DEPARTMENT OF MECHANICAL ENGINEERING
PARALA MAHARAJA ENGINEERING COLLEGE, SITALAPALLI, BERHAMPUR

MACHINING SCIENCE & TECHNOLOGY

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CONTENTS: MODULE II

- **Conventional machining process and machine tools** – Turning, Drilling, Shaping, Planning, Milling, Grinding. Machine tools used for these processes, their specifications and various techniques used.
- **Principles of machine tools** : Kinematics of machine tools, speed transmission from motor to spindle , speed reversal mechanism, mechanism for feed motion, Tool holding and job holding methods in different Machine tools.
- **Types of surface generated, Indexing mechanism and thread cutting mechanism, Quick return mechanism**,.
- **Production Machine tools** – Capstan and turret lathes, single spindle and multi spindle semiautomatics, Gear shaper and Gear hobbing machines, Copying lathe and transfer machine

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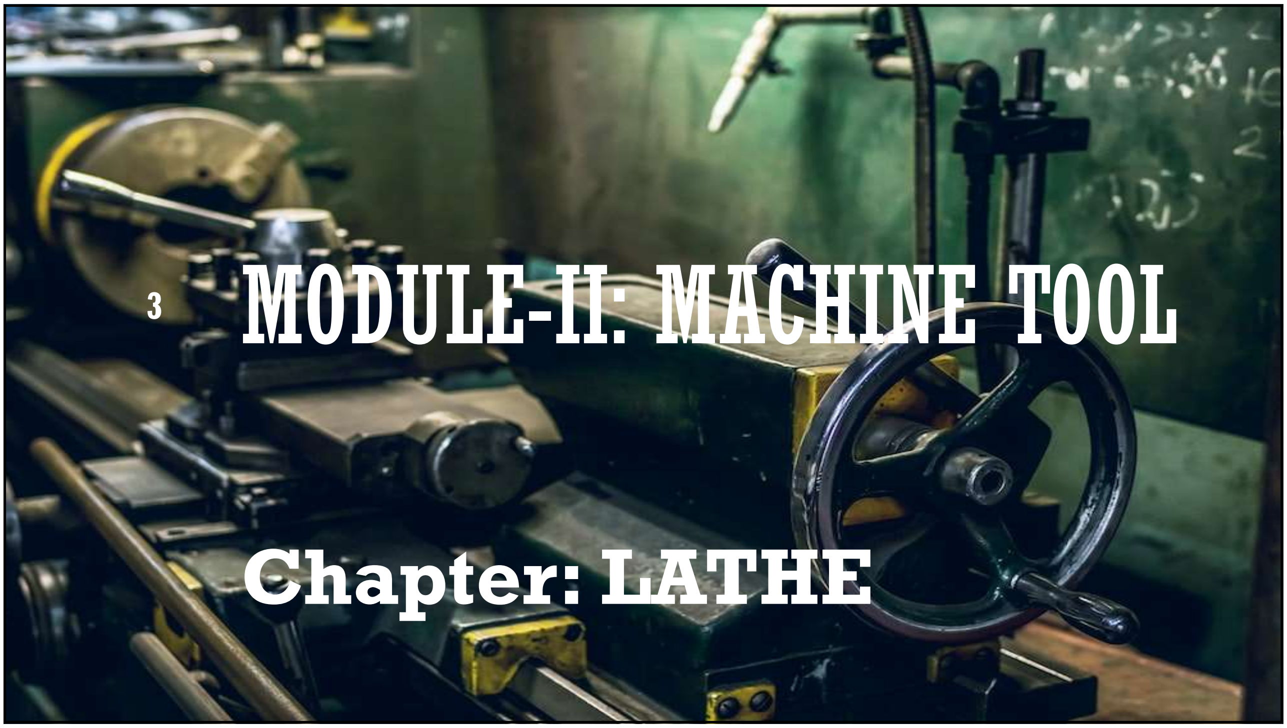

