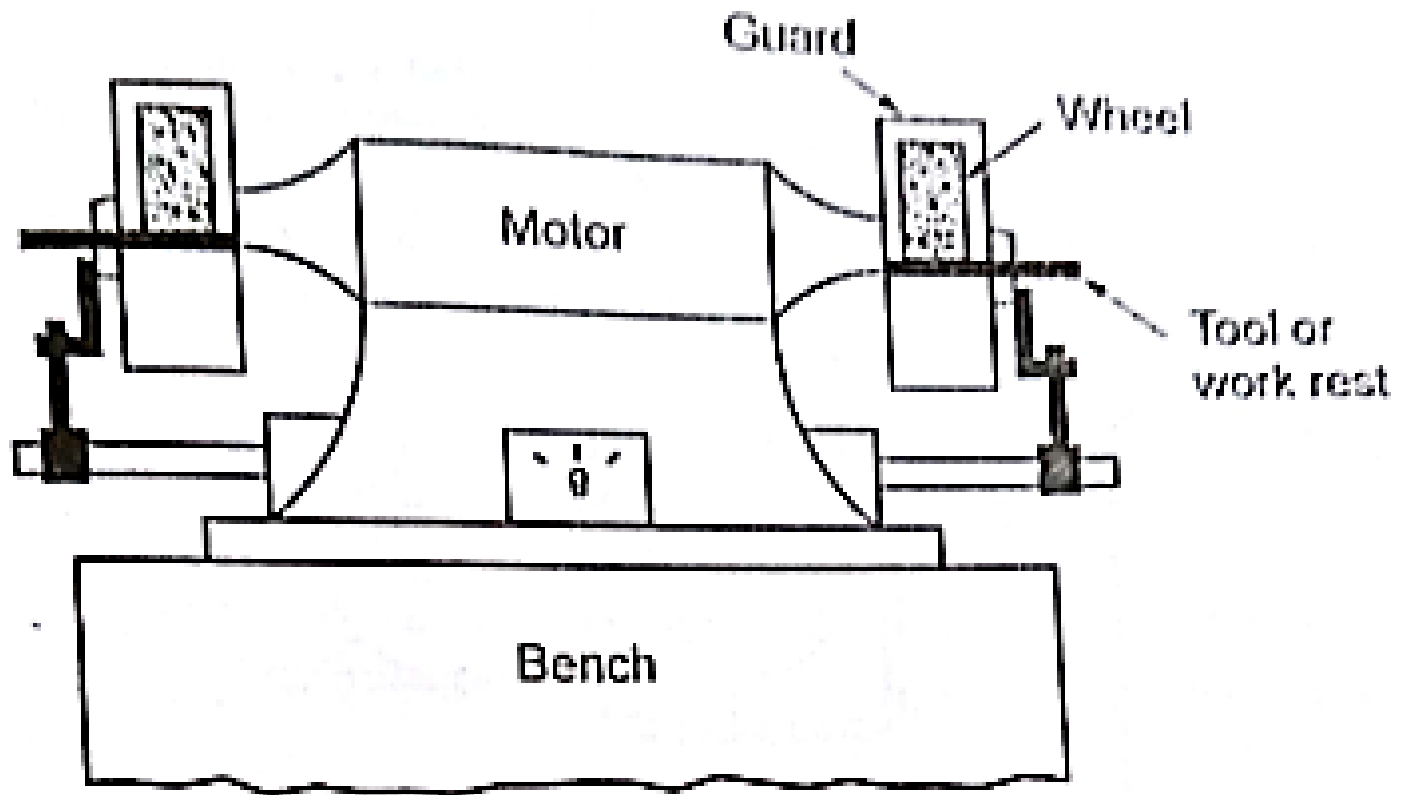
GRINDING MACHINES

Conventional grinding machines can be broadly classified as:

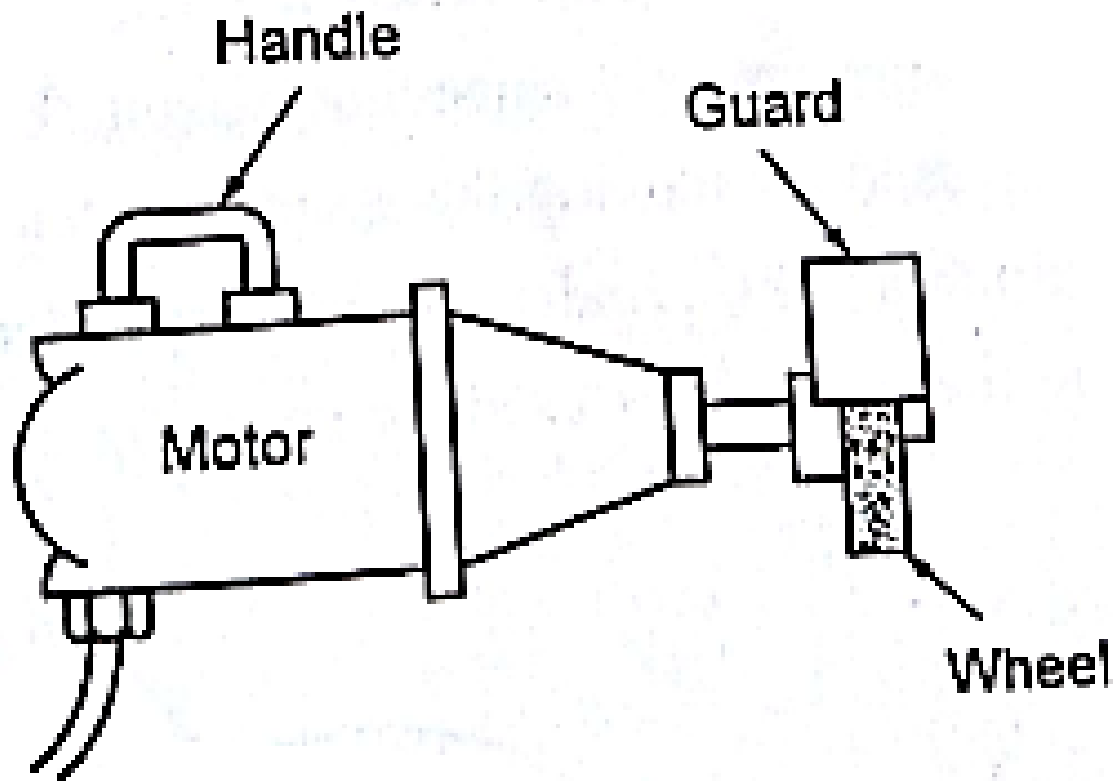
- (a) Surface grinding machine
- (b) Cylindrical grinding machine
- (c) Internal grinding machine
- (d) Tool and cutter grinding machine



Floor stand grinder

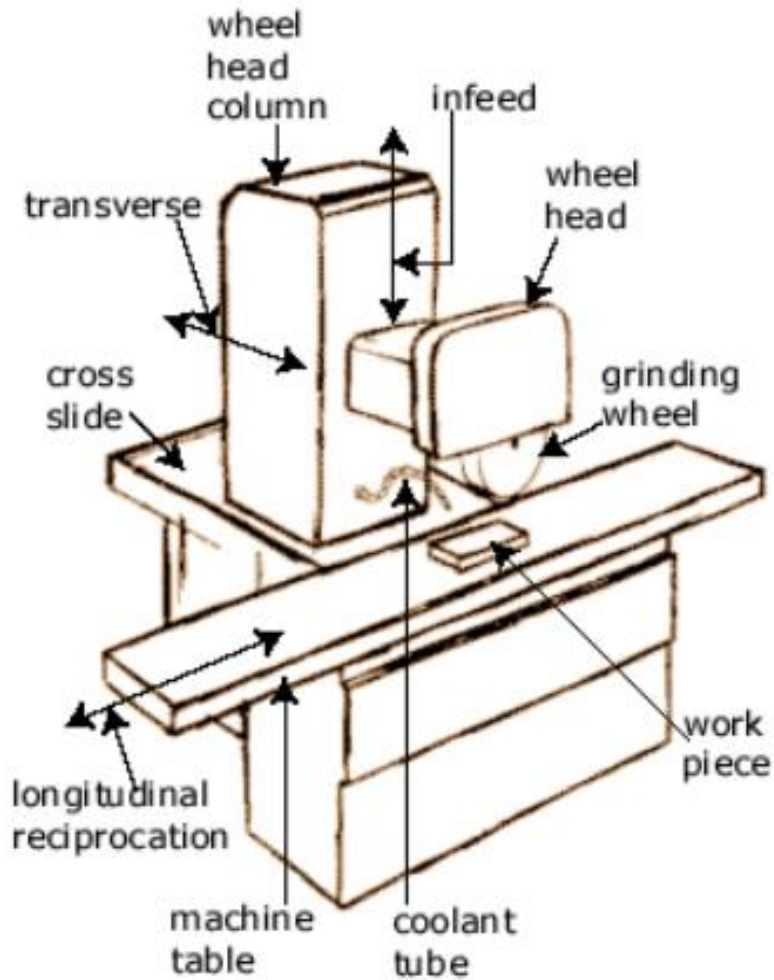


Bench grinder

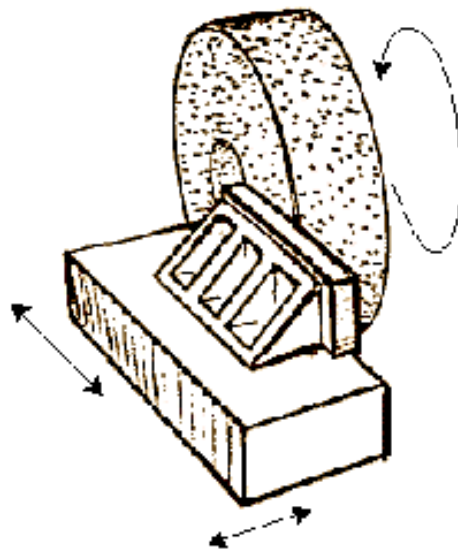
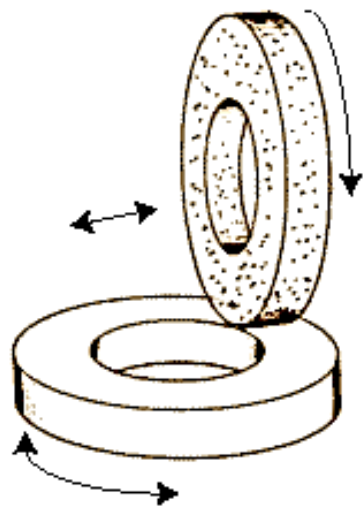
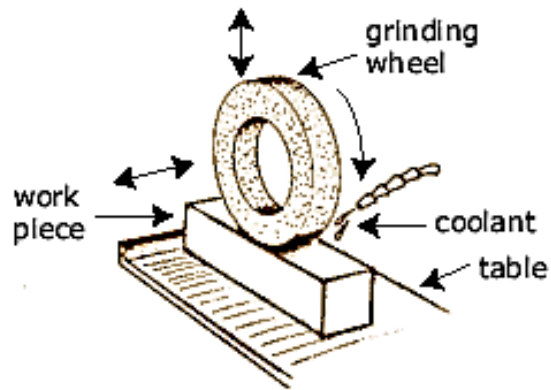


Portable grinder

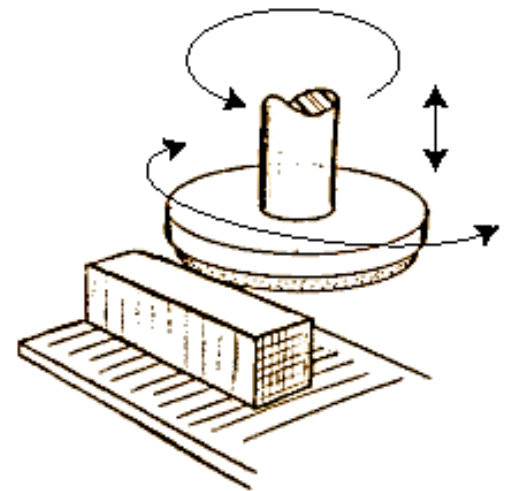
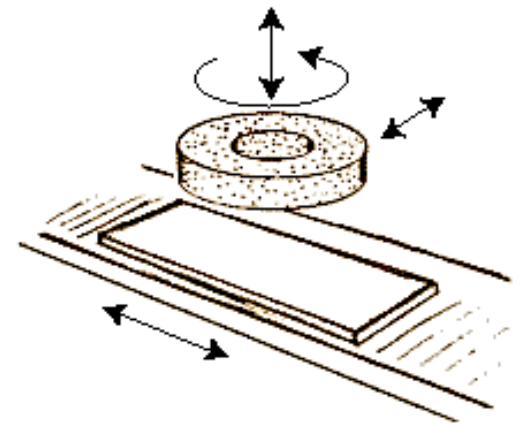
HORIZONTAL GRINDING



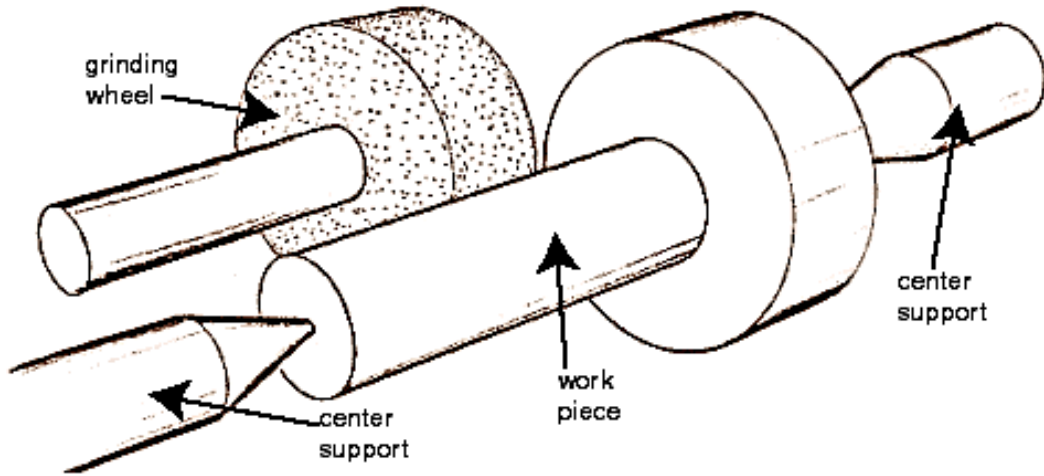
Horizontal grinding



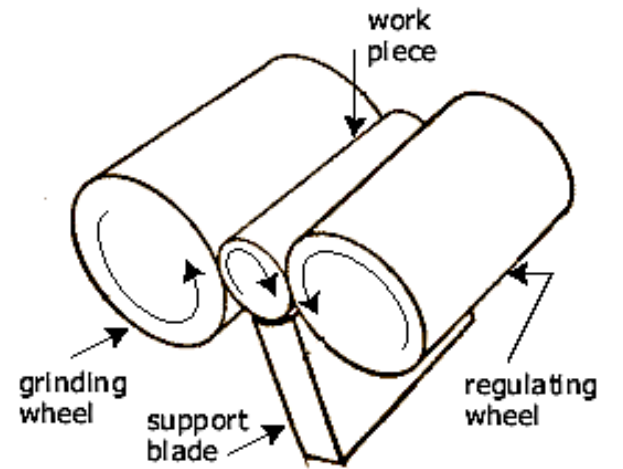
Vertical grinding



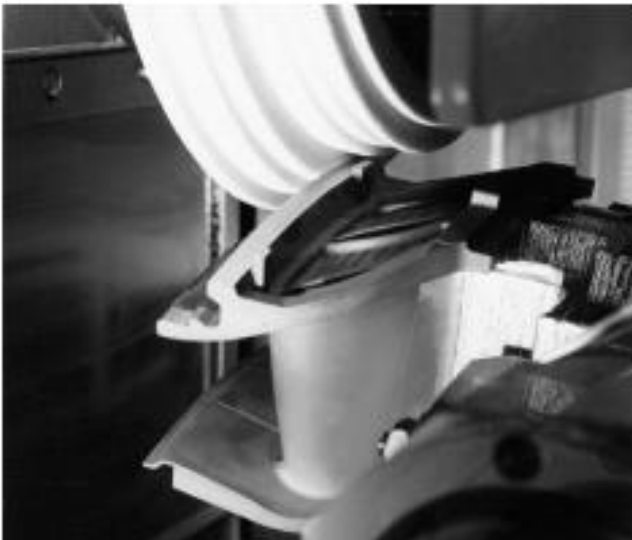
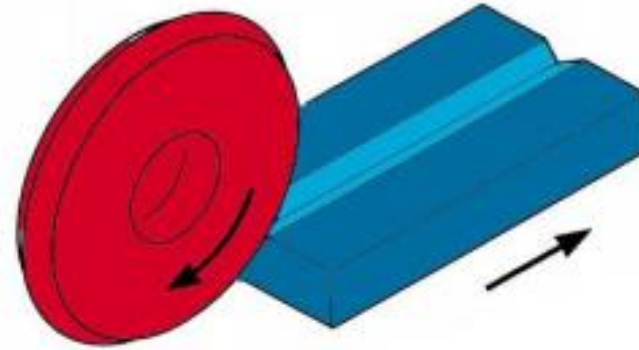
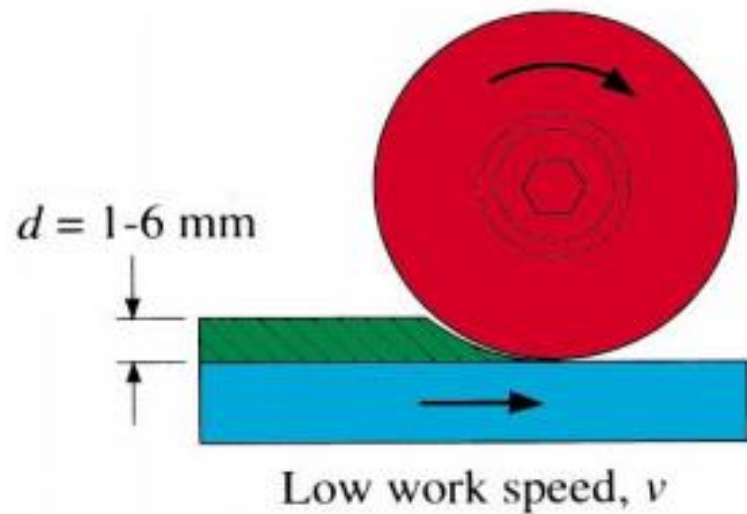
Centered grinding



