RECIPROCATING MACHINE TOOLS

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Reciprocating machines

- ✓ Tool or work piece motion will be in reciprocation
  - If tool stationary – work is in motion
  - If work is stationary – tool is in motion
- ✓ Machining surfaces, profile creation, slots, keyway, grooves, recesses, etc.,
- ✓ Configurations and basic functions of
  - Shaping machines
  - Planing machines
  - Slotting machines

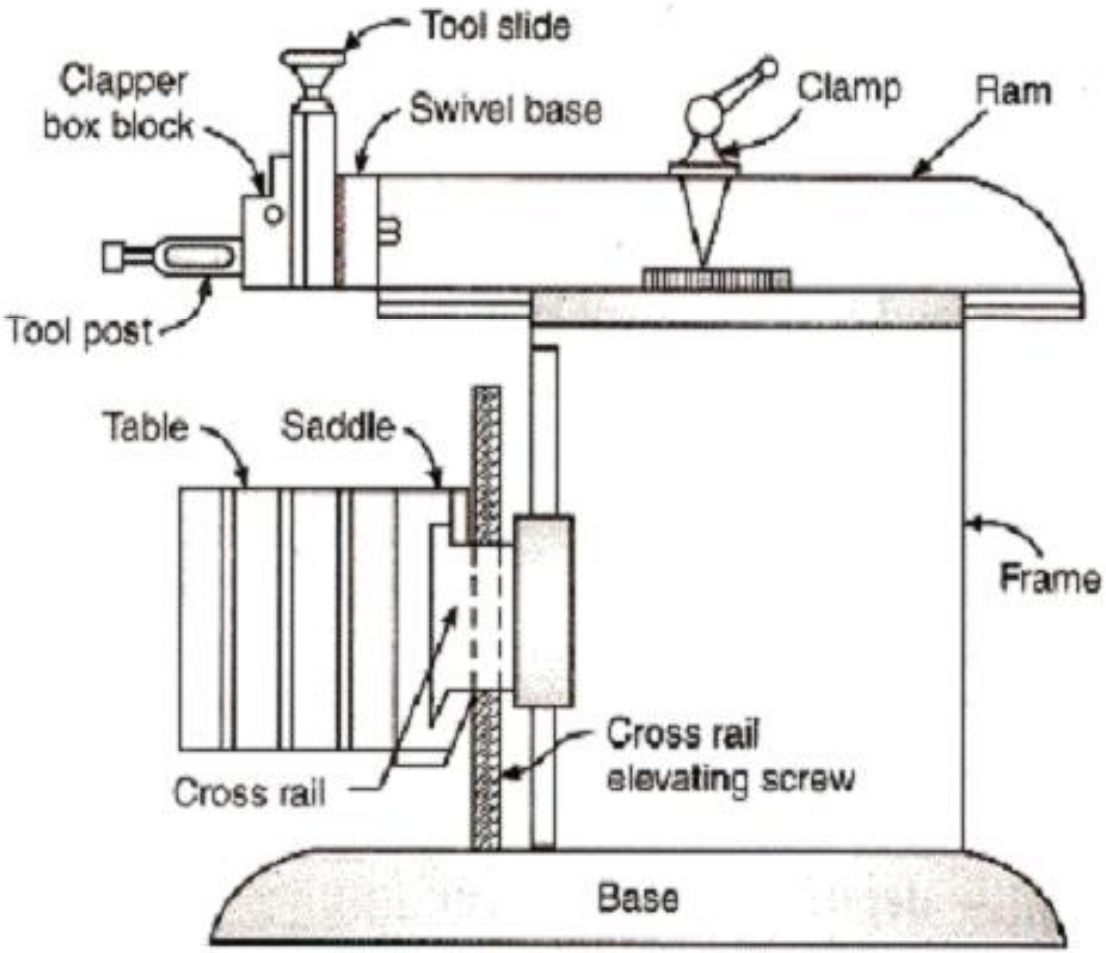
SHAPER
MACHINE TOOL

Introduction to Shaper

- A shaping machine is used to machine surfaces
- It is a reciprocating type of machine tool
- Tool used for producing flat surfaces (horizontal, vertical and inclined) with help of a single point cutting tool
- Tool clamped in ram and its reciprocates “to and fro” over the stationary workpiece
- Tool cuts the material in the forward stroke (cutting stroke), No cutting during return stroke (Idle stroke)

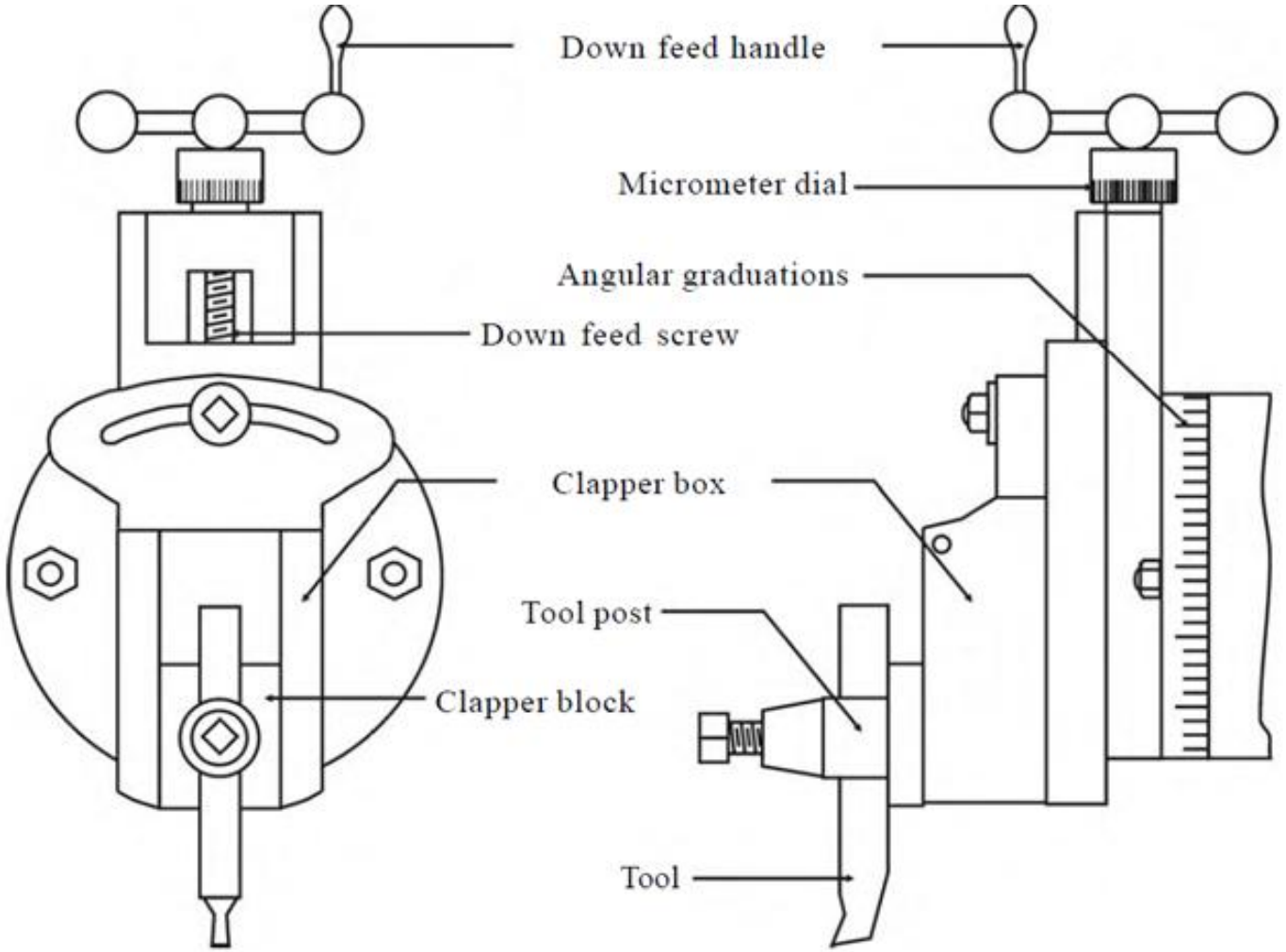
Photographic view

Principal parts of Shaper

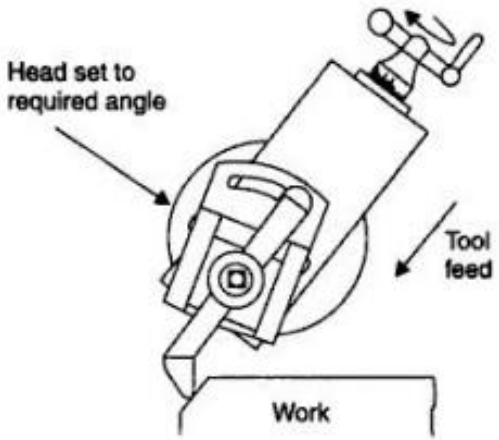


- Base
- Column
- Table
- Cross Rail
- Ram
- Tool Head

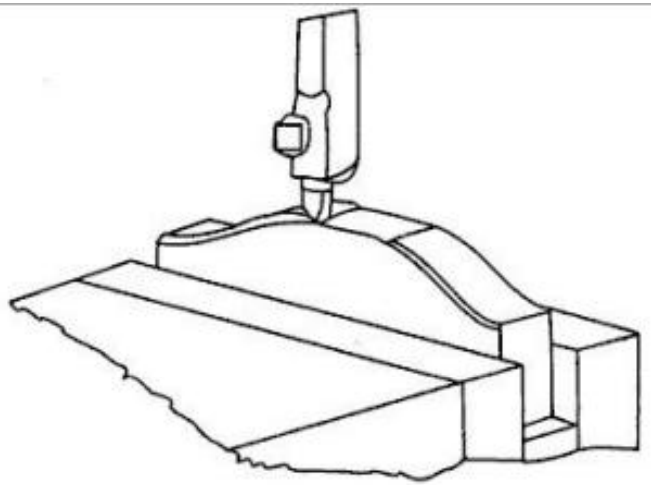
Swivel tool head



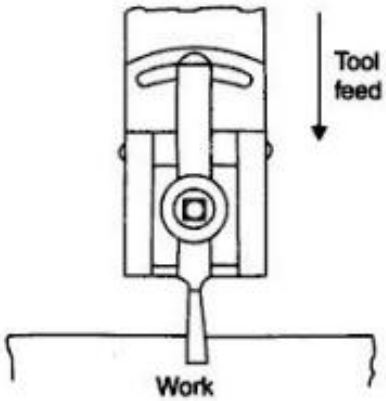
Tool positioning



Angular shaping



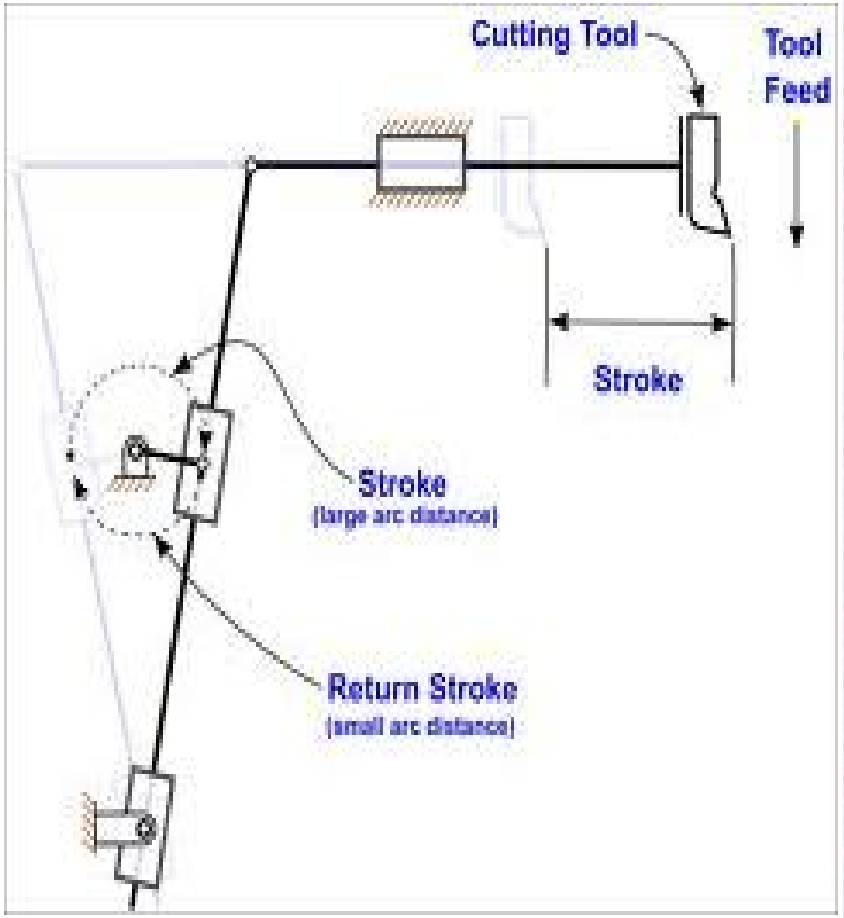
Irregular (or contour) cutting



Shaping grooves

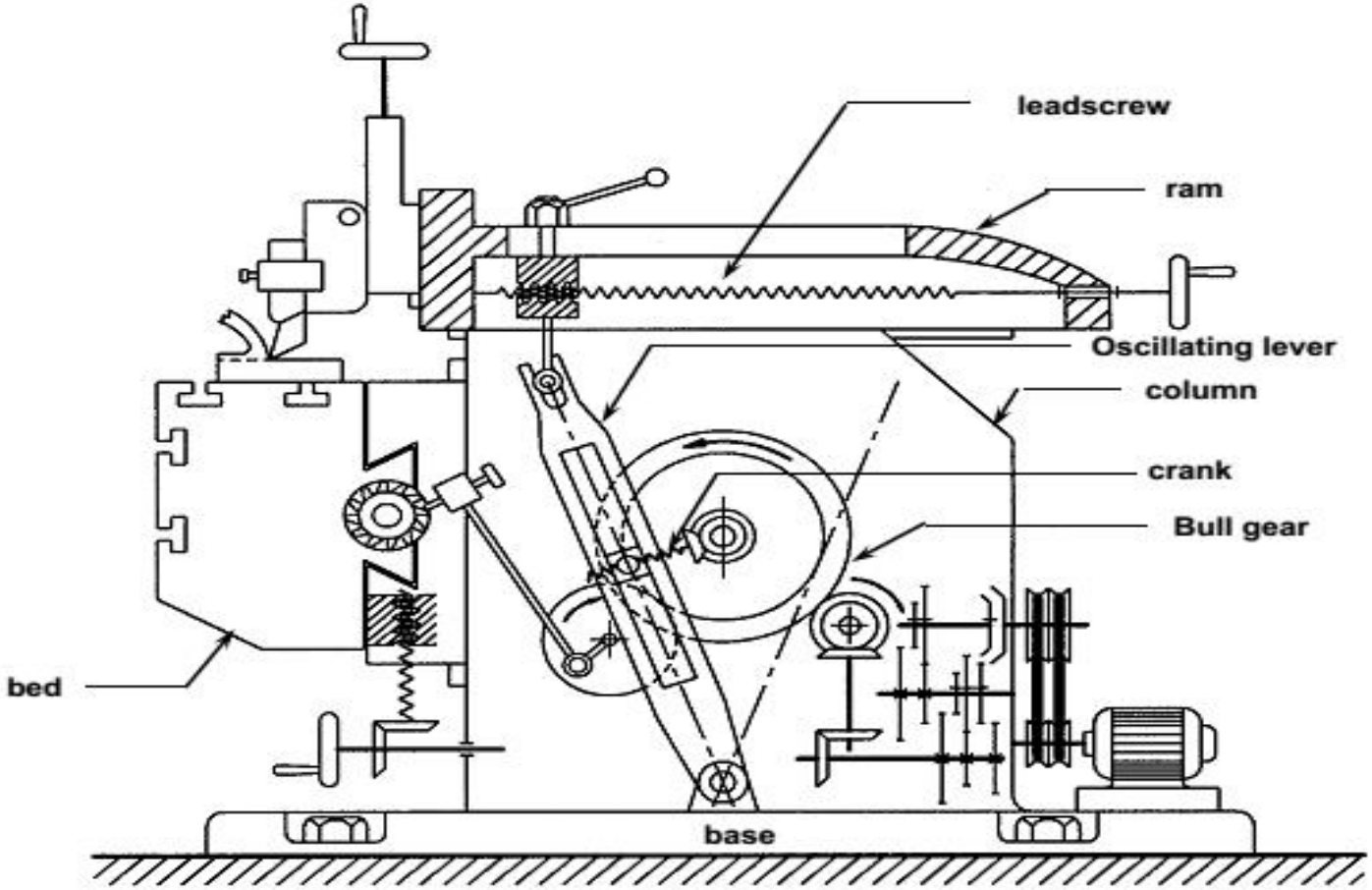
Working Principle

- ✓ The reciprocating motion of the ram is obtained by a quick return motion mechanism
- ✓ The forward and return strokes constitute one operating cycle of the shaper



Kinematic System

- ✓ **The usual kinematic system provided in shaping machine for transmitting power and motion from the motor to the tool**



Contd.,

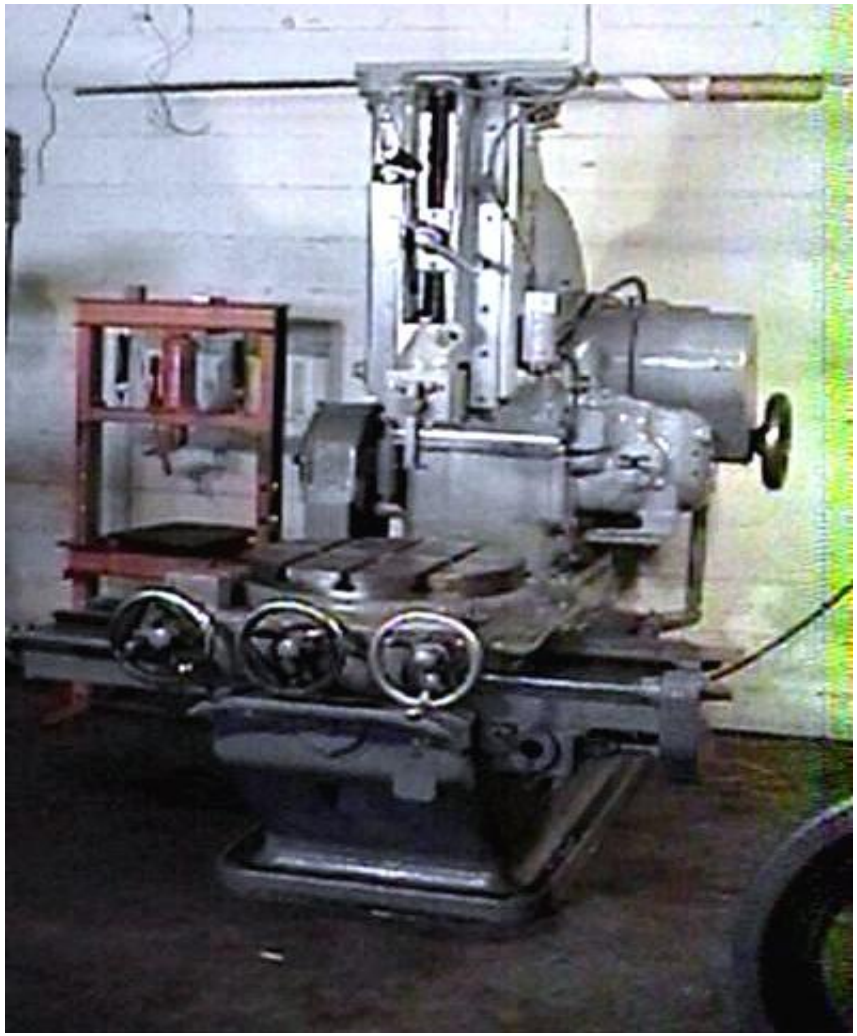
- ✓ The central large bull gear receives its rotation from the motor through the belt-pulley, clutch, speed gear box and then the pinion
- ✓ The rotation of the crank causes oscillation of the link and thereby reciprocation of the ram and hence the tool in straight path

Types of Shaper

- ✓ Acc. to the ram driving mechanism
  - Crank shaper
  - Geared shaper
  - Hydraulic shaper
- ✓ Acc to the position & travel of ram
  - Horizontal shaper
  - Vertical shaper
- ✓ Acc to the direction of cutting stroke
  - Push cut shaper
  - Draw cut shaper
- ✓ Acc to the design of the table
  - Standard shaper
  - Universal shaper

Horizontal Shaper

Vertical Shaper

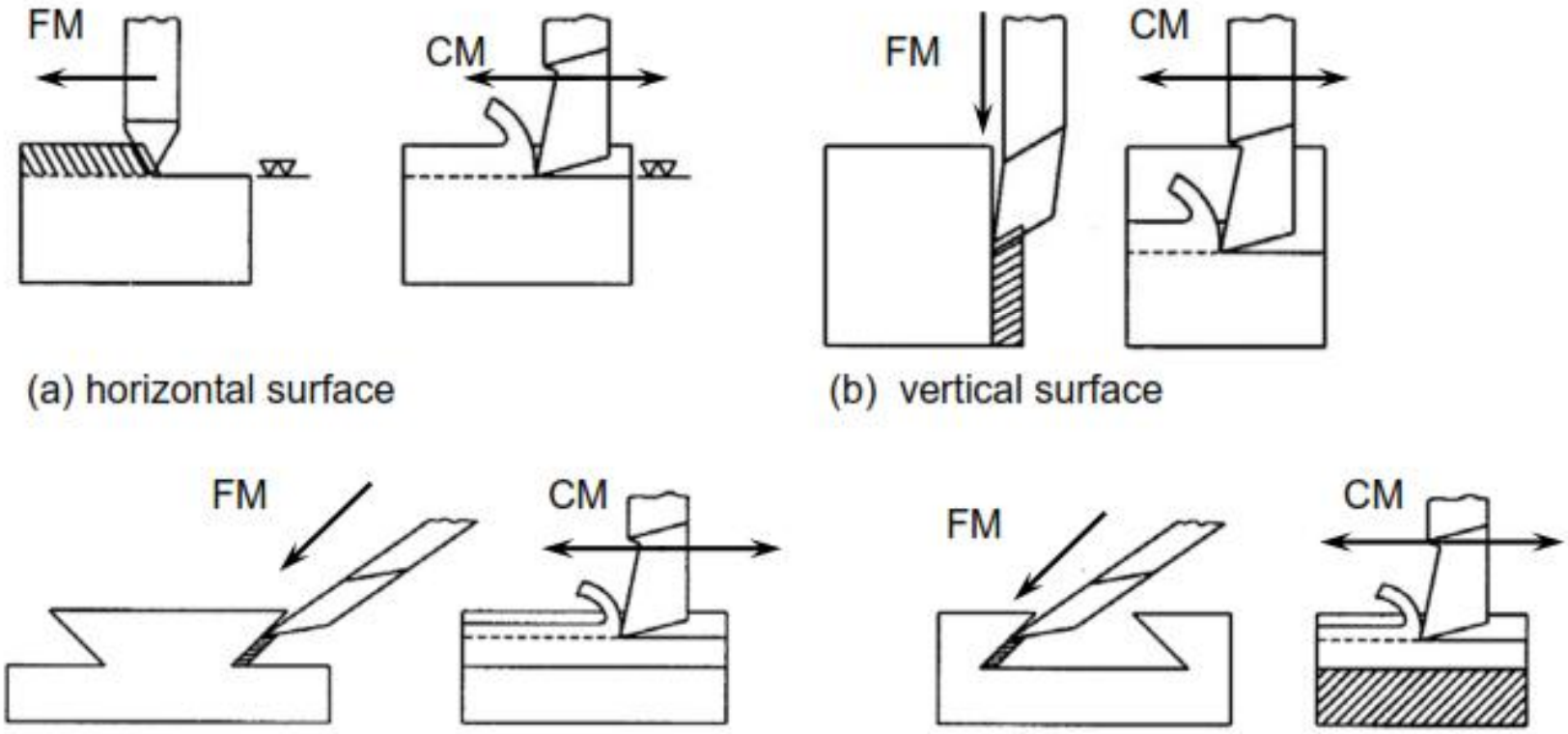


Hydraulic Shaper

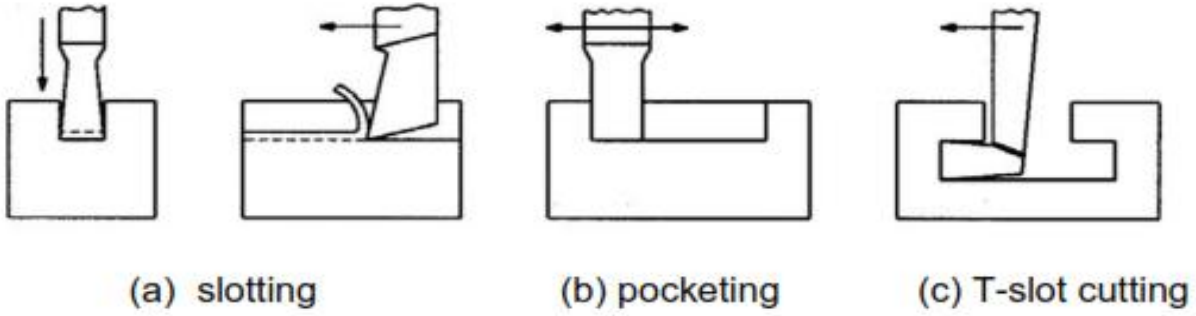
Operations done using a Shaper Machine tool

