ELEMENTS OF MECHANICAL ENGINEERING

PART – B

Unit - III

UNIT – VI

MILLING and GRINDING MACHINES

Machine Tools

Objectives:

1.1 To understand the Principle of working of Milling, Horizontal & Vertical Milling.

1.2 Classification/Types

1.3 Milling Processes.

1.4 Specification of Universal Milling Machine

1.5 To understand the Principle of working and classification of Grinding machines

1.6 Abrasives – Definition, Type & application

1.7 Types and working principles of Surface grinding, cylindrical grinding & Centerless Grinding

Milling: Is a machining process by which a surface is generated by progressive chip removal using a milling cutter.

They are usually used to machine flat surfaces,

can also produce irregular surfaces. They can also be used to drill, bore, cut gears, and

can also produce irregular surfaces.

Milling Machine: It is a m/c tool which removes metal from the work piece as w/p is fed against the rotating milling cutters.

Principle of milling:

Principle of milling:

W/p - M/c Table – Horizontal & Vertical – multi point milling cutters – spindle or arbor – motor – rotates – axis of spindle in vertical plane – w/p moved (fed) by m/c table – desired surface is obtained.

Depth of cut – multiple passes – interrupted cutting – enables cooling of cutter teeth.

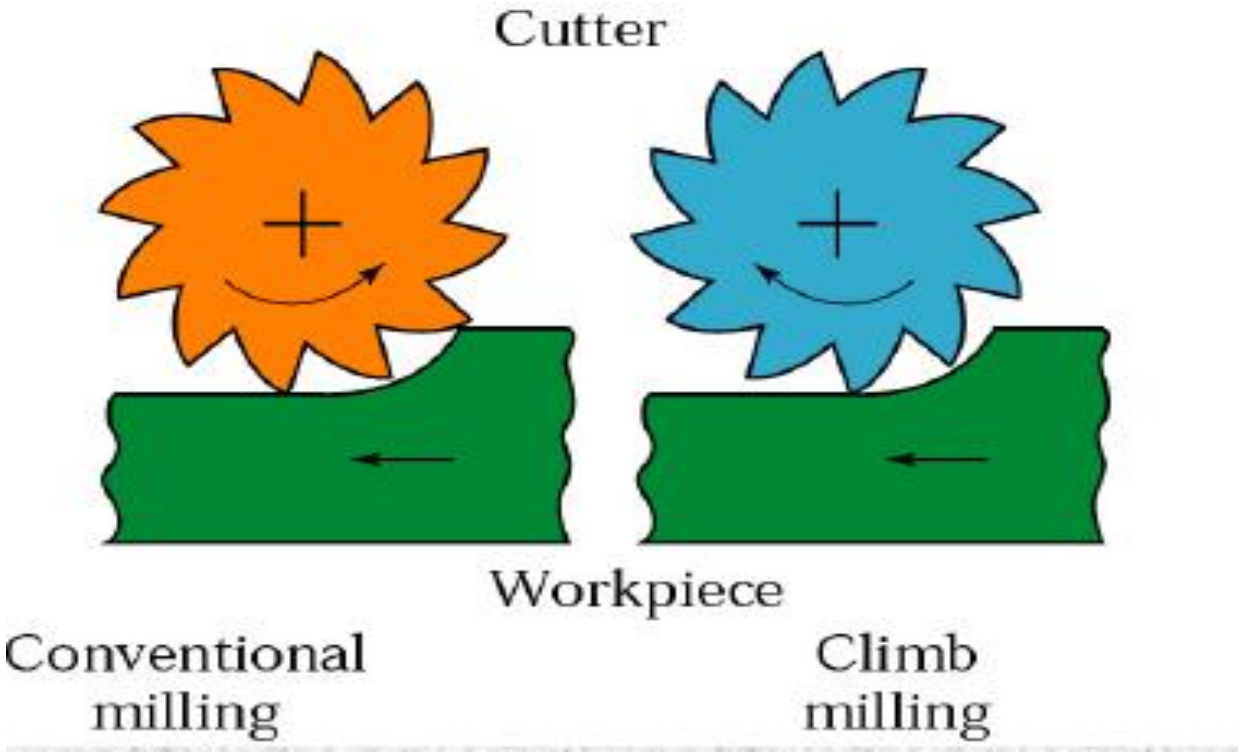
Classification:

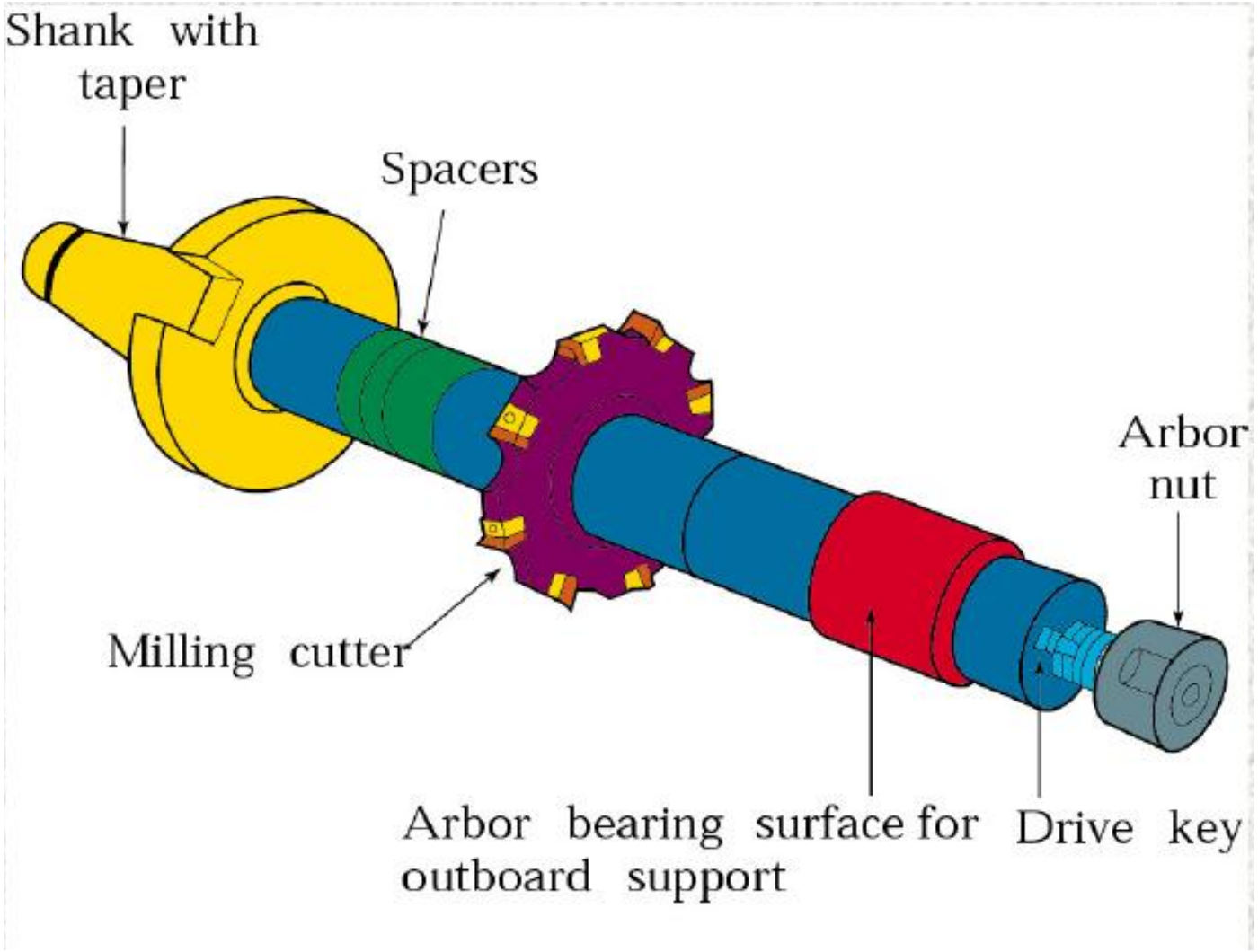
Peripheral Milling:

Axes of cutter and w/p are parallel to each other – cutter produces m/c surface parallel to its axis – called "Slab milling" – c/s of resulting surface of w/p depends on rotation of cutter relative to the direction of feed movement of w/p – left to right / right to left.