Centerless grinding

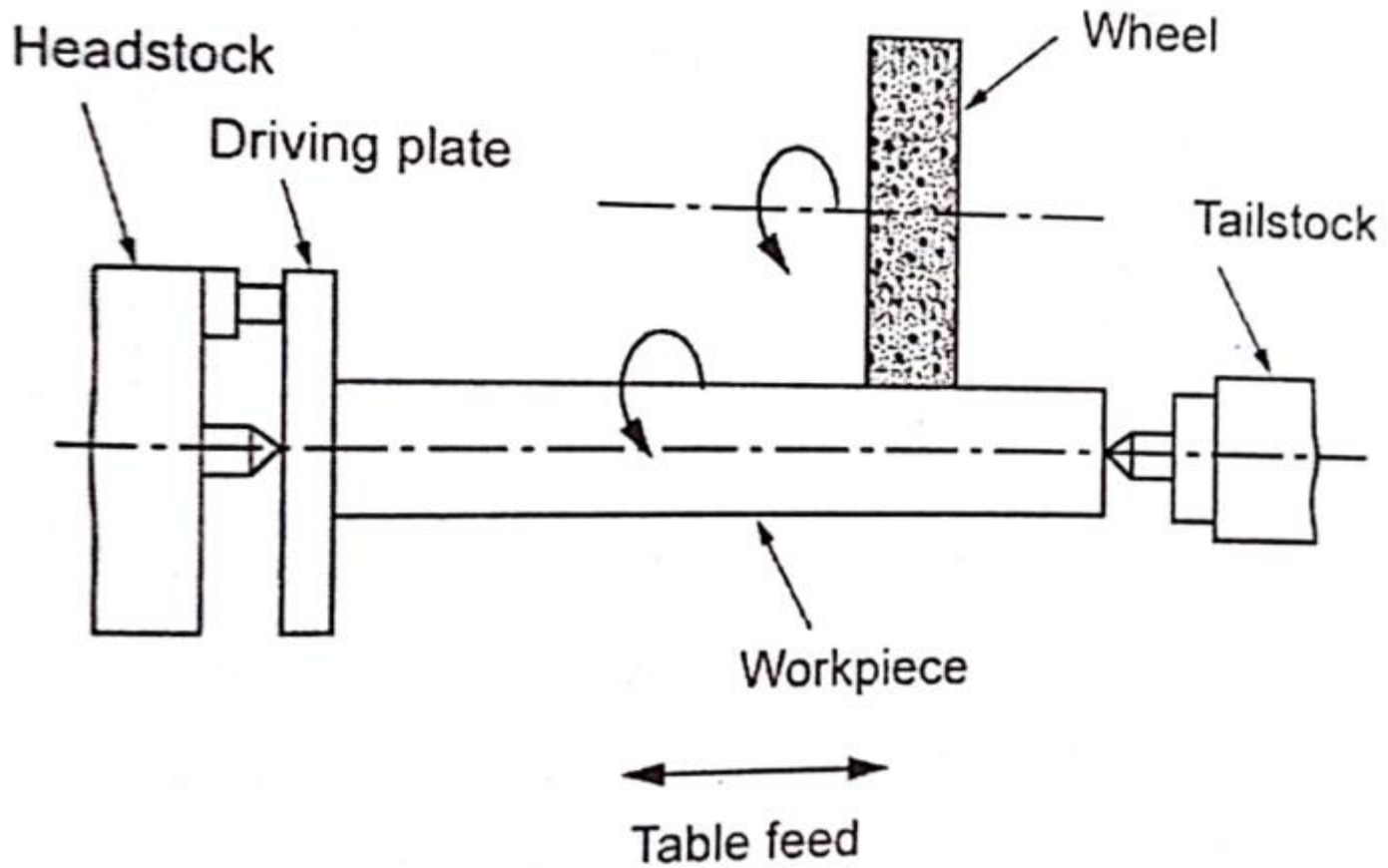


Creep Feed Grinding

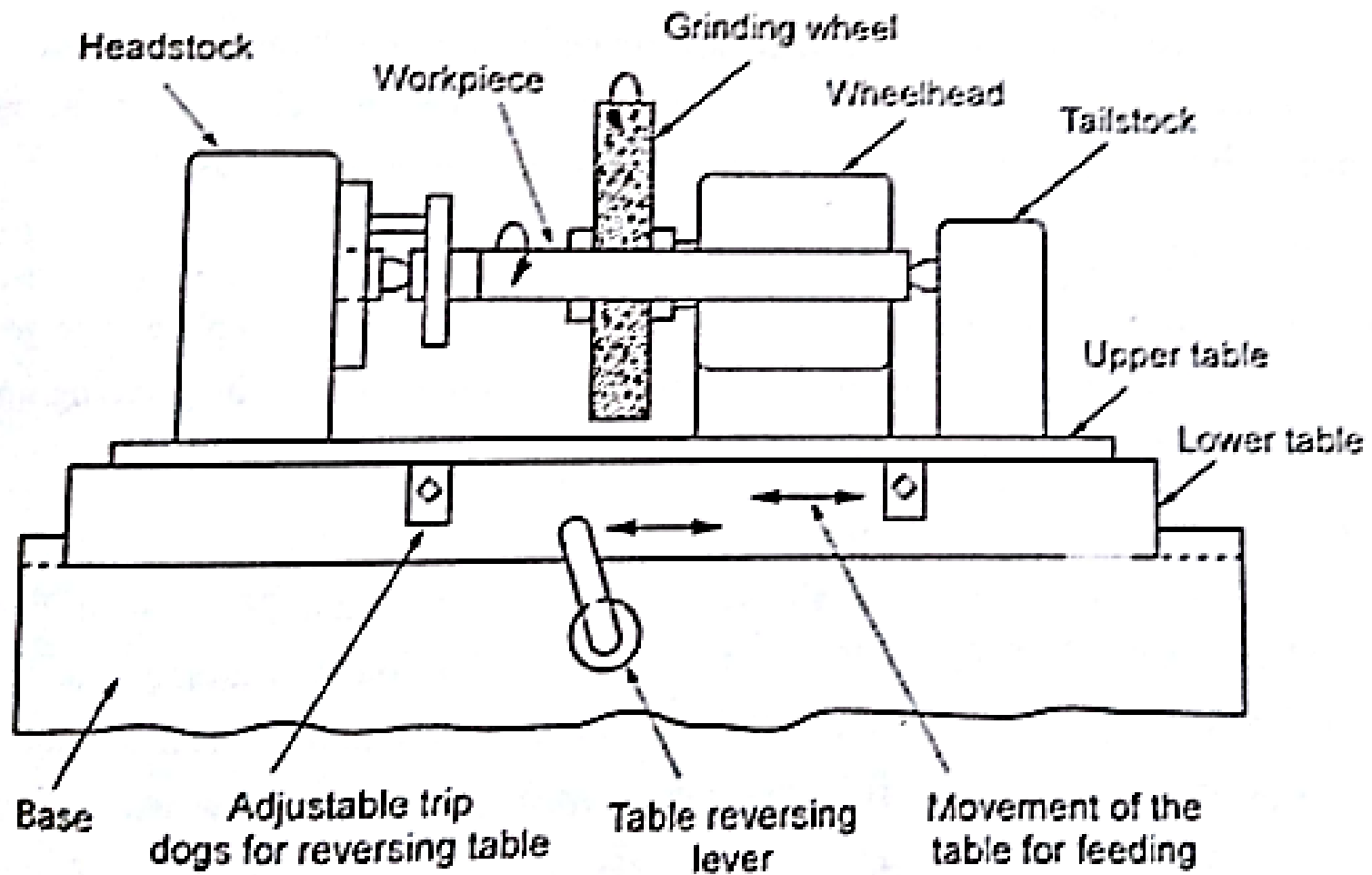


- Full depth and stock is removed with one or two passes at low work speed
- Very high forces are generated
- High rigidity and power

CYLINDRICAL GRINDING

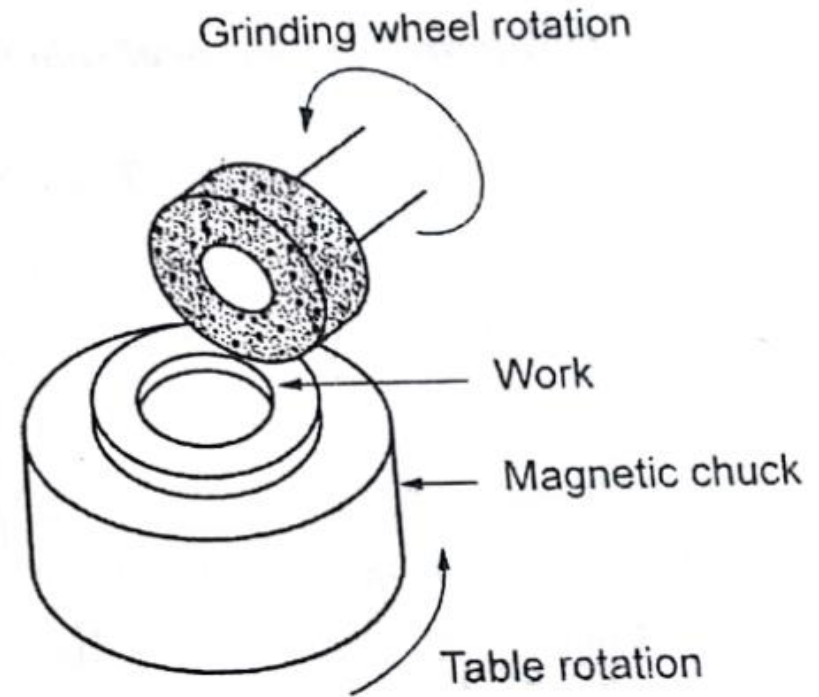
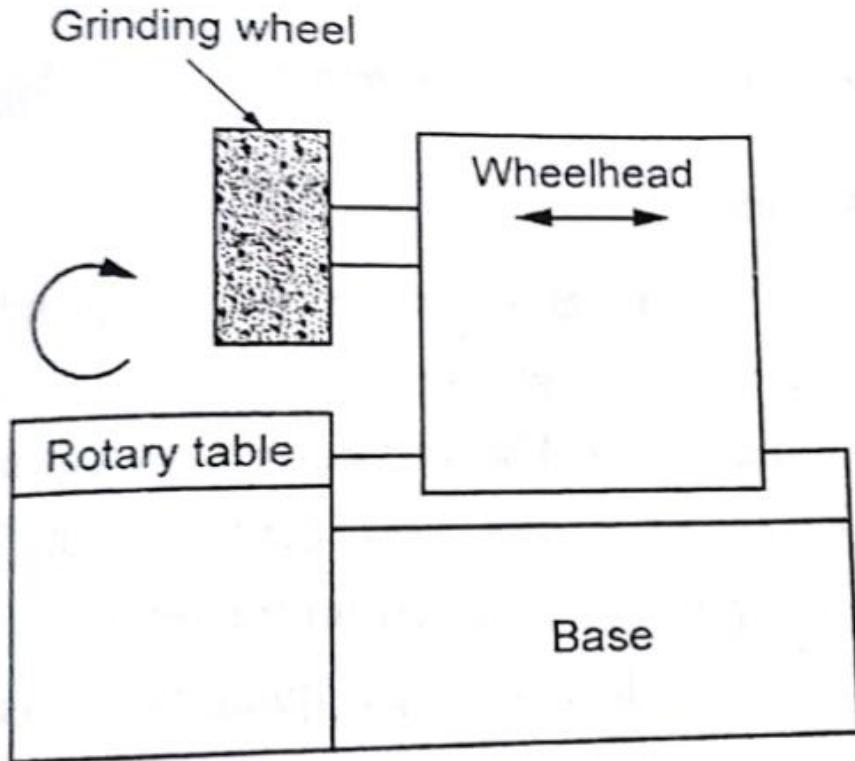


Cylindrical grinders



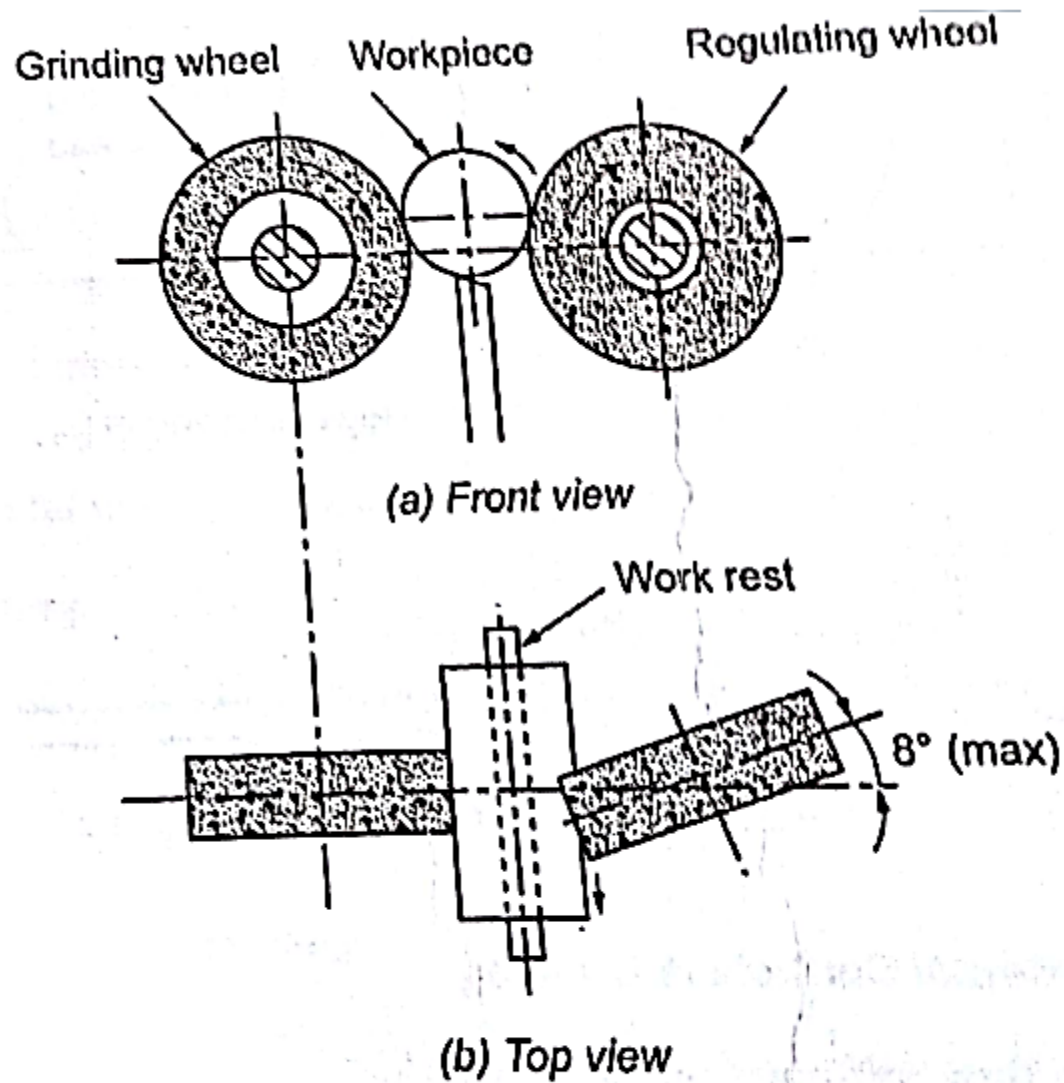
Plain centre type cylindrical grinding machine