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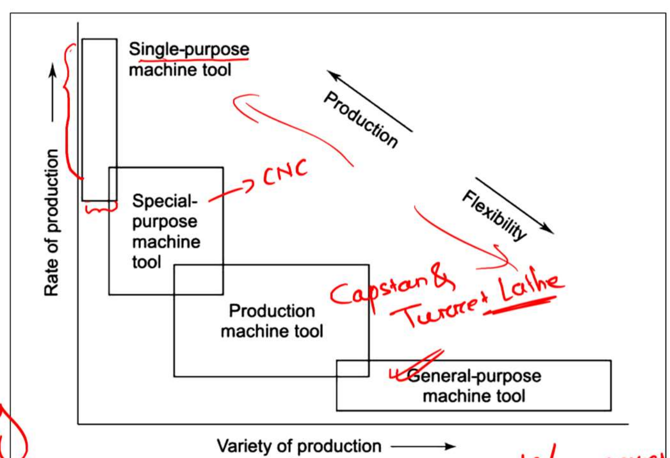
MODULE-II: MACHINE TOOL

Chapter: LATHE

INTRODUCTION

- **General Purpose Machine Tools Of Common Use**
- **Lathes**
- **Drilling machines**
- **Shaping machines**
- **Planning machines**
- **Slotting machines**
- **Milling machines**
- **Boring machines**
- **Hobbing machines**
- **Gear shaping machines**
- **Broaching machines**
- **Grinding machines**



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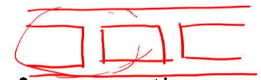
COMMON MAJOR PARTS IN MACHINE TOOLS



BED:

- **Function:** It is acting is rigid support to with stand for forces acting during machining and self weight of the workpiece. It used to absorb vibrations induced during machining so that it will have high damping qualities ; It will acts as house for keeping some other parts,
- **Materials used:** Generally grey cast iron is used as material because as it has high damping coefficient and rigidity.
- **Manufacturing process used:** Generally casting will be used to manufacture the beds because casting will give high damping qualities to the bed.
- **Shape of the bed**: Shape of the bed is selected such that the reduction in the rigidity will be minimum and should provide maximum amount of free space. Example: X, I, H cross sectioned shapes etc.

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2. Lead Screw :

(i) Function : It is used for feeding the cutting tool in a direction parallel to the axis of Rotation. (Converts rotational movement in to translational motion).

(ii) Material Used – Brass

* length limited to 2m.

(iii). Manufacturing Process :

– Machining

(iv). Shape -

– Square threads are generally used

↳ (High efficiency in power transmiss

3. Guideways :

(i) Function - Guideways are used to guide & allow the other parts moves in their direction relative to other parts.

(ii). Material Used : Medium Carbon Steel

High Carbon steel.

(iii). Manufacturing Process - Flame Hardening Process (to avoid surface wear).

(iv) Shape :

Rectangle shape 'V' shape Dovetail shape

4. Prime Mover :

Source of Energy required.

(i). IC Engine

(ii). Electrical Motor

↳ Disadvantages

– Excess Vibrations → Poor Surface finish

– Noise pollution.

1. Speed (N) = $\frac{1000 V}{\pi D}$ rpm

2. Feed (f) : unit : mm/rev

↳ Feed Velocity (F or V_f) = fN

unit = $\frac{mm}{rev} \times \frac{rev}{min} = \frac{mm}{min}$

3. Depth of Cut (d)

LATHE

- One of the most basic machining processes is turning, meaning that the part is rotated while it is being machined. The blank is generally a workpiece made by various processes, such as casting, forging, extrusion, drawing, or powder metallurgy,
- **Turning** operations, which typically are carried out on a **lathe** or by similar *machine tools*. These machines are highly versatile and capable of performing several machining operations that produce a wide variety of shapes, such as:
- **Turning:** to produce cylindrical, conical, curved, or grooved parts , such as shafts, spindles, and pins.
  Taper-turning (Dimetere of w/p is reduced).
- **Facing:** to produce a flat surface at the end of the part and perpendicular to its axis *face grooving* produces grooves for O-ring seats . (Length of w/p is reduced)
- **Machining with form tools:** to produce various axisymmetric shapes for functional or for aesthetic purposes.