- ✓ Machining Horizontal Surfaces
- ✓ Machining Vertical Surfaces
- ✓ Machining Angular Surfaces
- ✓ Cutting Slots, Grooves & Key ways
- ✓ Machining irregular surfaces
- ✓ Machining Splines / Cutting Gears

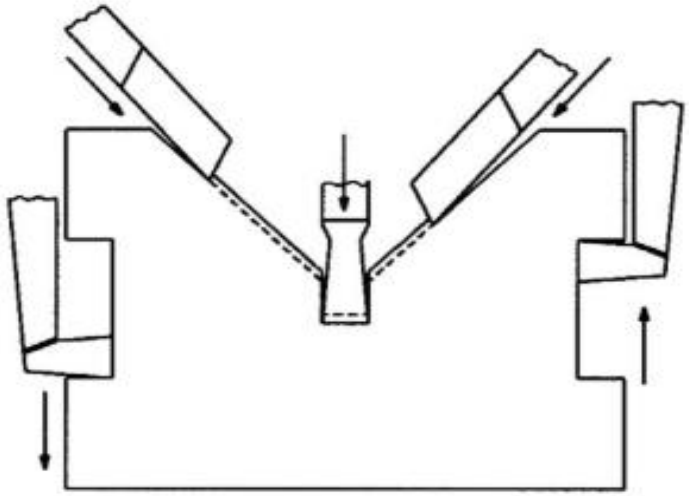
Machining of flat surfaces



Making of slot, pocket, T-slot and Vee block

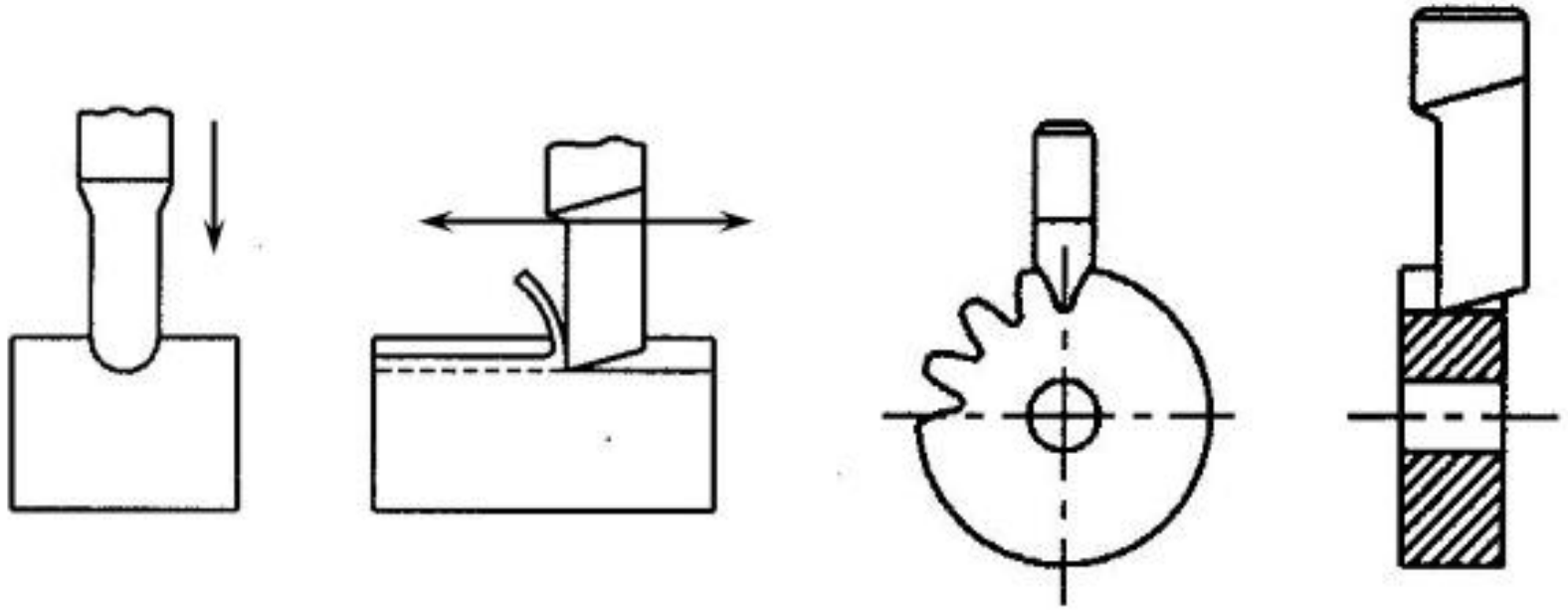


(a) slotting (b) pocketing (c) T-slot cutting



(d) Vee-block

Making of grooves and gear teeth cutting



(a) grooving

(b) straight tooth cutting for spur gears

Advantages of Shapers

- ✓ The single point cutting tools used in shapers are inexpensive, these tools can be easily grounded to any desirable shape
- ✓ The simplicity and ease of holding work, its easy adjustment, and the simple tool give the shaper its great flexibility
- ✓ Shaper set up is very quick and easy and can be readily changed from one job to another
- ✓ Thin or fragile jobs can be conveniently machined on shapers because of lower cutting forces

Limitations

- ✓ Shape only one piece of stock at a time

  Not suitable for mass production

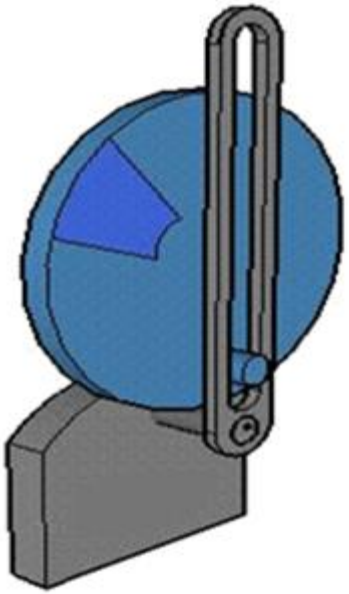
- ✓ Shape stock only if longer than 25 cm
- ✓ Support long pieces of wood with extension tables or roller supports

Specifications of Shaping Machine

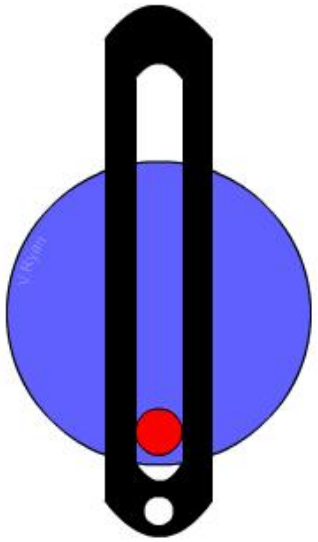
- ✓ Maximum length of Stroke of Ram
- ✓ Type of Drive
- ✓ Power input
- ✓ Floor Space required
- ✓ Weight of the Machine
- ✓ Cutting to Return Stroke ratio (QRR)

Quick Return Mechanisms

- ✓ Basic mechanism:
  - ➢ Conversion of rotary motion into reciprocating motion
- ✓ In order to reduce the time wasted during the return non-cutting stroke, shaping machines are fitted with a quick-return mechanism
- ✓ Usually crank and slotted-link design has been used
- ✓ As the disc rotates the black slide moves forwards and backwards



3D View

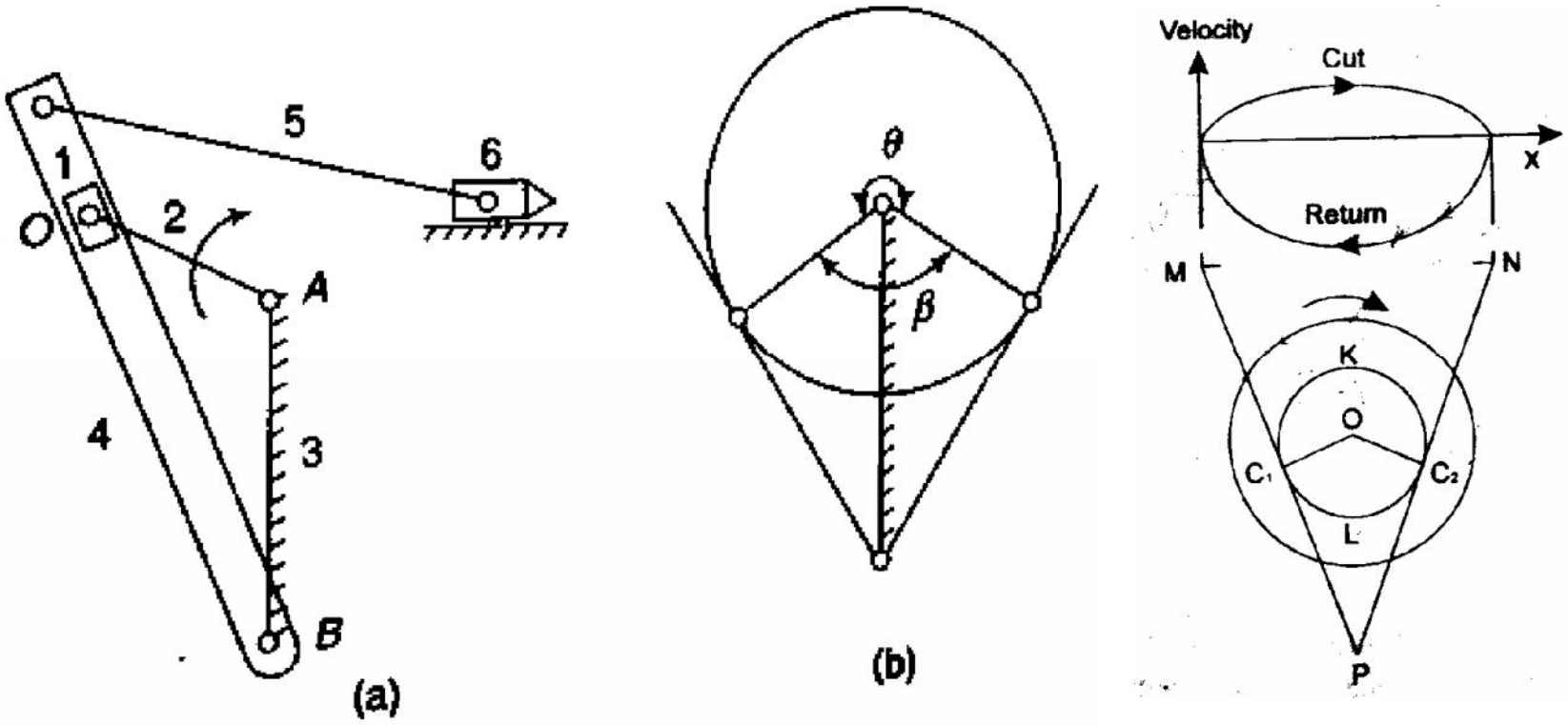


Front View

Types of QRM

- ✓ Crank and slotted lever mechanism
- ✓ Whitworth mechanism
- ✓ Hydraulic mechanism

Crank and slotted lever mechanism



- ✓ Here smallest link 2 is crank this gives oscillation motion to link 4.
- ✓ It is used in shaping machine

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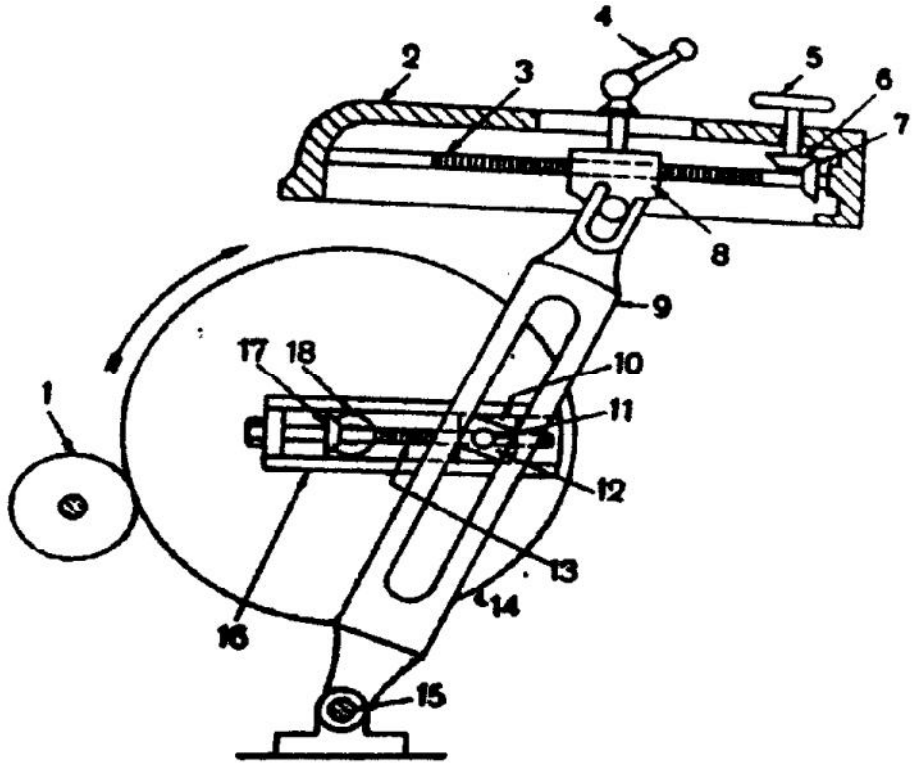
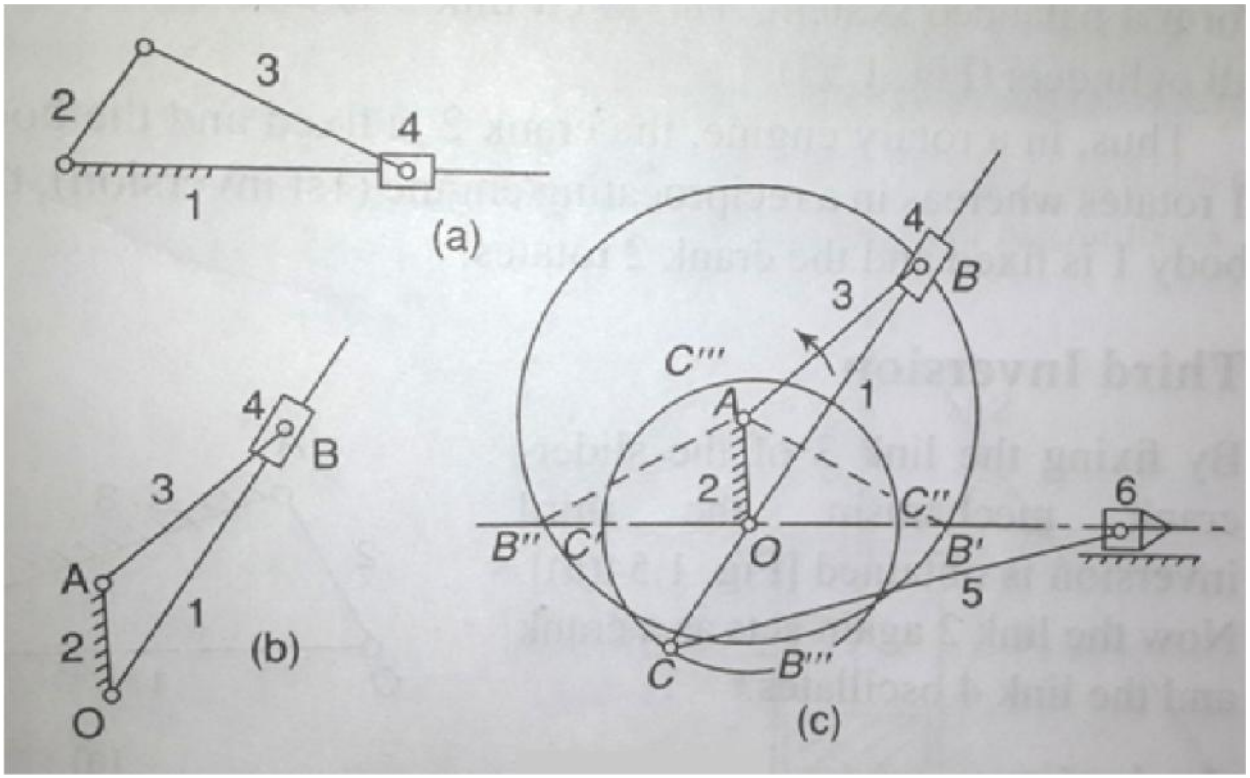


Figure 7.3 Crank and slotted link mechanism

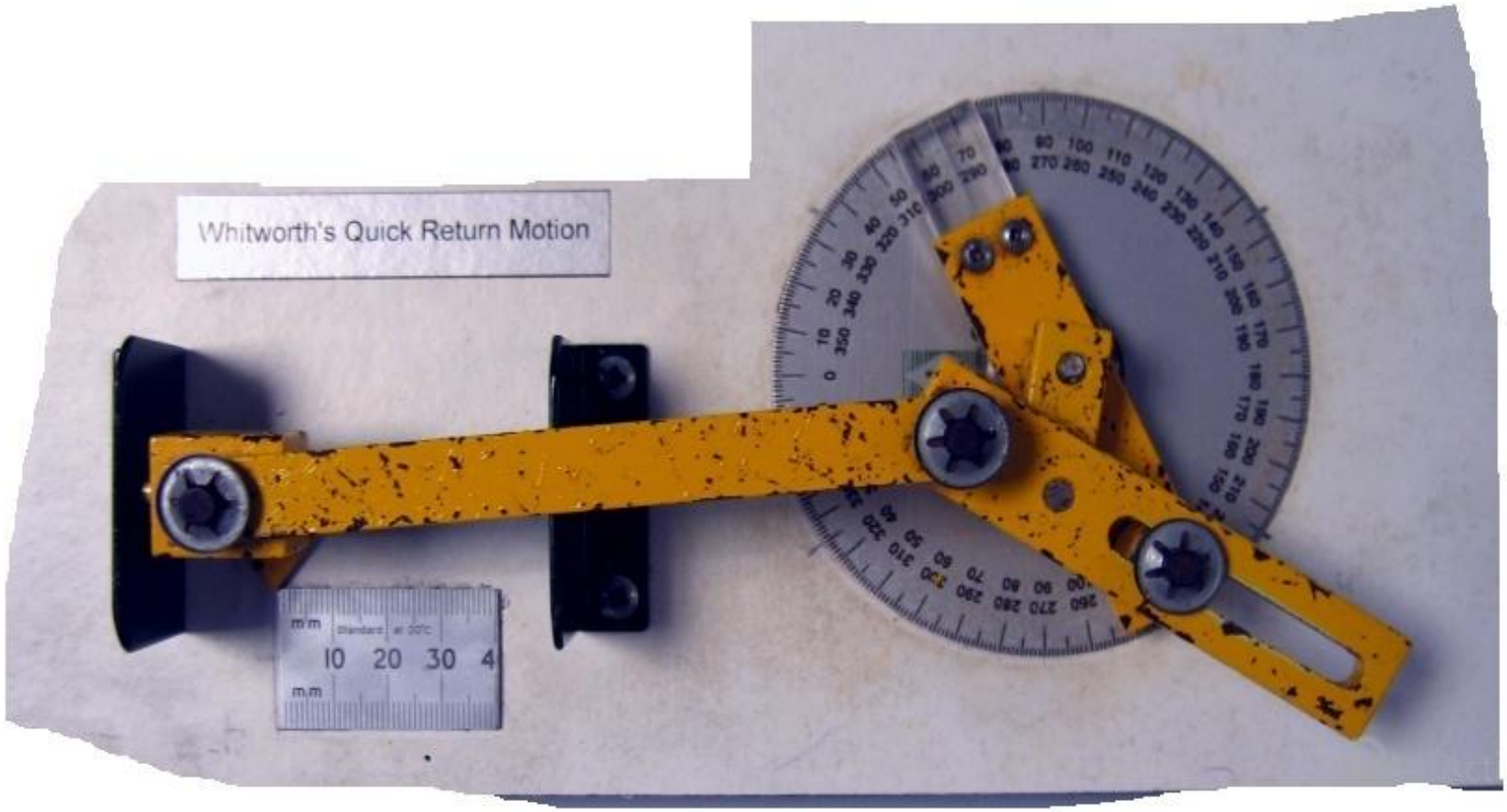
1. Driving pinion, 2. Ram, 3. Screwed shaft, 4. Clamping lever, 5. Handwheel for position of stroke adjustment 6.7. Bevel gears, 8. Ram block, 9. Slotted link or rocker arm, 10. Bull gear sliding block, 11. Crank pin, 12. Rocker arm sliding block, 13. Lead screw. 14. Bull gear, 15. Rocker arm pivot, 16. Bull gear slide.