SURFACE GRINDING

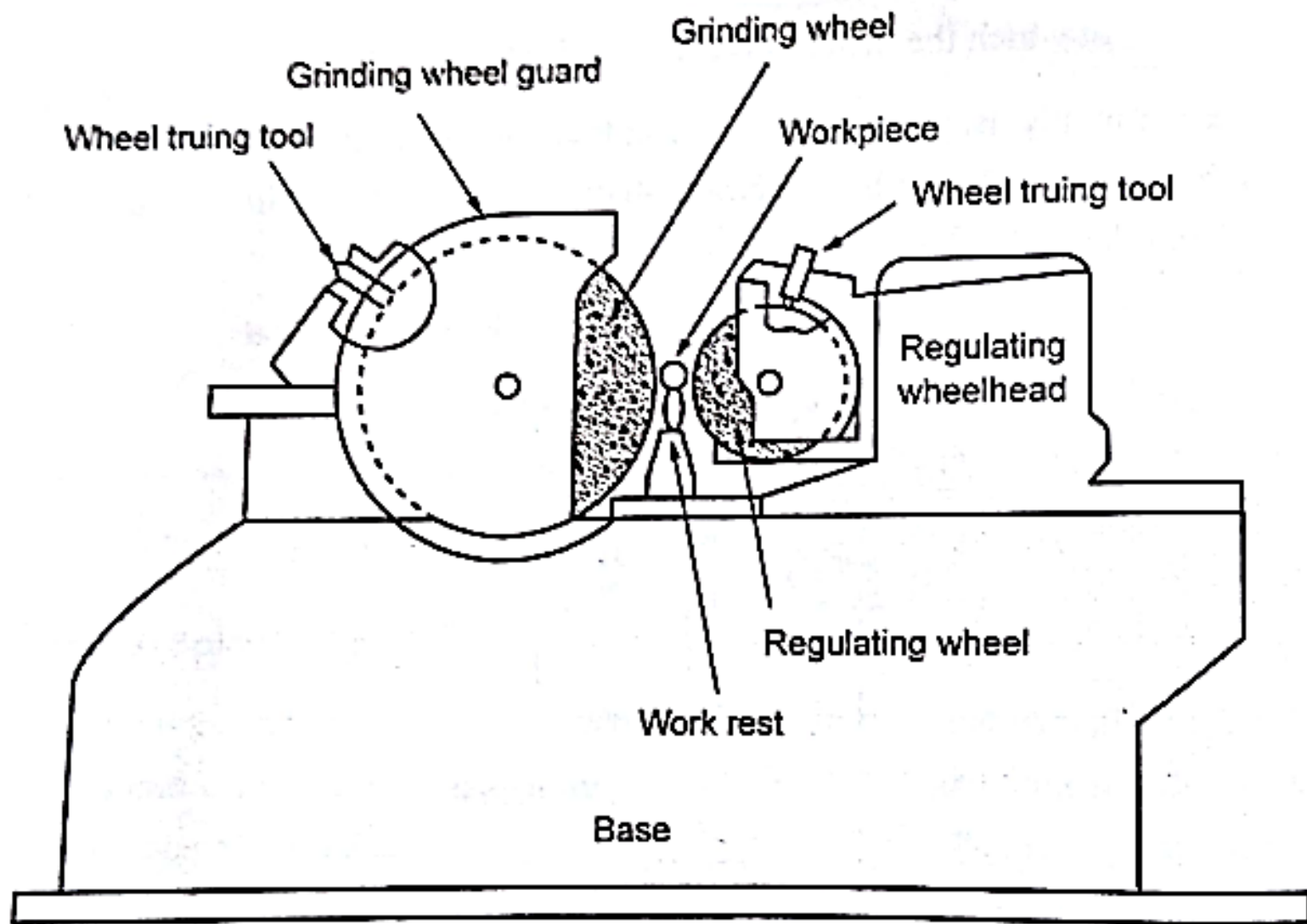


Horizontal spindle rotary table surface grinder

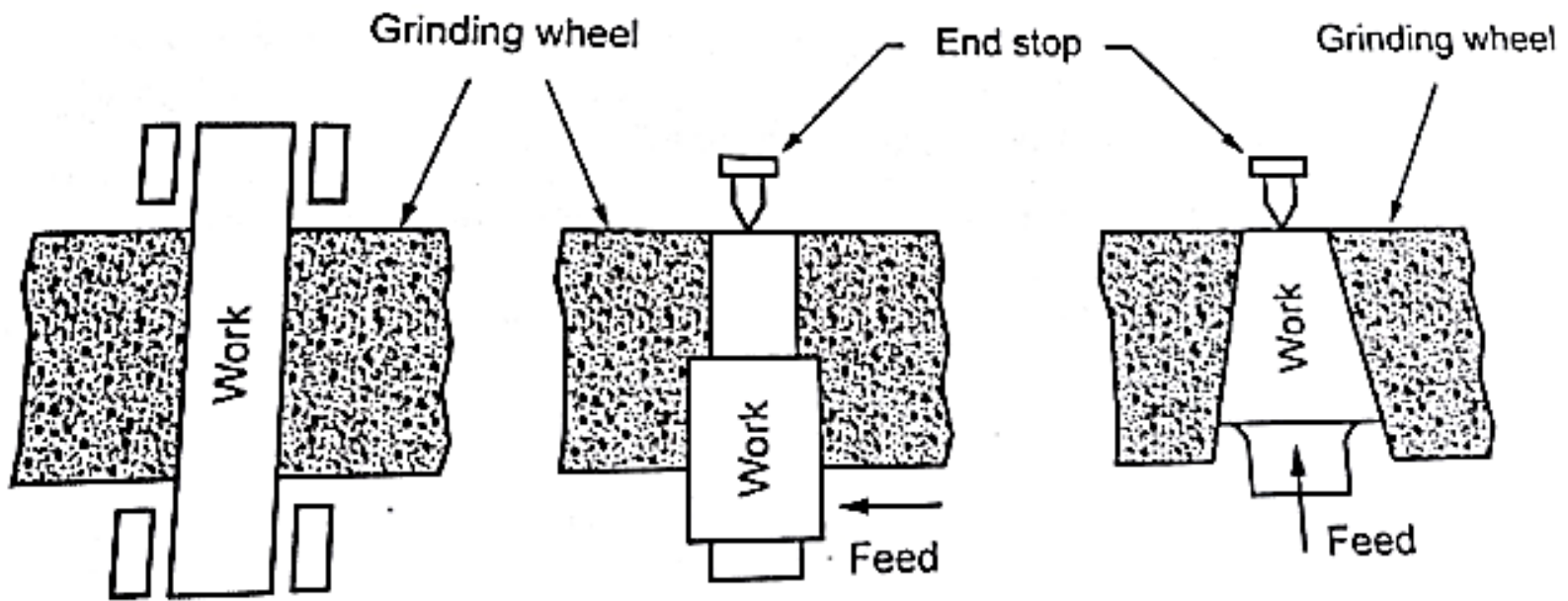
CENRELESS GRINDING



Principle of centreless grinding



Centreless grinders



(a) Through-feed

(b) In-feed

(c) End-feed grinding

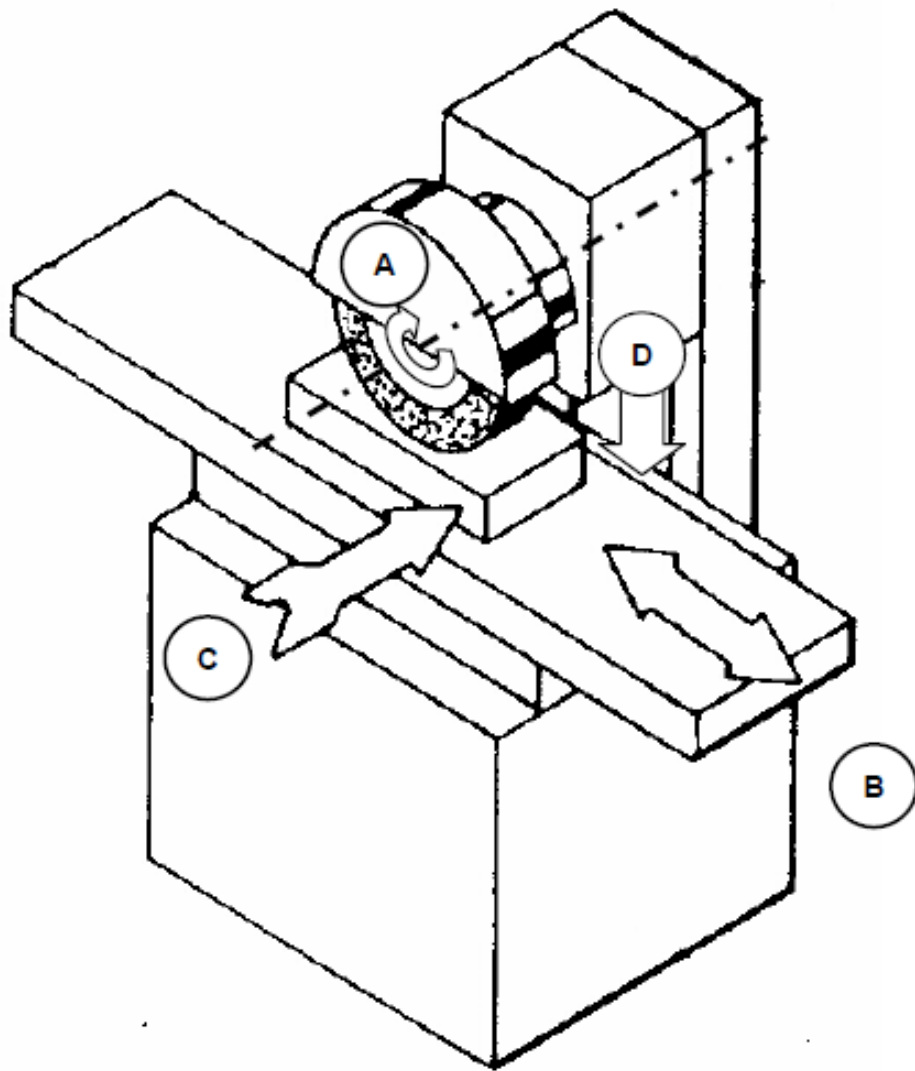
Methods of centreless grinding

Surface grinding machine

Machine may be similar to a milling machine used mainly to grind flat surface

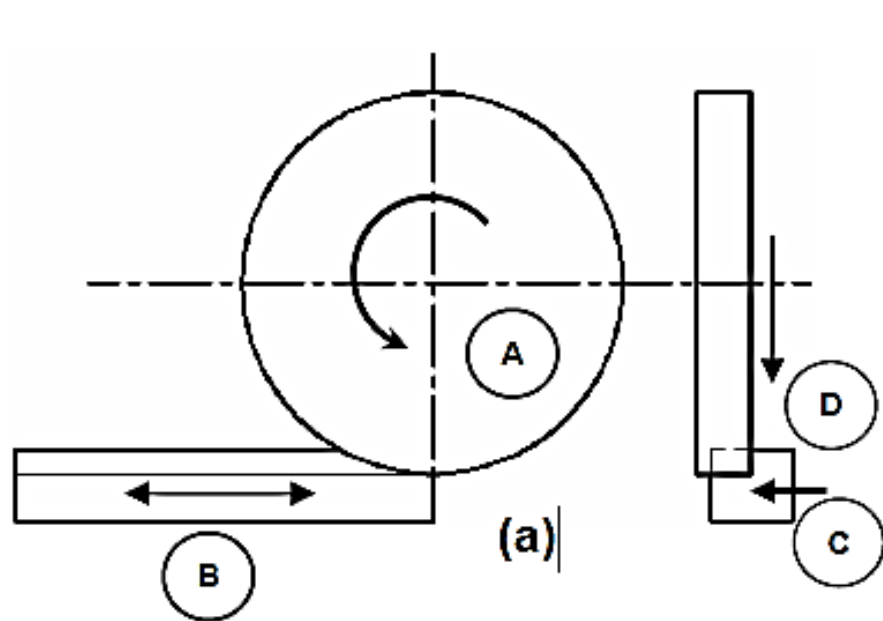
Basically there are four different types of surface grinding machines characterized by the movement of their tables and the orientation of grinding wheel spindles

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

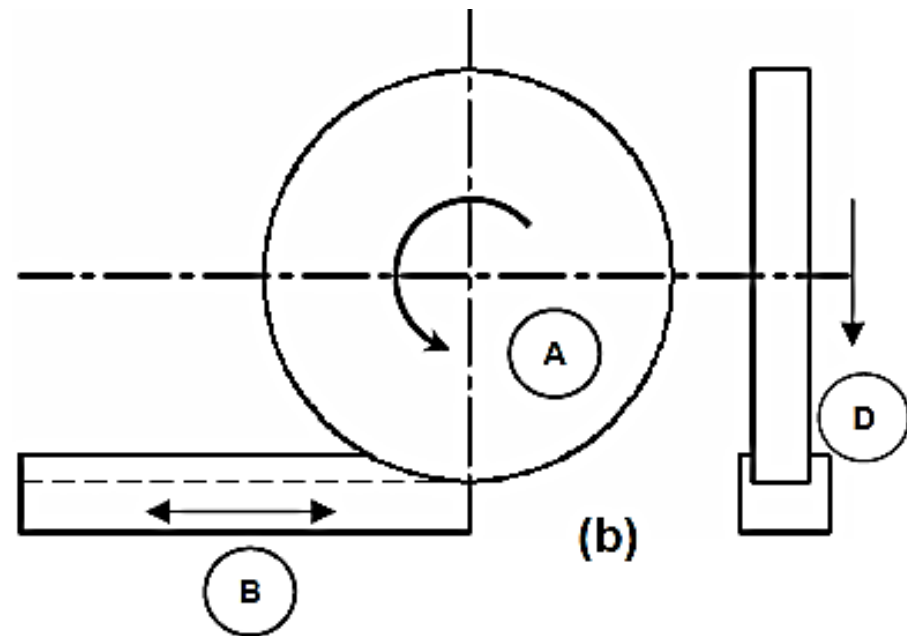


- A: rotation of grinding wheel
- B: reciprocation of worktable
- C: transverse feed
- D: down feed

Horizontal spindle reciprocating table surface grinder



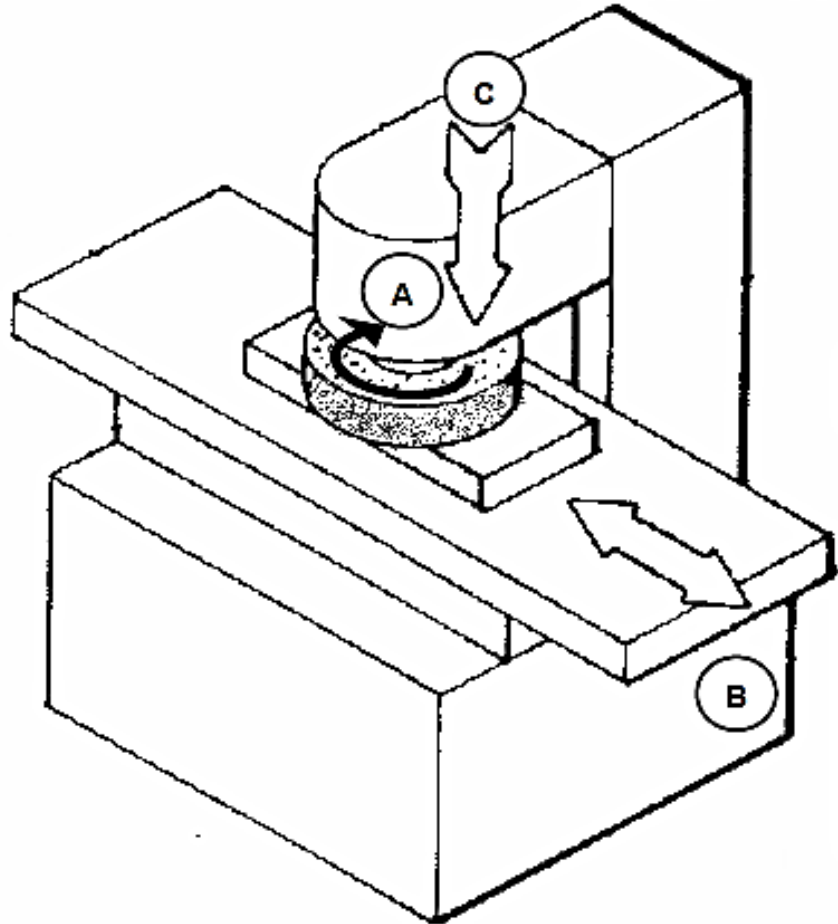
A: rotation of grinding wheel
C: transverse feed



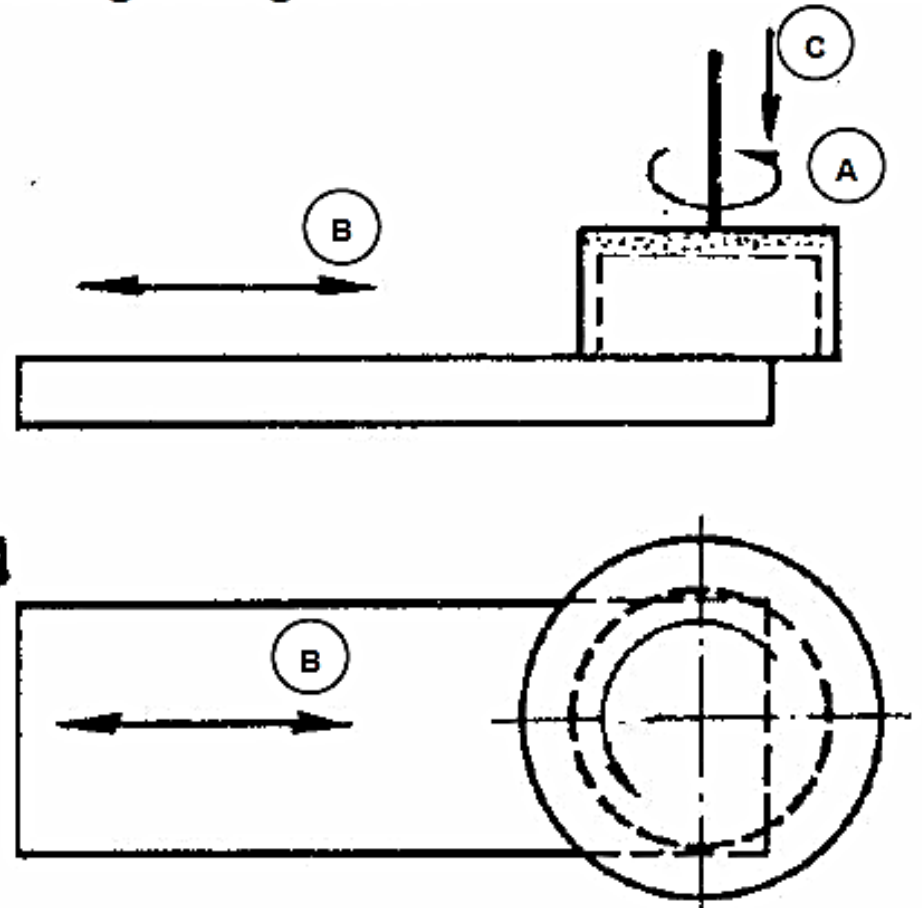
B: reciprocation of worktable
D: down feed

Surface grinding (a) traverse grinding (b) plunge grinding

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



Vertical spindle reciprocating table surface grinder



Surface grinding in Vertical spindle reciprocating table surface grinder

Cylindrical grinding machine

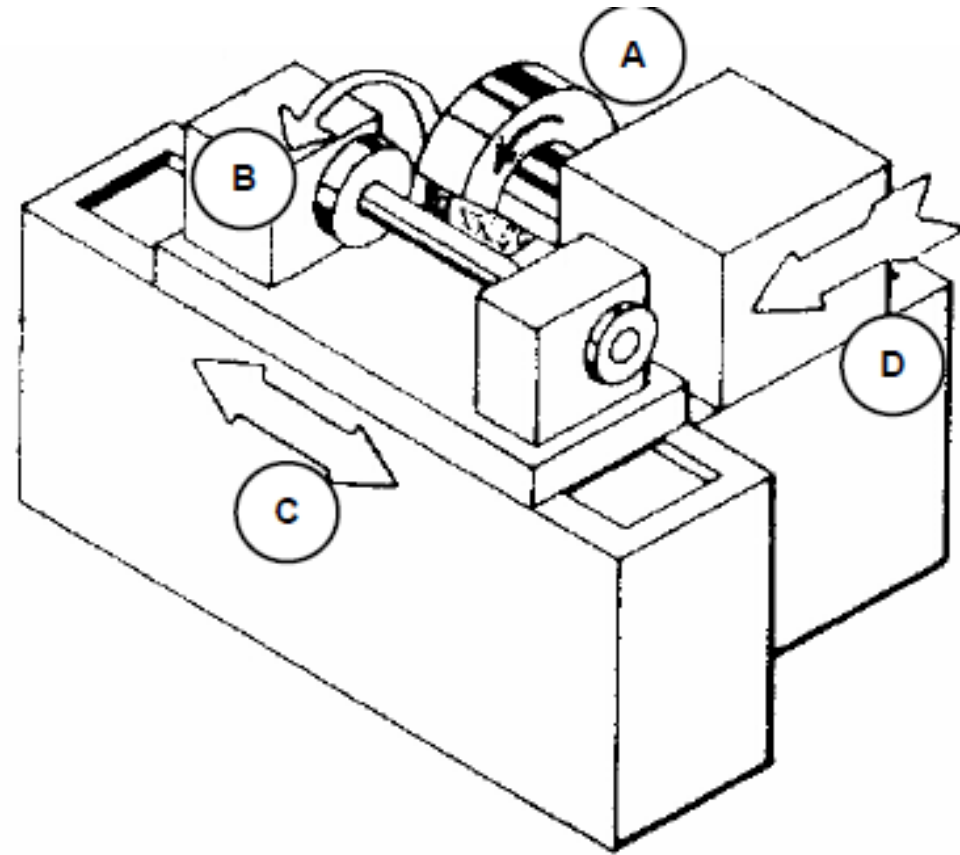
This machine is used to produce external cylindrical surface.

Surfaces may be straight, tapered, steps or profiled.

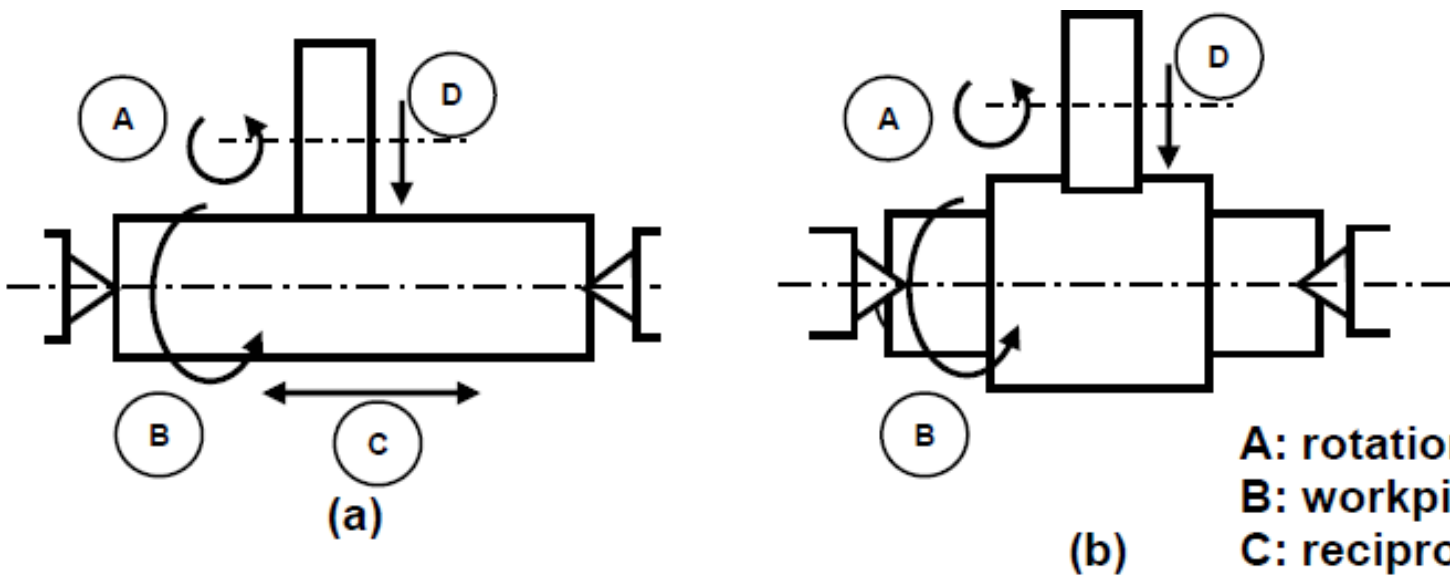
Broadly there are three different types of cylindrical grinding machine as follows:

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

Plain centre type cylindrical grinder



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



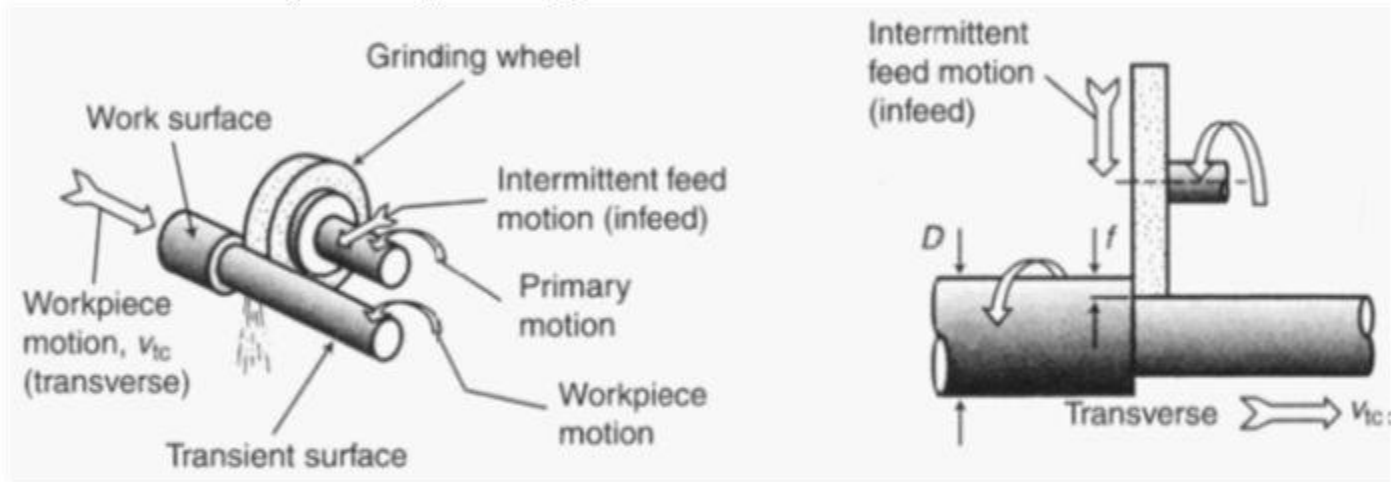
A: rotation of grinding wheel
B: workpiece rotation
C: reciprocation of worktable
D: infeed