Two types

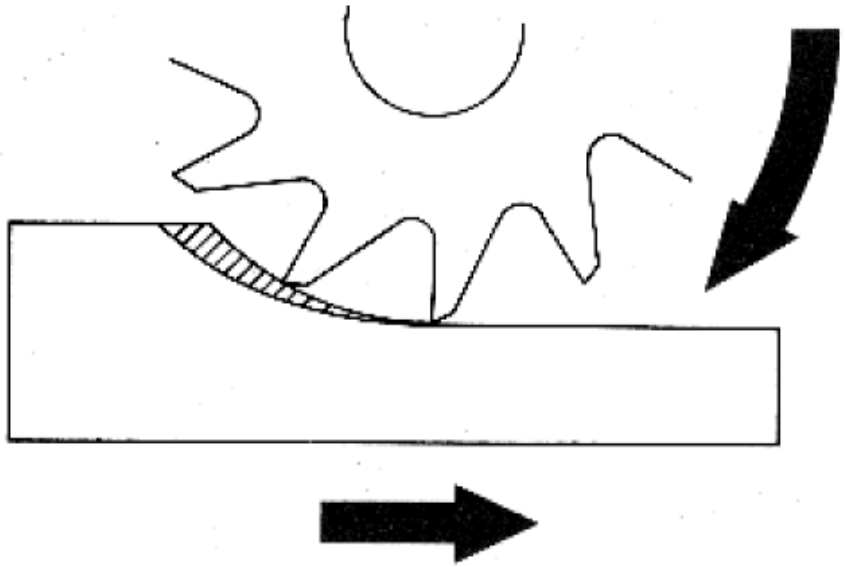
1) Up Milling (Conventional Milling)
2) Down Milling (Climb Milling)


Cutter
Workpiece
Conventional milling
Climb milling

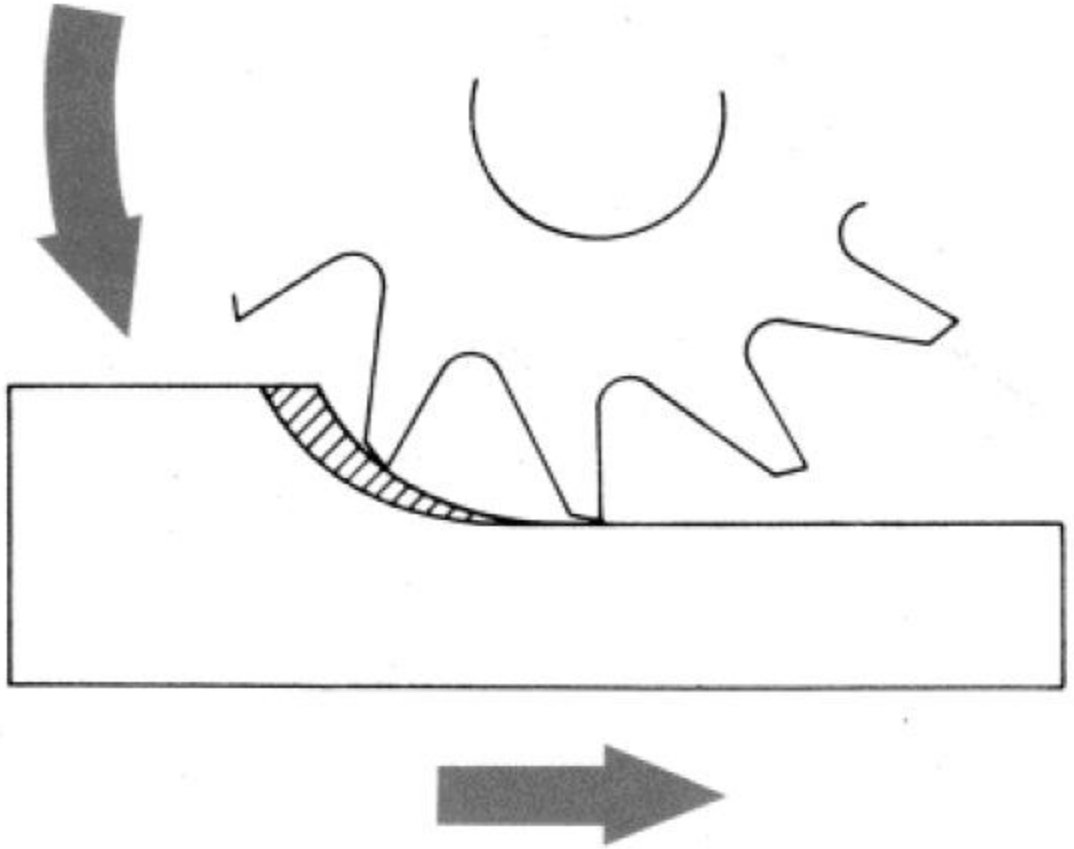

Shank with taper
Spacers
Arbor nut
Milling cutter
Arbor bearing surface for outboard support
Drive key

Climb vs. Conventional Milling

When milling, one should be aware of the difference between conventional, and climb milling. In conventional milling, the workpiece is fed into the rotation of the cutter. This type of cut requires lower forces and is preferred for roughing cuts. In climb milling, the work moves with the rotation of the cutter. This produces a better finish. It is not recommended if the workpiece cannot be held securely or cannot support high forces.