Whitworth mechanism

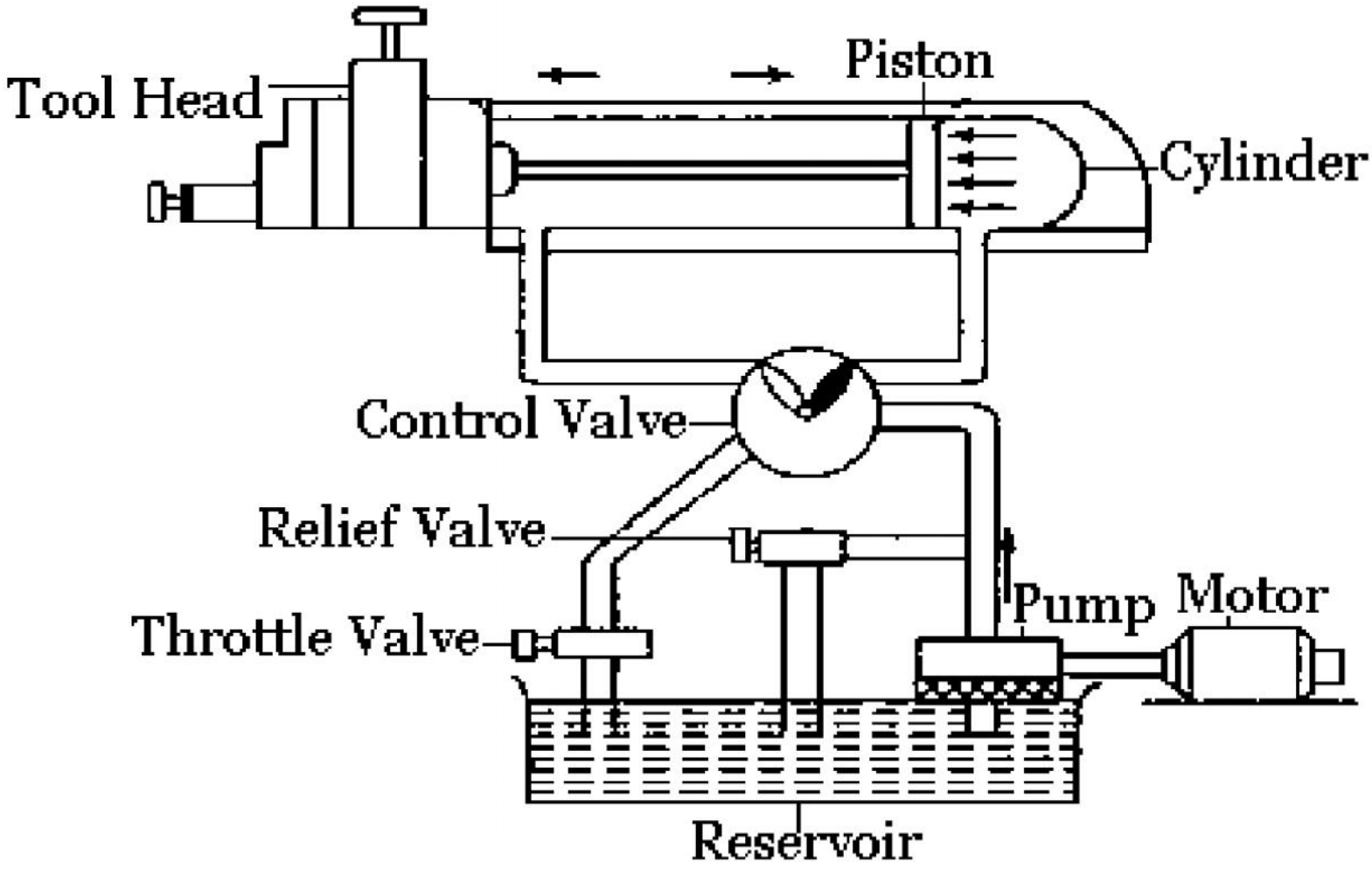


- ✓ Here link 3 acts as crank which is driving and link 1 acts as slider which is driven.
- ✓ It is used in slotting machine

Ex. for model

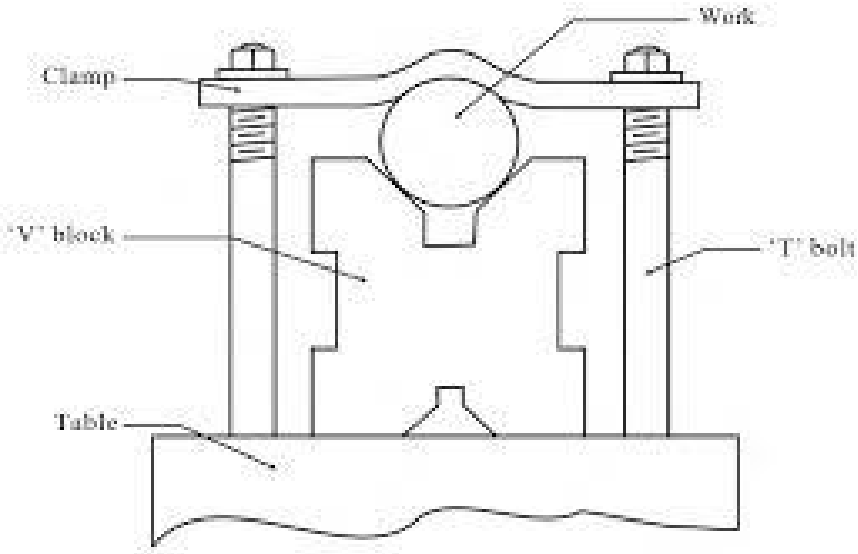


Hydraulic mechanism

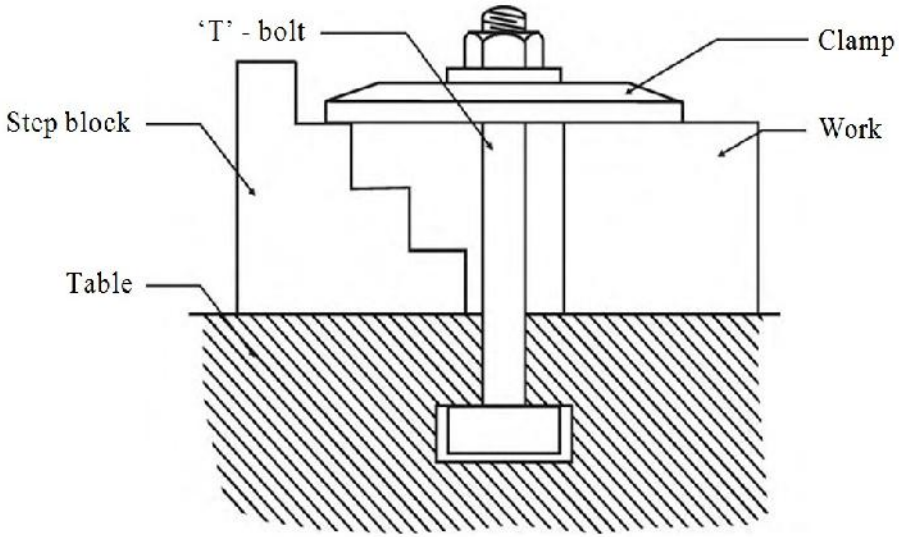


Work holding devices

- ✓ Angle Plate
- ✓ Step Block
- ✓ Vice
- ✓ Parallel strips
- ✓ V-Blocks
- ✓ T- Bolt
- ✓ Clamps

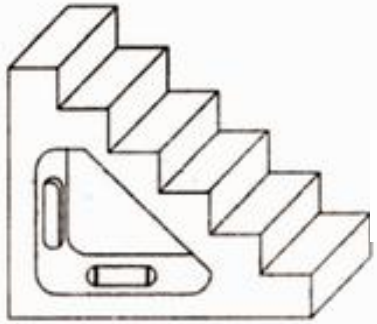


'V' block

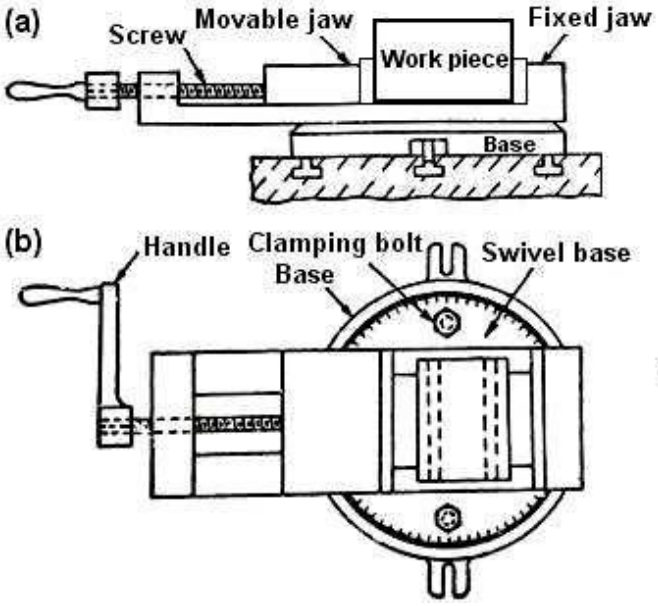


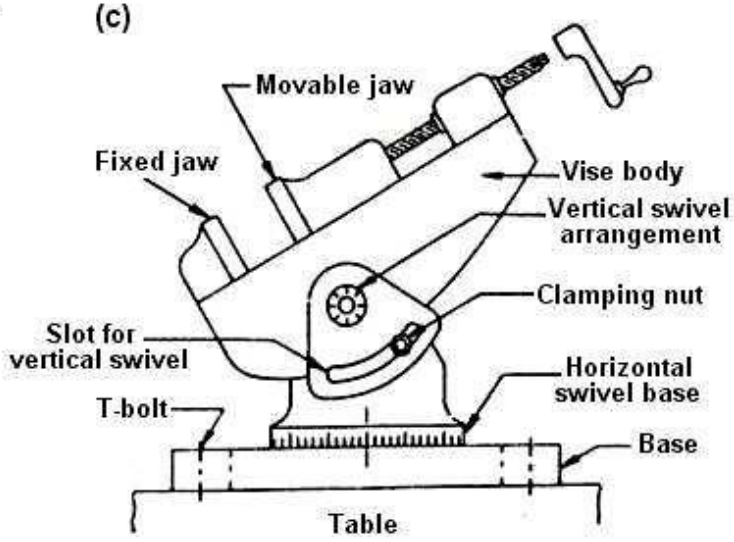
T- bolt, Clamp & Step Block

Angle plates



step blocks



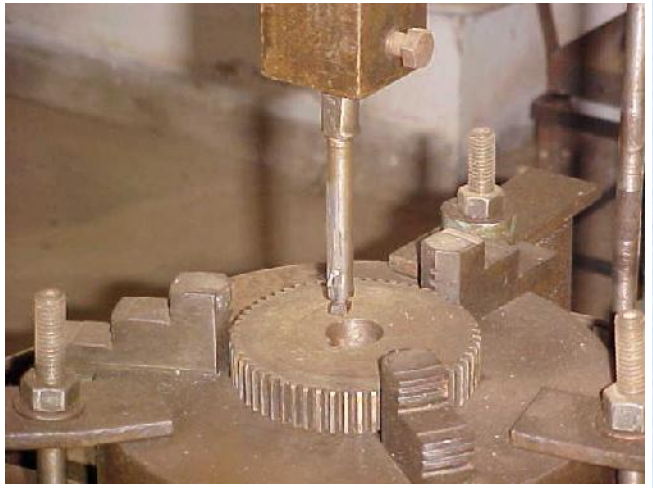


SLOTTER
MACHINE TOOL

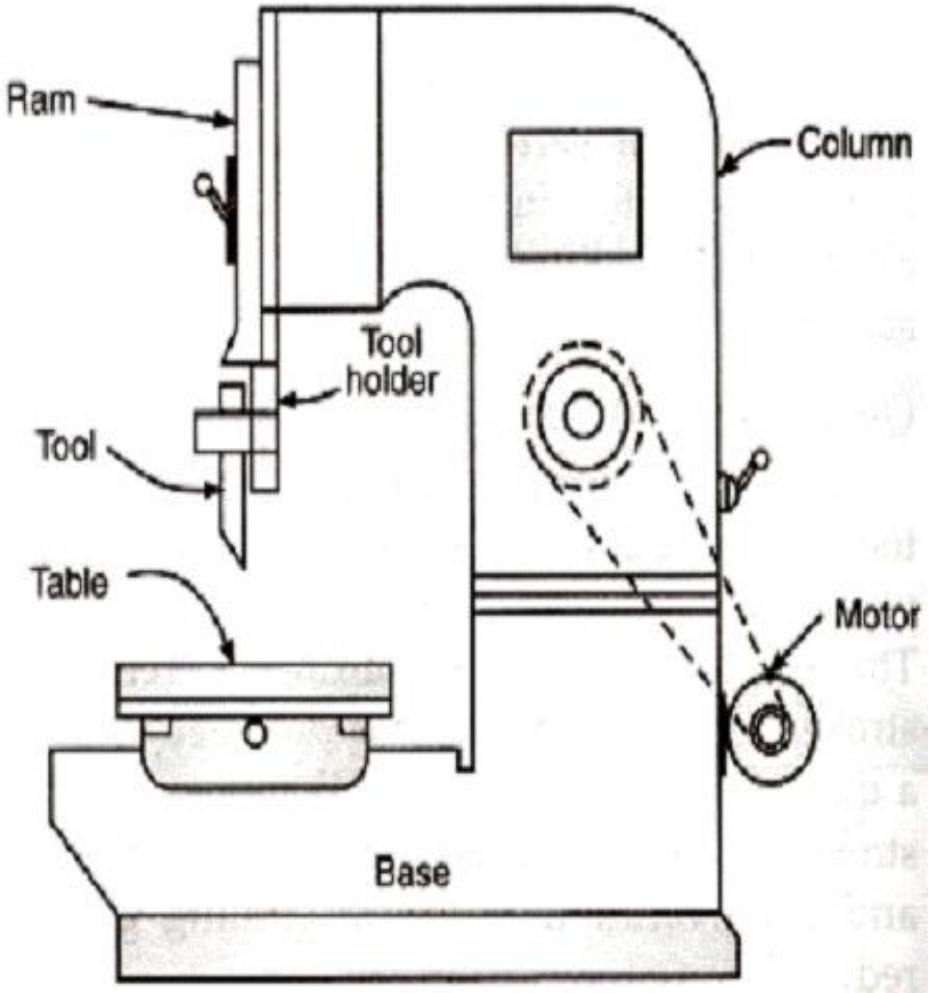
Introduction to slotter machine

- ✓ It is also called vertical Shaper
- ✓ The tool moves vertically rather than in a horizontal direction
- ✓ A rotary table is mounted on the regular table
- ✓ Used mostly for machining internal surfaces
- ✓ Slots and key ways can be made at quit accurately with spaced intervals
- ✓ It can work either outside or inside of part
- ✓ Generally for maintenance and repair work rather than production (mostly for piece production)

Photographic view of Slotter

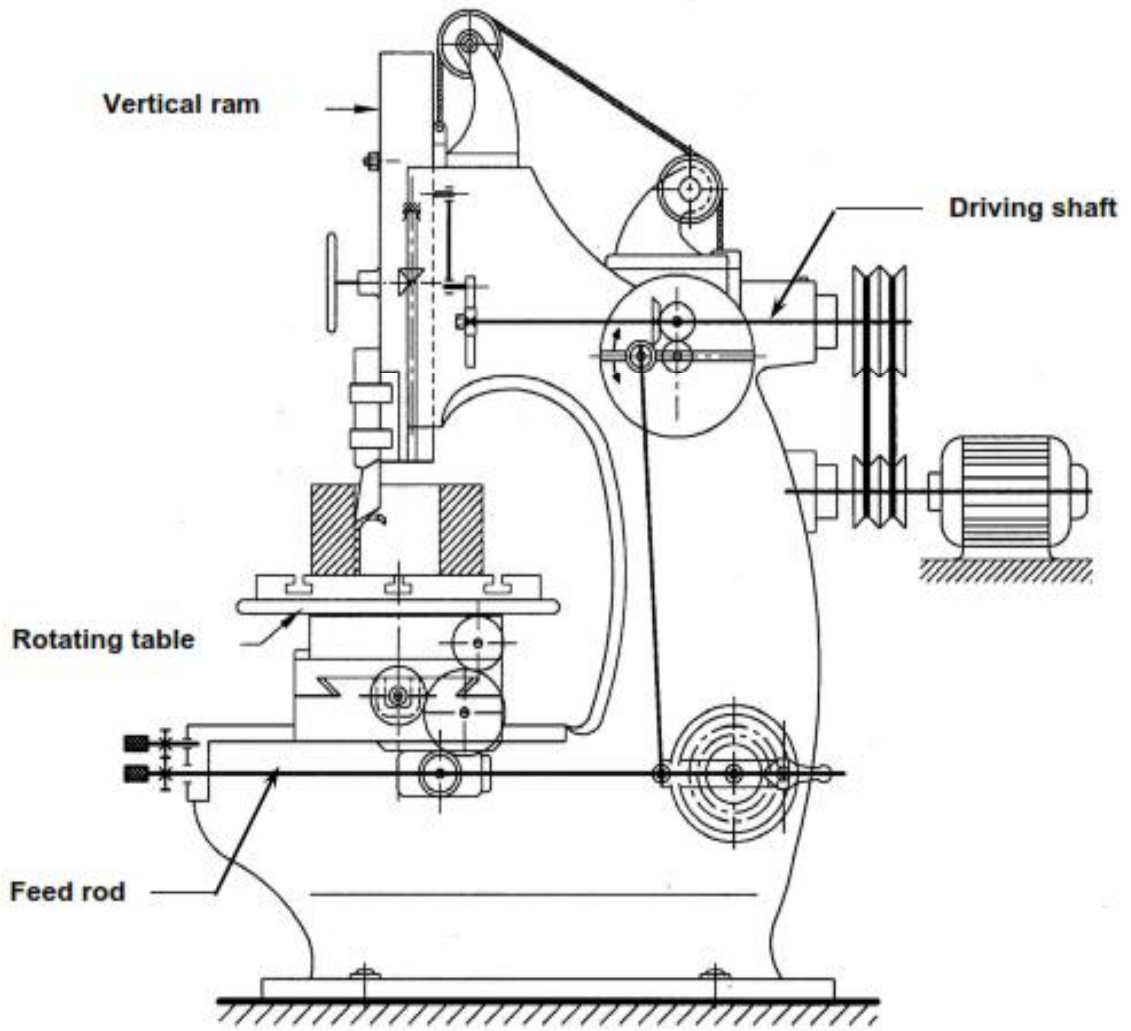


Principal parts



- Base
- Column
- Table
- Ram
- Tool Head

Kinematic system of slotter



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- ✓ Vertical tool reciprocation with down stroke acting
- ✓ The vertical slide holding the cutting tool is reciprocated by a crank and connecting rod mechanism.
- ✓ The job, to be machined, is mounted directly or in a vice on the work table.
- ✓ The intermittent rotation of the feed rod is derived from the driving shaft with the help of a four bar linkage as shown in the kinematic diagram.
- ✓ An additional rotary feed motion of the work table

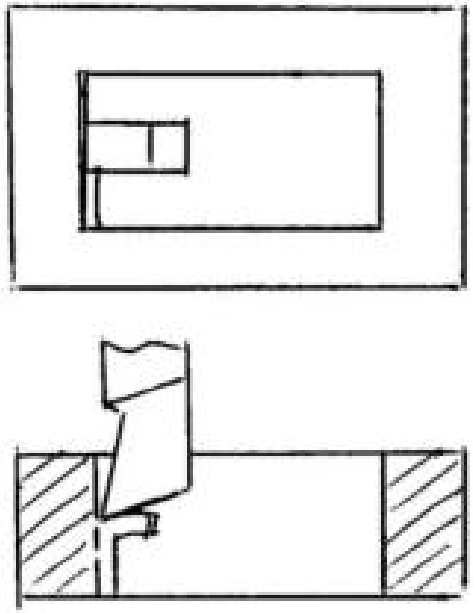
Types of slotter

- ✓ Punch slotter
- ✓ Tool room slotter
- ✓ Production slotter
- ✓ Special purpose slotter

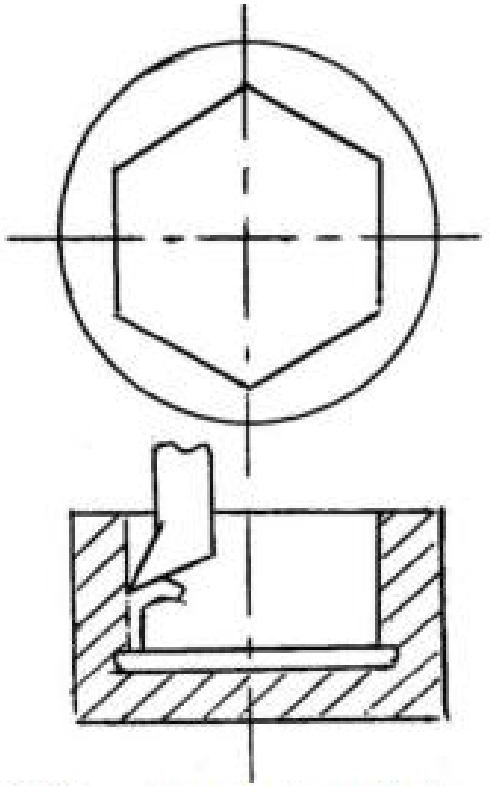
Operations / applications

- The following operations can be performed on the slotter
  - Internal flat surfaces
  - Enlargement and / or finishing non-circular holes – ‘n’ numbers
  - Blind geometrical holes like hexagonal socket
  - Cutting of
    - internal grooves
    - key ways
    - internal gears
    - slots
    - Recesses
    - Curved sections

Typical machining application



(a) through rectangular hole



(b) hexagonal socket

Work holding devices

- ✓ Clamps
- ✓ T-bolts & step block
- ✓ Vice
- ✓ Adjustable block
- ✓ Parallel strips
- ✓ Chuck
- ✓ Special fixtures for holding work

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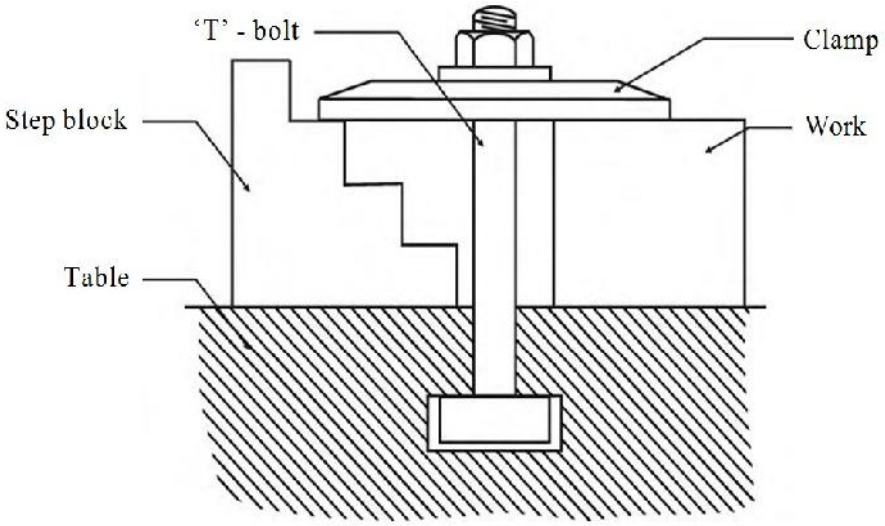
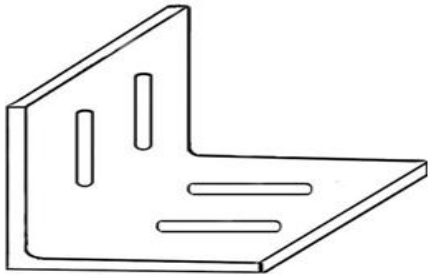