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

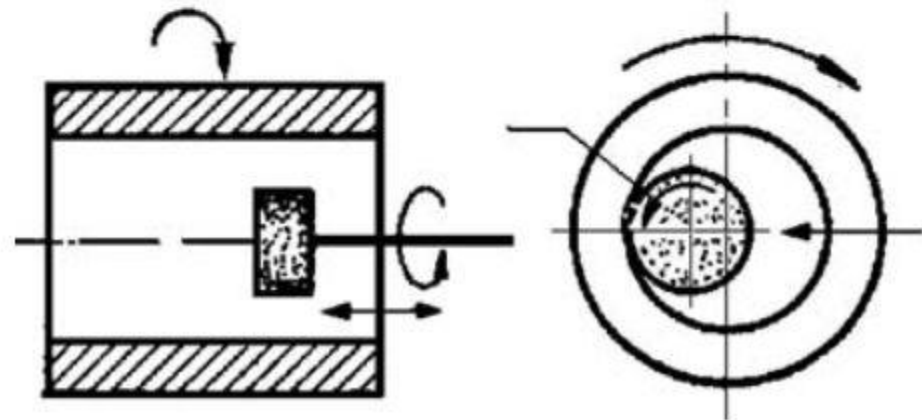
2- cylindrical Grinding

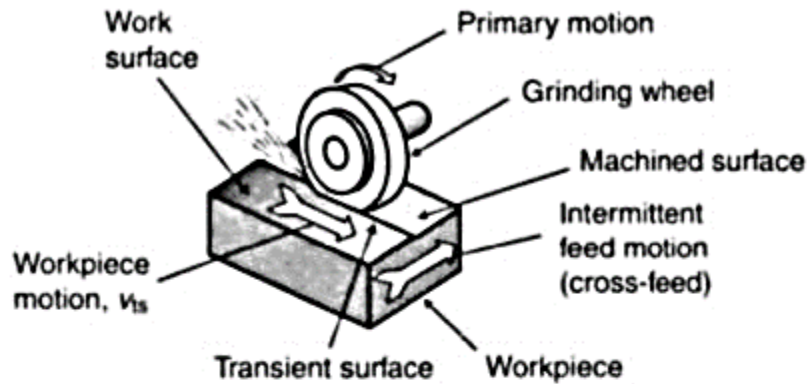
a- External cylindrical grinding

the feed motions are either traverse feed (the wheel or workpiece or both) or plunge cut.

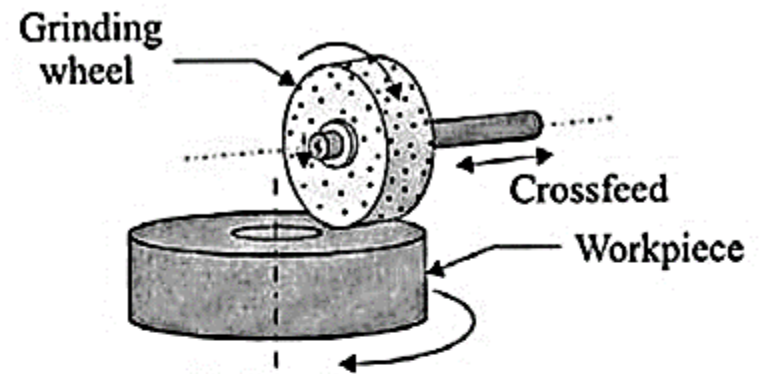


b- Internal cylindrical grinding

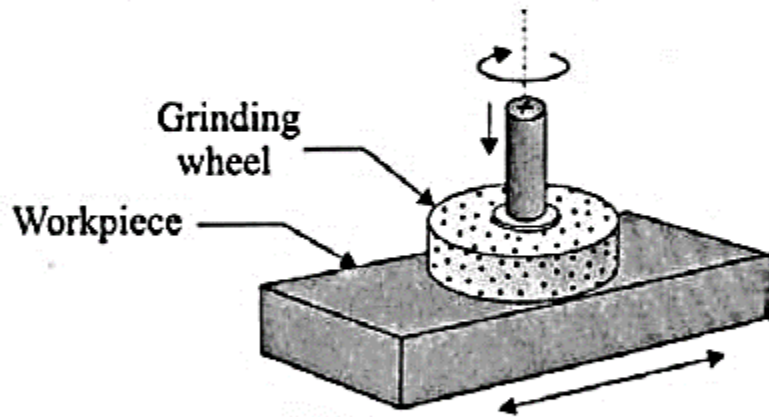




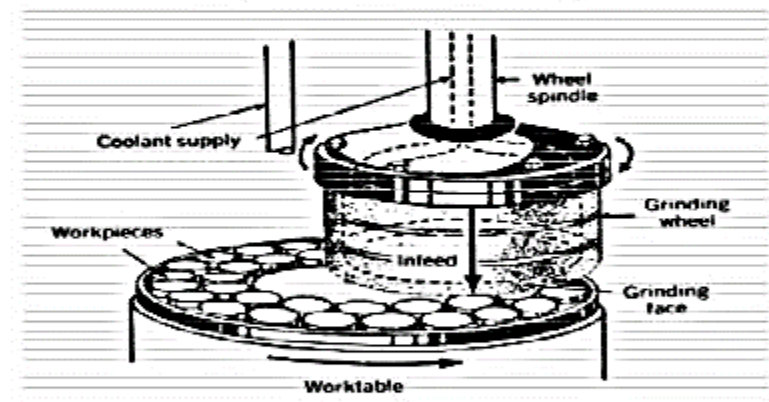
horizontal spindle with reciprocating worktable.



Horizontal spindle with rotary worktable.



vertical spindle with reciprocating worktable.



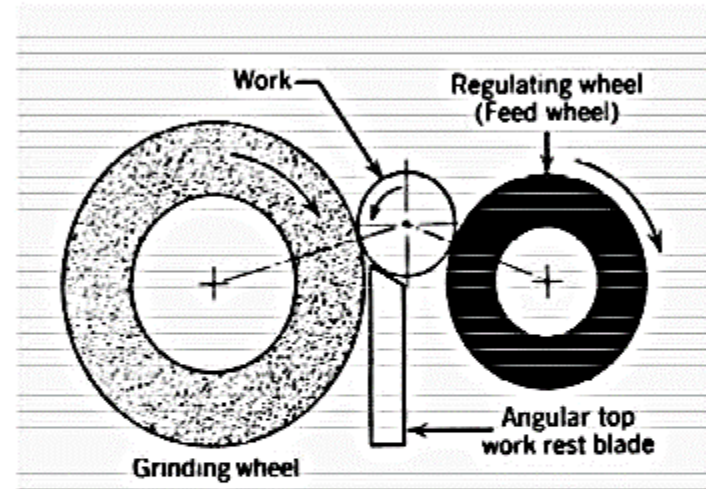
Vertical spindle with rotary worktable.

Note the direction of the cross feed and in-feed

3- Centerless Grinding

- The workpiece is not held between center, then it used for high production rate machining, no holding time.
- The regulating wheel rotates at lower speed and is inclined at a slight angle I , the feed rate of this wheel depending on its diameter, rotating speed, and its angle.

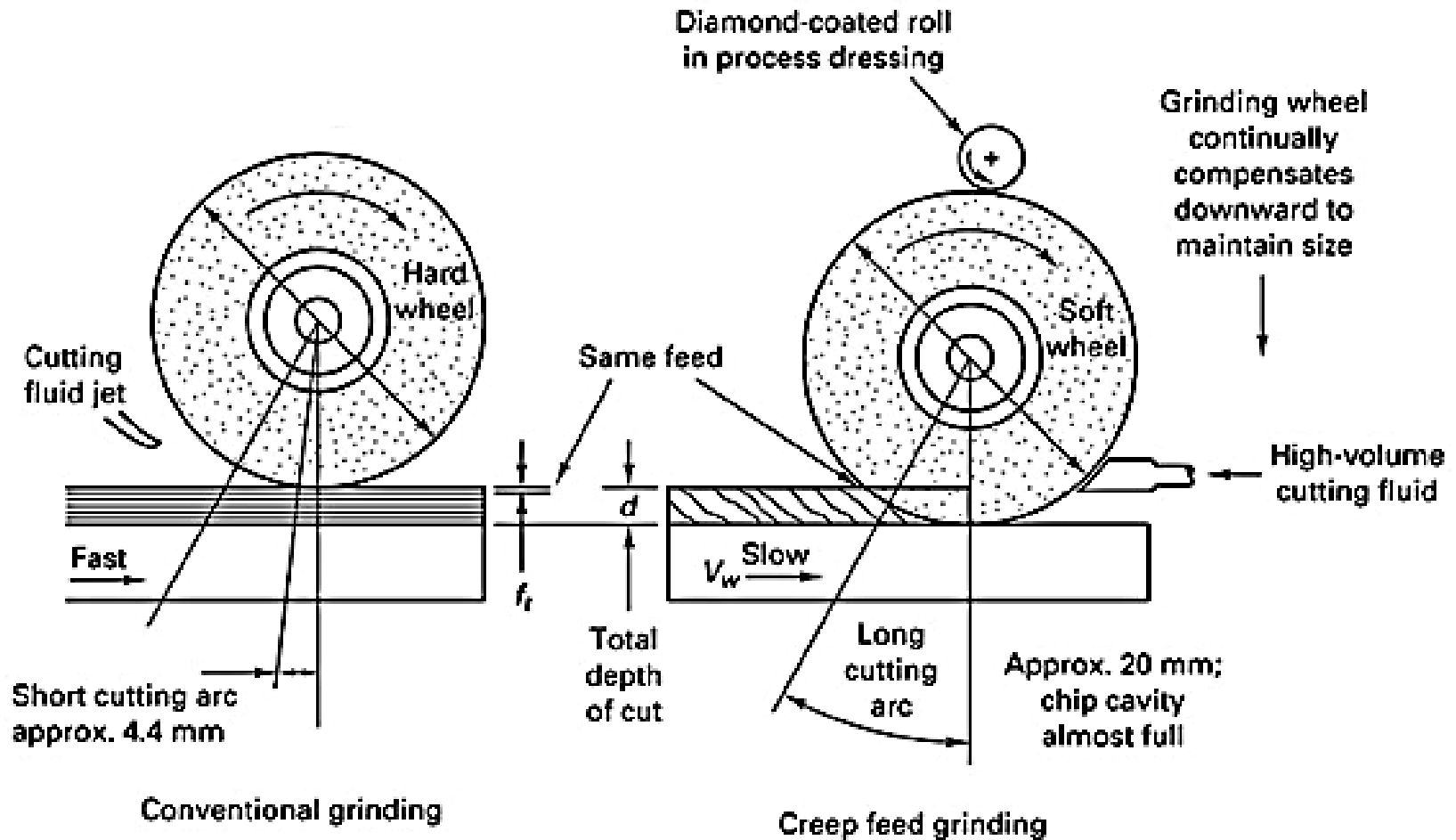
$$f_r = \pi D_r N_r \sin I$$



External Centerless Grinding

- Grinding is done in three ways
 - Infeed – moving the wheel across the surface
 - Plunge-cut – the material is rotates as the wheel moves radially into the surface.
 - Creep Feed Grinding – the material is feed past the wheel.

Conventional Grinding



Classification of Grinding Machines

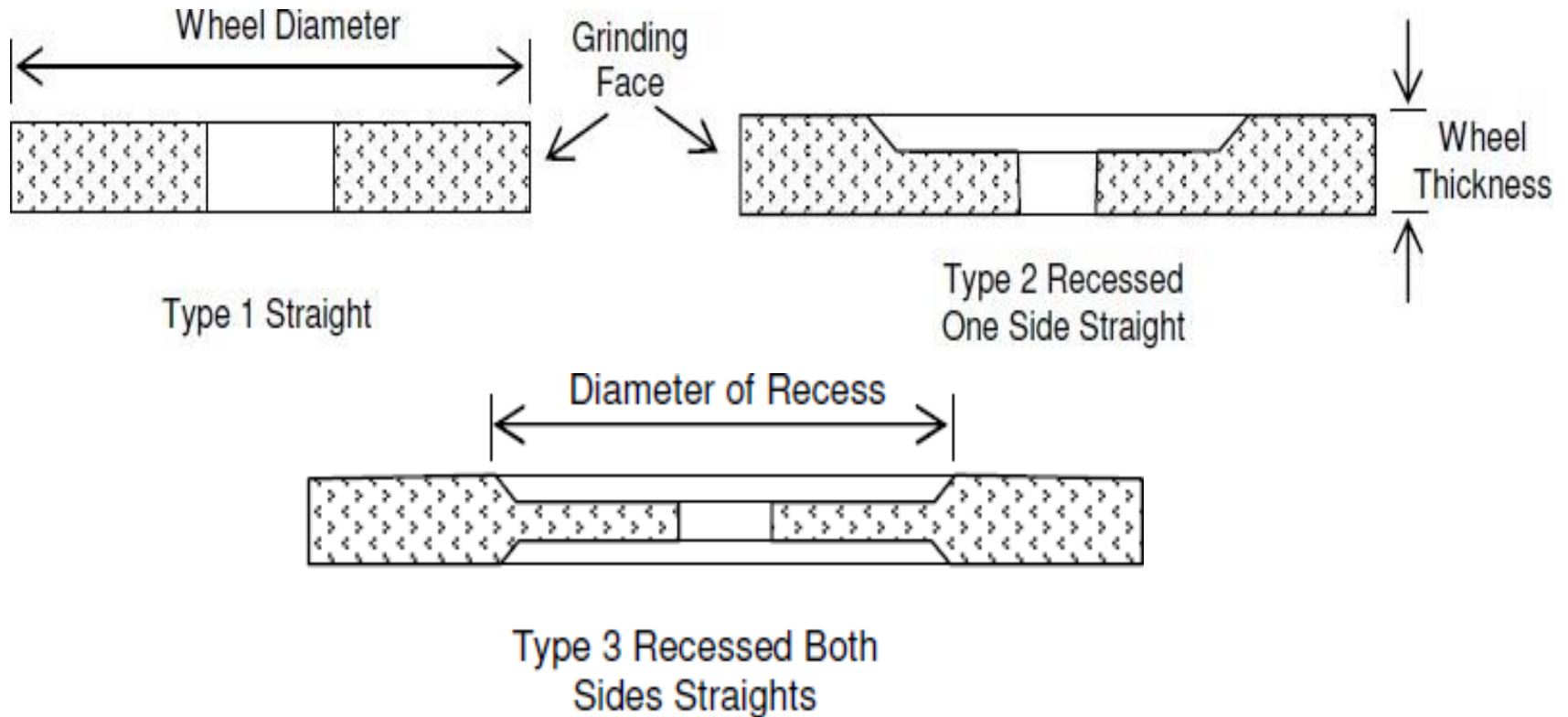
Type of Machine	Type of Surface	Specific Types or Features
Cylindrical external	External surface on rotating, usually cylindrical parts	Work rotated between centers Centerless Centerless Chucking Tool post Crankshaft, cam, etc.
Cylindrical internal	Internal diameters of holes	Chucking Planetary (work stationary) Centerless
Surface conventional	Flat surfaces	Reciprocating table or rotating table Horizontal or vertical spindle
Creep feed	Deep slots, profiles in hard steels, carbides, and ceramics using CBN and diamond	Rigid, chatter-free, creep feed rate Continuous dressing Heavy coolant flows NC or CNC control Variable speed wheel
Tool grinders	Tool angles and geometries	Universal Special
Other	Special or any of the above	Disk, contour, thread, flexible shaft, swing frame, snag, pedestal, bench

TYPES OF GRINDING WHEELS

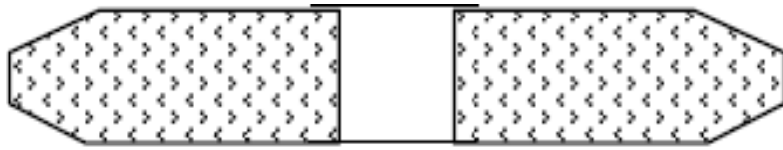
Grinding Wheels



Straight Wheel

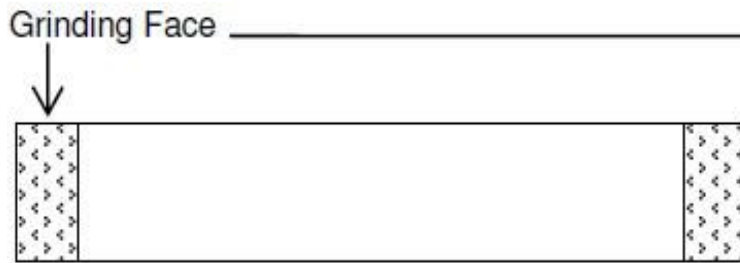


These are generally used for cylindrical, internal, centreless and surface grinding operations. These wheels vary in size, diameter and width of the face.



Type 4 Tapered Face
Straight Wheel

It is also a straight wheel but its free is slightly tapered to facilitate the grinding of threads and gear teeth.



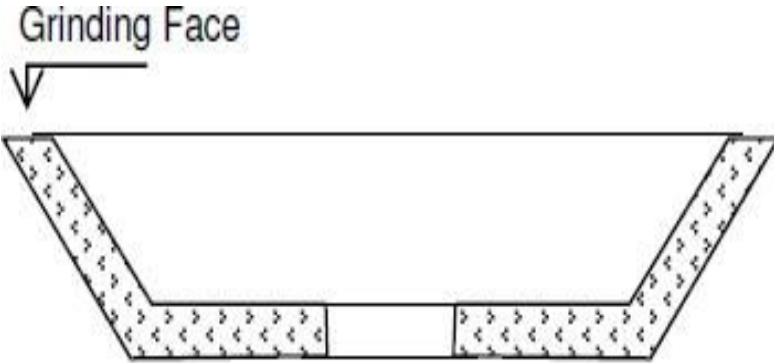
Type 5 Cylindrical or
Wheel Ring



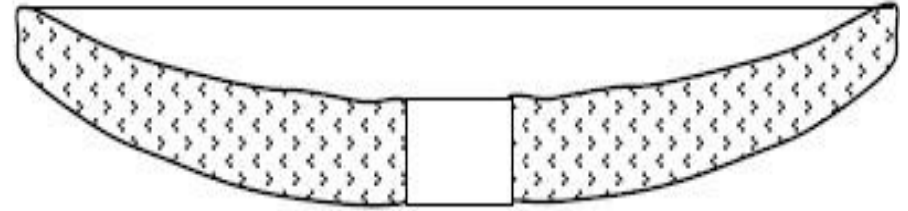
Type 6 Straight Cup Wheel

Type 5. It is used for surface grinding, i.e. production of flat surfaces. Grinding takes place with the help of face of the wheel.

Type 6. It is used for grinding flat surfaces with the help of face of grinding wheel.