Conventional Milling

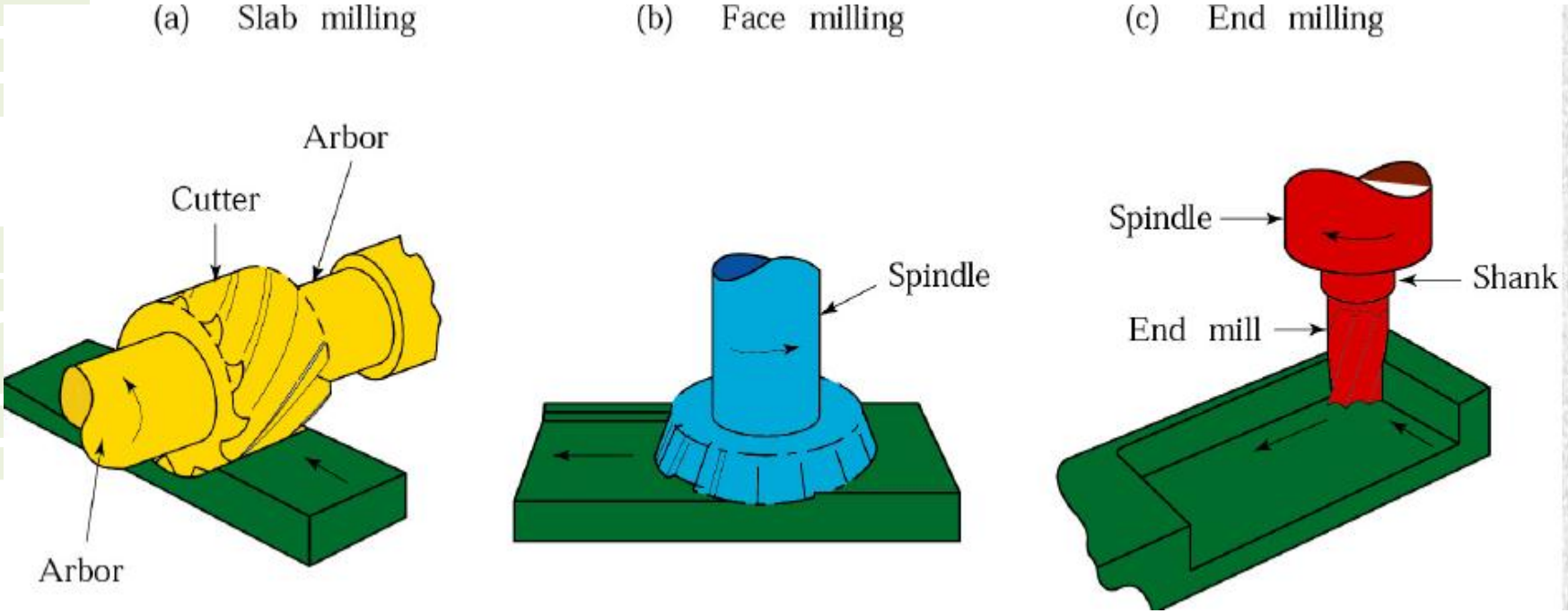


Climb Milling

Face Milling:

Axes of cutter and w/p are perpendicular to each other. As cutter rotates w/p may be fed in either directions – up & down milling can be performed – finishing operation – chip thickness is min – beginning & end – max when work passes thro centre line of cutter.

End Milling: combination of peripheral and face milling operation – cutter has teeth both on periphery and its end – if direction of helix of cutter is same as direction of rotation - end cutting edges are used to remove metal - opposite direction – peripheral edges are used to remove metal.

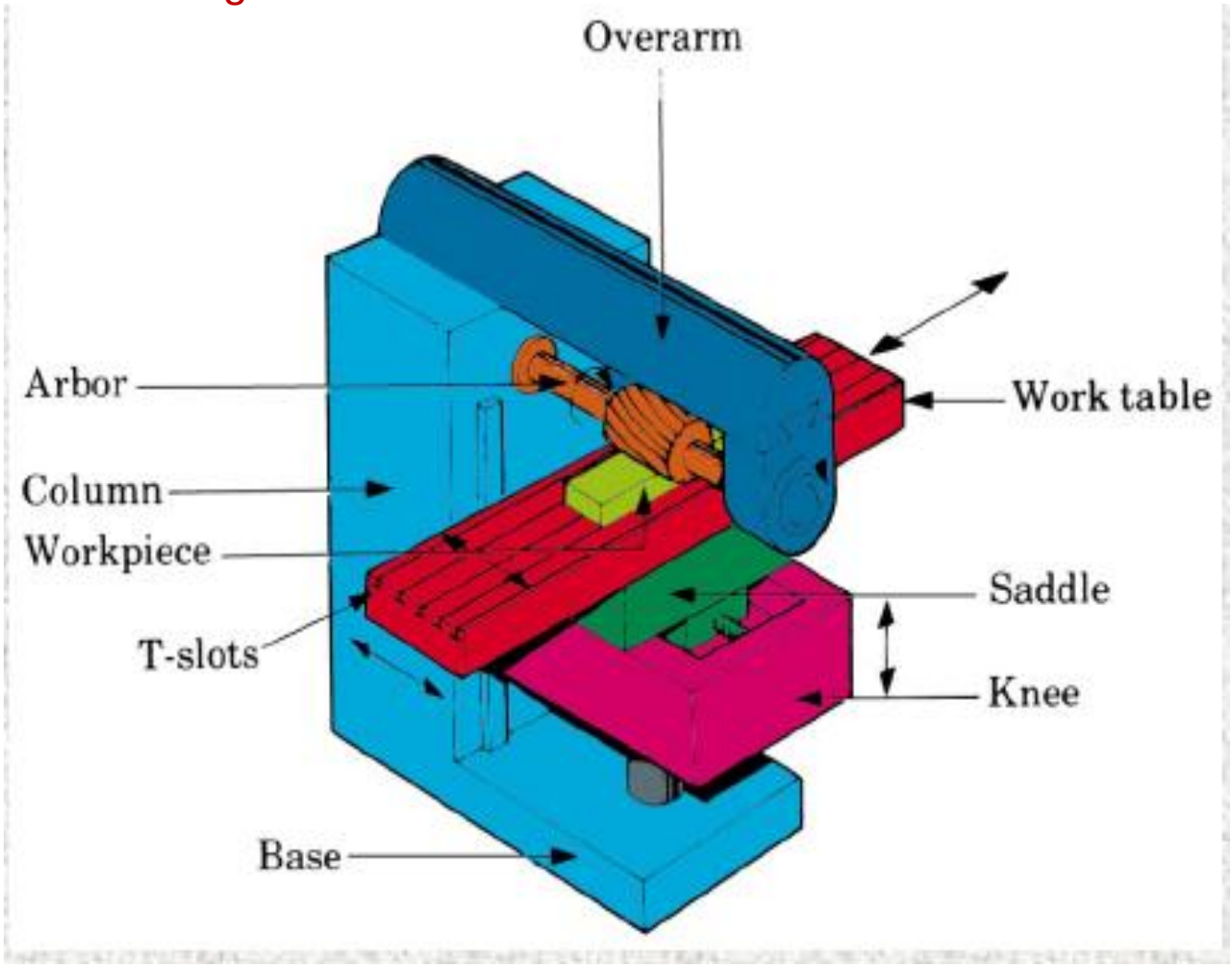

(a) Slab milling
Arbor
Cutter
Arbor
(b) Face milling
Spindle
(c) End milling
Spindle
Shank
End mill

Classification of Milling M/Cs: on nature of work – General, Special, Mass production, reproduction Etc.

Broadly classified as :

1) Horizontal
2) Vertical
3) Universal
4) Planer
5) Special type milling machines

Plain Horizontal Milling Machine



Construction:

Base : Foundation – supports all parts – column at one end.

Column: houses – driving mechanisms – spindle & table feed – spindle receives power from motor – top over arm, spindle nose – knee (elevating screw & guide ways) – knee supports working table, saddle & feed mechanism - table moved longitudinally- surface finished with T slots to clamp w/p & fixtures – circular base is graduated in degrees – saddle moved horizontally – Arbor receives power from spindle – milling cutters mounted on arbor.

Operation: w/p on table – contour, feed depth of cut – suitable cutter – mounted on arbor – knee raised till it touches w/p – m/c started – moving table, saddle, knee – job is finished.