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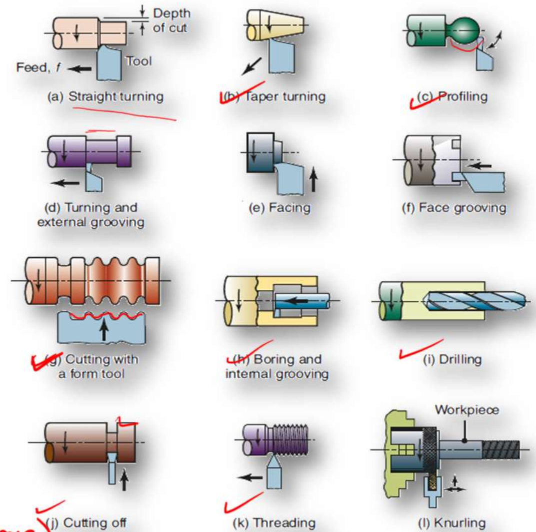
CONTINUE…

→ Surface finishing oper^n

- **Boring**: to enlarge a hole or cylindrical cavity made by a previous process, or to produce circular internal grooves
- **Drilling**: to produce a hole which then may be followed by boring it, to improve its dimensional accuracy and surface finish.
- **Cutting off**: also called **parting**, to cut a piece from the end of a longer piece
- **Threading**: to produce external or internal threads
- **Knurling**: to produce a regularly shaped texture on cylindrical surfaces, as in making knobs and handles. (Gripping Purpose)



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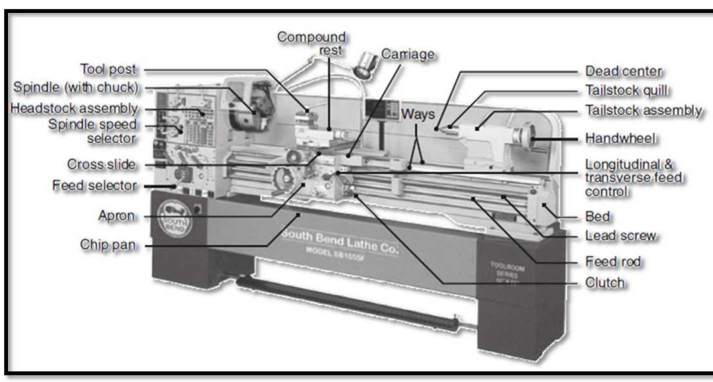
LATHE:DEFINATION

- A lathe machine tool as a versatile machining tool used to shape and cut various materials, such as wood, metal, and plastic.
- The primary purpose of a lathe machine: to rotate a workpiece while a cutting tool removes material to achieve desired shapes, dimensions, and finishes.



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LATHE: CLASSIFICATION

Lathe Vs Milling

- **(a) According to configuration**
  - **Horizontal**-Most common for ergonomic conveniences
  - **Vertical** -Occupies less floor space, only some large lathes are of this type.
- **(b) According to purpose of use**
  - **General purpose**- Very versatile where almost all possible types of operations are carried out on wide ranges of size, shape and materials of jobs; example : centre lathes
  - **Single purpose**-Only one (occasionally two) type of operation is done on limited ranges of size and material of jobs; example – facing lathe, roll turning lathe etc.
  - **Special purpose**- Where a definite number and type of operations are done repeatedly over long time on a specific type of blank; example: gear blank machining lathe etc.

- **(c) According to size or capacity**
  - **Small (low duty)**-In such light duty lathes (upto 1.1 kW), only small and medium size jobs of generally soft and easily machinable materials are machined
  - **Medium (medium duty)**- These lathes of power nearly upto 11 kW are most versatile and commonly used
  - **Large (heavy duty)**
  - **Mini or micro lathe** - These are tiny table-top lathes used for extremely small size jobs and precision work; example : swiss type automatic lathe.
- **(d) According to degree of automation**
  - **Non-automatic**-Almost all the handling operations are done manually; example: centre lathes
  - **Semi-automatic**- Nearly half of the handling operations, irrespective of the processing operations, are done automatically and rest manually; example : capstan lathe, turret lathe, copying lathe relieving lathe etc.
  - **Automatic**-Almost all the handling operations (and *obviously all the processing* operations) are done automatically; example – single spindle automat (automatic lathe), swiss type automatic lathe, etc.

- **(e) According to type of automation**

  Fixed automation- Conventional; example – single spindle automat, swiss type automatic lathe etc.

  Flexible automation - Modern; example CNC lathe, turning centre etc.