T- bolt, Clamp & Step Block

Adjustable block

T-slot clamp



Angle Plate

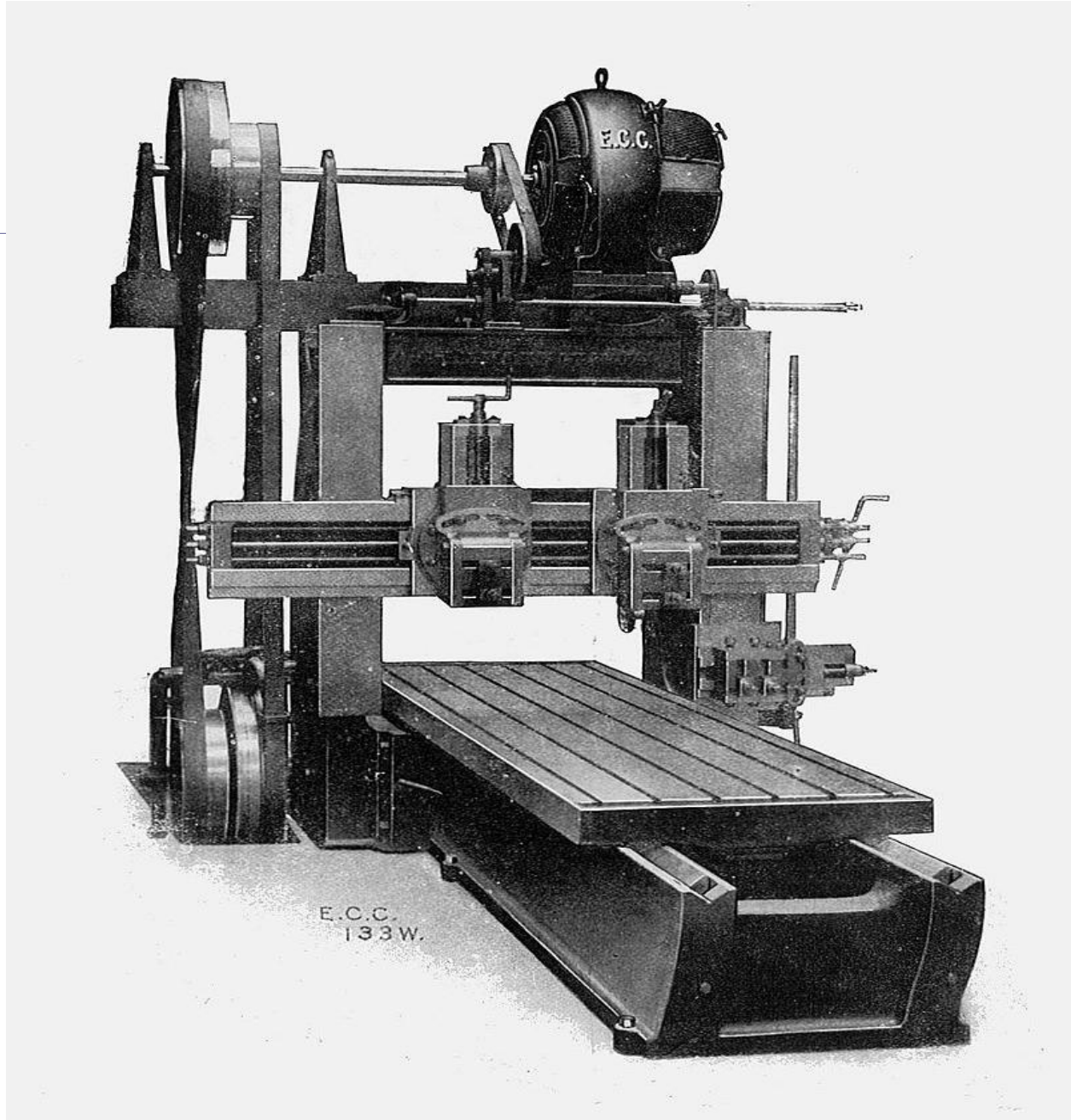
Plain Vice

Universal Vice

PLANER
MACHINE TOOL

Introduction to Planer

- ✓ A planer machine is used to produce plane & flat surface by single point cutting tool
- ✓ It is also a reciprocating type of machine tool
- ✓ Cutting speed is achieved by a reciprocating worktable that moves the part past the cutting tool
- ✓ It is similar to shaper but its size is very large and is adopted for producing flat surface of much larger work than a shaper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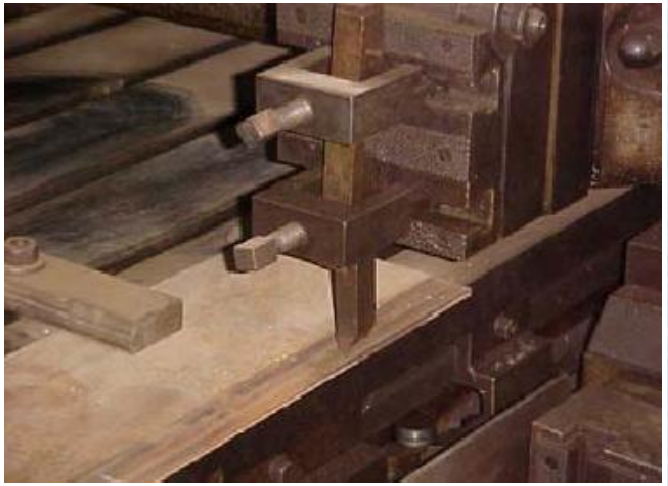
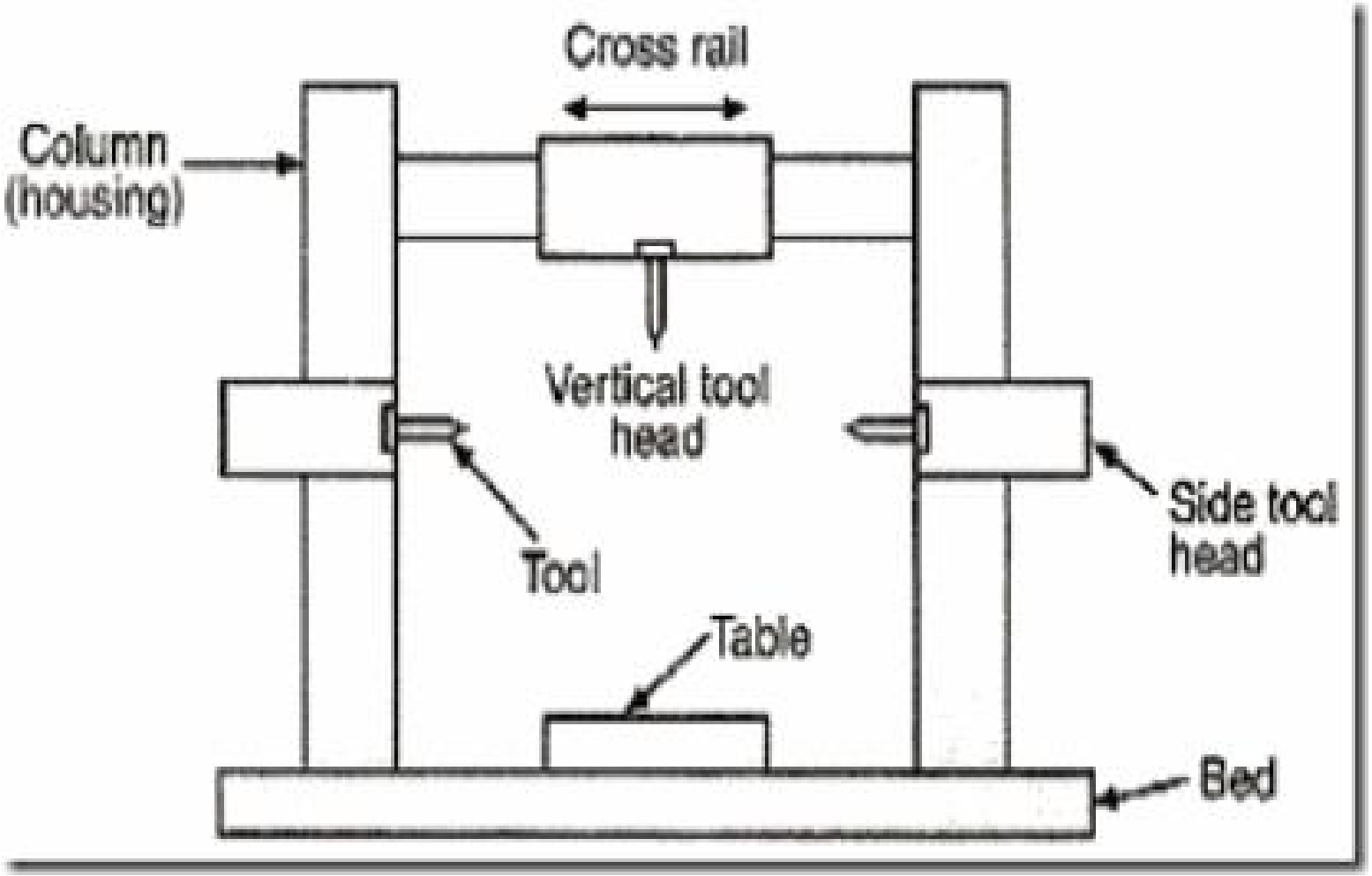
133W.

Photographic View of Planer



Principal Parts of Planer



Kinematic system of Planer

- ✓ The simple kinematic system of the planing machine enables transmission and transformation of rotation of the main motor into reciprocating motion of the large work table and the slow transverse feed motions (horizontal and vertical) of the tools
- ✓ The reciprocation of the table, which imparts cutting motion to the job, is attained by rack-pinion mechanism

Contd.,

- ✓ The rack is fitted with the table at its bottom surface and the pinion is fitted on the output shaft of the speed gear box which not only enables change in the number of stroke per minute but also quick return of the table
- ✓ The blocks holding the cutting tools are moved horizontally along the rail by screw-nut system and the rail is again moved up and down by another screw nut pair

Basic types of Planer

- ✓ The open side planer, also known as a single-housing planer
  - It has a single column supporting the cross rail on which a tool head is mounted
  - The configuration of the open side planer permits very wide work parts to be machined
- ✓ Double-housing planer
  - It has two columns, one on either side of the bed and worktable and housing are connecting at the top
  - The columns support the cross rail on which one or more tool heads are mounted
  - The two columns provide a more rigid structure for the operation but limit the width of the work that can be handled

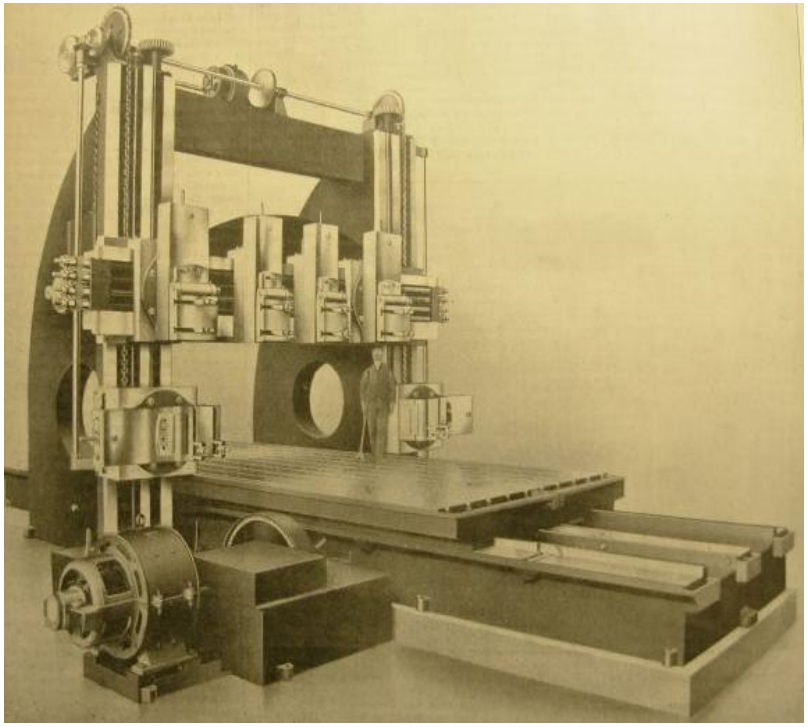
Other Types

- ✓ Pit Planer
- ✓ Plate Planer
- ✓ Planer (Plano) Miller or Grinder

Pit Planer

- ✓ **Used when work becomes extremely heavy**
- ✓ **Table is kept stationary and tool reciprocates**
- ✓ **Design is used to plane the largest kind of works**
- ✓ **It is convenient and economical to move machine than work piece**

Plate planer

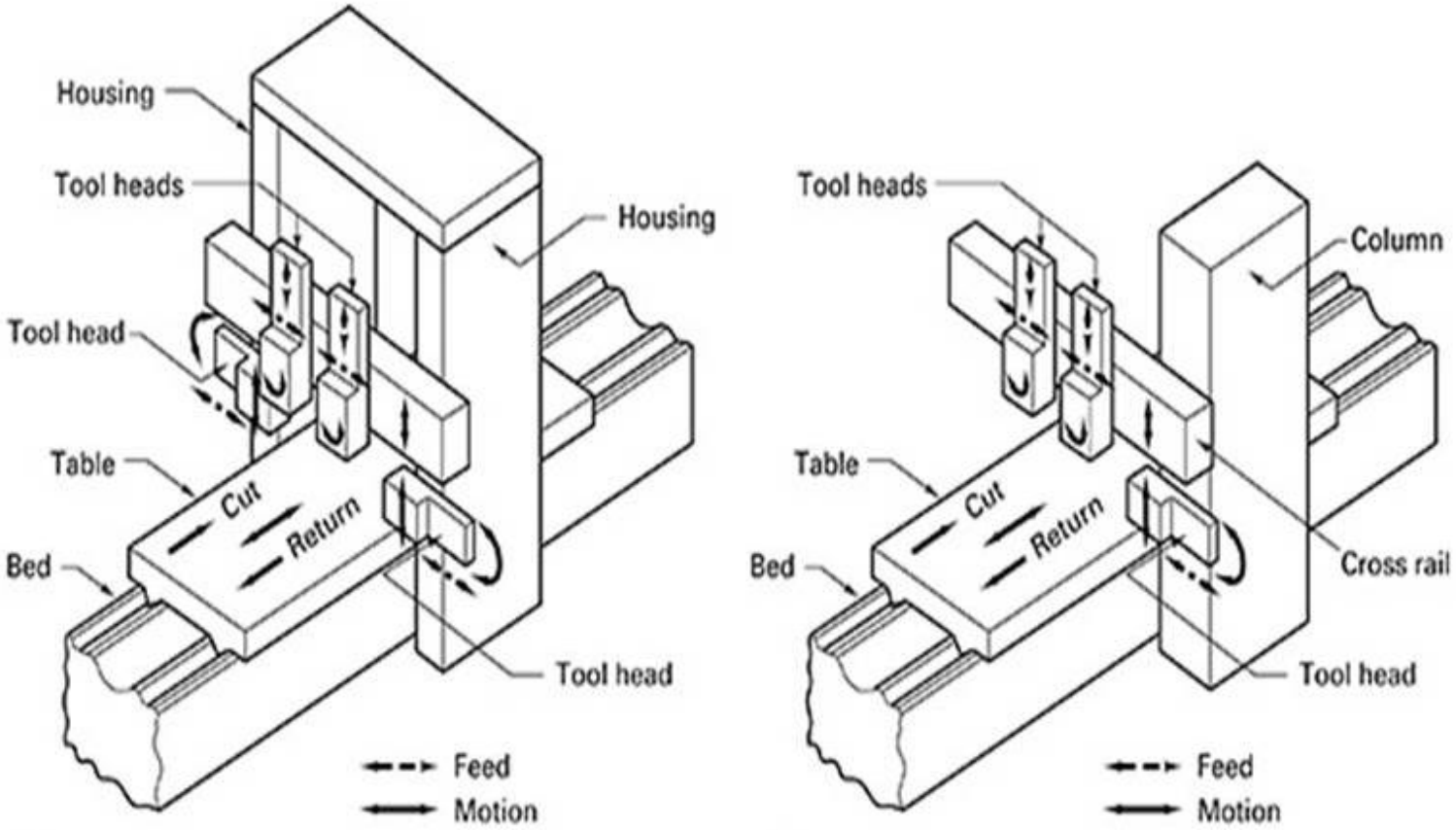


- ✓ **Special purpose machine tool designed**
- ✓ **Specially used for squaring or leveling edges of heavy steel plates**
- ✓ **The plate is clamped to a bed and the side mounted carriage is move back and forth**

Planer Miller / Grinder

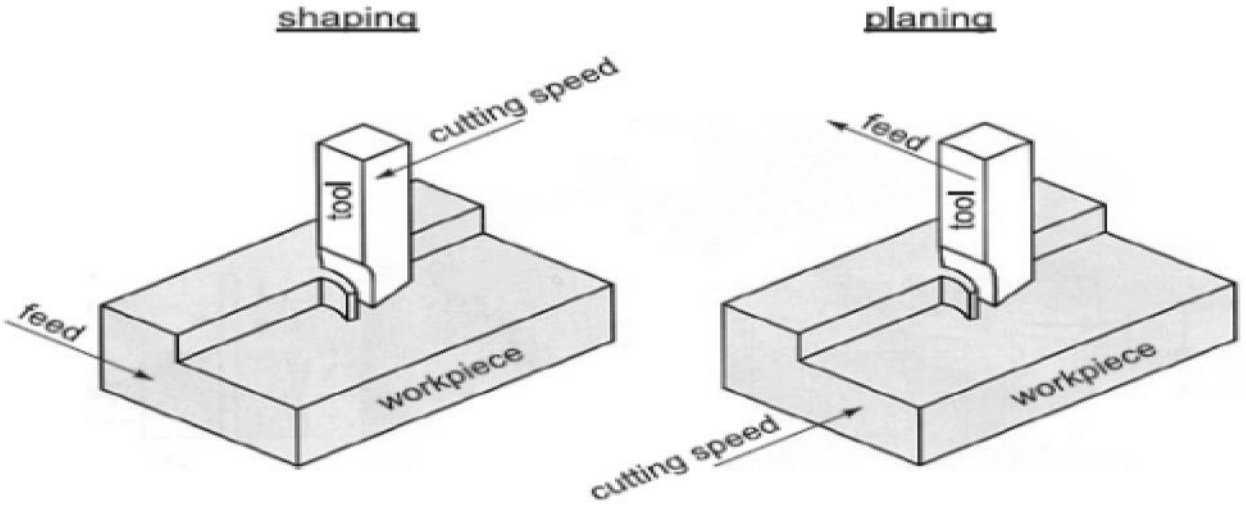
- ✓ **Same as Double Housing Planer**
- ✓ **It has milling cutter or a grinding head in place of one or more**
- ✓ **Conventional tool heads on cross rails**

Diff. in Basic types of Planer



Difference between Planer and Shaper

- ✓ Planing and shaping are similar operations, which differ in the kinematics of the process
- ✓ In planer, the primary cutting motion is performed by the work piece and feed motion is imparted by the cutting tool
- ✓ In shaper, the primary motion is performed by the tool, and feed by the work piece

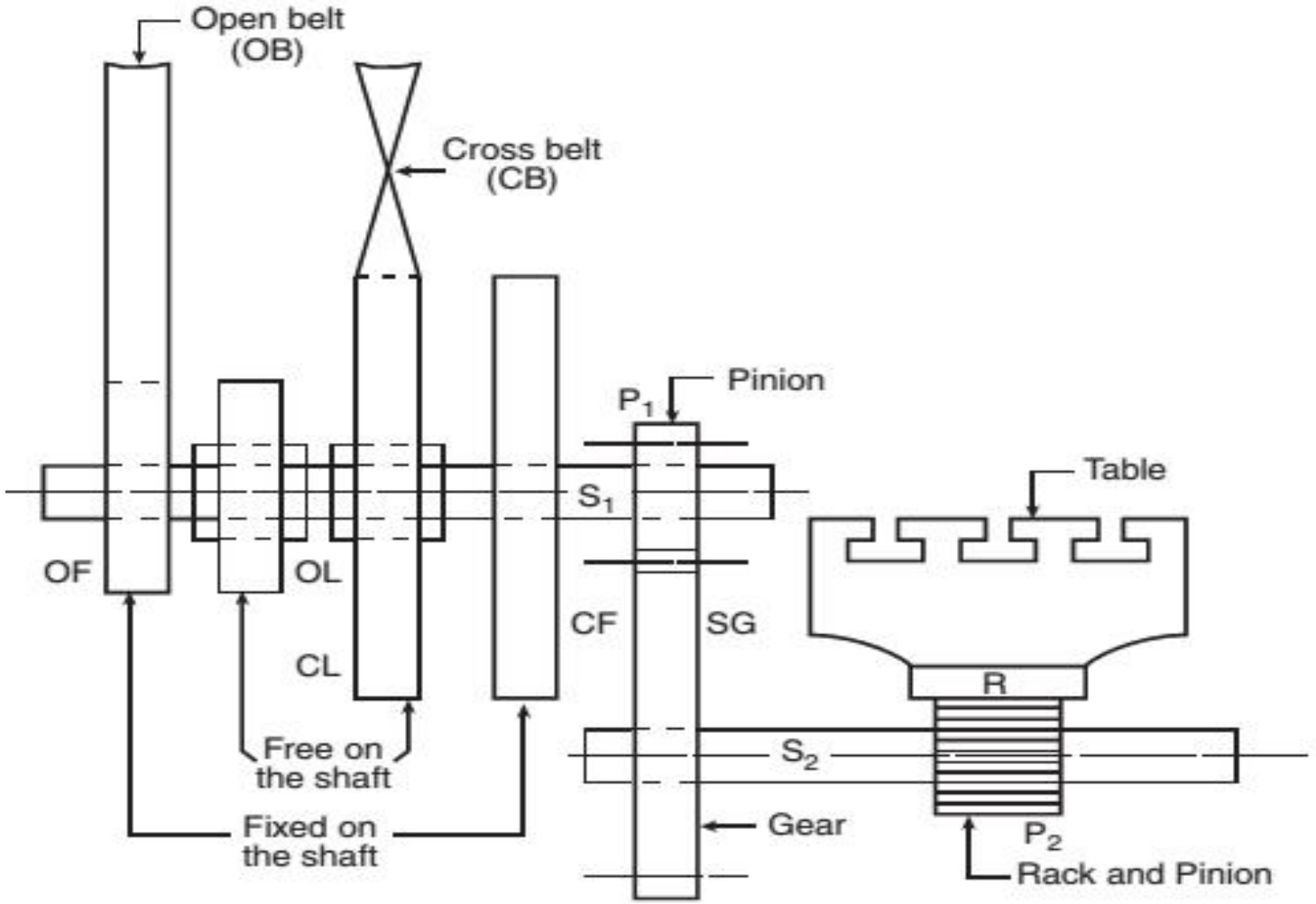


Kinematics of shaping and planing.