Operations on Horizontal milling machine:

1) Plain /Slab Milling: produces flat / formed surfaces parallel to cutter axis – cutter straight/ helical teeth – Up milling & Down Milling.

2) Slot Milling: Produce slots , grooves, keyways (side milling cutter – teeth on periphery & sides) using different cutters.

T-slots – 2 steps – plain milling & T slot cutter.

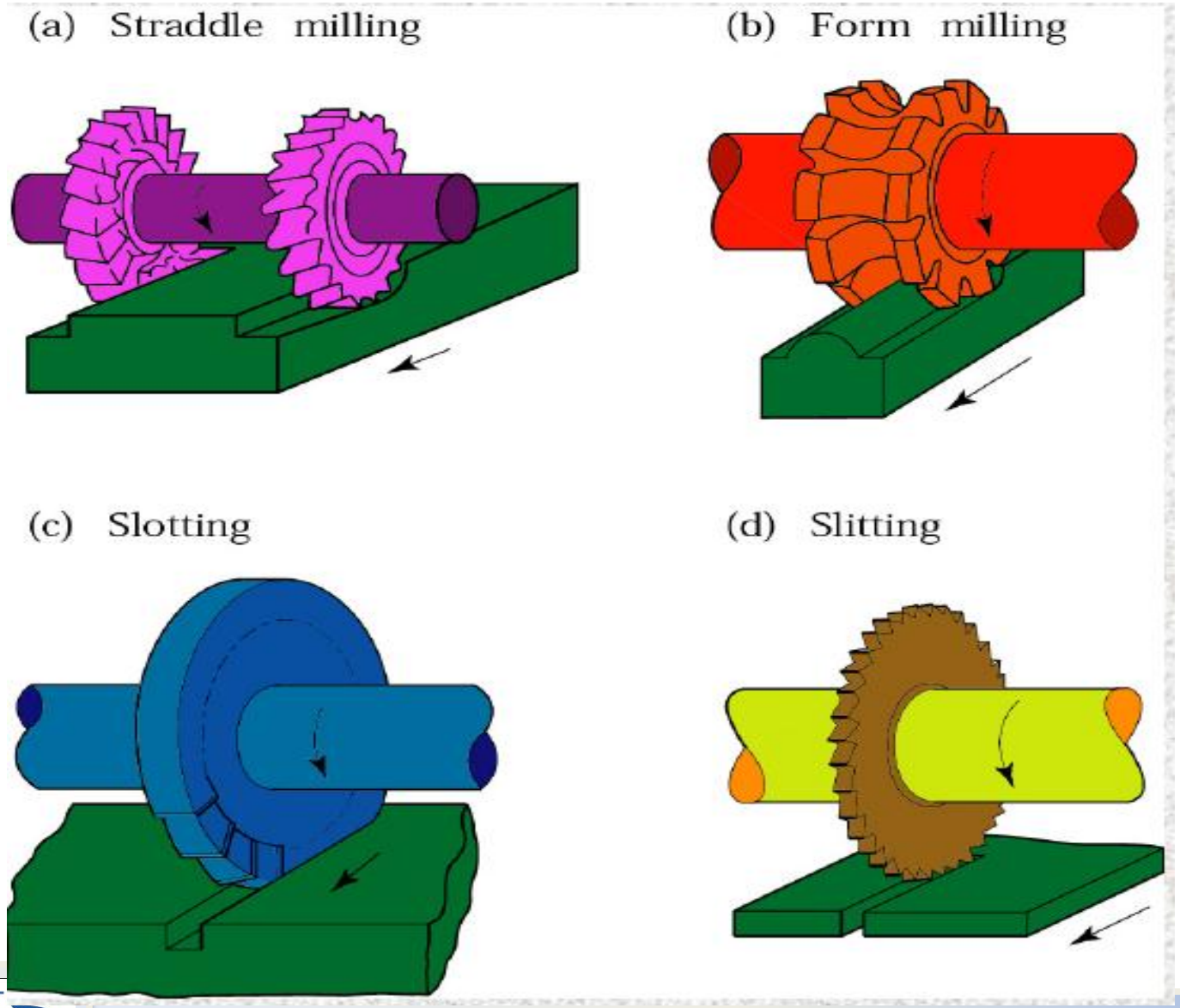
3) Angular milling: V- Blocks, Angular Groves- single /double angle cutter.

4) Form Milling: Produce irregular contours like concave, convex, shaped grooves.

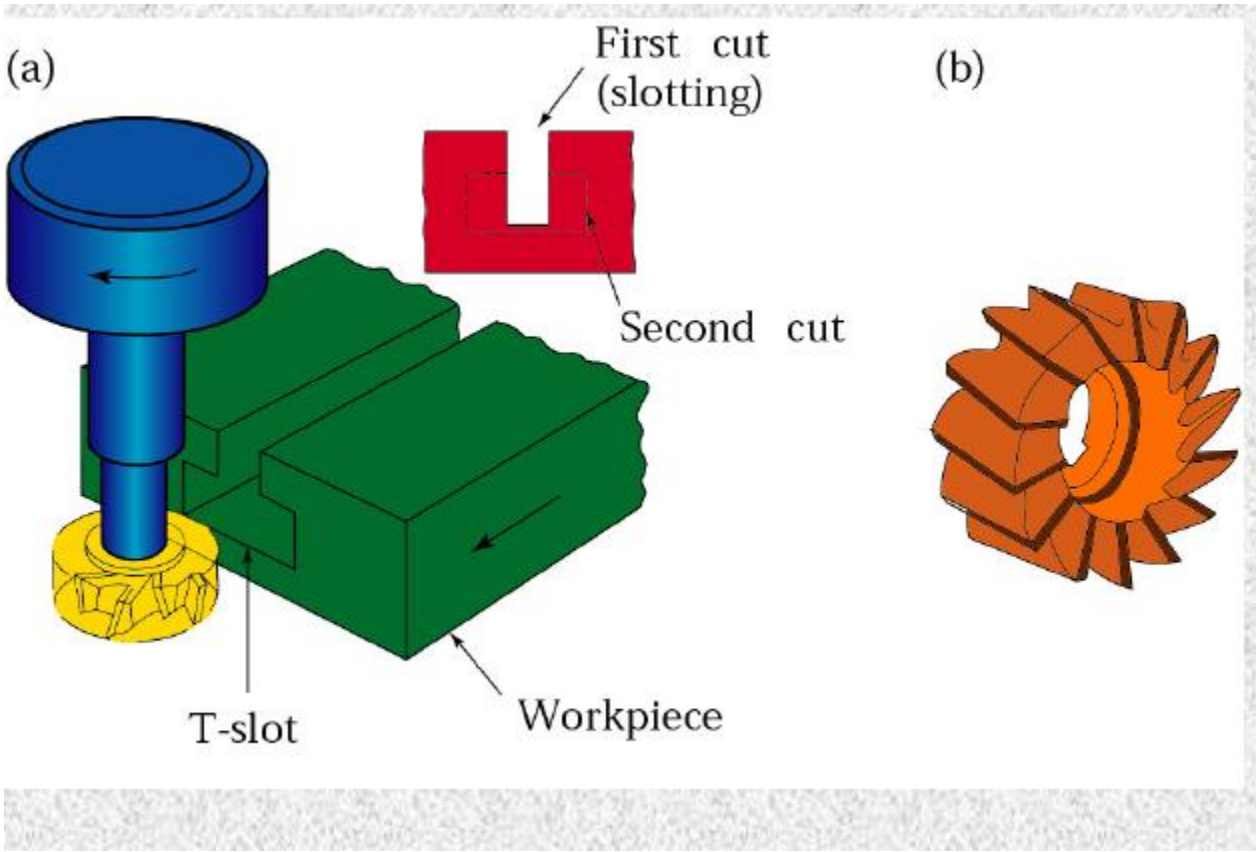
Operations on Horizontal milling machine:

5) Straddle milling: Square or hexagonal surfaces vertically on w/p using two side milling cutters simultaneously. Distance bet cuters maintained using collars.