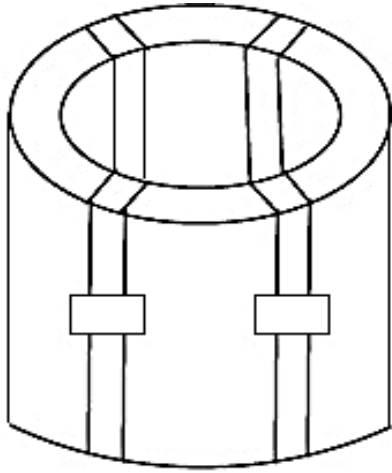
Type 7 Flaring Cup Wheel



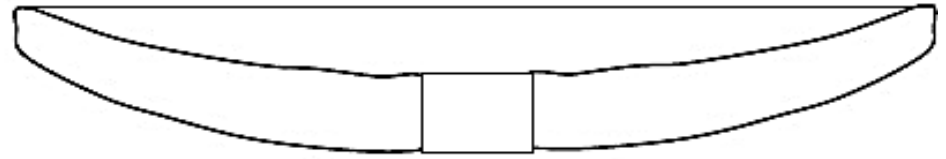
Type 8 Saucer Wheel

Type 7 used in grinding of tools in tool room.

Type 8. It is used for sharpening of circular or band saw.



Type 9 Segmented Wheel

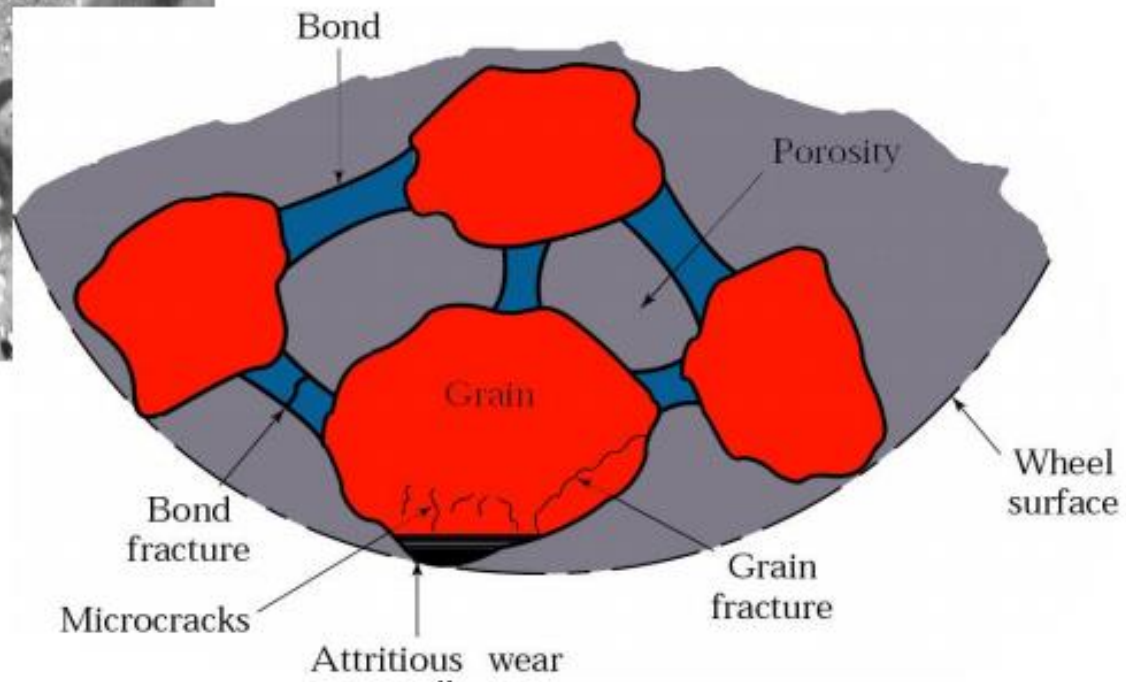
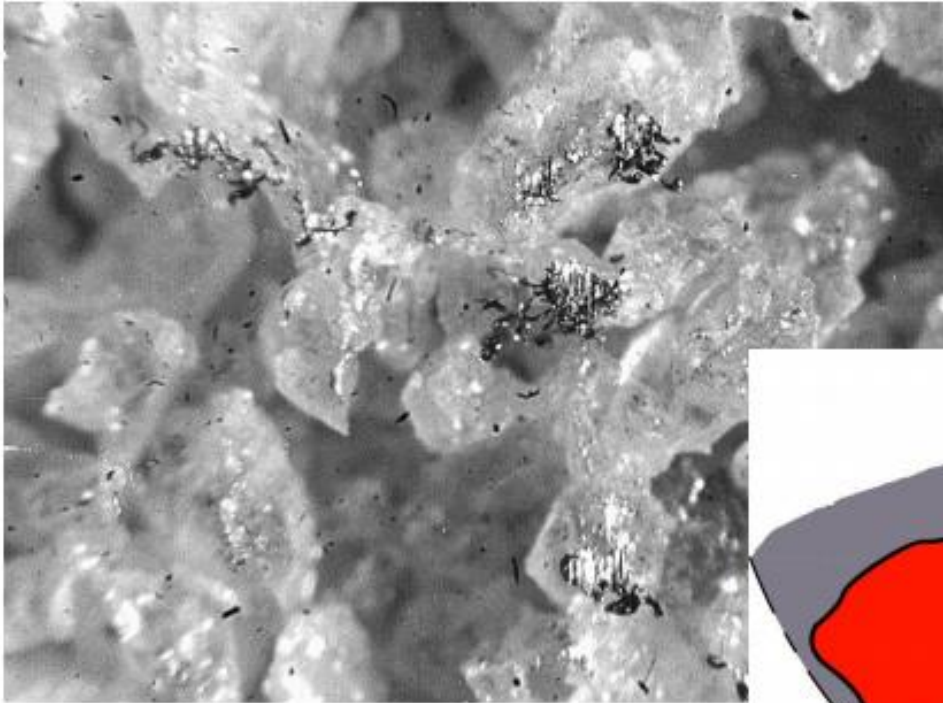


Type 10 Dish Wheel

Type 9. These are normally on vertical spindle, rotary type and reciprocating type surface grinders

Type 10. It is also used for grinding of tools in tool room. It is capable to grind very narrow places due to its thinness.

Grinding Wheel Surface



Coding of a Grinding Wheel

Indian Standard Coding system of grinding wheel is IS : 551-1954. It provides uniform system of coding of grinding wheels to designate their various characteristics. It gives a general indication of the hardness and grit size of any wheel as compared with another. Coding of a grinding wheel consists of six symbols as described below

W : Symbol for Manufacturer's Abrasive Type (Prefixed)

C : Name of Abrasive

30 : Grain Size

L : Grade

5 : Structure Type

R : Bond Type

17 : Manufacturer Symbol for Record (Suffix)

Generally abrasive properties like hardness, toughness and resistance to fracture uniformly abrasives are classified into two principal groups :

(a) Natural abrasives, and

(b) Artificial abrasives.

Natural Abrasives

Sand stone (solid quartz) These are relatively soft. These cannot be used for grinding of hard material and at faster speed.

Emery is a natural aluminium oxide containing 55 to 65% alumina, rest are iron oxide and impurities.

Corundum : If percentage of aluminium oxide is more, ranging from 75 to 95% then it is called corundum.

Diamond is not recommended to use as abrasive due to its cost in effectiveness.

Artificial Abrasives

Silicon Carbide

It is also called carborundum. It is manufactured from 56 parts of silica sand, 34 parts of powdered coke, 2 parts of salt, 12 parts of saw dust in a long rectangular electric furnace of resistance type

There are two types of silicon carbide abrasive, green grit with approximately 97% silicon carbide black grit with approximately 95% silicon carbide.

It is less harder than diamond and less tough than aluminium oxide.

It is used for grinding of material of low tensile strength like cemented carbide, stone and ceramic, gray cast iron, brass, bronze, aluminium vulcanized rubber, etc.

Aluminium Oxide

It is prepared by heating mineral bauxite, a hydrated aluminum oxide clay containing silica, iron oxide, titanium oxide mixed with ground coke and iron borings in a arc type electric furnace.

Preferred for grinding of materials of higher tensile strengths like steel; high carbon and high speed steel and tough bronze

Grits: The grain or grit number indicates in a general way the size of the abrasive grains used in making a wheel, or the size of the cutting teeth, since grinding is a true cutting operation.

Coarse	10	12	14	16	20	24	-
Medium	30	36	46	54	60	-	-
Fine	80	100	120	150	180	-	-
Very Fine	220	240	280	320	400	500	600

Grain size is denoted by a number indicating the number of meshes per liner inch (25.4 mm) of the screen through which the grains pass when they are graded after crushing.

The following list ranging from very coarse to very fine includes all the ordinary grain sizes commonly used in the manufacture of grinding wheels.

Grade: The term "grade" as applied to a grinding wheel refers to the tenacity or hardness with which the bond holds the cutting points or abrasive grains in place. It does not refer to the hardness of the abrasive grain.

The grade shall be indicated in all bonds and processes by a letter of the English alphabet.

A denoting the softest and the letter Z denoting the hardest grade. The term "soft" or "hard" refer to the resistance a bond offers to disruption of the abrasives. A wheel from which the abrasive grains can easily be dislodged is called soft whereas the one which holds the grains more securely is called hard.

The grades are denoted below.

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

Structure: Abrasive grains are not packed tightly in the wheel but are disturbed through the bond.

The relative spacing is referred to as the structure and denoted by the number of cutting edges per unit area of wheel face as well as by number and size of void spaces between grains.

The primary purpose of structure is to provide clearance of chip and it may be open or dense. The structure commonly used is denoted by numbers as follows.

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

Bonds

A bond is an adhesive material used to held abrasive particals together; relatively stable that constitute a grinding wheel. Different types of bonds are :

- (a) Vitrified bond,
- (b) Silicate bond,
- (c) Shellac bond,
- (d) Resinoid bond,
- (e) Rubber bond, and
- (f) Oxychloride bond.

Vitrified Bond

- This bond consists of mixture of clay and water.
- Clay and abrasives are thoroughly mixed with water to make a uniform mixture.
- The mixture is moulded to shape of a grinding wheel and dried up to take it out from mould.
- Perfectly shaped wheel is heated in a kiln just like brick making.
- In this way clay vitrifies and fuses to form a porcelain or glass grains.
- High temperature also does annealing of abrasive.

This wheel possesses a good strength and porosity to allow high stock removal with coal cutting.

Disadvantages of this type of wheel are, it is sensitive to heat, water, oil and acids. Their impact and bending strengths are also low. This bond is denoted by the symbol 'V' in specification.

Silicate Bond

Silicate bonds are made by mixing abrasive particles with silicate and soda or water glass. It is moulded to required shape, allowed to dried up and then taken out of mould. The raw moulded wheel is baked in a furnace at more than 200°C for several days. These wheel exhibits water proofing properly so these can be used with coolant. These wheels are denoted by 'S' in specification.

Shellac Bond

These are prepared by mixing abrasive with shellac than moulded by rolling and pressing and then by heating upto 150°C for several hours. This bond exhibit greater elasticity than other bonds with appreciable strength. Grinding wheels having shellac bond are recommended for cool cutting on hardened steel and thin sections, finishing of chilled iron, cast iron, steel rolls, hardened steel cams and aluminium pistons. This bond is denoted by 'E' in specifications

Resinoid Bond

These bonds are prepared by mixing abrasives with synthetic resins like bakelite and redmanol and other compounds. Mixture is moulded to required shape and baked upto 200°C to give a perfect grinding wheel.

These wheels have good grinding capacity at higher speed. These are used for precision grinding of cams, rolls and other objects where high precision of surface and dimension influence the performance of operation. A resinoid bond is denoted by the letter 'B'.

Rubber Bond

Rubber bonded wheels are made by mixing abrasives with pure rubber and sulphur.

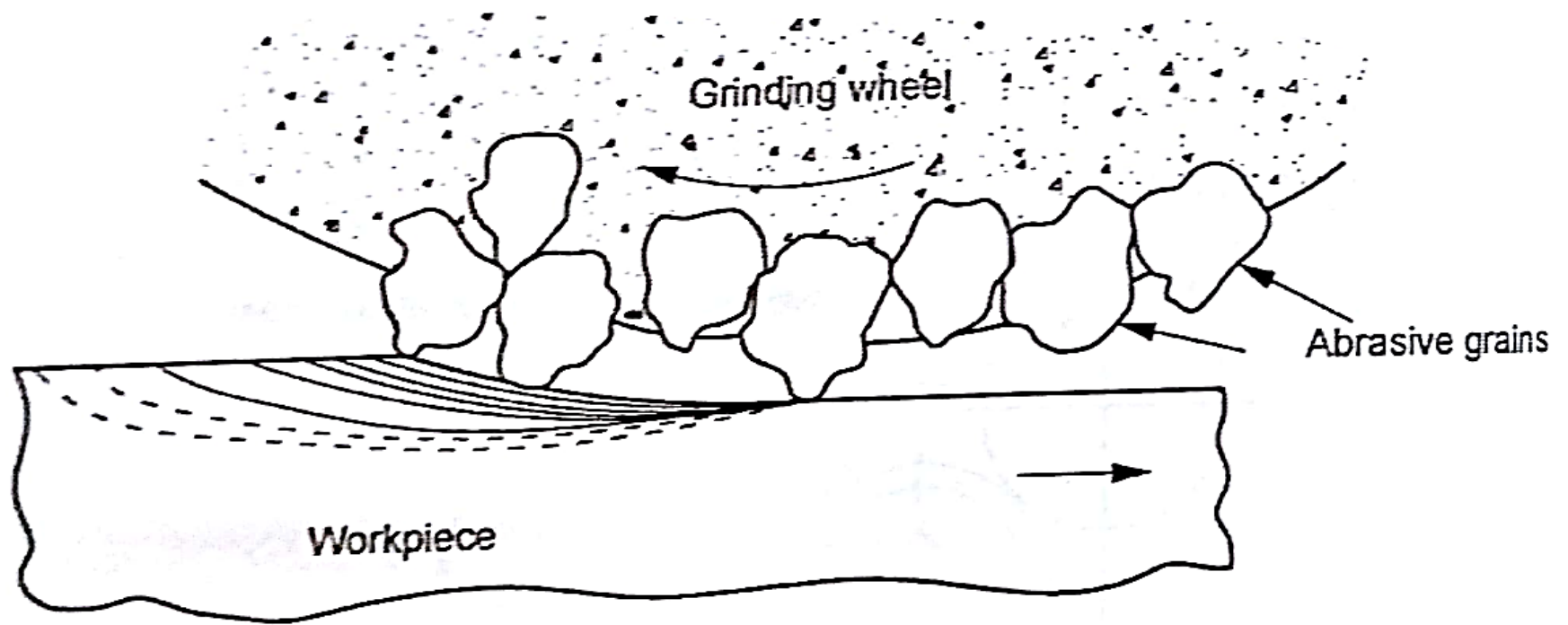
After that the mixture is rolled into sheet and wheels are prepared by punching using die and punch.

The wheels are vulcanized by heating then in furnace for short time.

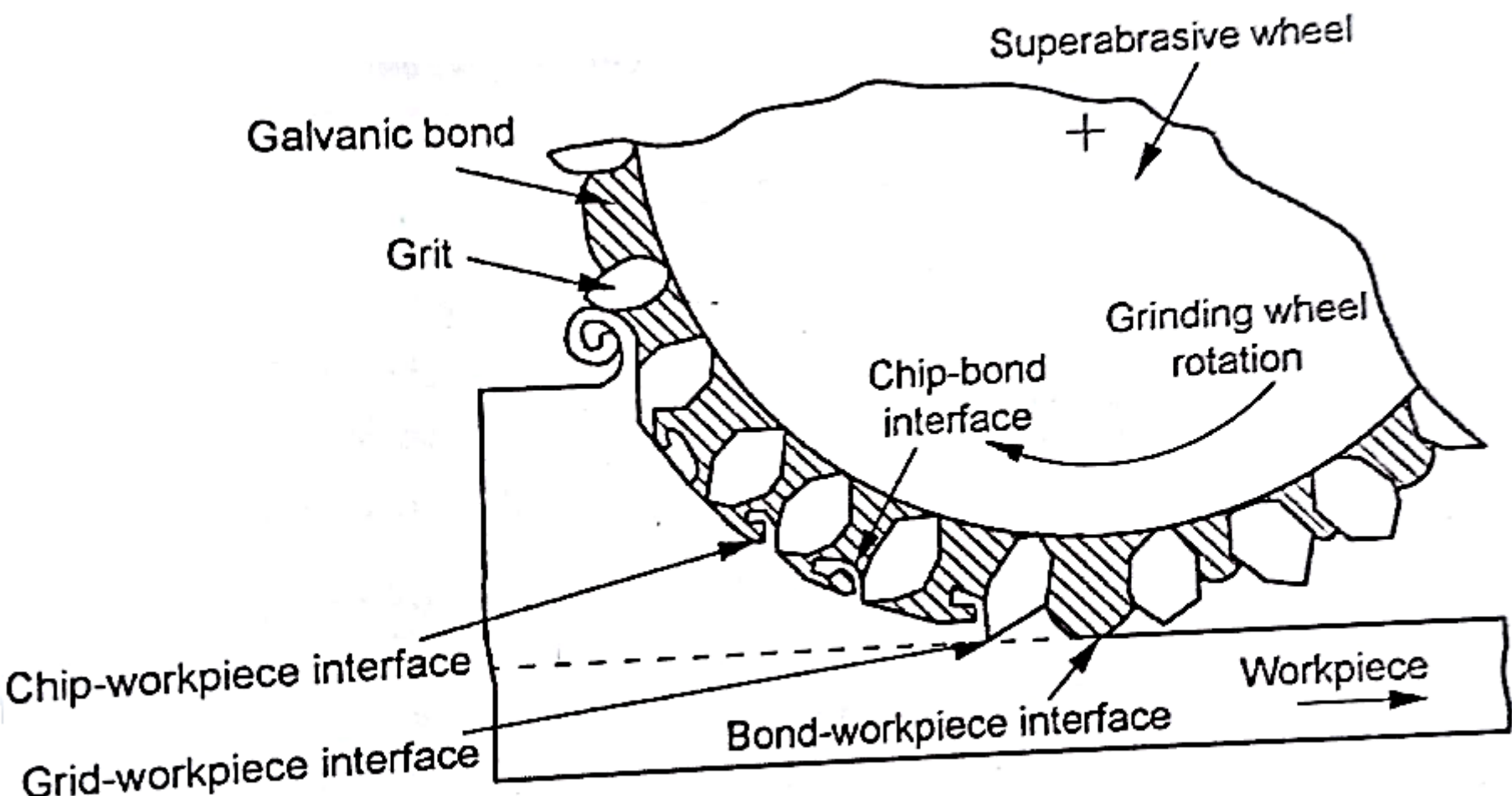
- Rubber bonded wheels are more resilient and have larger abrasive density.
- Used for precision grinding and good surface finish. Rubber bond is also preferred for making thin wheels with good strength and toughness.
- Associated disadvantage with rubber bond is, these are lesser heat resistant.
- A rubber wheel bonded wheel is denoted by the letter 'R'.

Oxychloride Bond

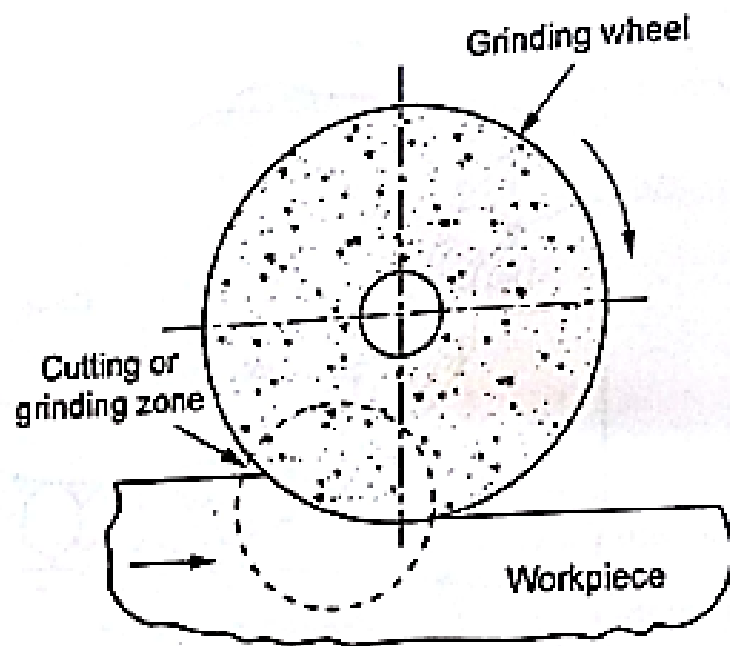
- These bonds are processed by mixing abrasives with oxides and chlorides of magnesium.
- The mixture is moulded and baked in a furnace to give shape of a grinding wheel.
- These grinding wheels are used for disc grinding operations. An oxychloride bonded wheel is specified the letter 'O'.