Operations of Planer Machine

- ✓ Planing flat horizontal, vertical and curved surfaces
- ✓ Planing at an angle and machining dovetails
- ✓ Slots and grooves

Quick Return Mechanism of Planer



Work Holding Devices

- ✓ Heavy duty vice
- ✓ T-bolts and Clamps
- ✓ Step blocks
- ✓ Poppets or stop pins
- ✓ Angle plates
- ✓ V-blocks
- ✓ Planer jacks
- ✓ Planer centres

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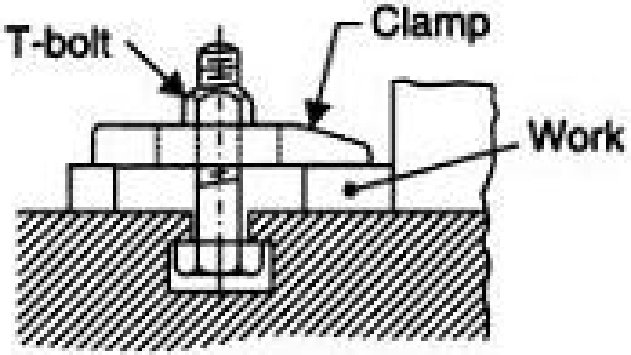
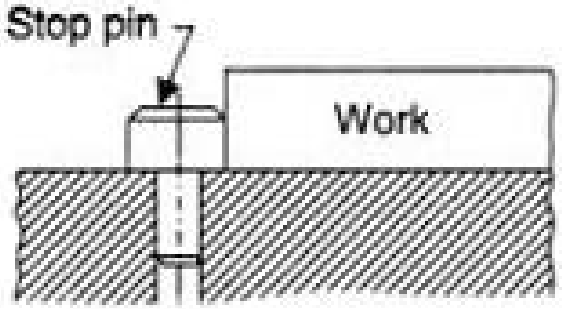
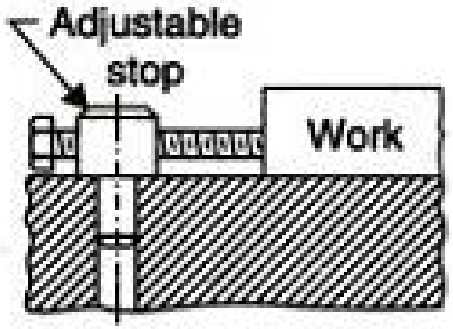


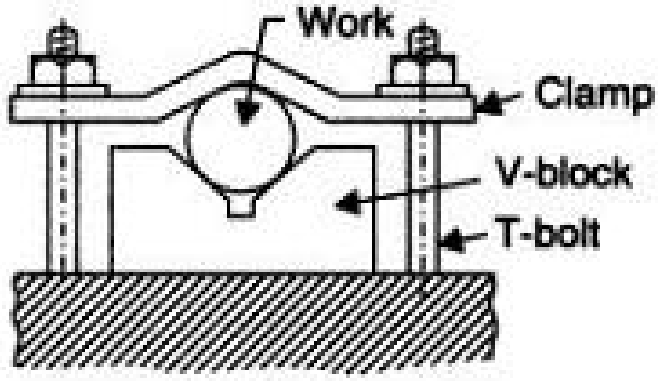
T-bolt and clamp



Stop pins



Adjustable stop



V-block

Driving & Feed System

- ✓ Tool Heads maybe fed in crosswise or vertical direction.
- ✓ Motor drive is usually at one side of planar & drive mechanism is located under the table.
- ✓ V=LN(1+K)/1000 m/min
  - where, V= speed of cut

    L= length of ram stroke

    N= no. of full stroke

    K= ratio of return time to cutting time

MILLING MACHINE TOOL

Introduction to Milling

- **Milling:** is a metal cutting operation in which the excess material from the work piece is removed by rotating multipoint cutting tool called milling cutter.

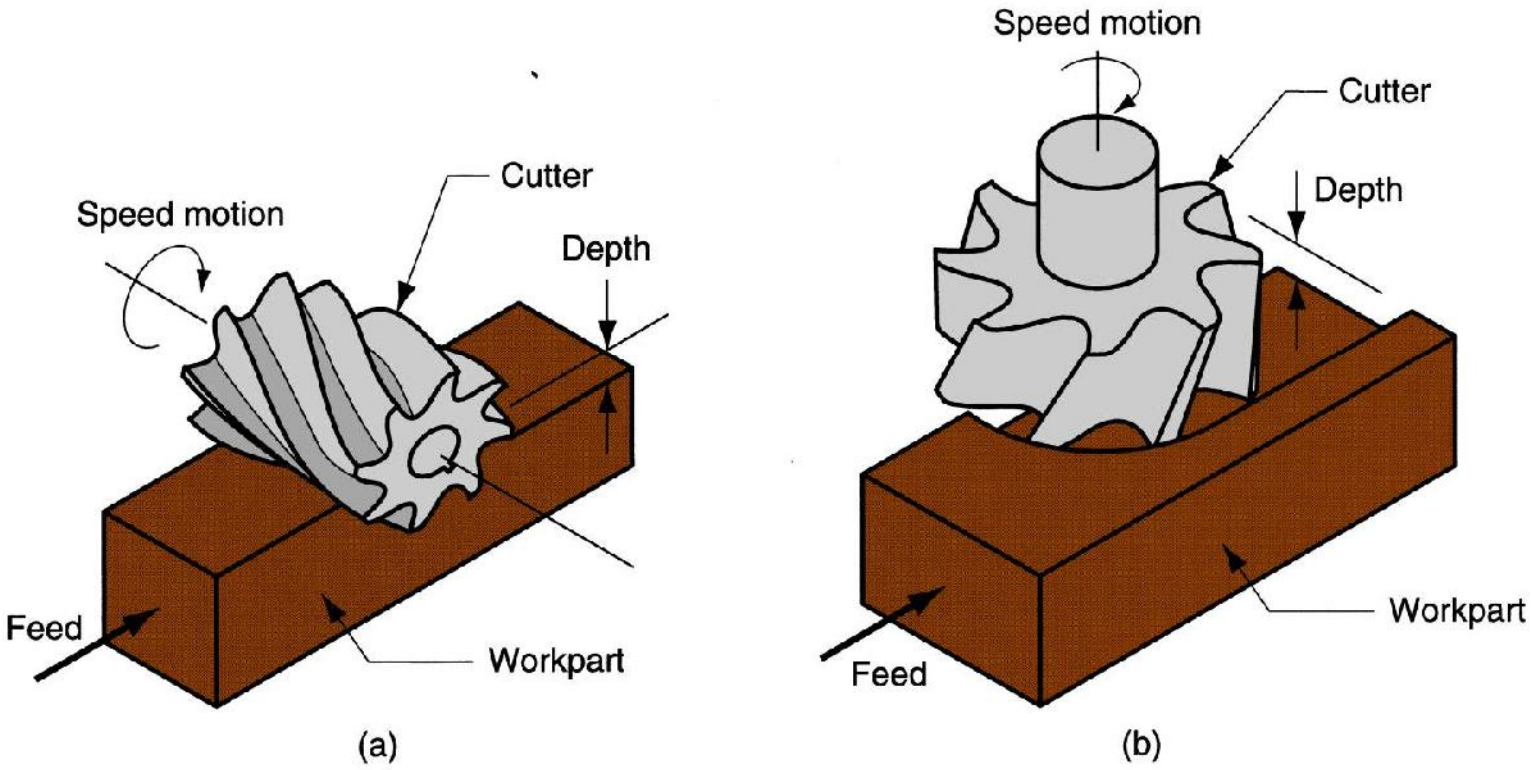
- **Milling machine:** is a power operated machine tool in which work piece mounted on a moving table is machined to various shapes when moved under a slow revolving serrated cutter.

Contd.,

- ✓ In milling machine, The cutting tool is held on a spindle called arbor and the work piece is fixed on a table
- ✓ The table reciprocates past the cutting tool and metal removal takes place
- ✓ Feed for the next cut and the depth of the cut are given by the movement of the table
- ✓ Each tooth has the same profile
- ✓ Each tooth after taking a cut comes in operation after some interval
- ✓ This allows the tool to cool down before the next cut takes place

Photographic view of milling machine

Two Forms of Milling

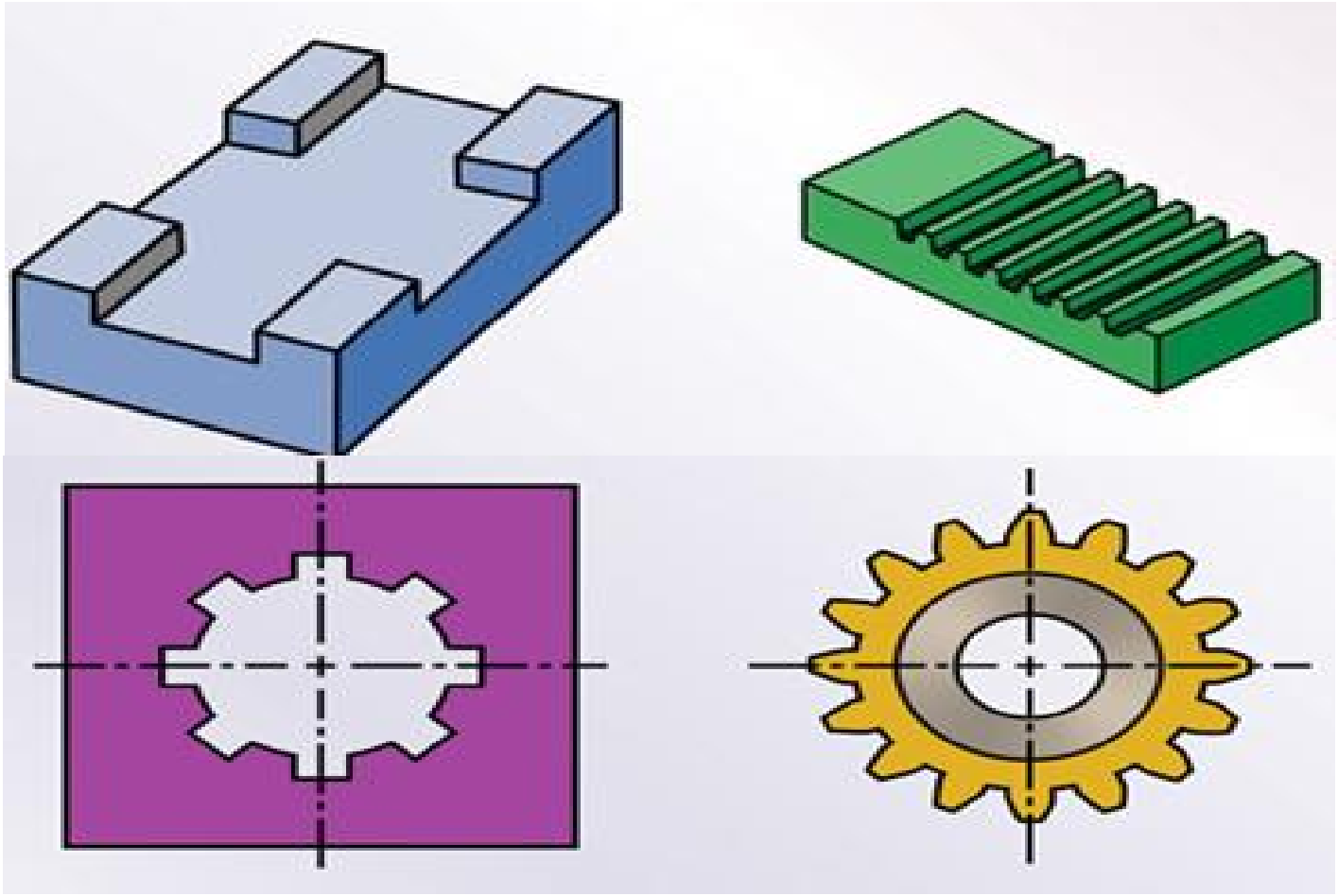


Two forms of milling: (a) peripheral milling, and (b) face milling.

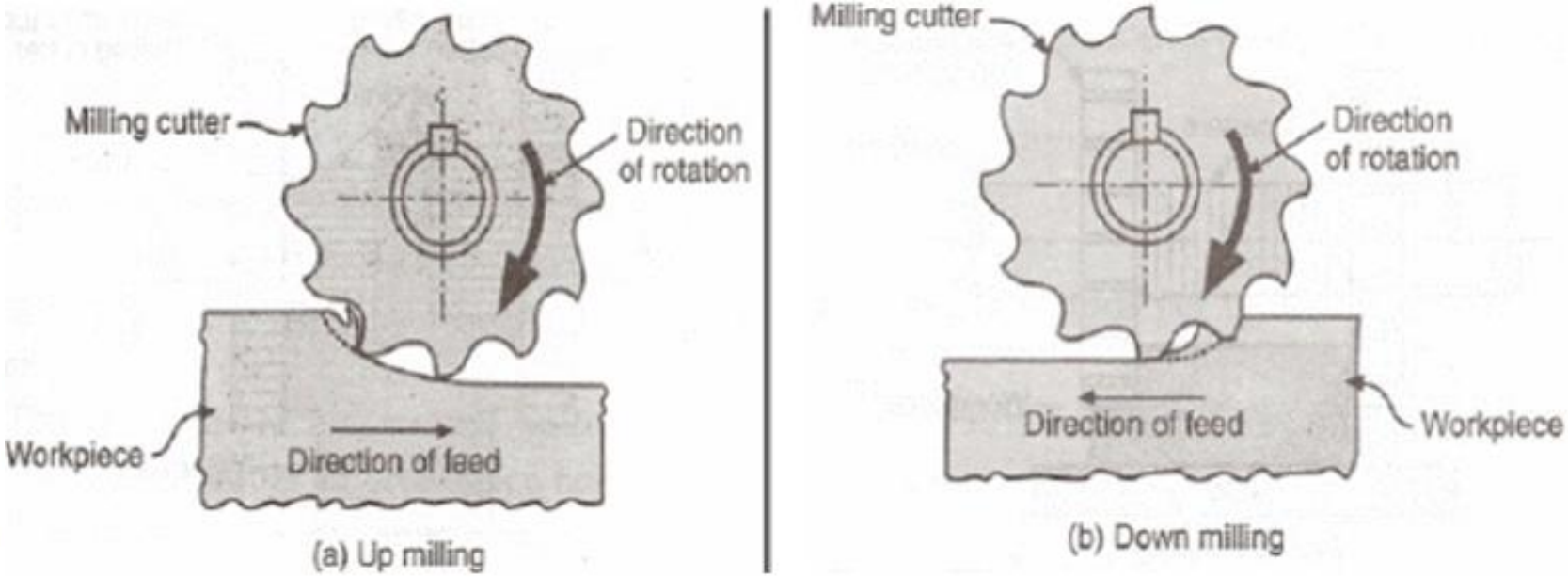
Peripheral Milling vs. Face Milling

- ✓ Peripheral milling
  - – Cutter axis parallel to surface being machined
  - – Cutting edges on outside periphery of cutter
- ✓ Face milling
  - – Cutter axis perpendicular to surface being milled
  - – Cutting edges on both the end and outside periphery of the cutter

Basic uses of Milling machine



Principle of Milling



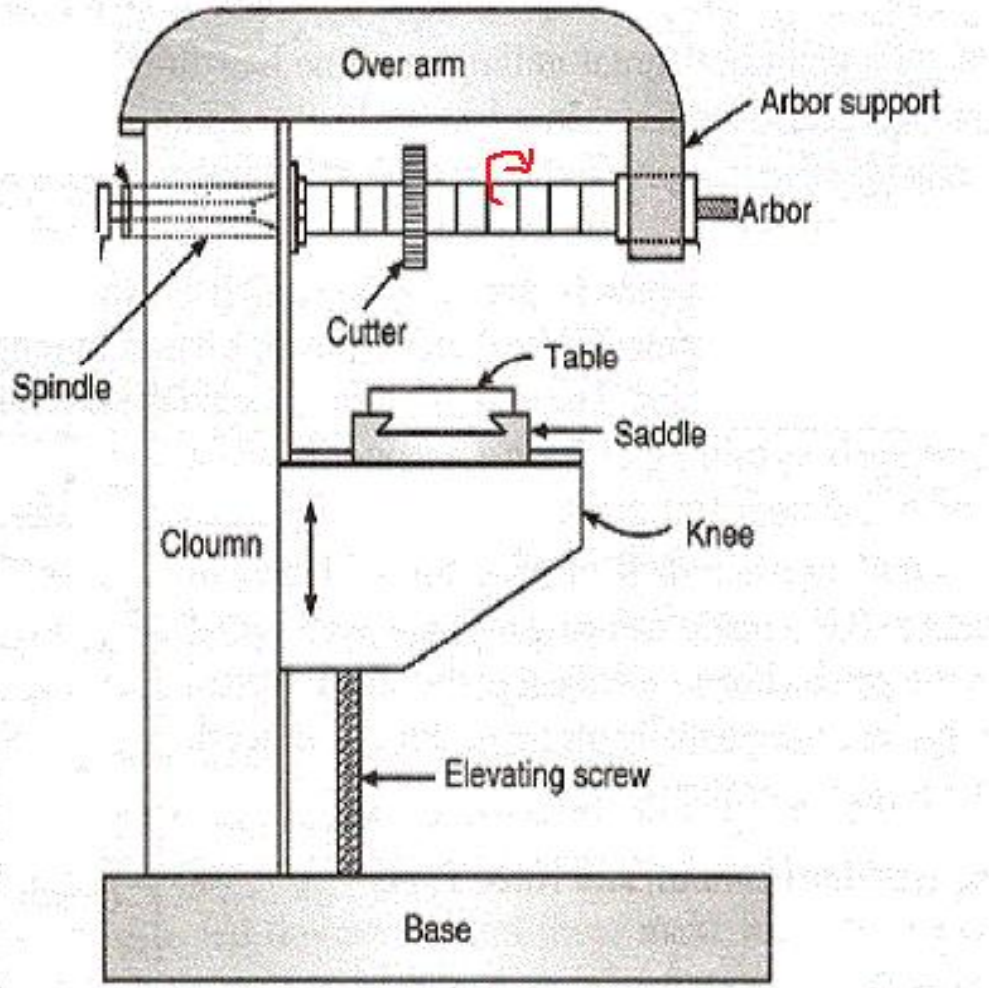
SL. NO.	UP MILLING (CONVENTIONAL MILLING)	DOWN MILLING (CLIMB MILLING)
01	Work piece fed in the opposite direction that of the cutter.	Work piece fed in the same direction that of the cutter.
02	Chips are progressively thicker.	Chips are progressively thinner.
03	Strong clamping is required since the cutting force is directed upwards & tends to lift the work piece.	Strong clamping is not required since the cutting force is directed downwards & keep the work piece pressed to the table.
04	Gives poor surface finish, since chips gets accumulated at the cutting zone.	Gives good surface finish, since the chips are thrown away during cutting.
05	Used for hard materials.	Used for soft materials and finishing operations.

Classification

1. Column and knee milling machines
    a. Horizontal spindle type
    b. Vertical spindle type
    c. Universal type
2. Bed type milling machine
    a. Simplex
    b. Duplex
    c. Triplex
3. Planer type milling machine (Plano millers)

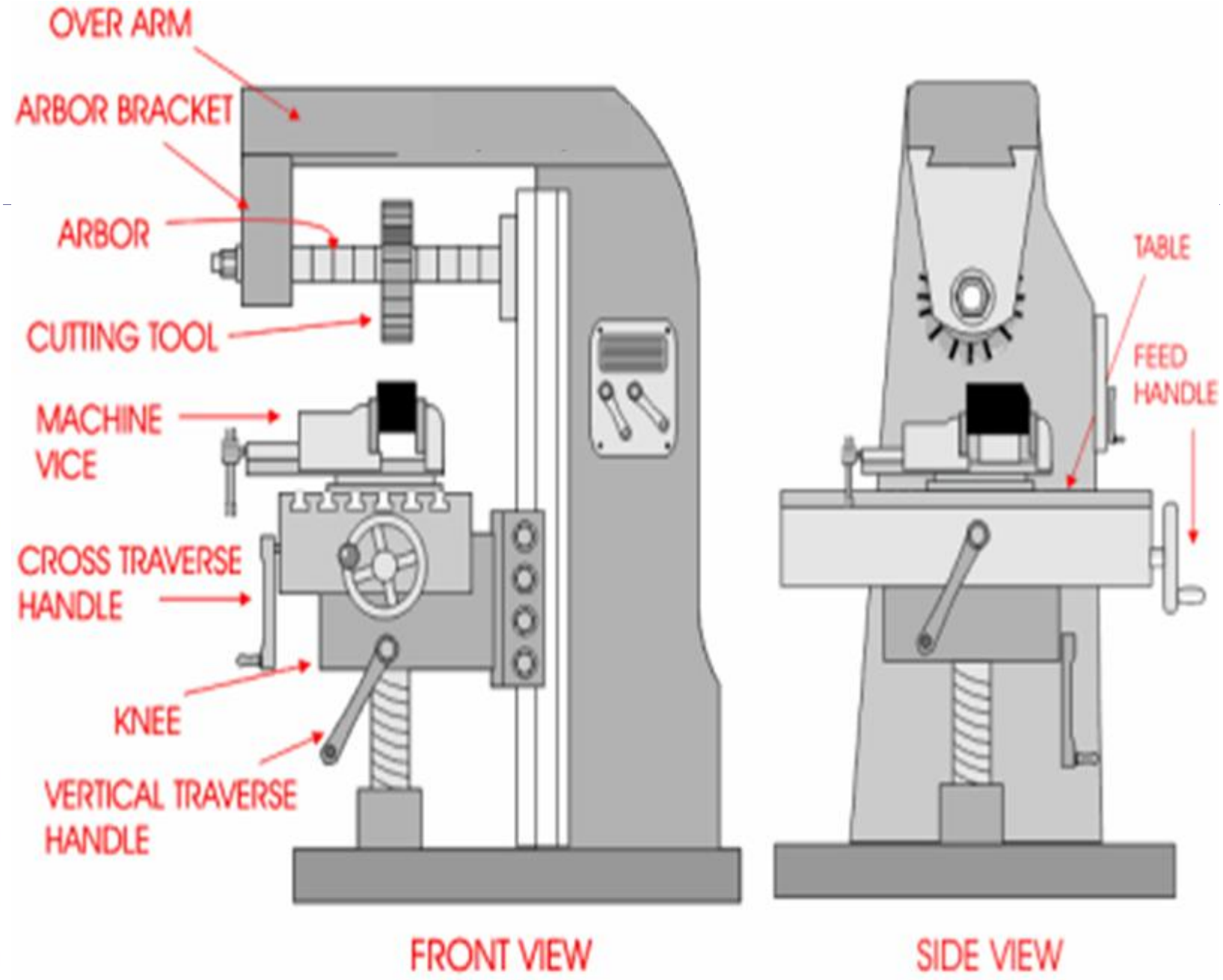
4. Special purpose milling machine
    a. Tracer controlled milling machine
    b. Thread milling machine
    c. CNC milling machine