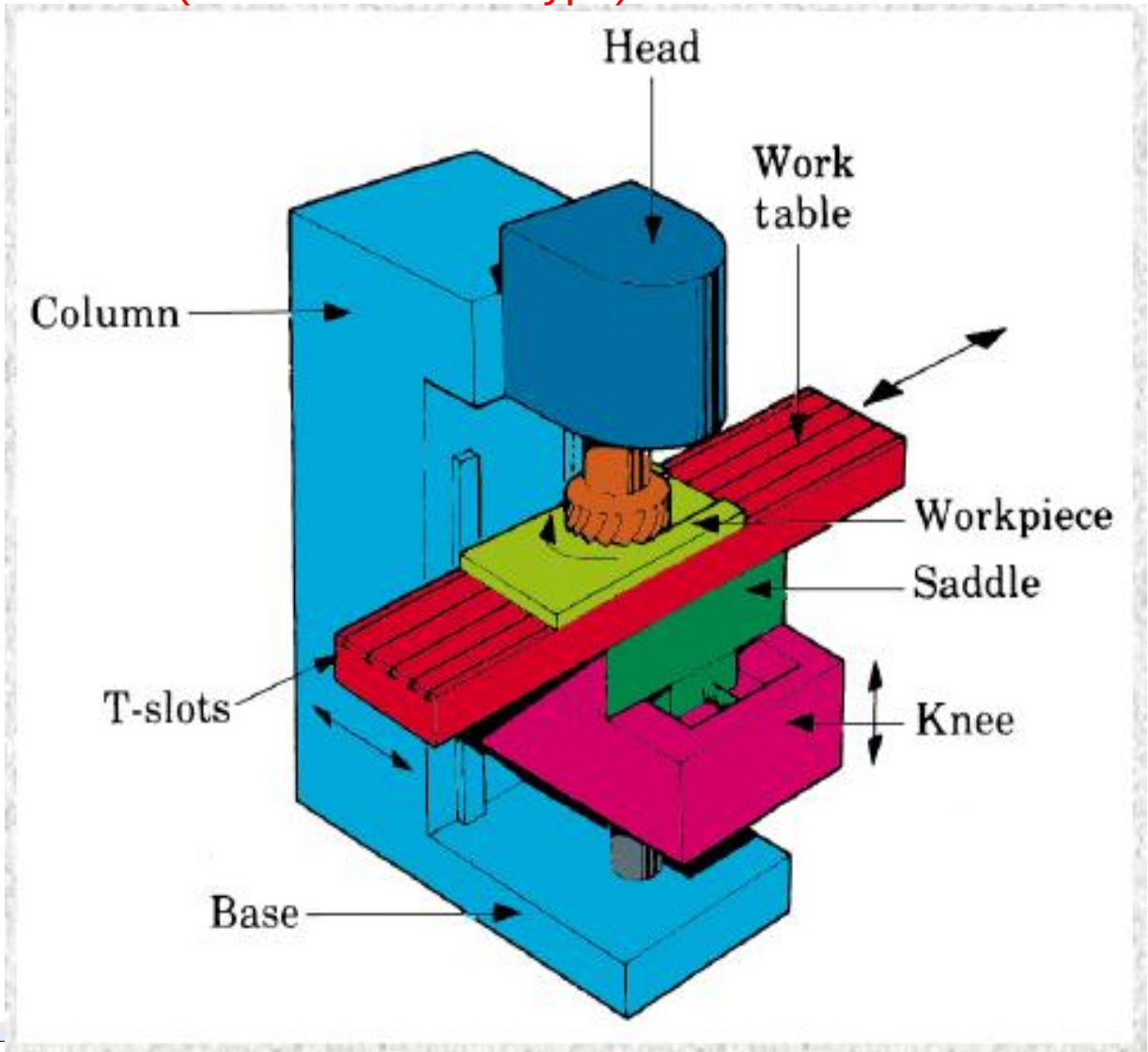
6) Gang Milling: It is a process of milling several surfaces of w/ps simultaneously at one pass. No of cutters are mounted on same arbor to save machining time.


(a) Straddle milling
(b) Form milling
(c) Slotting
(d) Slitting

Unit – VI, Milling & Grinding Machines



Vertical Milling machine (Knee & Column Type)



Construction:

Base, Column, Spindle Head, Swiveling base, Vertical Spindle, motor, cutter on spindle, knee, saddle, work table.

Operation: w/p on table with fixtures – feed, depth of cut, contour, suitable cutter, Knee & cutter moved vertically – touches w/p – moving table, saddle, swiveling base for specified feed, angle, depth of cut.

Operations on Vertical Milling machines

1) Face Milling
2) End Milling

Comparison

Particulars	Horizontal M M	Vertical M M
Spindle Position	Parallel to work table	Perpendicular to work table
Spindle Movement	Rotates only about its axis	Swiveled to desired angle
Motor position	In column	Over spindle head
Cutter position	On arbor	On spindle
Cutter movement	Rotates about its axis	Also moved Up & Down
Cutters used	Plain, Side, Angular, Form milling cutters	End & Slot milling cutter
Operations	Peripheral, slab, Slot, Gear cutting	Face & End milling

Specifications of Universal Milling Machine

1) Table Size – Length & Width or Clamping Area
2) Power Traverse – Longitudinal, Cross, Vertical
3) Spindle Speed , rpm
4) Power Capacity of machine, kW

Grinding Machines:

GRINDING

Definition: Another material removal process, in which abrasive particles are contained in bonded grinding wheel, that operates at very high surface speed.

The grinding wheel is usually in disk shaped and is precisely balanced for high rotational speeds.

It is an act of dressing, shaping or finishing surfaces using abrasive wheels and points act as cutting tool.

Metal removed – 25 microns to 0.5 mm –Accuracy 25 microns. Finishing of castings, forgings, welds.

Two Types – Rough & Precision grinding.

Abrasive materials

Different abrassive materials are appropriate for grinding different work material. Abrasives are hard substances used in various forms as tools for grinding and other surface finishing operations. They are also able to cut materials which are too hard for other tools and give better finishes and hold closer tolerances.

Ex: Emery, Sandstone, Diamond – these are crushed into grains and used in grinding wheels, discs, belts, points, lapping compound.

Classification of Abrasives

1) Natural abrasives : earth's crust as mineral deposit- contain impurities – difficult to extract & Process Ex: Emery, Sand, Flint, garnet, corundum, diamonds (costly – limited use).
2) Artificial or Manufactured Abrasives: produced by artificial means. Ex: carborundum (Artificial diamond), silicon carbide Sic, Aluminium oxide. Purity & Grain Size can be derived.