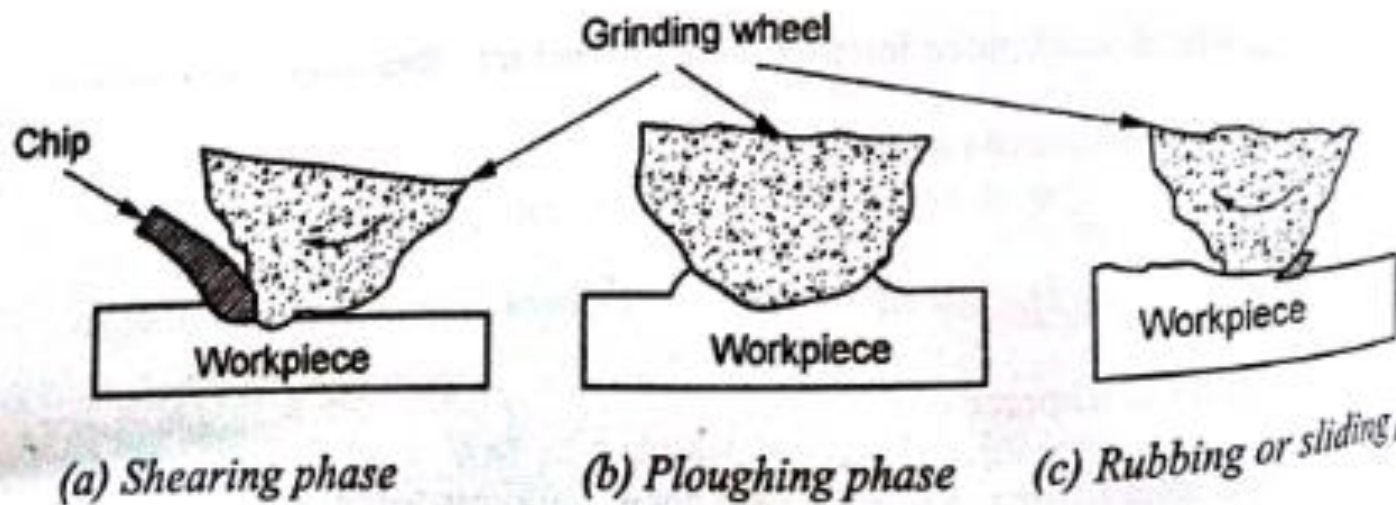
Cutting action of abrasive grains in grinding process



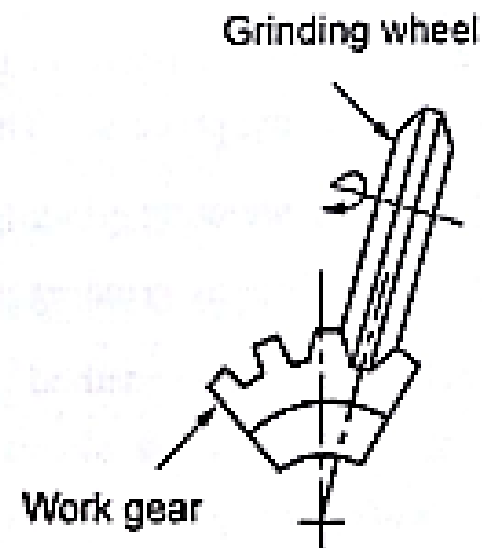
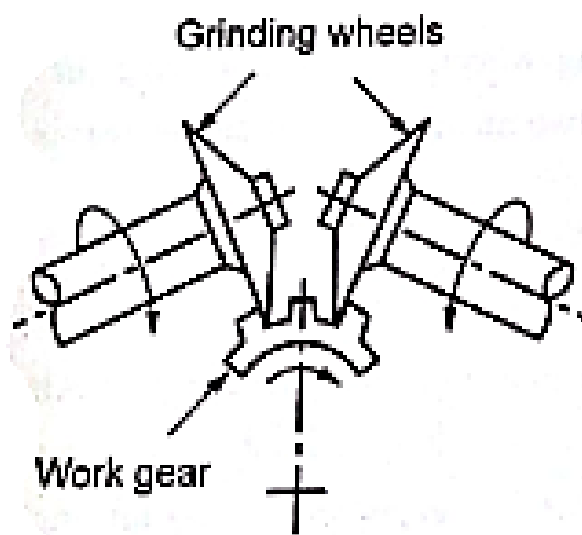
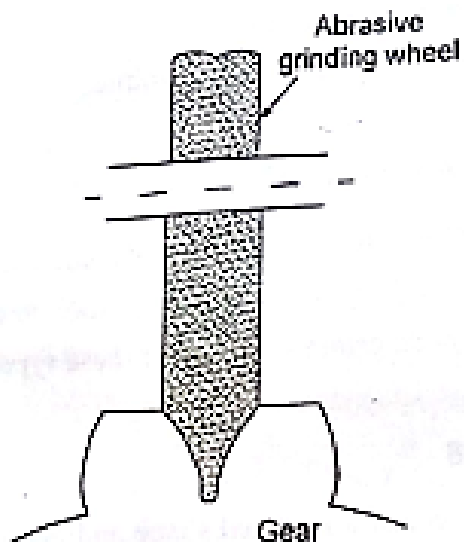
Grinding wheel-workpiece interaction



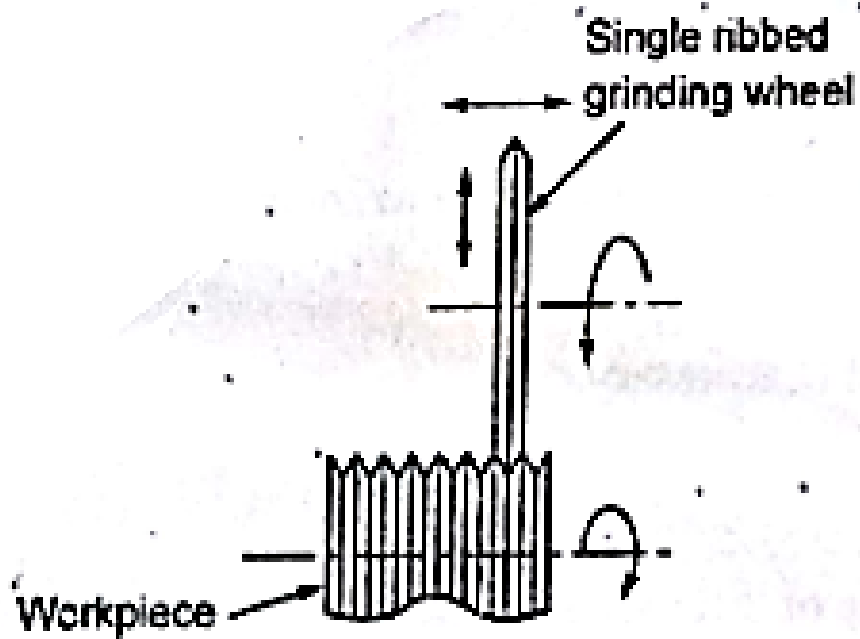
Phases in grinding mechanism



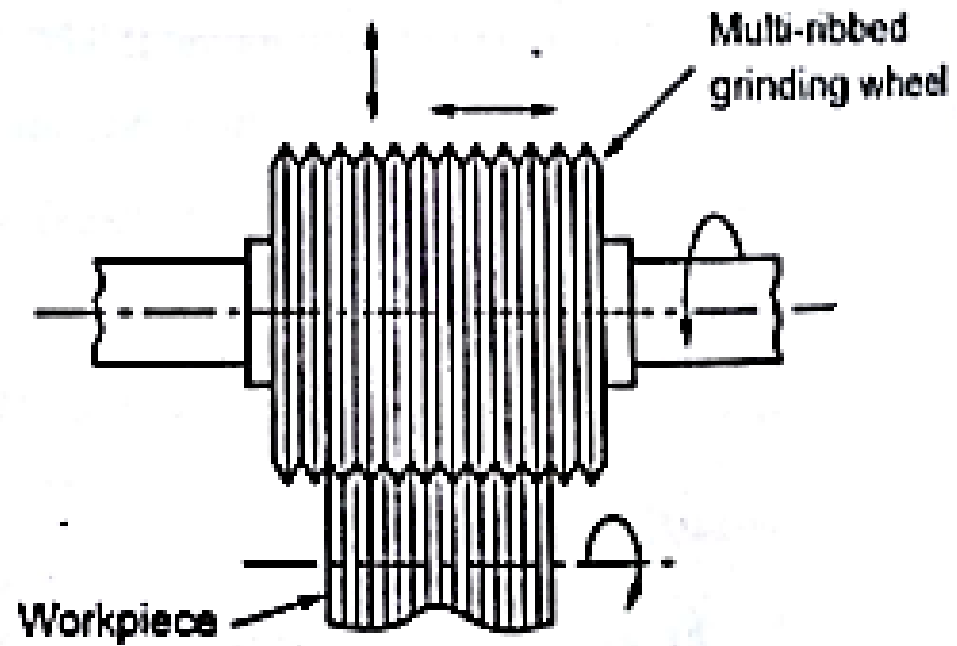
Grits engagement with workpiece in grinding process



Gear teeth grinding



(a) Single ribbed thread grinding



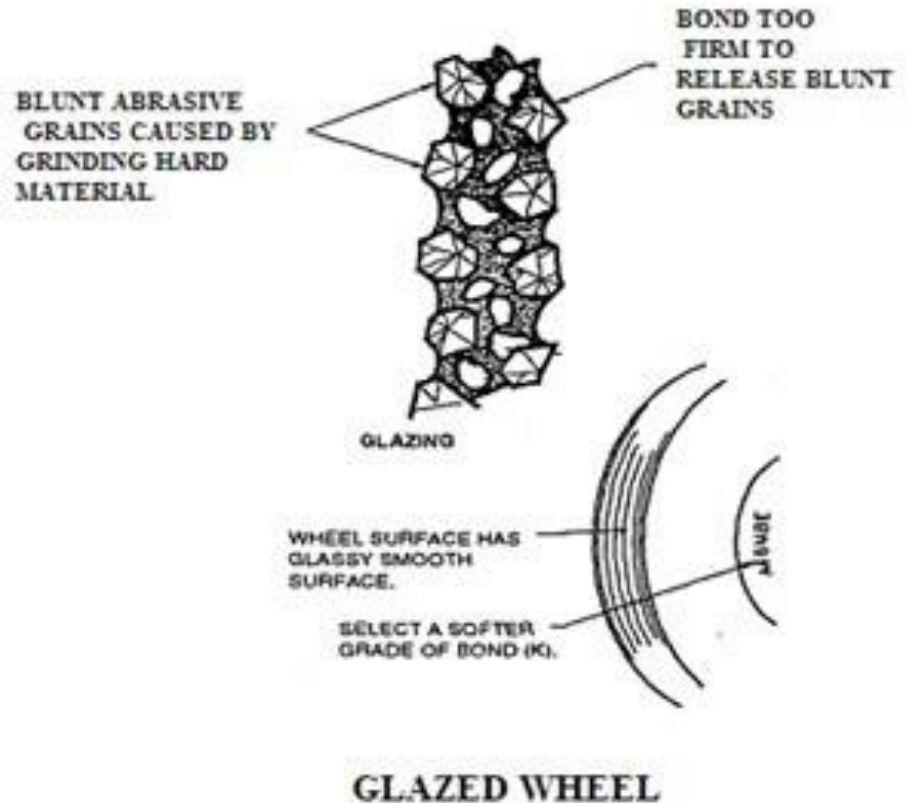
(b) Multi-ribbed thread grinding

Thread grinding

GLAZING AND LOADING, THEIR EFFECTS, CAUSES AND REMEDIES

When the surface of a grinding wheel develops a smooth and shining appearance, it is said to be glazed.

This indicates the abrasive particles on the wheel face are not sharp.

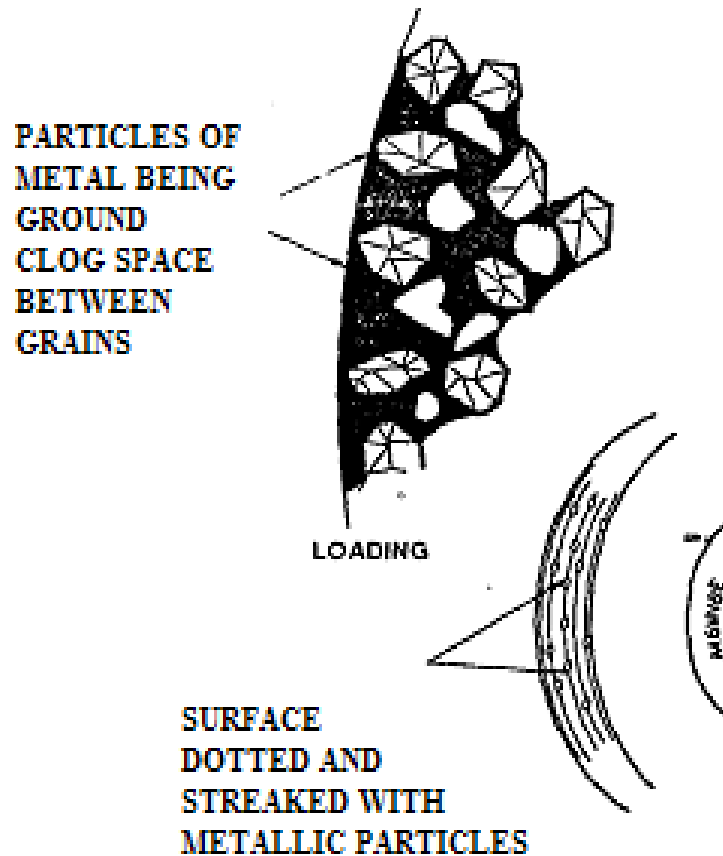


- **Loading**

When soft materials like aluminium, copper, lead, etc. are ground the metal particles get clogged between the abrasive particles. This condition is called loading.

The effects of a glazed or a loaded grinding wheel are almost the same.

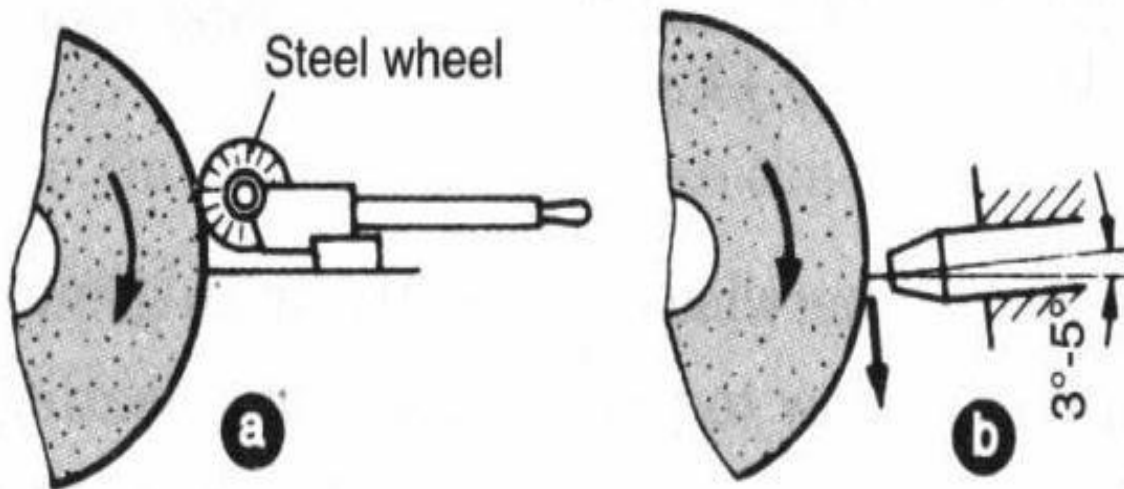
Fig. 2



**SELECT A MORE OPEN STRUCTURE WHEEL (8)
LOADED WHEEL**

Dressing

Dressing removes loading and breaks away the glazed surface so that sharp abrasive particles are again presented to the work. This is done **with** various type of dressers. A common type of wheel dresser, known as the star-dresser,



Dressing of grinding wheels. (a) Dressing with steel wheel, (b) dressing with diamond.

- For precision and high finish grinding, small industrial diamonds, known in the trade as *bors*, are used.
- Diamond or group of diamonds is mounted in a holder. The diamond should be kept pointed, since only the point can be used for cutting.
- This is done by the holder down at a 15° angle and using a new surface each time the wheel is dressed.
- Good supply of coolant should be used when dressing with a diamond, as overheating can cause the diamond to fracture or drop out of its setting. Very light cuts only may be taken with diamond tools.

- **Truing :**

Truing is the process **of** changing **the** shape of **the** grinding wheel as it becomes worn from an original shape, owing to the breaking away of the abrasive and bond.

This is done to make the wheel true and concentric **with** the bore, **or to** change the face contour for form grinding. Truing and dressing are done with the same tools, but not for the same purpose

The only satisfactory method of truing a wheel is by the use of a diamond tool in a similar manner as explained before. In turning a wheel with a diamond, the feed rate must not exceed 0.02 mm, otherwise grooves may be cut into the wheel

CUTTING FLUIDS

Recommended cutting fluids

Soluble mineral oil and pure water are mixed in the ratio of 1:40 or 50 (depending upon the grinding wheel) and is used for grinding the following materials.

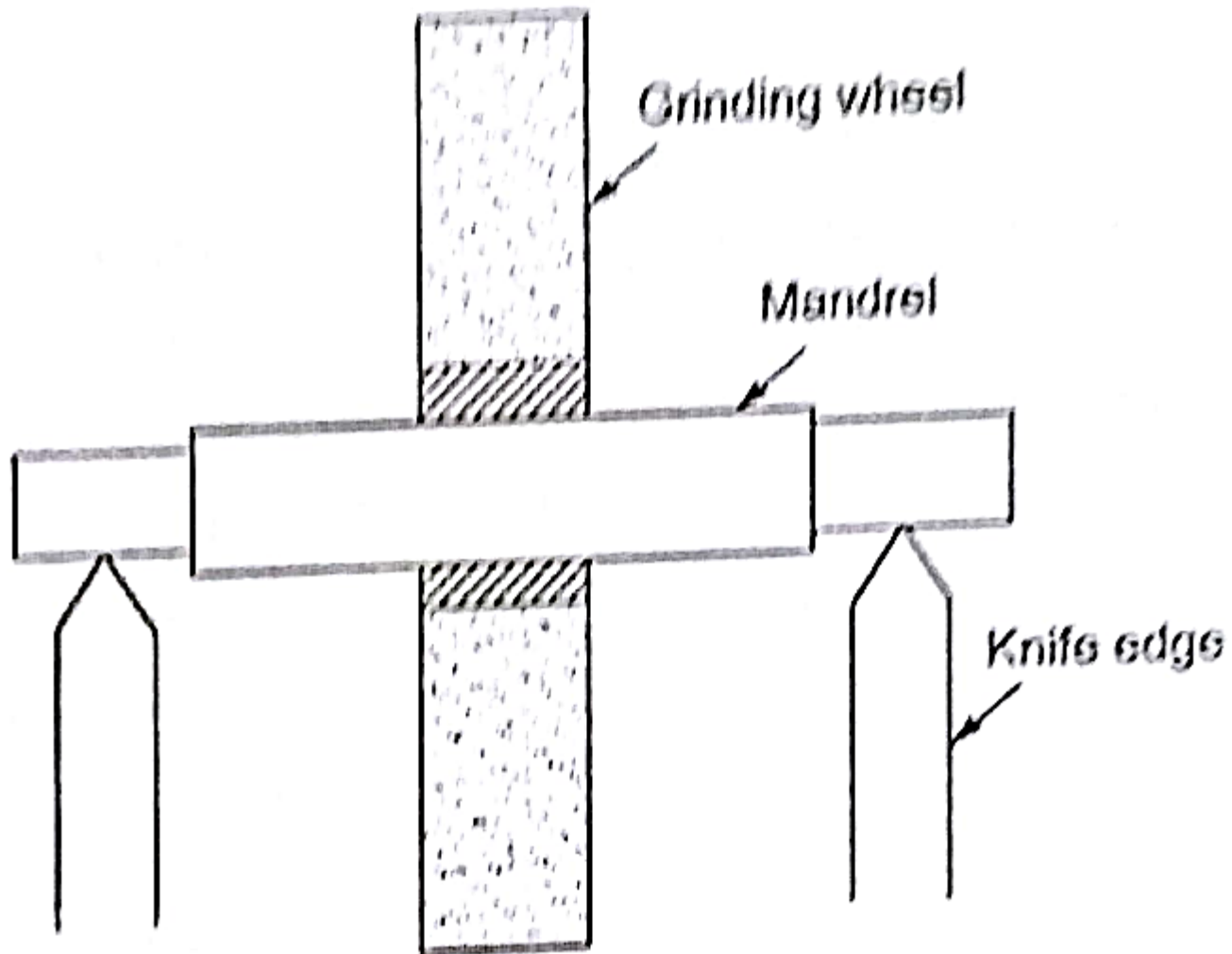
- Cast iron or hardened steel

- Soft steel

- Connected carbide tools (using silicon wheel) In India we use IOC Servocut oils as cutting fluid.