Horizontal Milling Machine

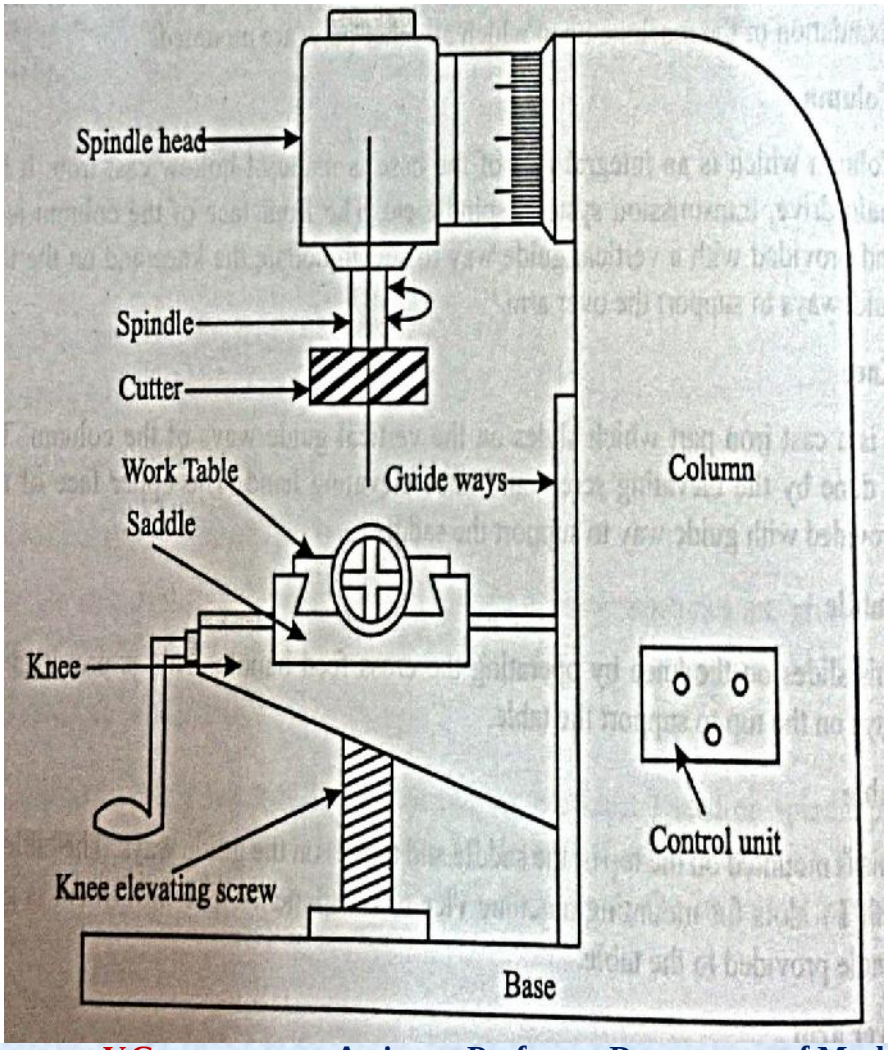


MAJOR PARTS

- **Base**
- **Column**
- **Spindle**
- **Over arm**
- **Knee**
- **Saddle**
- **Worktable**


OVER ARM
ARBOR BRACKET
ARBOR
CUTTING TOOL
MACHINE VICE
CROSS TRAVERSE HANDLE
KNEE
VERTICAL TRAVERSE HANDLE
TABLE
FEED HANDLE
FRONT VIEW
SIDE VIEW

Vertical Milling Machine



MAJOR PARTS

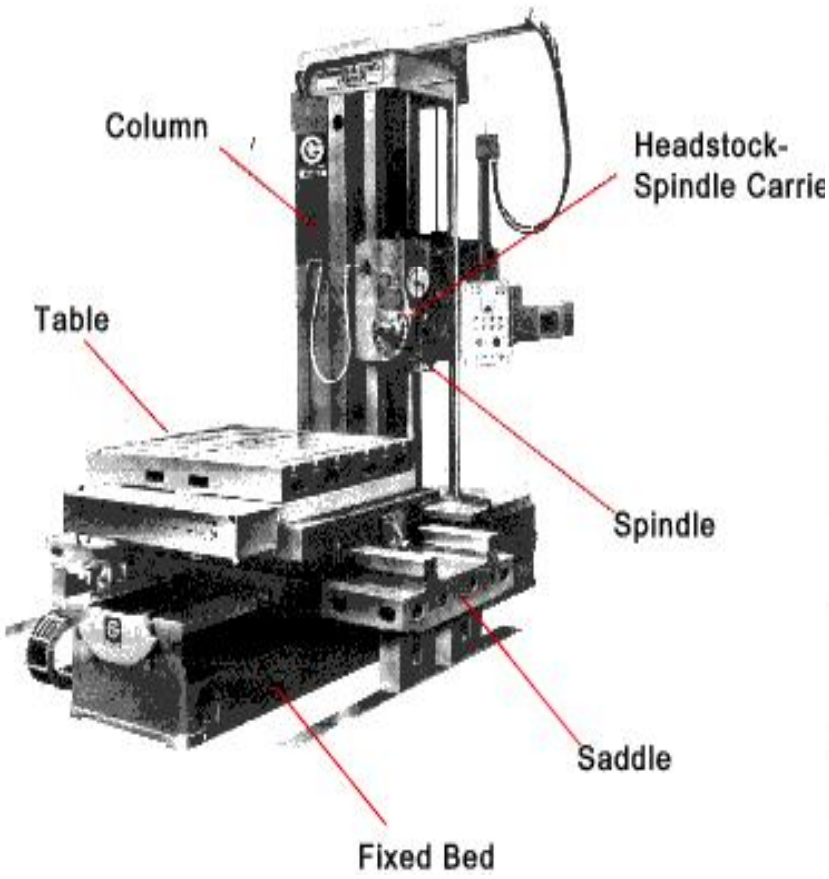
- **Base**
- **Column**
- **Spindle**
- **Spindle Head**
- **Knee**
- **Saddle**
- **Worktable**

SL. NO.	HORIZONTAL MILLING MACHINE	VERTICAL MILLING MACHINE
01	Spindle is horizontal & parallel to the worktable.	Spindle is vertical & perpendicular to the worktable.
02	Cutter cannot be moved up & down.	Cutter can be moved up & down.
03	Cutter is mounted on the arbor.	Cutter is directly mounted on the spindle.
04	Spindle cannot be tilted.	Spindle can be tilted for angular cutting.
05	Operations such as plain milling, gear cutting, form milling, straddle milling, gang milling etc., can be performed.	Operations such as slot milling, T-slot milling, angular milling, flat milling etc., can be performed and also drilling, boring and reaming can be carried out.

Universal Type

Universal Knee Type Milling Machine

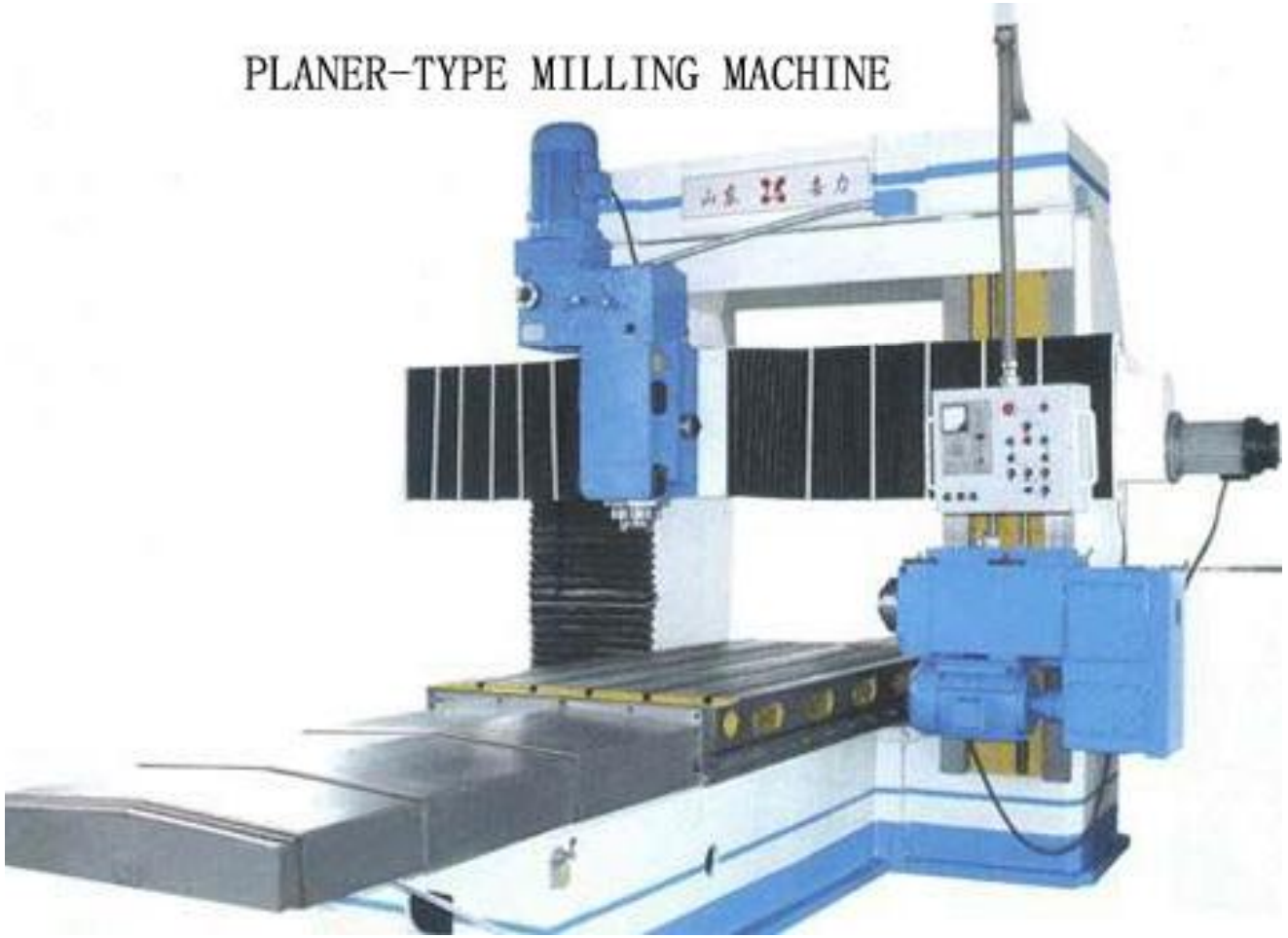
Bed Type


Column
Headstock-
Spindle Carrie
Table
Spindle
Saddle
Fixed Bed

Planer type milling machines

- ✓ Utilize several milling heads
- ✓ Can remove large amount of metal while permitting the table and work piece to move quite slowly
- ✓ Often, only single pass is required
- ✓ Good for heavy pieces

Contd.,



Special types

- ✓ **Tracer mills (Profiling milling machines):**
  - Also called duplicators
  - Designed to reproduce an irregular part geometry that can be created on an template
  - In two dimensions- ***tracer***
  - In three dimensions- ***duplicator***
- ✓ **CNC milling machines:**
  - Cutter path controlled by numerical data
  - Suited to profile, pocket, surface contouring.

Specifications of Milling Machine

- ✓ Size of the work table: expressed in length x width
- ✓ Longitudinal movement: Total movement of table in mm (X-direction)
- ✓ Transverse movement: Total movement of saddle along with table in mm (Y-direction)
- ✓ Vertical movement: Total movement of table, saddle & knee in mm mm (Z-direction)
- ✓ Range of the speed: Speed variation in the gear box in RPM
- ✓ Power capacity of the motor in HP

Milling Cutters

- ✓ The tool used in milling is known as a ***milling cutter***, the cutting edges called teeth. Types of milling cutters are related to the milling operations can be classified as:
- ✓ **Plain milling cutters:**
  - Used in peripheral milling operations
  - Cylindrical or disk shaped
  - Have several straight or helical teeth on periphery
  - Used to mill flat surfaces
- ✓ **Side milling cutters:**
  - Similar to plain milling cutters
  - Teeth extend radial part way across one or both ends of cylinder toward the center
  - Relatively narrow

Contd.,

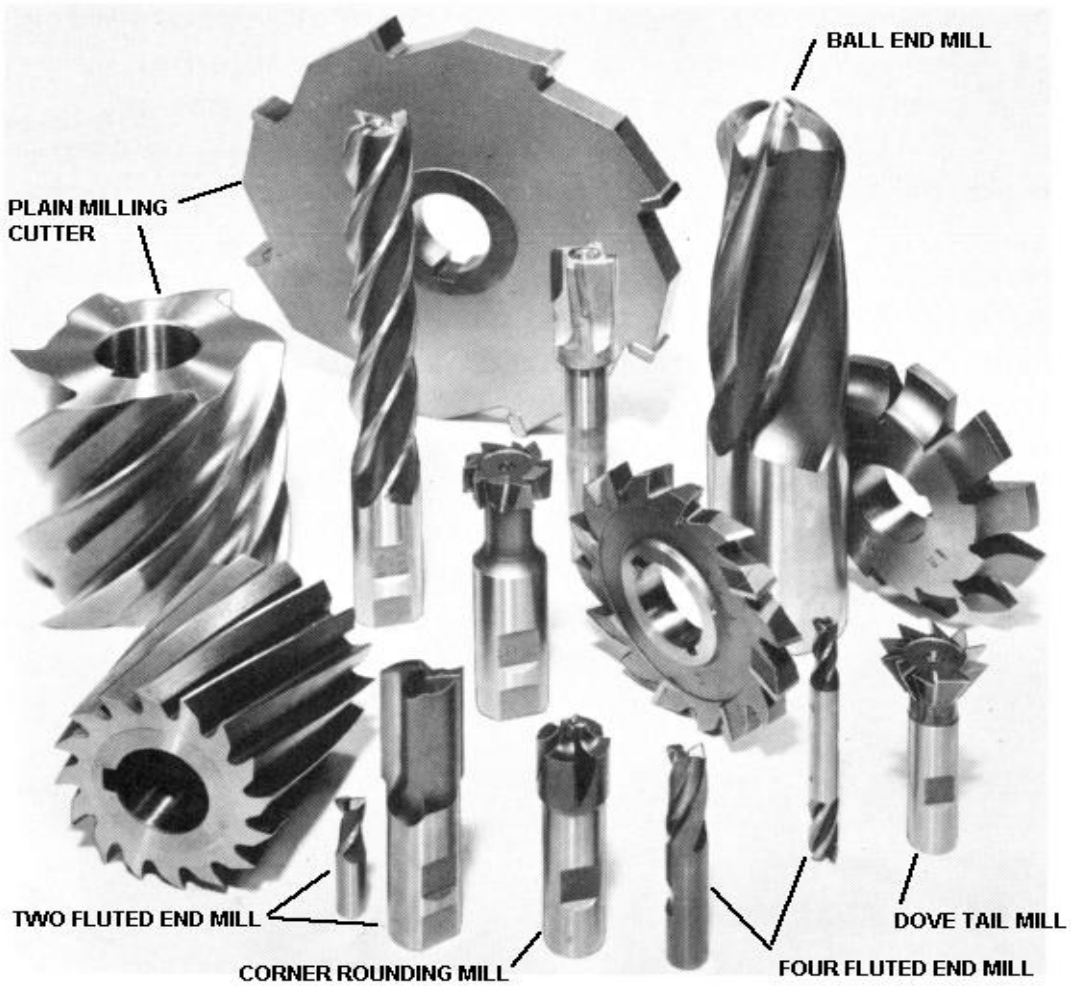
- **Form milling cutters:**
  - Another peripheral milling cutter
  - Teeth ground to a special shape to produce a surface having a desired transverse contour, convex, concave shape.
- **End milling cutters:**
  - Looks like a drill bit, but it cuts with peripheral teeth instead of it's end.
  - Have multiple teeth
  - Used in milling slots, profiling and facing narrow surfaces.

Contd.,

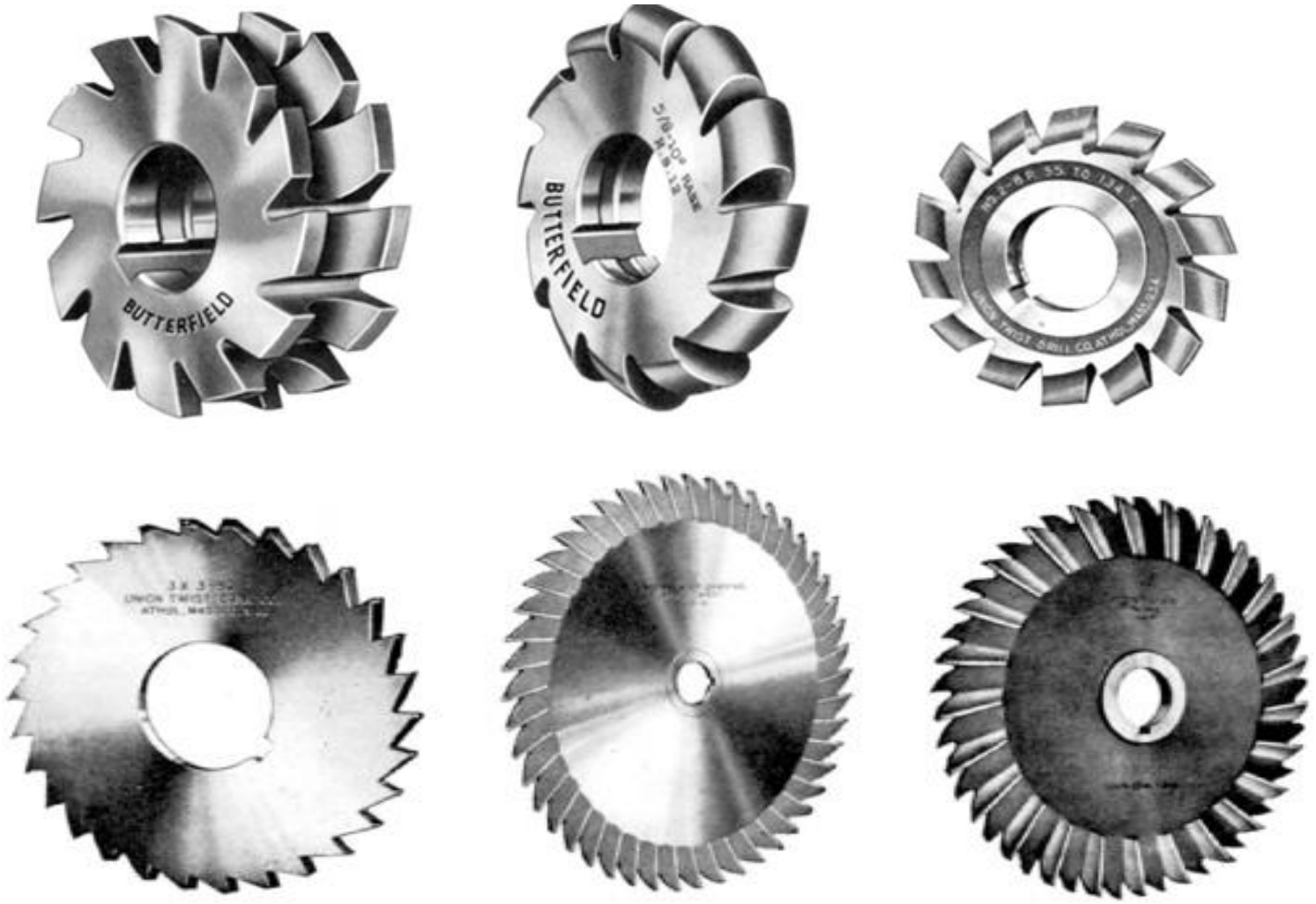
- ✓ **Face milling cutters:**
  - Have teeth on periphery and both sides
  - Made of HSS
- ✓ **T-slot cutters:**
  - Have teeth on periphery and both sides
  - Used for milling the wide groove of a T-slot
  - In order to use them, a vertical groove must first be made with a slotting mill or an end mill to provide a clearance for the shank
  - T-slot cutter must be fed carefully, because it cuts in 5 surfaces