Common abrasive materials

1. Aluminum Oxide (Al_2O_3) known as Alundum or Aloxide. Various substances may be added to enhance hardness, toughness, etc. Plain Al_2O_3 is white, and used to grind: steel, ferrous, high strength alloys.
2. Silicon Carbide (SiC) known in trade as Carborundum and Crystalon. Harder than Al_2O_3 but not as tough. Used to grind: aluminum, brass, stainless steel, cast irons, certain brittle ceramics.

3. Boron Nitride in the forms of single-crystal cubic boron nitride (CBN) and microcrystalline cubic boron nitride (MCBN) under trade names such as Borazon or Borpax. Used for hard materials such as hardened tool steels and aerospace alloys.
4. Diamond, a pure form of carbon, both natural and artificial. Used on hard materials such as ceramics, cemented carbides and glass.

Application of abrasives.

Emery & Corundum: to sharp tool edges.

SIC: Grind - CI, ceramics, tungsten carbide, non ferrous metals.

AL_2O_3 : Grind - steels, wrought iron, bronzes.

Carborundum: Grind carbides, marbles, gems, stones etc.

Bonding materials

To get wide range of properties needed in grinding wheels, abrasive materials bonded by using organic or ingorganic materials.

Bonds are adhesive substances such as clay, glues, resins, varnish, shellac, rubber & sulphur, silicates etc.. - Used to hold abrasives on the backing of belts, sheets like paper, cloth, metal wheels, discs etc. these are called coated abrasives.

Grinding wheels are made in, many shapes & sizes (standardized – name & no) like straight, cylindrical, cup, dish etc. Called mounted abrasives.

Bonding materials

To get wide range of properties needed in grinding wheels, abrasive materials bonded by using organic or ingorganic materials.

Inorganic bonds

1. Vitrified bond: Clay bond melted to a porcelain or glass like consistency. It can be made strong and rigid for heavy grinding and not effected by water, oil, acids. Most grindig wheels have vitrified bonds.

2. Slicate bond is essentially water glass hardened by baking. It holds grains more loosely than a vitrified bond and give closer cut. Large wheels can be made more easily with slicate bond. Usually used in situation where heat generation must be minimized.
3. Metallic bond: Cubic boron nitride and diamond abrassives are usually (but not always) embeded in metallic bonds, for utmost in strength and tendency to hold the costly long-wearing grains.

Organic bonds

1. Rubber bond is a flexible bond, used in cutoff wheels.
2. Resinoid bond is a high strength bond, used for rough grinding and cutoff operations.
3. Shellac bond is relatively strong but not rigid, used in applications that requires good finishing.

Grain size

Important parameter in determining surface finish and material removal rate. Small grit sizes produce better finishes, larger grit sizes permit larger material removal rates. Also, harder materials need smaller grain sizes to cut effectively, while softer materials require larger grit size.

Grain sizes used in grinding changes between 8-250, whilw 8 is very coarse, but 250 is very fine.

Terminology in Grinding

Grain / Grain size : Number which indicates the size of the abrasive grains used in making wheels.12 – 24 – Coarse, 30 – 60 Medium, 70-120 Fine.

Grade: Hardness with which the bond holds the abrasive upon it. Represented by letter. Very soft E-G, Soft H-K, Medium L-O.

Structure : Distributed structure of abrasive grains on the wheel. Dense 1-8, open 9-15.

Bond: Type of adhesive used for wheel. Represented by letter V,E, B, S etc.

Grinding Machines & Types

Machines which perform abrasive machining – portable & Stationary

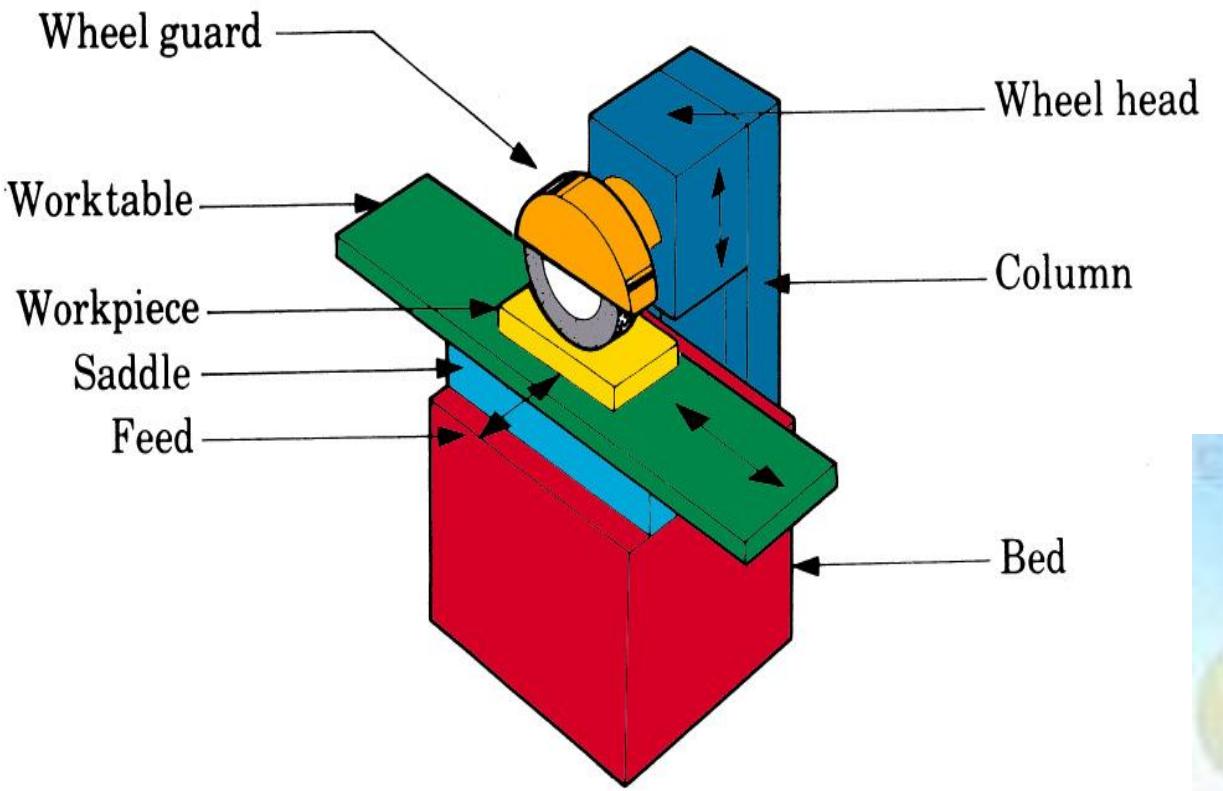
Basis	Types
Quality of Surface finish	Rough & Precision Grinding m/c s
Finish on Flat surfaces	Surface grinding
Finish on Cylindrical Surfaces	Cylindrical grinding
Finish on straight, tapered & formed holes	Internal grinding
Sharpening & reconditioning – cutting tools	Tool & cutter grinder
Finish special contours	Special grinding

Types of HSGM

1) Horizontal Spindle and Reciprocating Table
2) Horizontal Spindle and Rotary Table
3) Vertical Spindle and Reciprocating Table
4) Vertical Spindle and Rotary Table.