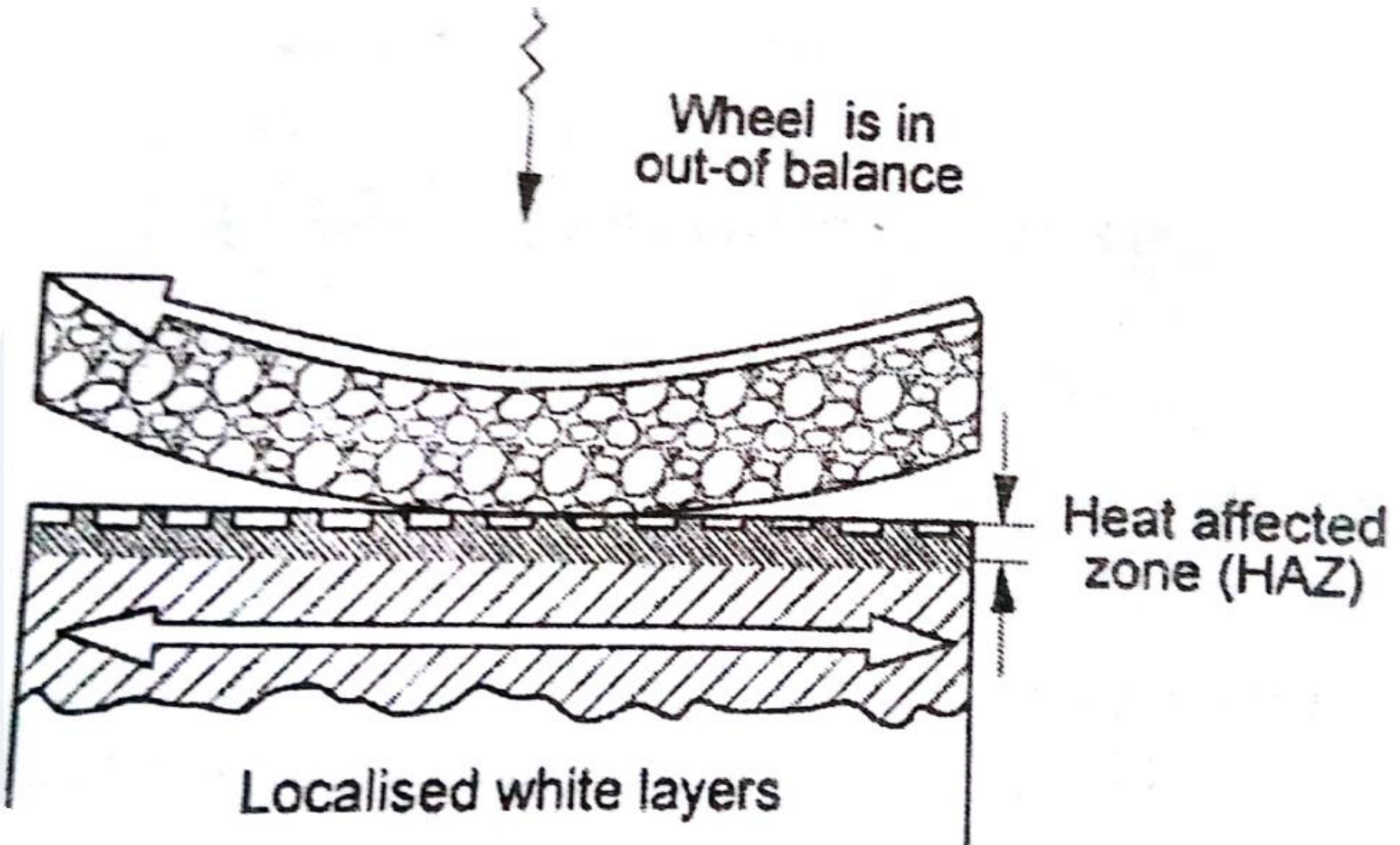
There is a special grade oil manufactured by IOC for grinding alone. It is called Servocut - clear.

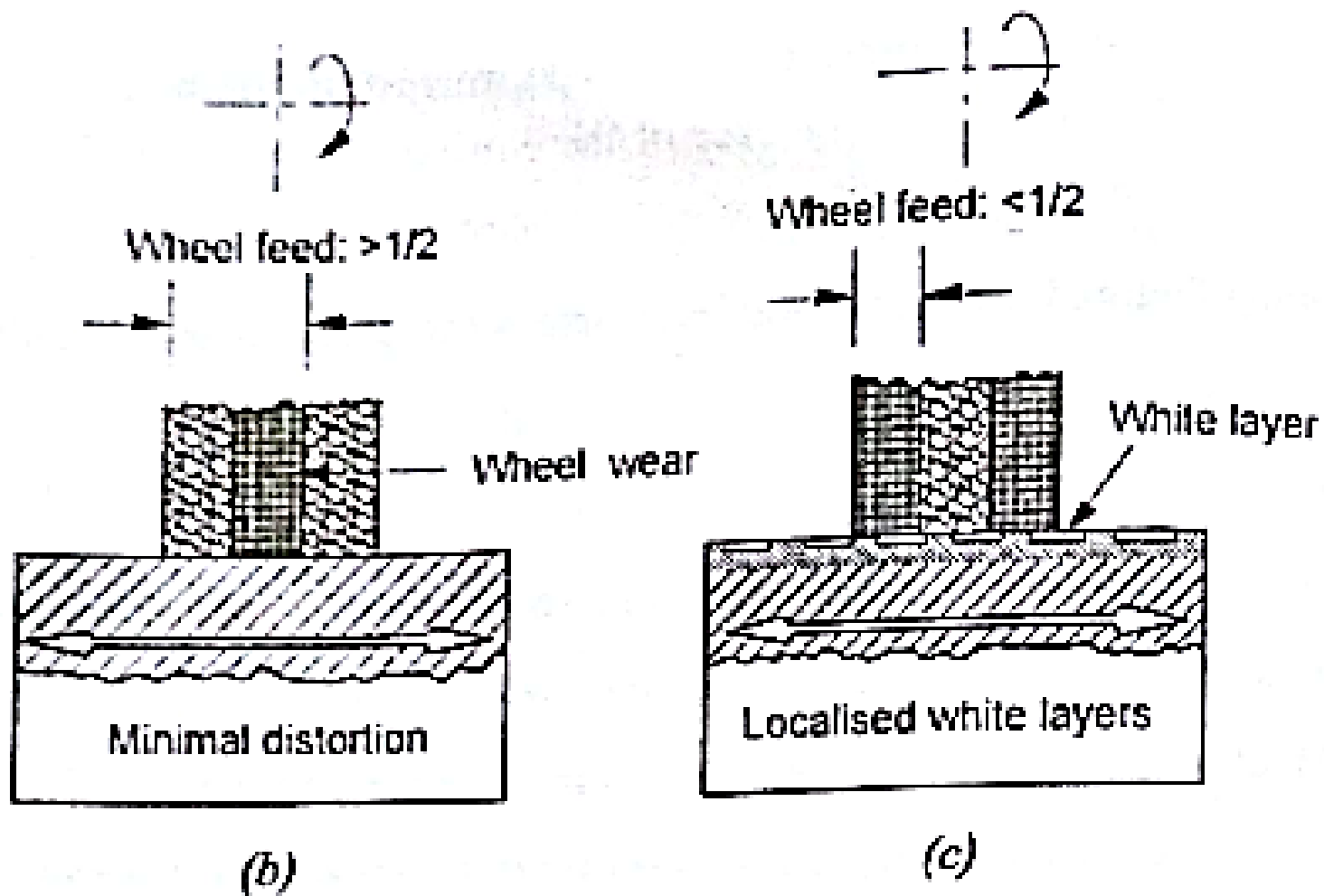
WHEEL BALANCING OF GRINDING WHEEL



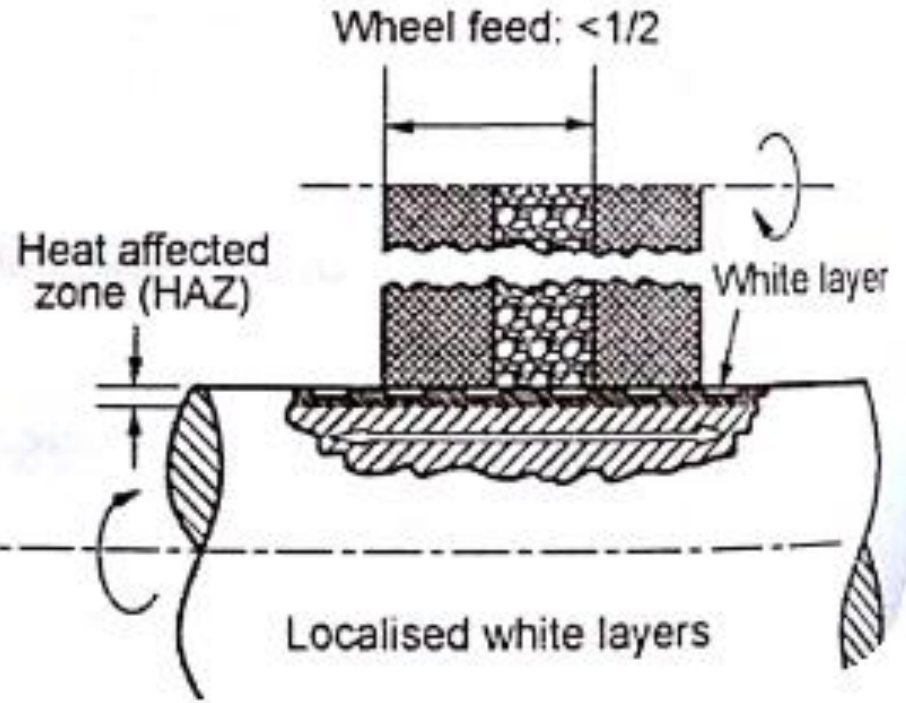
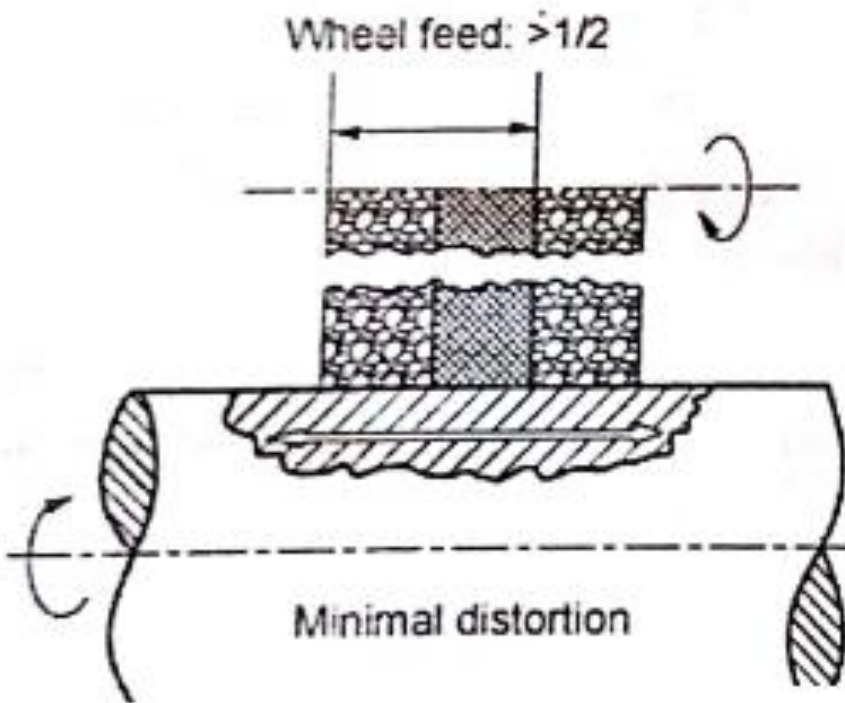
Balancing of grinding wheels

SURFACE ROUGHNESS OBTAINABLE

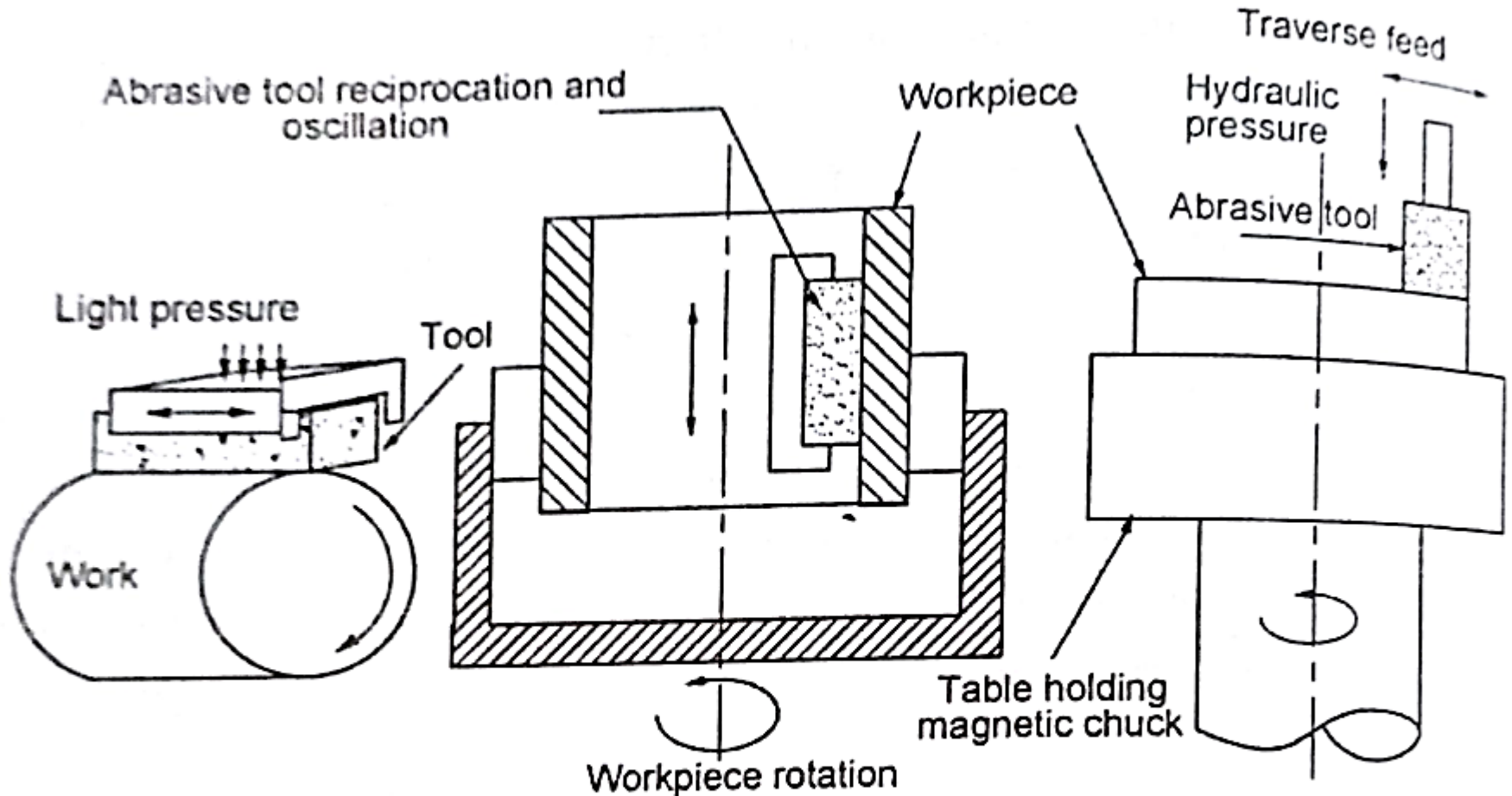




Effect on machined surface integrity during surface grinding



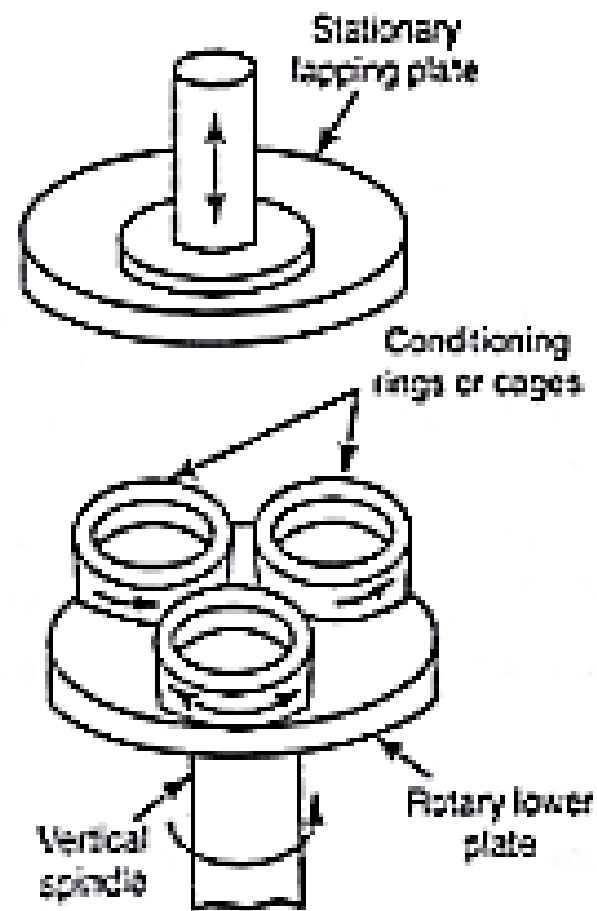
SUPER FINISHING



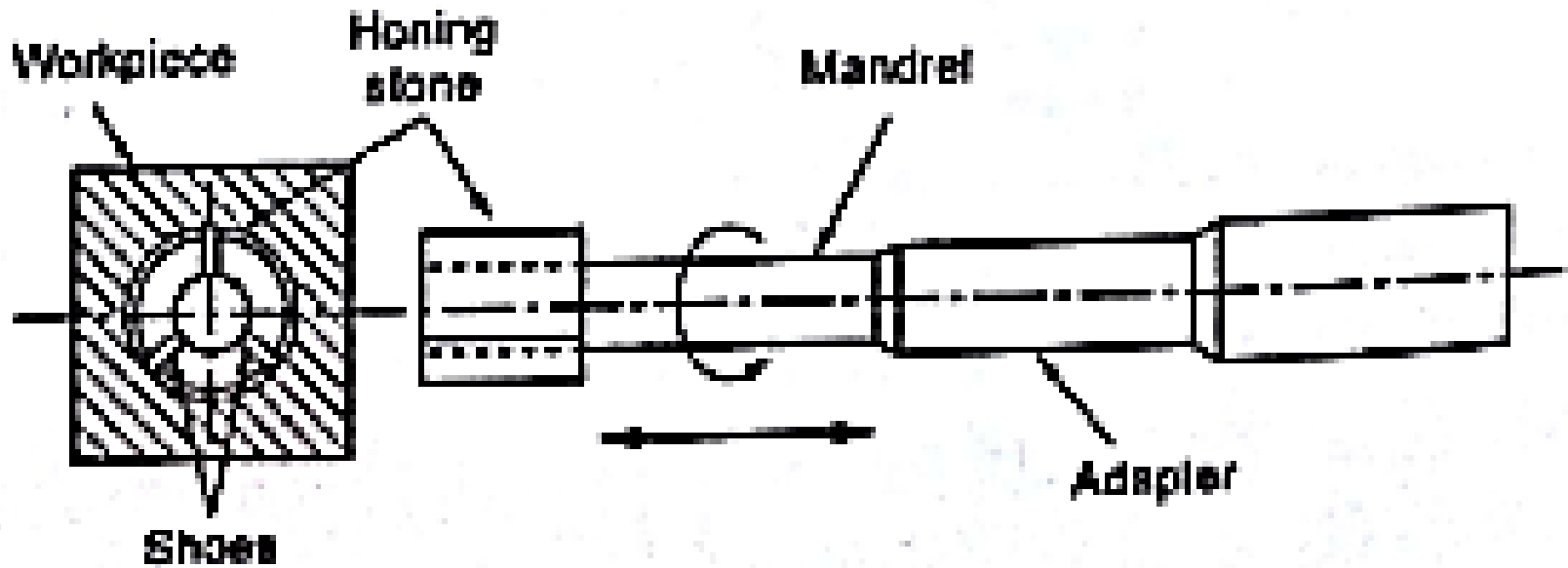
(a) Super finishing the internal cylindrical surface