Face-Milling Cutter with Inserts

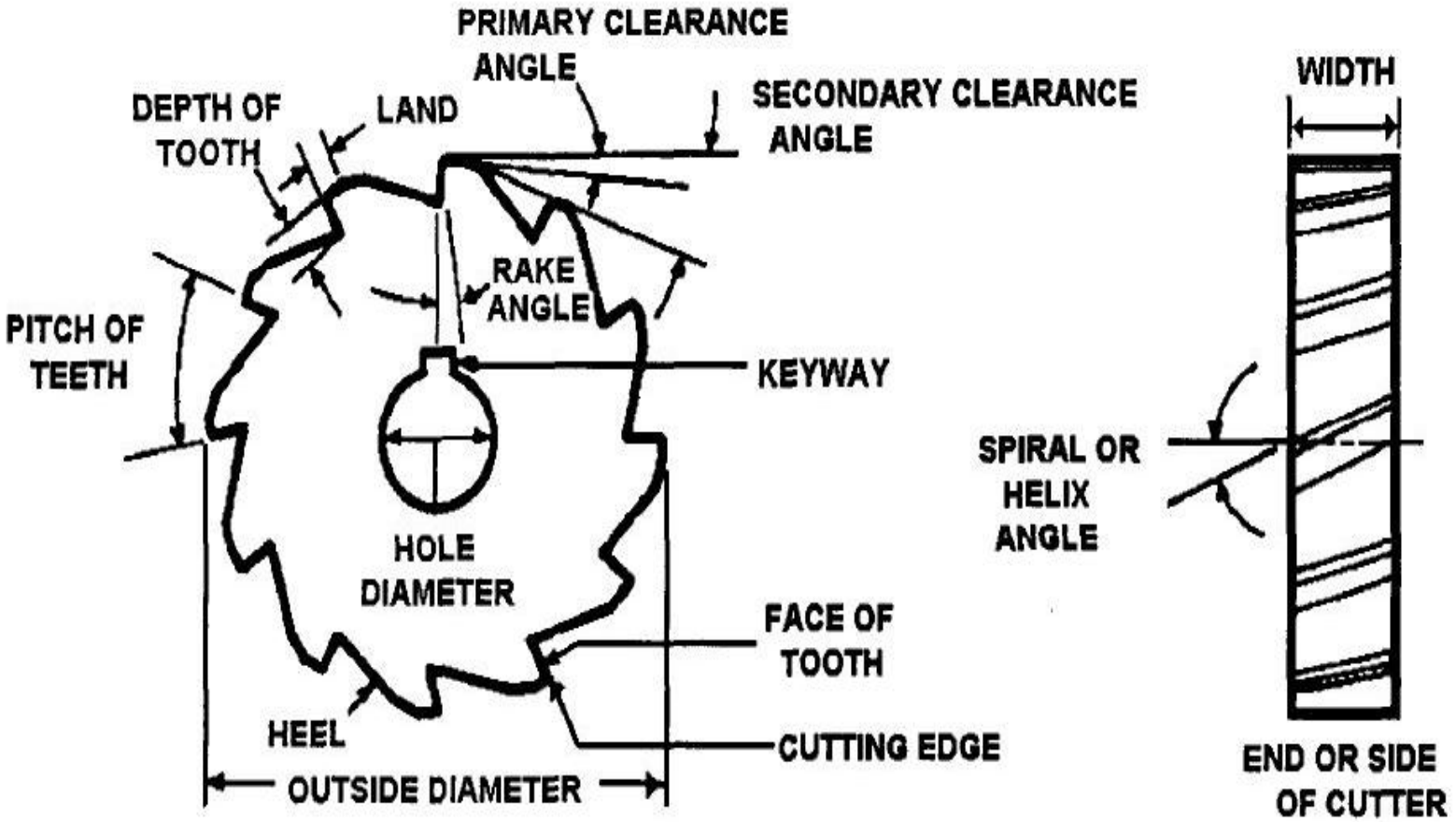
Contd.,


BALL END MILL
PLAIN MILLING CUTTER
TWO FLUTED END MILL
CORNER ROUNDING MILL
FOUR FLUTED END MILL
DOVE TAIL MILL

Contd.,



Nomenclature of a Plain Milling cutter



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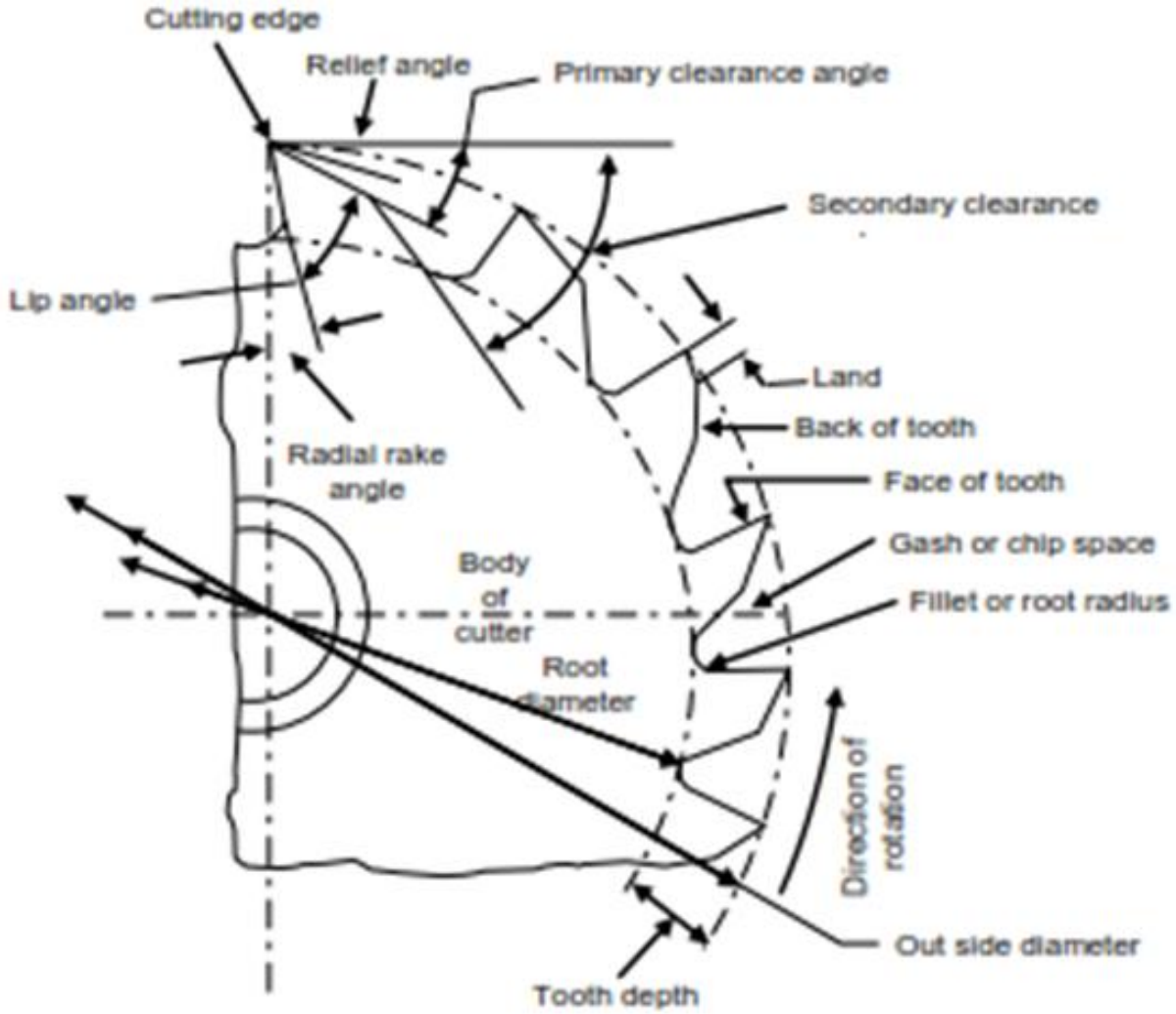
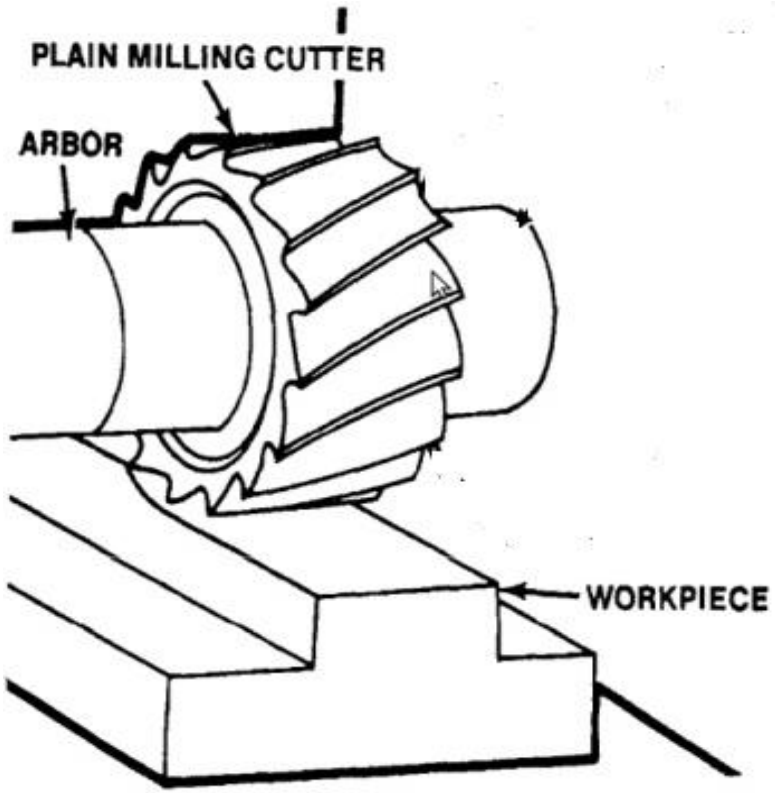

Cutting edge
Relief angle
Primary clearance angle
Secondary clearance
Lip angle
Land
Back of tooth
Radial rake angle
Face of tooth
Gash or chip space
Body of cutter
Fillet or root radius
Root diameter
Direction of rotation
Out side diameter
Tooth depth

Milling Operations

- ✓ Plain or slab milling
- ✓ Face milling
- ✓ End milling
- ✓ Slot milling
- ✓ Angular milling
- ✓ Form milling
- ✓ Straddle milling
- ✓ Gang milling
- ✓ Slitting or saw milling
- ✓ Gear cutting

Plain / Surface / Slab Milling

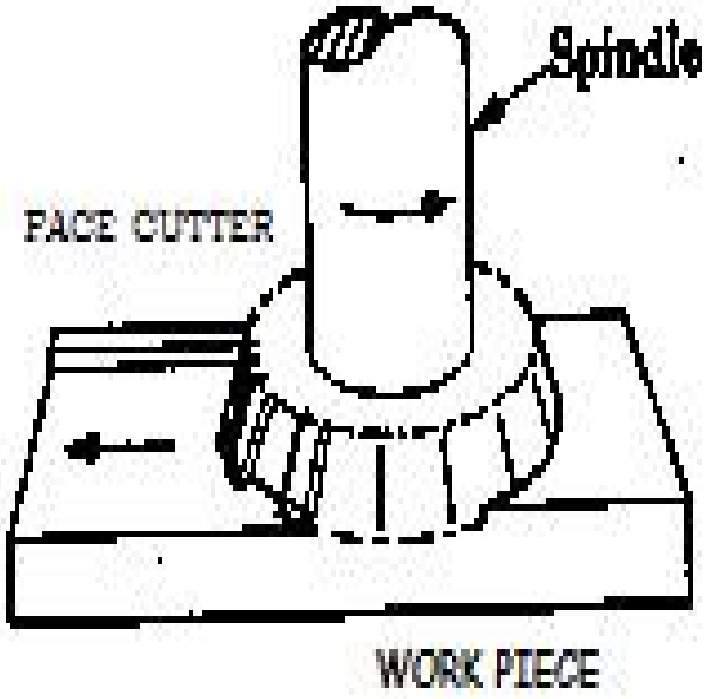


Plain Milling:
Process to get the flat surface on the work piece in which the cutter axis and work piece axis are parallel.

Cutter: Plain/ Slab milling cutter.

Machine: Horizontal Milling m/c.

Face Milling

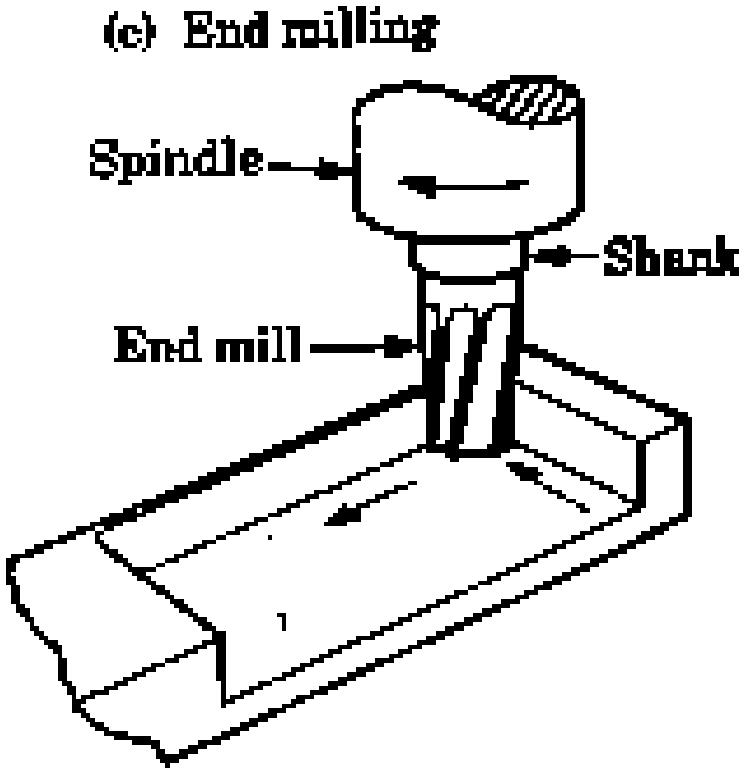


Face Milling:
Operation carried out for producing a flat surface, which is perpendicular to the axis of rotating cutter.

Cutter: Face milling cutter.

Machine: Vertical Milling Machine

End Milling

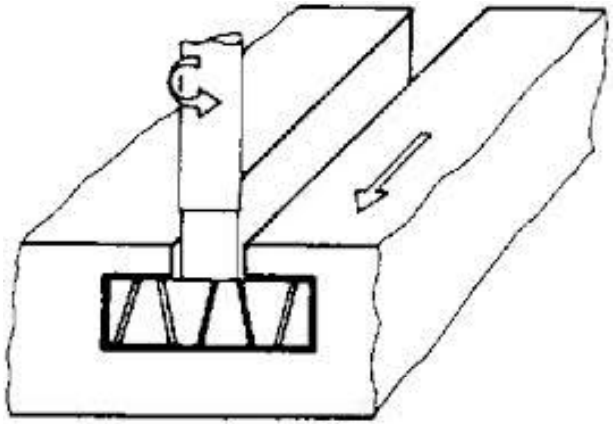


End Milling:
Operation performed for producing flat surfaces, slots, grooves or finishing the edges of the work piece.

Cutter: **End milling cutter.**

Machine: **Vertical Milling Machine**

Slot Milling



T-slot Milling

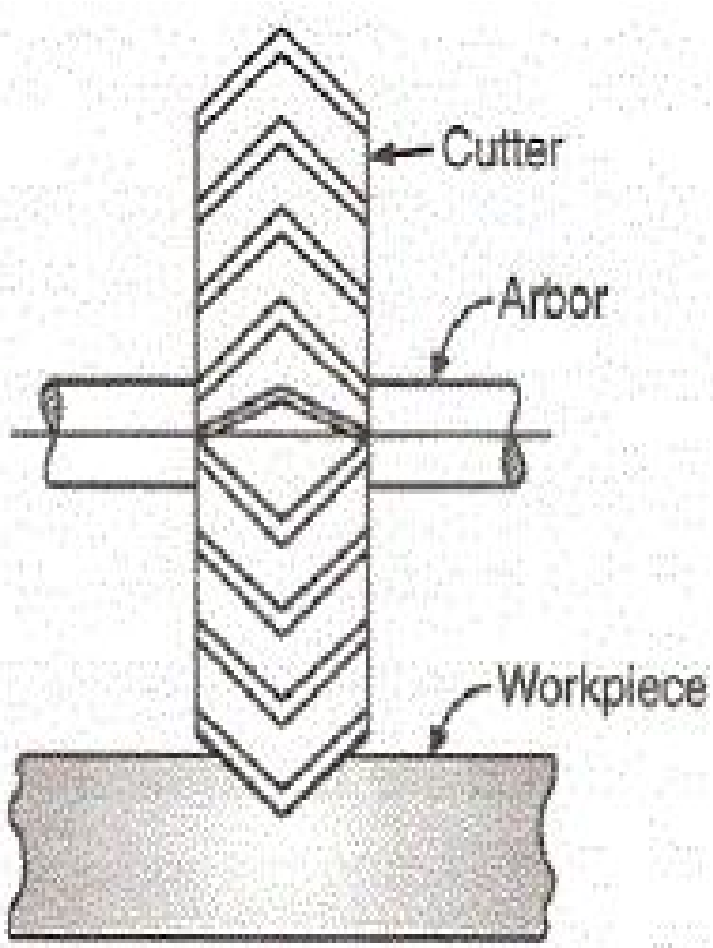
Dove Tail Slot Milling

Slot Milling:
Operation of producing slots like T-slots, plain slots, dovetail slots etc.,

Cutter: End milling cutter, T-slot cutter, dovetail cutter or side milling cutter

Machine: Vertical Milling Machine

Angular Milling

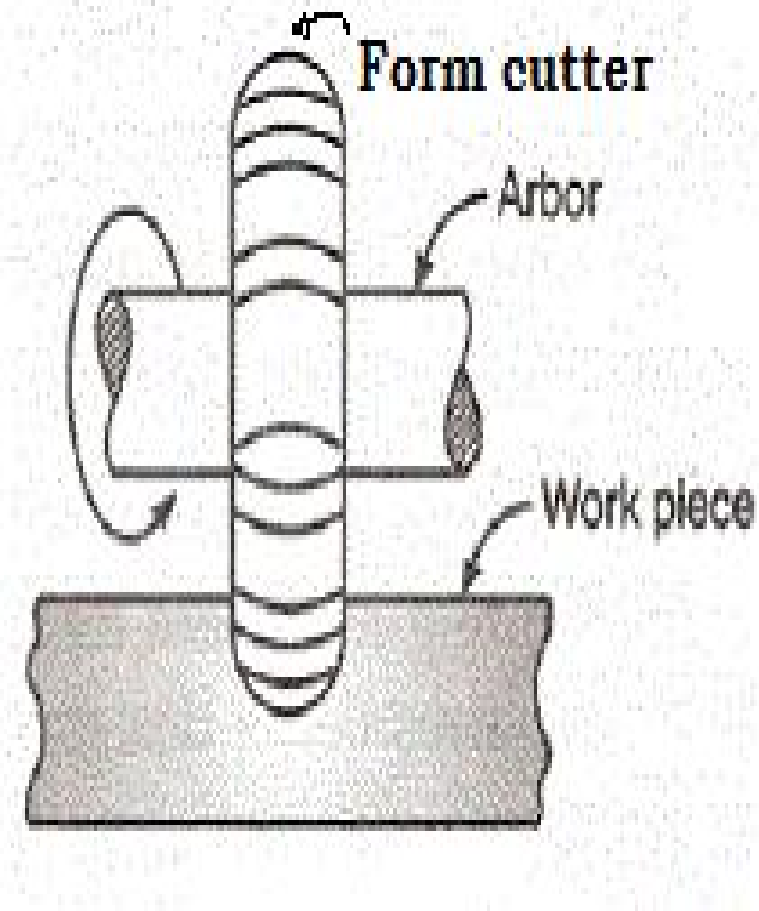


Angular Milling:
Operation of producing all types of angular cuts like V-notches and grooves, serrations and angular surfaces.

Cutter: Double angle cutter.

Machine: Horizontal Milling Machine

Form Milling

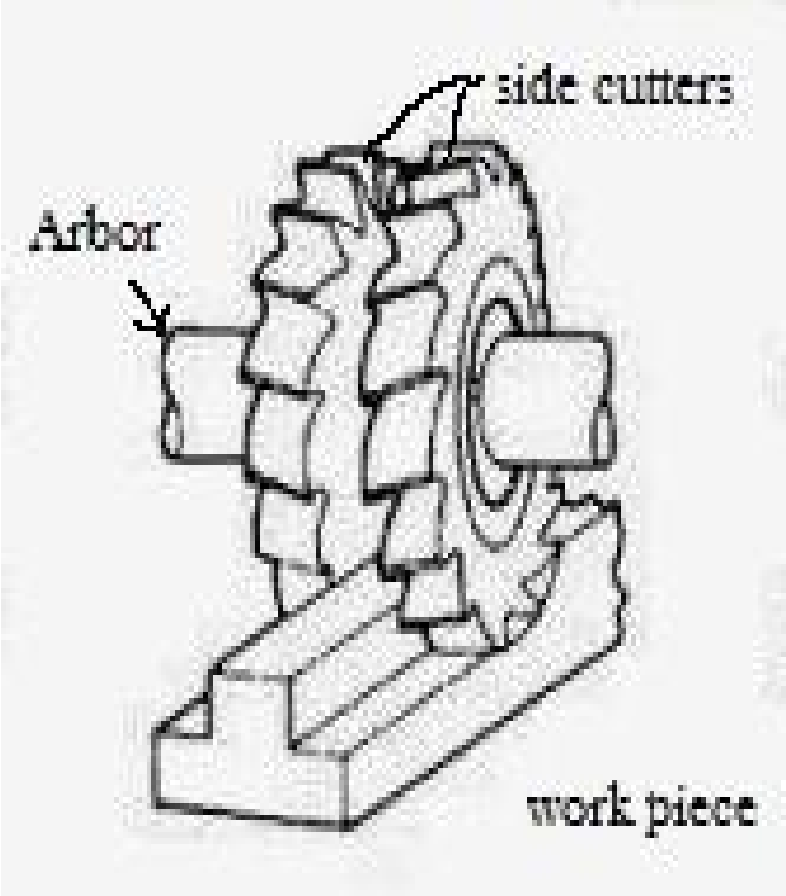


End Milling:
Operation of producing all types of angular cuts like V-notches and grooves, serrations and angular surfaces.

Cutter: Double angle cutter.

Machine: Horizontal Milling Machine

Straddle Milling

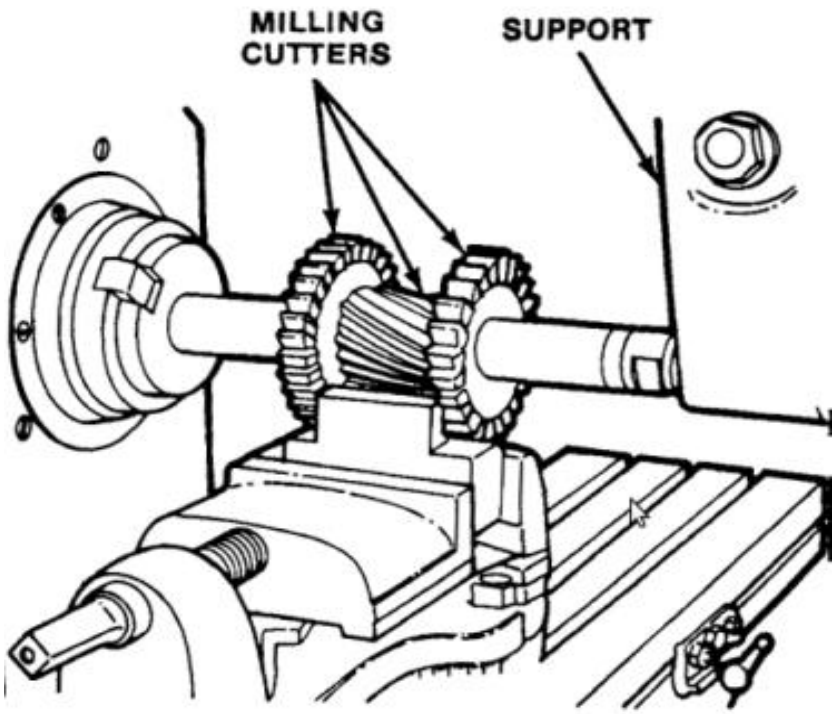


Straddle Milling:
Operation of machining two parallel surfaces simultaneously on a work piece.

Cutter: 2 or more side & face milling cutters

Machine: Horizontal Milling Machine

Gang Milling



Gang Milling:
Process to get different profiles on the work piece simultaneously with two or more cutters at one stretch.

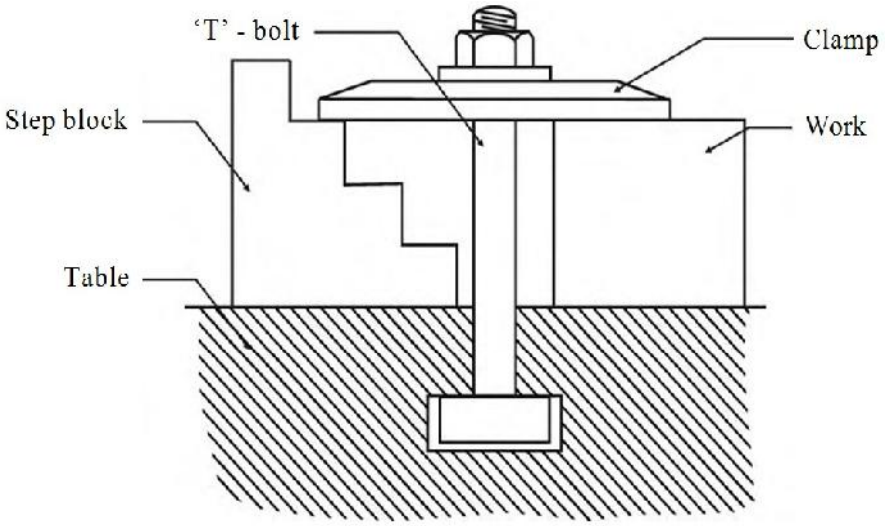
Cutter: Different cutters as required.