- **(f) According to configuration of the jobs being handled**

  Bar type- Slender rod like jobs being held in collets

  Chucking type- Disc type jobs being held in chucks

  Housing type- - Odd shape jobs, being held in face plate.

- **(g) According to precision**

  Ordinary

  Precision (lathes)- These sophisticated lathes meant for high accuracy and finish and are relatively more expensive.

- **(h) According to number of spindles**

  Single spindle- Common

  Multispindle (2, 4, 6 or 8 spindles)- Such uncommon lathes are suitably used for fast and mass production of small size and simple shaped jobs.

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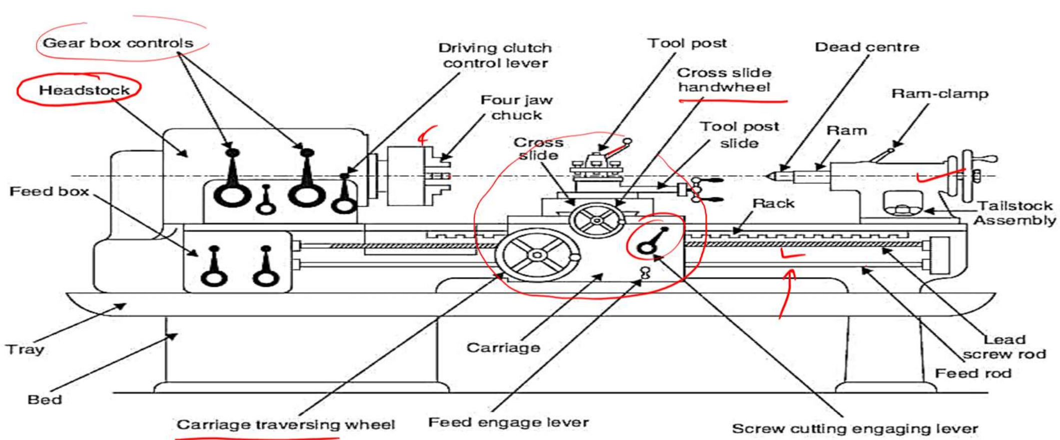
LATHE: SCHEMATIC DIAGRAM WITH MAJOR PARTS



Engine lathe

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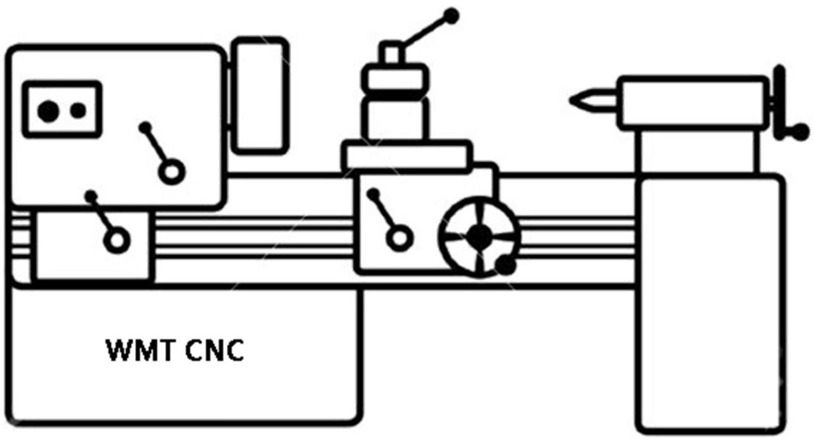
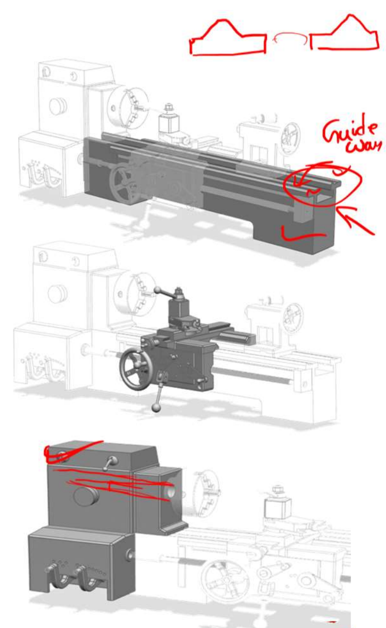
SIMPLE DIAGRAM