Principle: w/p – work table – reciprocating motion – grinding wheel – mounted on horizontal spindle – move up, down, to & fro. Down movement s feed – depth of cut- to & fro Cross feed – horizontal surface finish. Table moved parallel to direction of rotation of wheel – down grinding – opp direction up grinding.

Horizontal Surface Grinding Machine: Used to grind Flat Surfaces.



Grinding Wheels


Aarti

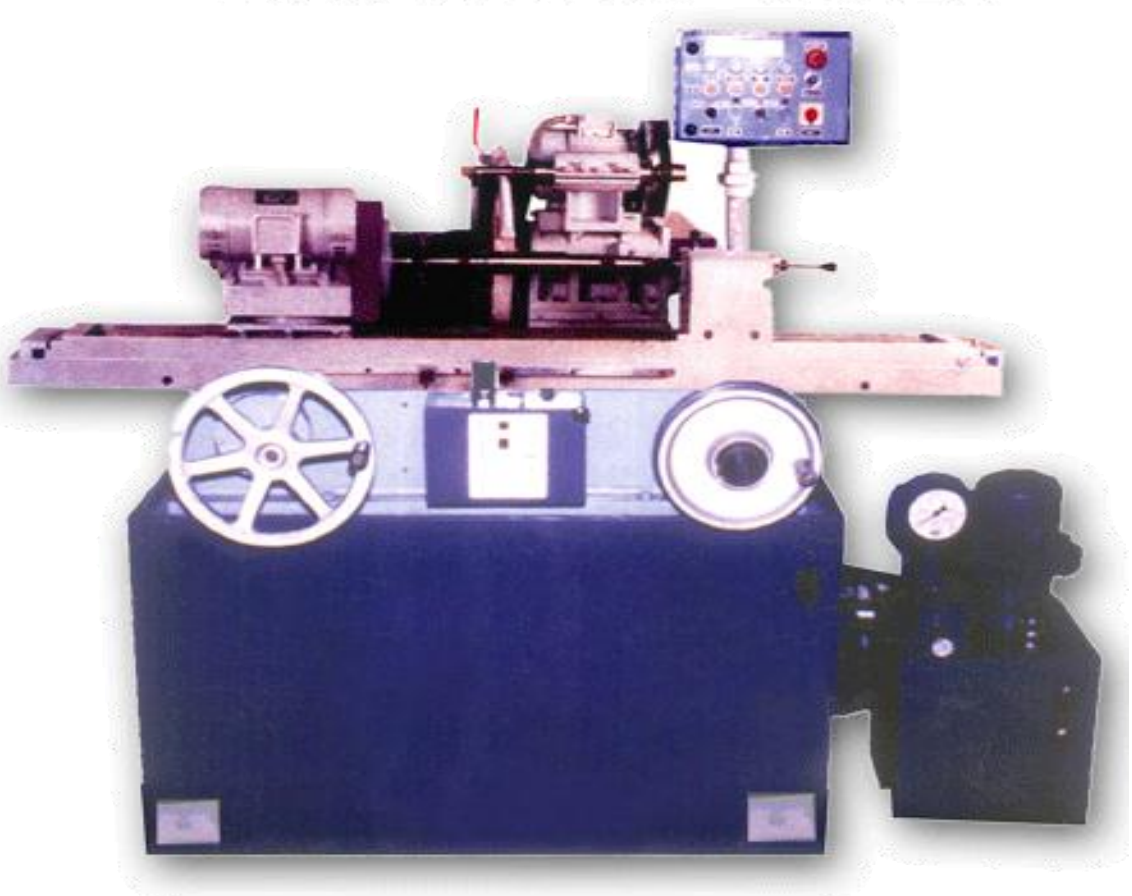
Construction:

Hollow base, Column, Mechanisms, Work table, Saddle, Grinding Wheel, Spindle, Wheel Head, Hand Wheel.

Operation: w/p – work table – select suitable grinding wheel- fix on spindle – feed – w/p moved to & fro – surface finish.

Cylindrical Grinding Operations

Cylindrical Grinding Machine



Cylindrical Grinding machines: Used to grind cylindrical surfaces to reduce diameter with fine finish. Also to grind Cams, fillets, eccentrics.

Types: Plain Centre Type, Universal centre type and centre less grinding machines.

Plain Centre type Cylindrical grinding Machine:

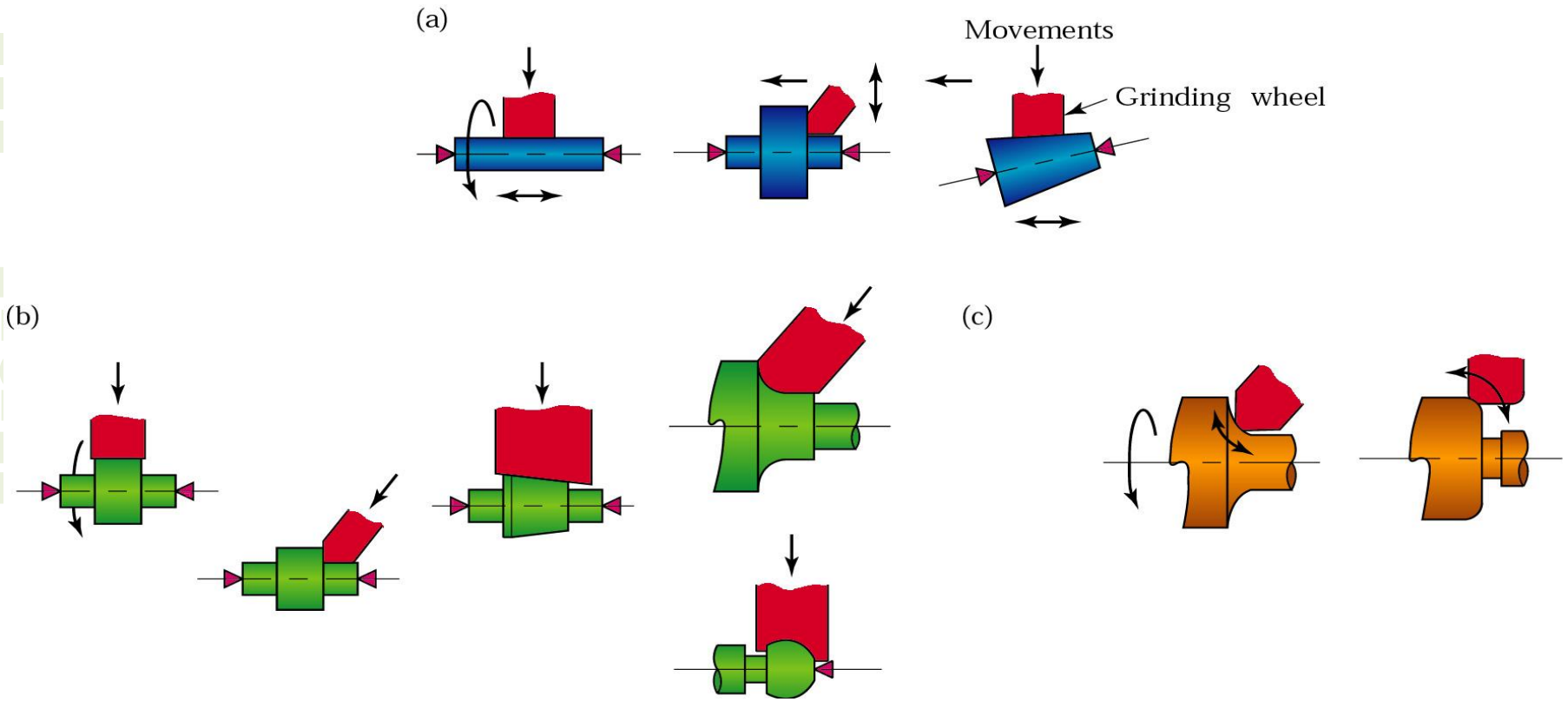
Principle: w/p – between centers – revolves – grinding wheel behind w/p rotate at high speeds n opposite direction of job rotation – wheel moved parallel to axis of job – wheel positioned above job to provide feed.