Machine: Horizontal Milling Machine

Work holding devices

- ✓ Angle Plate
- ✓ Step Block
- ✓ Parallel strips
- ✓ T- Bolt
- ✓ Clamps
- ✓ Different types of Vice

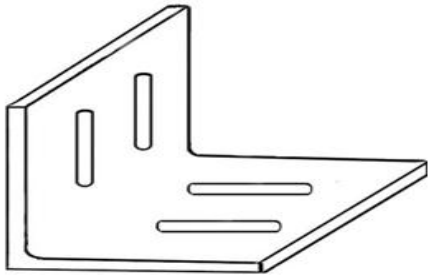
Contd.,



T- bolt, Clamp & Step Block

Adjustable block

T-slot clamp

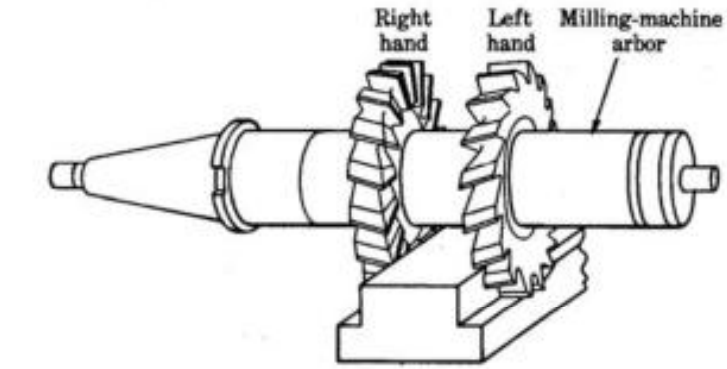


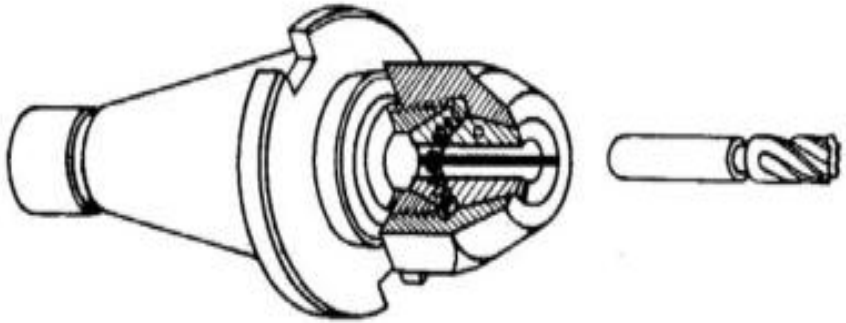
Angle Plate

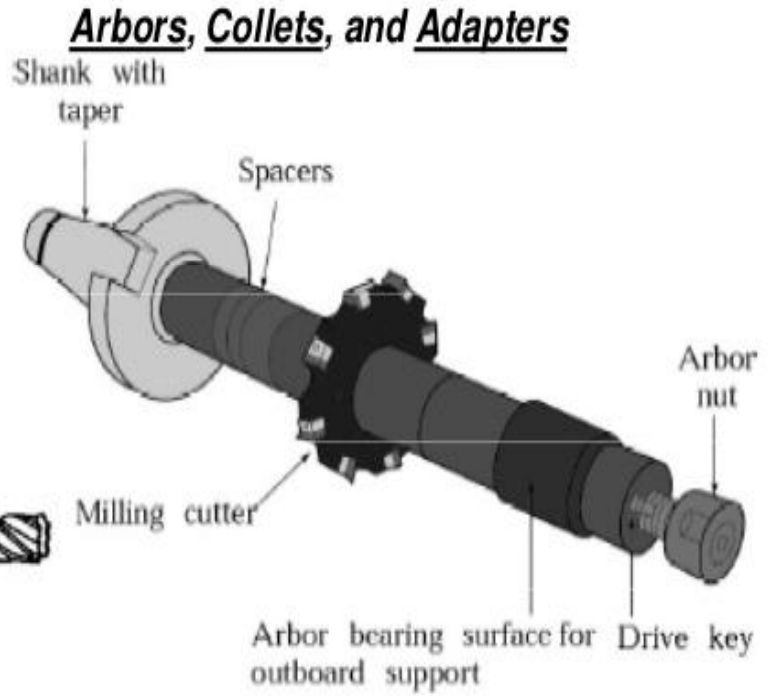
Plain Vice

Universal Vice

Tool holding devices





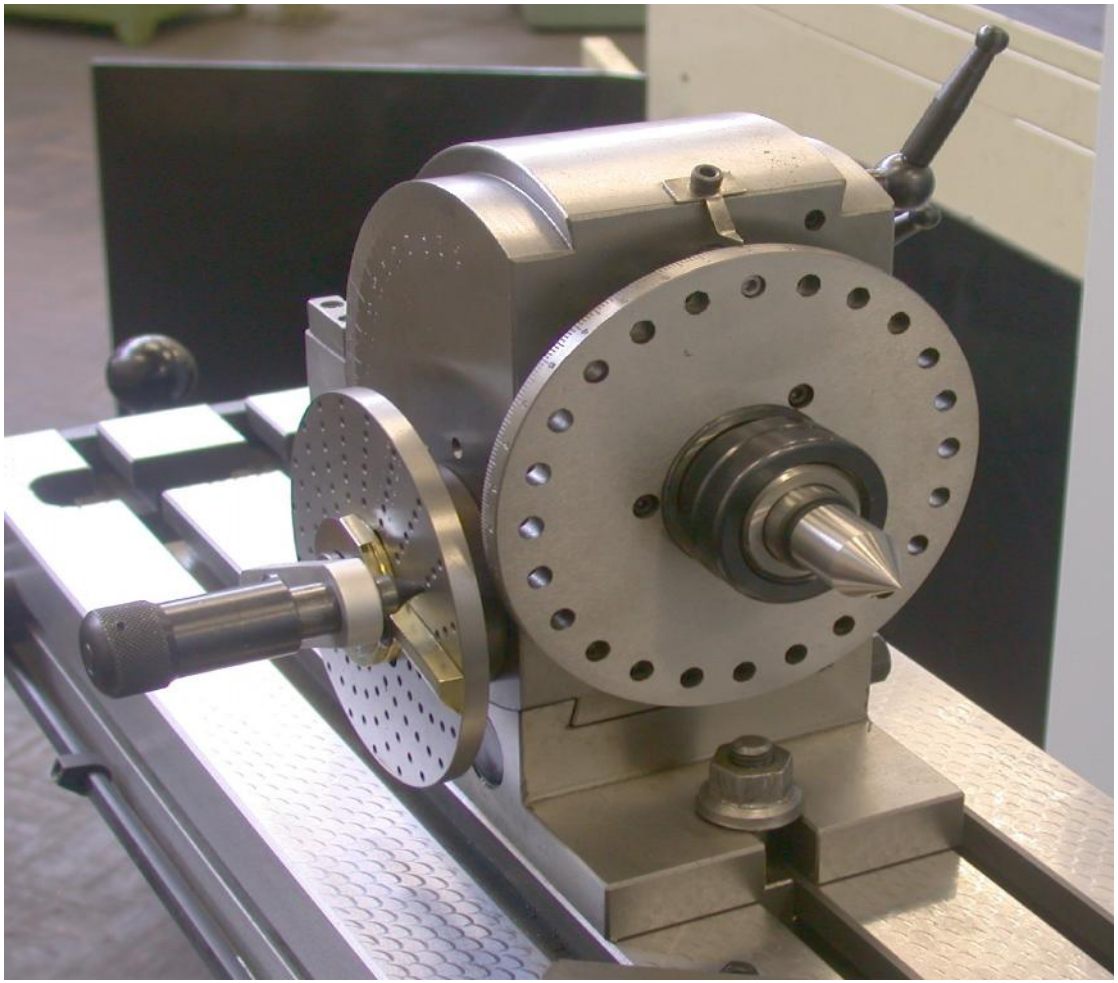


Indexing…

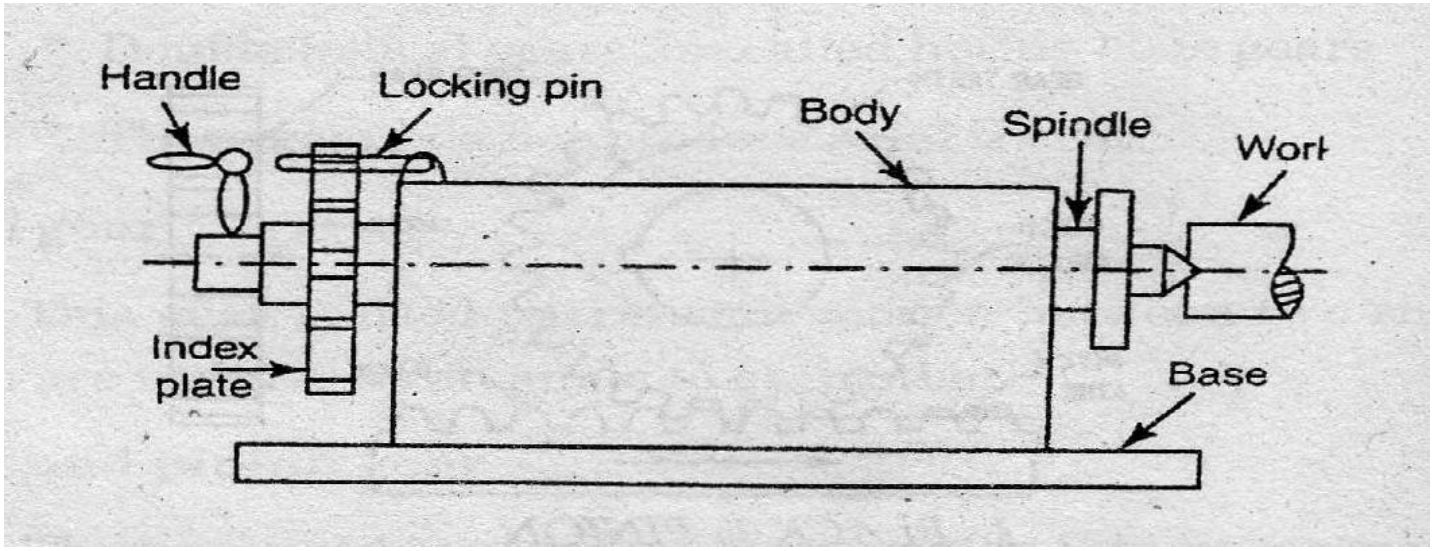
Index Head / Dividing Head

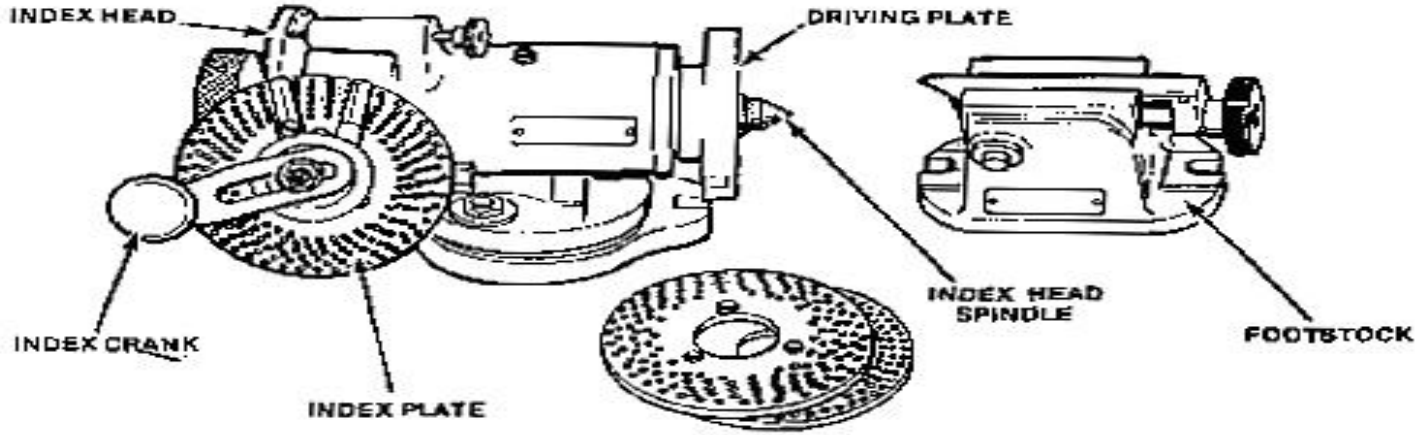
- ✓ It is one of the most important attachments for milling machine
- ✓ Used to divide circumference of work piece into equally spaced divisions when milling gear teeth, squares, hexagons, and octagons
- ✓ Also used to rotate work piece at predetermined ratio to table feed rate

Photo view of Index Head

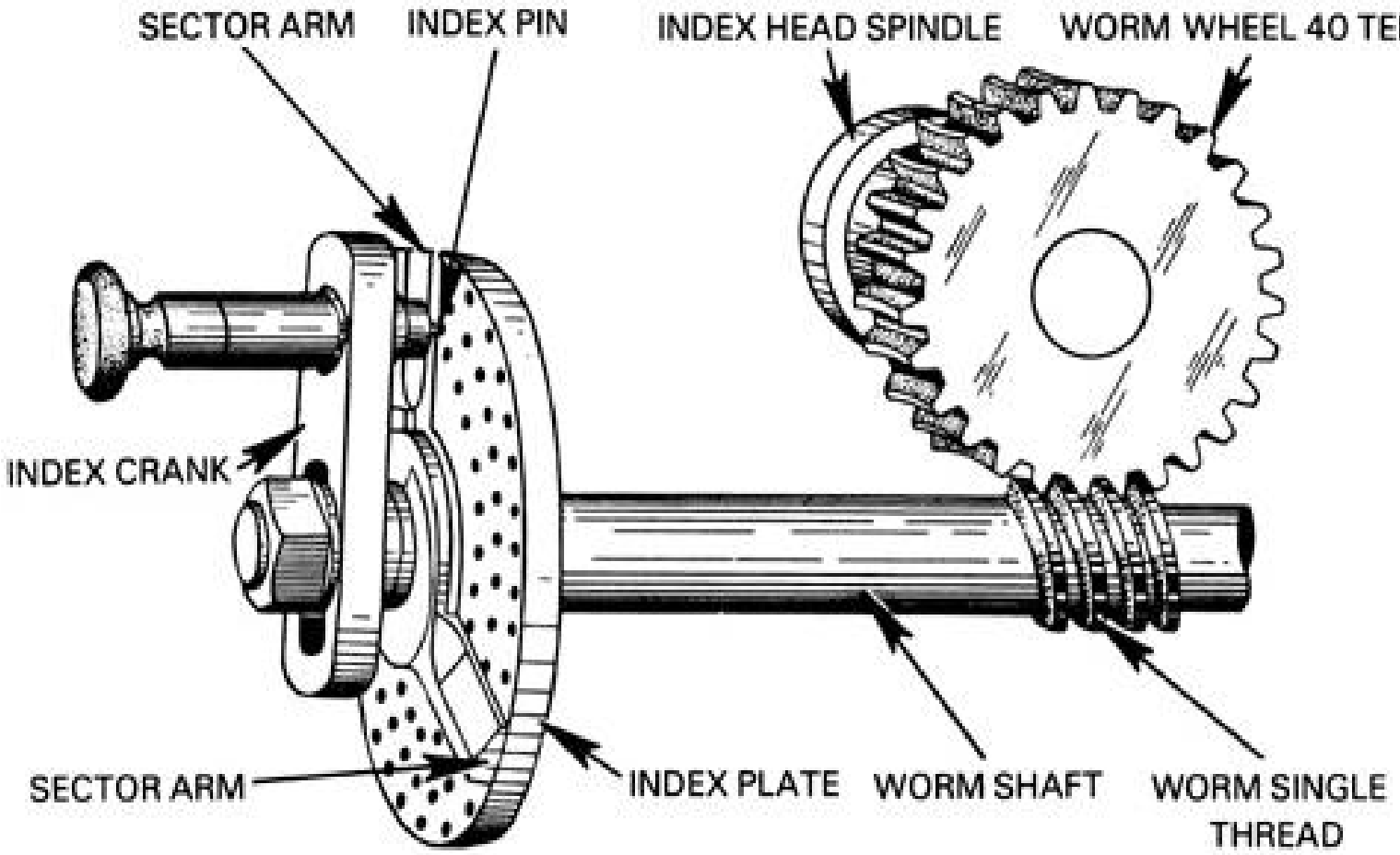


Construction of Index Head





Parts in Index Head



Indexing Methods

- ✓ Direct or Rapid Indexing
- ✓ Plain or Simple Indexing
- ✓ Differential Indexing
- ✓ Angular Indexing

Simple Indexing

- To index the work through any required angle, the index crank pin is withdrawn from the hole of the index plate than the work is indexed through the required angle by turning the index crank through a calculated number of whole revolutions and holes on one of the hole circles, after which the index pin is relocated in the required hole

Contd.,

- If the number of turns that the crank must be rotated for each indexing can be found from the formula

$$N = \frac{40}{Z}$$

Where

- Z - No of divisions or indexing needed on the work
- 40 - No of teeth on the worm wheel attached to the indexing plate, since 40 turns of the index

Contd.,

- ✓ 40 turns of indexing crank = 1 revolution of index head spindle
- ✓ *For cutting 30 tooth;*

$$\frac{40}{30} = 1 + \frac{1}{3}$$

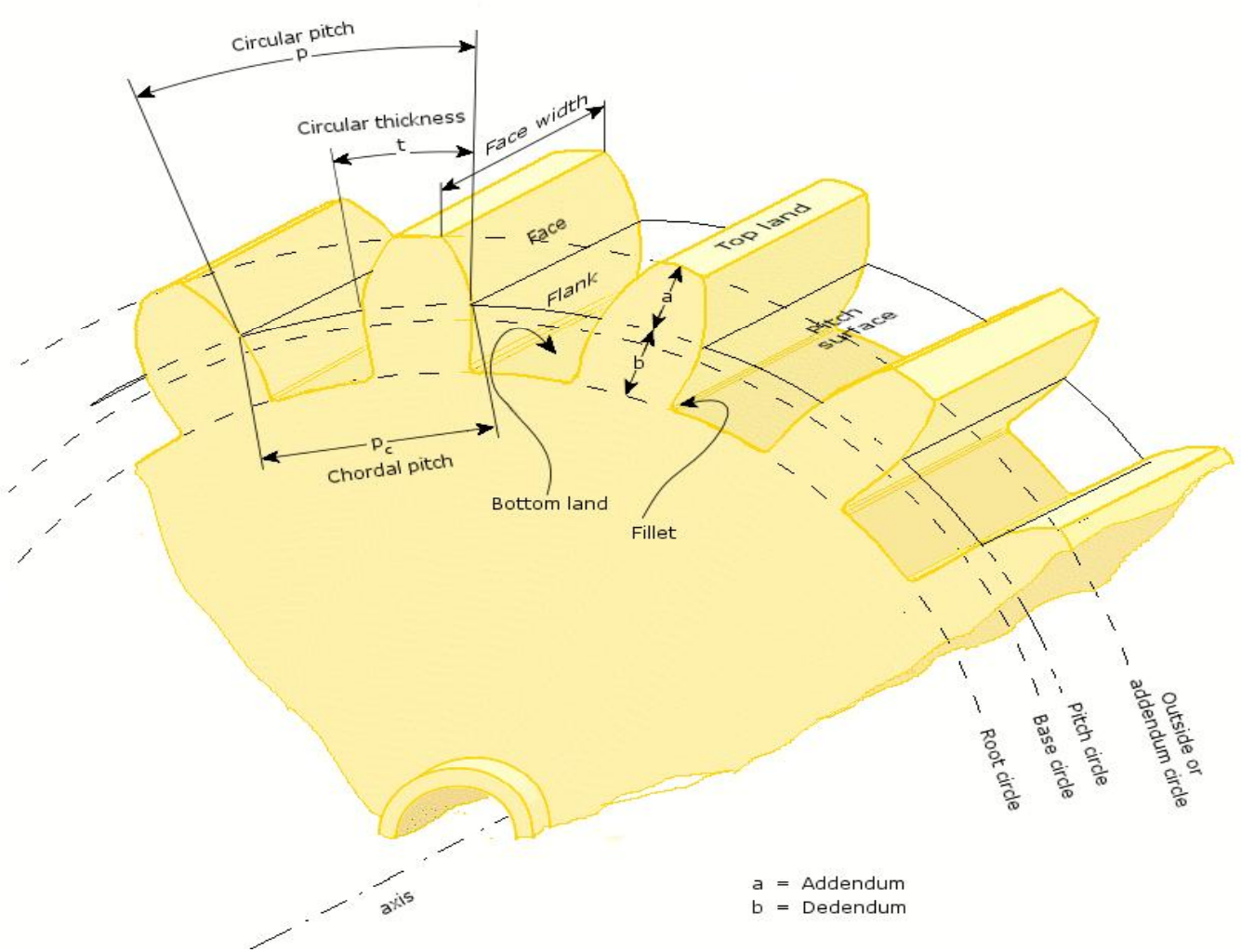
$$= 1 + \frac{7}{21}$$

- *One complete turn of indexing crank*
- *7 holes in 21 hole circle of the index plate*

Index Plate Types

- ✓ **Brown and Sharpe type consists of 3 plates of 6 circles each drilled as follows:**
  - **Plate I - 15, 16, 17, 18, 19, 20 holes**
  - **Plate 2 - 21, 23, 27, 29, 31, 33 holes**
  - **Plate 3 - 37, 39, 41, 43, 47, 49 holes**
- ✓ **Cincinnati type consists of one plate drilled on both sides with circles divided as follows:**
  - **First side - 24, 25, 28, 30, 34, 37, 38, 39, 41, 42, 43 holes**
  - **Second side - 46, 47, 49, 51, 53, 54, 57, 58, 59, 62, 66 holes**

Spur Gear


Circular pitch
p
Circular thickness
t
Face width
Face
Flank
Top land
a
b
Pitch surface
p_c
Chordal pitch
Bottom land
Fillet
Root circle
Base circle
Pitch circle
Outside or addendum circle
axis
a = Addendum
b = Dedendum

Gear Generation

- ✓ Calculate the blank diameter and find the data of gear milling for a spur gear of pitch circle diameter (PCD) 36mm and 18 teeth
- ✓ Index crank movement = 40/Z
- ✓ The holes available in Brown & Sharpe index plates are
  - Plate 1: 15-16-17-18-19-20
  - Plate 2: 21-23-27-29-31-33
  - Plate 3: 37-39-41-43-47-49

Basic Data for Gear Milling

Calculate the gear blank and a tooth proportions:

Sl.No	Name of tooth element	Gear tooth proportions
1.	Pitch diameter	Zxm
2.	Addendum	1m
3.	Dedendum	1.25m
4.	Working depth	2m
5.	Tooth depth	2.25m
6.	Outside diameter	(Z+2)m
7.	Tooth thickness	1.5708m
8.	Clearance	0.25m