(b) Super finishing the flat surface

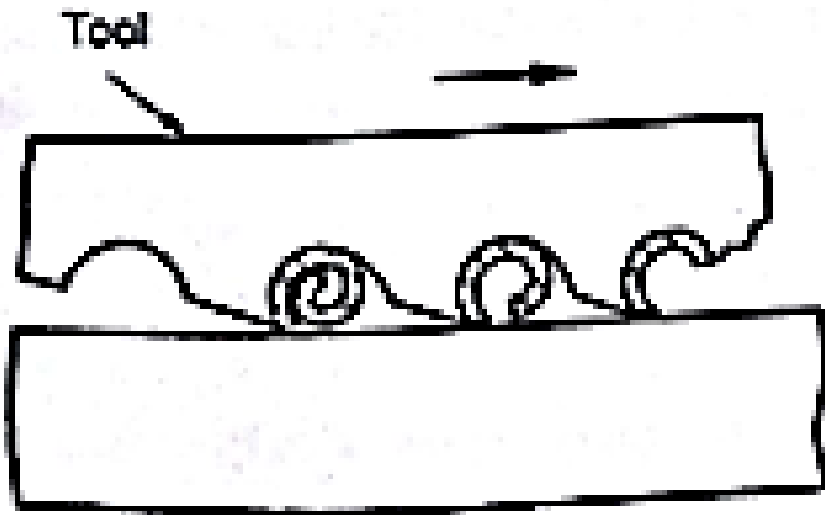
Super finishing



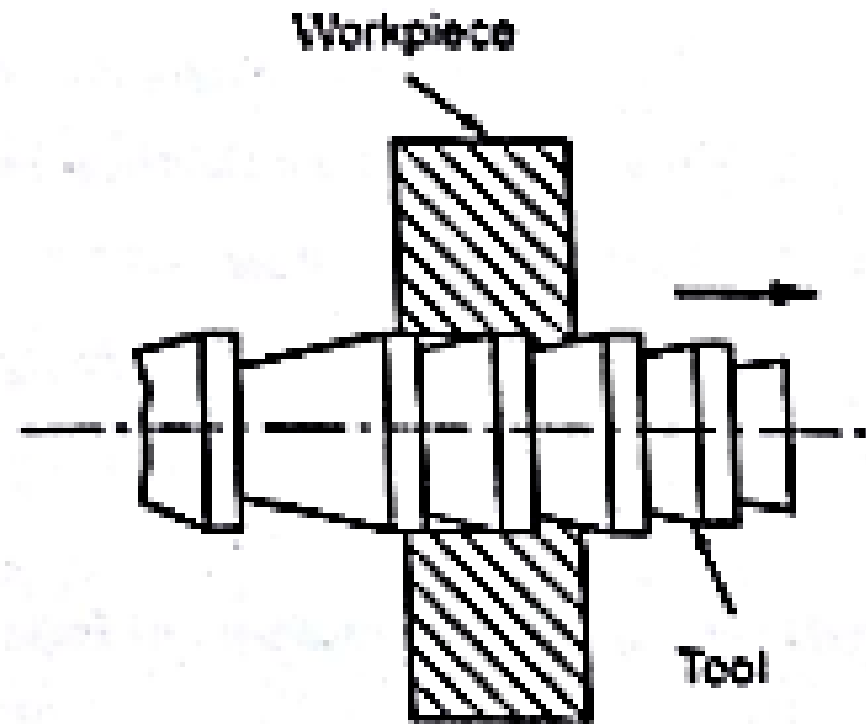
Machine lapping



A hand honing tool and honing process

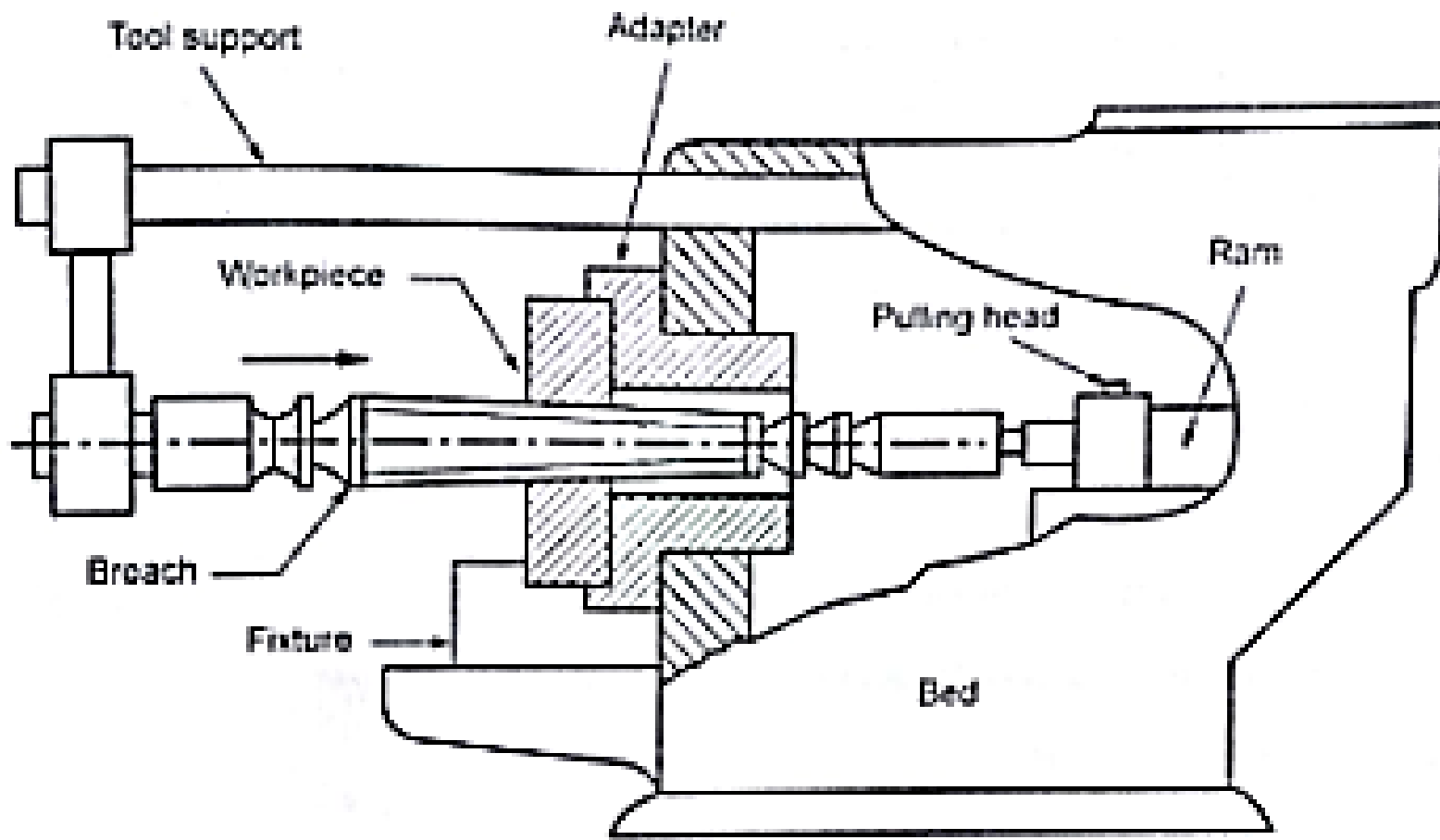


(a) External broaching

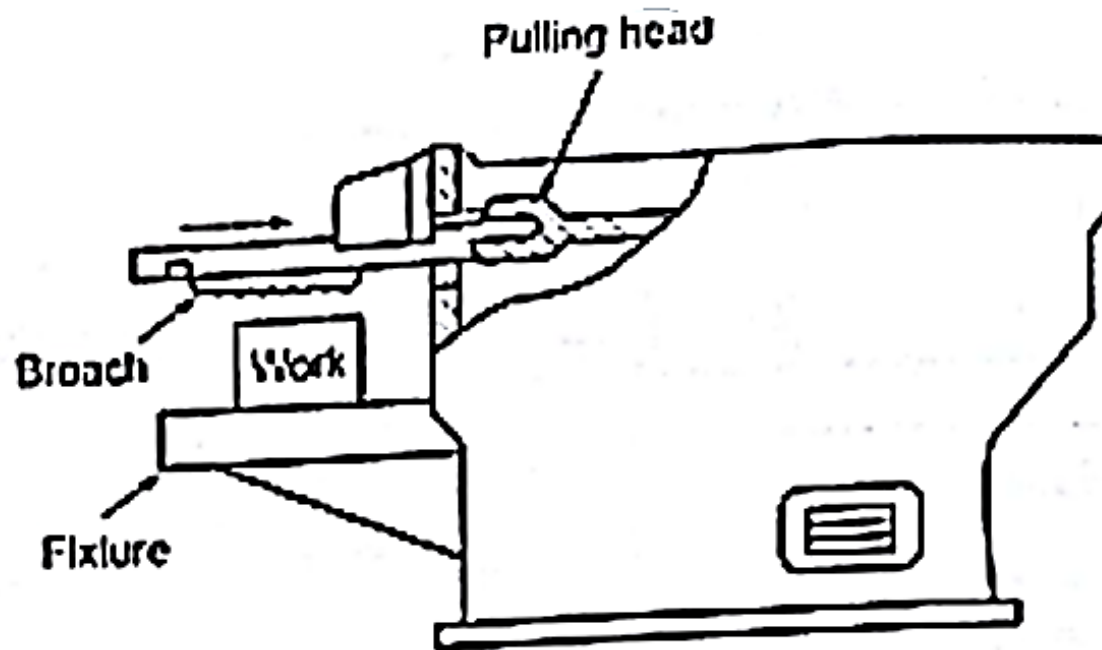


(b) Internal broaching

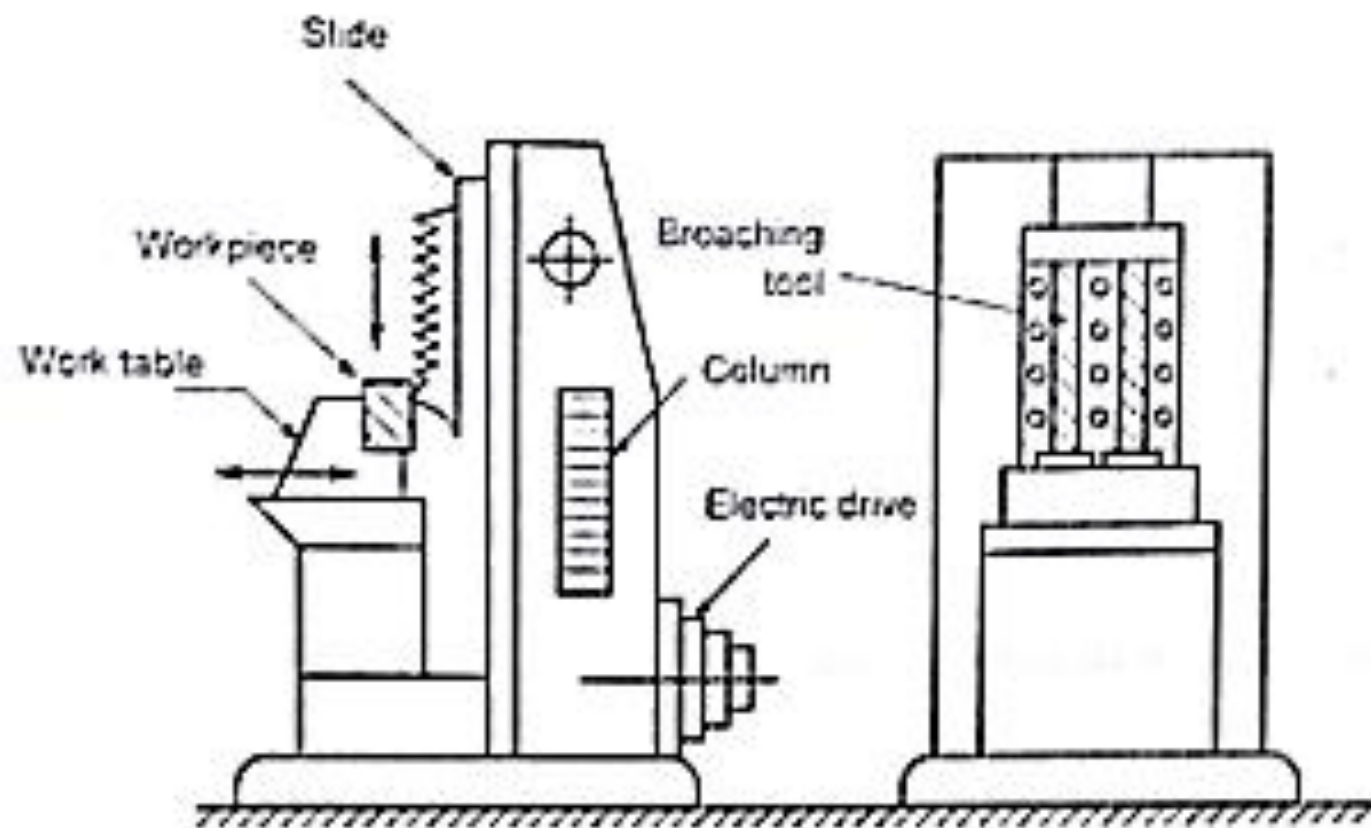
Broaching principle



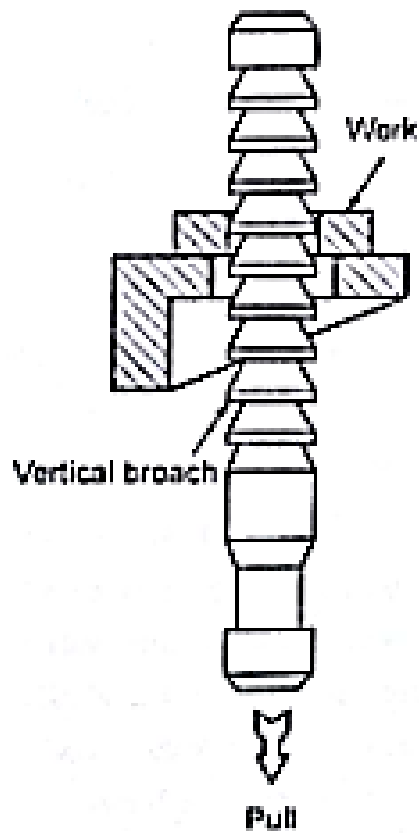
Horizontal type internal broaching machine



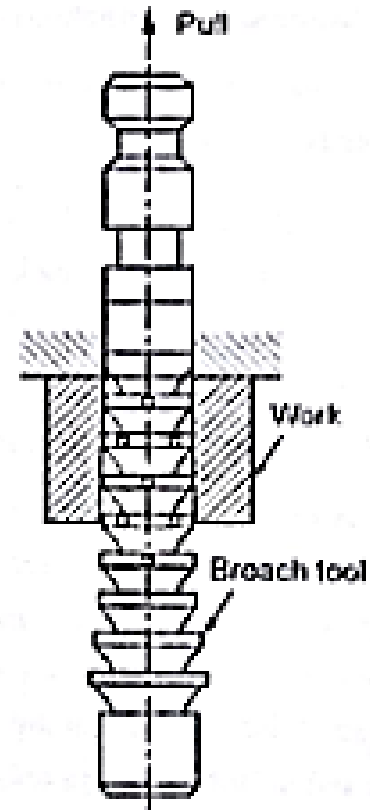
Horizontal type surface broaching machine



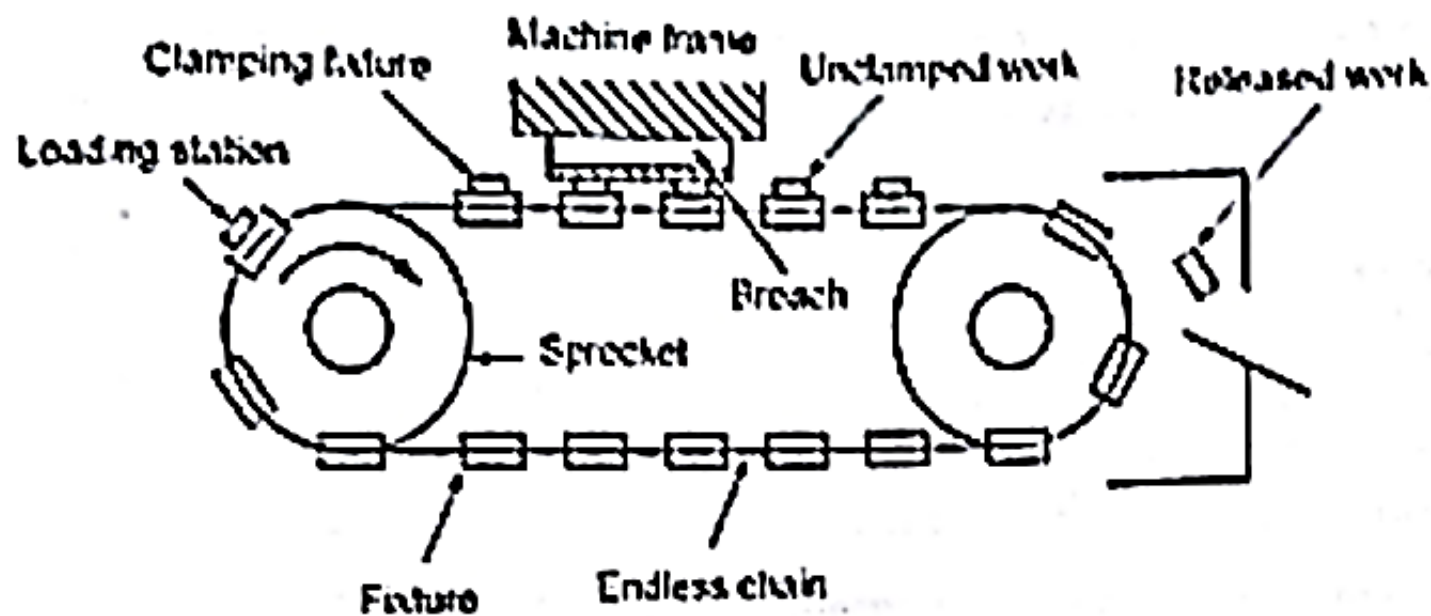
Push down type vertical broaching machine



Pull down type vertical broaching machine



Pull up type vertical broaching machine



Horizontal type continuous broaching machine