Construction:

Hollow base, Mechanisms (on base), Slide table (longitudinal), Work table (swiveling), Head stock, Tail Stock, Wheel head, Grinding Wheel (horizontally & vertically), Hand Wheels.

Operation: w/p – Between centres– select suitable grinding wheel- fix on wheel head – both ob & grinding wheel rotated (opp direction) – feed (wheel) – moved to & fro – cylindrical surface finish.

Cylindrical Grinding Operations

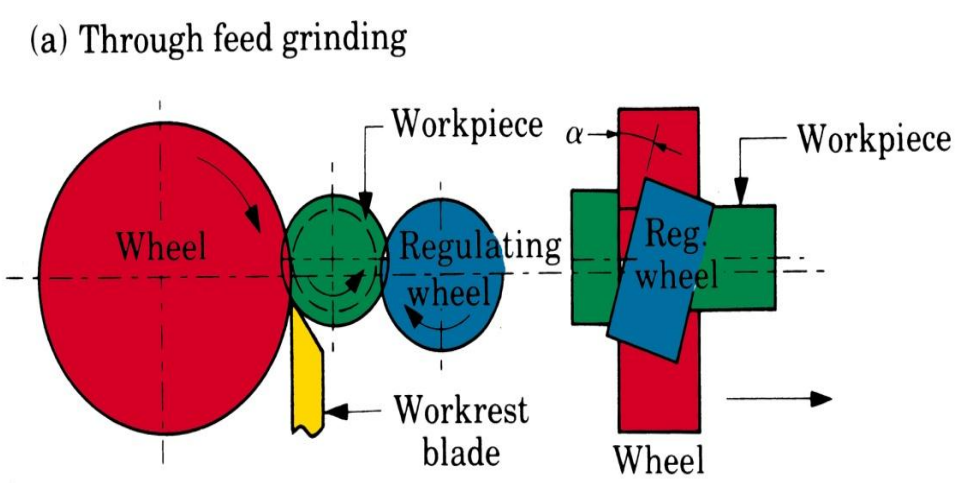


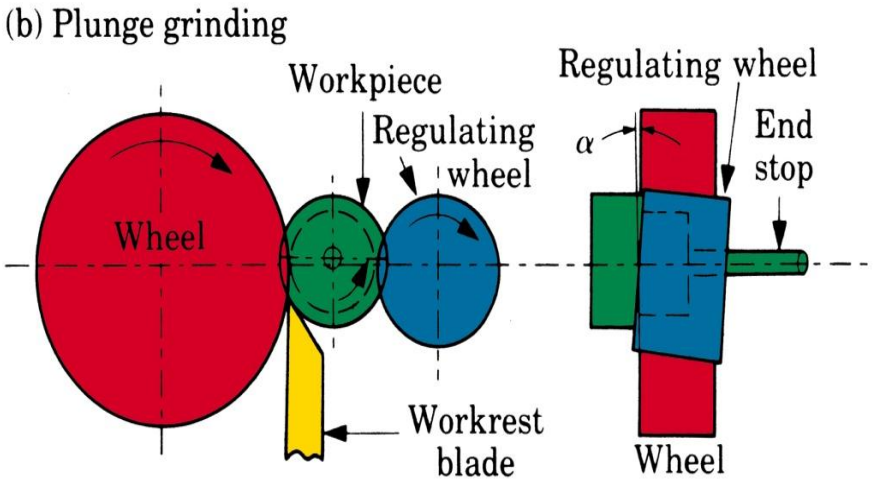
Examples of various cylindrical grinding operations. (a) Traverse grinding, (b) plunge grinding, and (c) profile grinding.

Centreless Cylindrical Grinding machines: Used to grind cylindrical surfaces to reduce diameter with fine finish.

Principle: w/p – Held over work rest between two wheels – larger is the grinding wheel do grinding – smaller is regulating wheel or pressure wheel (plastic/rubber) – purpose is to control speed of rotation, longitudinal motion of w/p and rate of feed – at an angle 8 to 10 deg – rotates at low speed – w/p rotates at speed of regulating wheel in same direction – w/p is not supported between centres – centreless.

Centerless Grinding



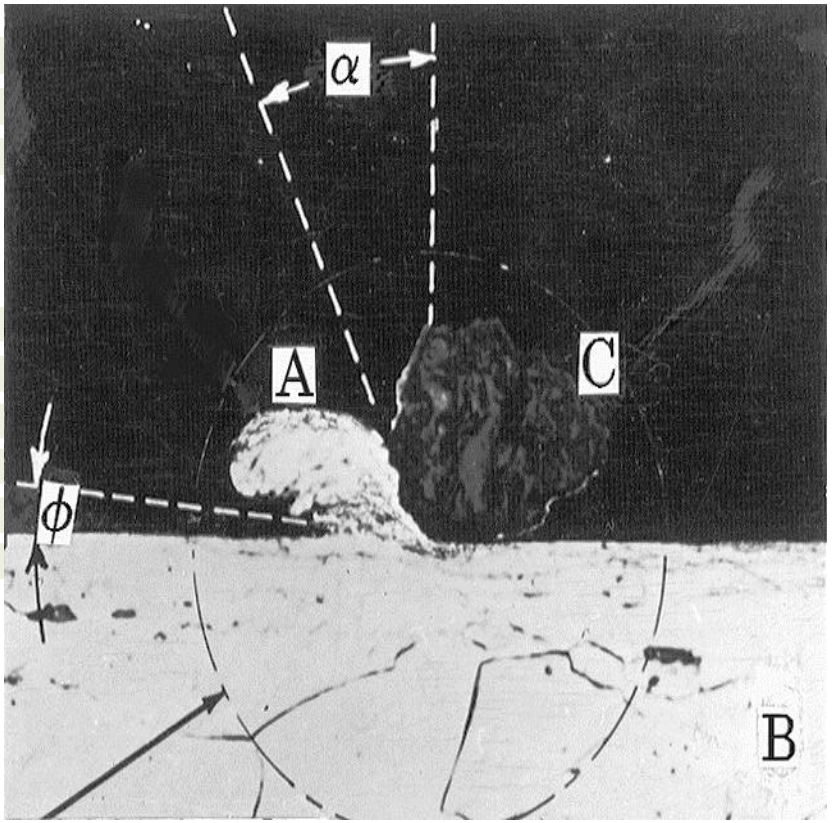


Applications: Exterior cylindrical grinding, through grinding, in feed & end feed grinding.

The principle dimensions that designate the size of a grinding wheel are the **outside diameter**, **width**, and **hole diameter**. Standard wheel shapes are made in certain sizes only, but the variety is large.

Grinding Chips

(a)



(b)