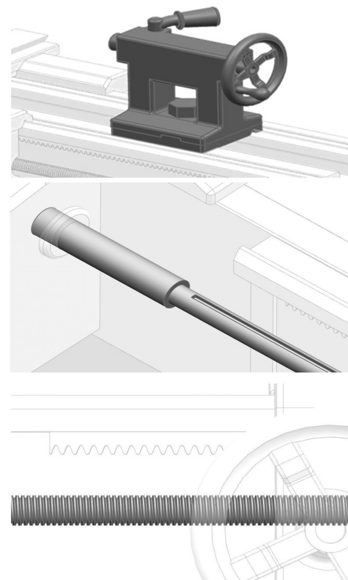
LATHE: MAJOR COMPONENTS

- **Bed.** The bed supports all major components of the lathe; it has a large mass and is built rigidly, usually from grey or nodular cast iron. The top portion of the bed has two **ways**, with various cross sections that are hardened and machined for wear resistance and good dimensional accuracy during turning. In a *gap-bed lathe*, a section of the bed in front of the headstock can be removed to accommodate work pieces with larger diameters.
- **.Headstock.** The headstock is fixed to the left side of the bed and is equipped with motors, pulleys, and V-belts, supplying power to a *spindle* at various rotational speeds, which can be set through manually controlled selectors or by electrical controls. Most headstocks are equipped with a set of gears, and some have various drives to provide a *continuously variable* range of speed to the spindle. Headstocks have a *hollow spindle* to which work holding devices (such as *chucks* and *collets*) are mounted; long bars or tubing can thus be fed through them for various turning operations. The dimensional accuracy of the spindle is important for precision in turning, particularly in high-speed machining. Preloaded tapered or ball bearings are typically used to rigidly support the spindle.



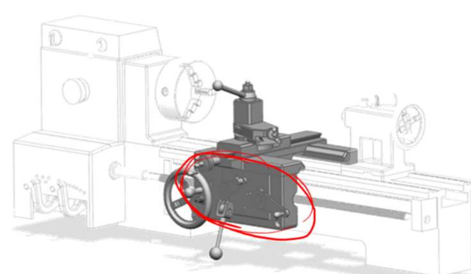
LATHE: MAJOR COMPONENTS

- **Tailstock.** The tailstock, which can slide along the ways and be clamped at any position, supports the right end of the workpiece. It is equipped with a *center*, which may be fixed (called *dead center*) or it may be free to rotate with the workpiece (*live center*). Drills and reamers can be mounted on the tailstock *quill* (a hollow cylindrical piece with a tapered hole) to drill axial holes in the workpiece.
- **Feed Rod and Lead Screw.** The feed rod is powered by a set of gears through the headstock. It rotates during the lathe operation, and provides movement to the carriage and the cross-slide by means of gears, a friction clutch, and a keyway along the length of the rod. Closing a *split nut* around the lead screw engages the rod with the carriage; the split nut is also used for cutting threads accurately.



LATHE: MAJOR COMPONENTS

- **Carriage.** The carriage, or *carriage assembly*, slides along the ways;
- It consists of an assembly of the *cross-slide*, *tool post*, and *apron.*
- The cutting tool is mounted on the *tool post*, usually with a *compound rest* that swivels for tool positioning and adjustments.
  → Taper Turning
- The *cross-slide* moves radially in and out, controlling the radial position of the cutting tool in such operations as facing .
- The apron is equipped with mechanisms for both manual and mechanized movement of the carriage and the cross-slide by means of the *lead screw.*



LATHE SPECIFICATION

- *Swing*, the maximum diameter of the workpiece that can be accommodated ; it may be as much as 2 m.
- Maximum distance between the headstock and tailstock centers.
- Swing over the cross slide.

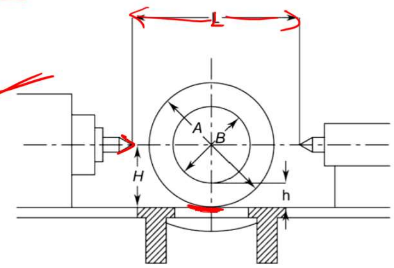


Fig. 4.3 *Capacity specifications for a lathe*

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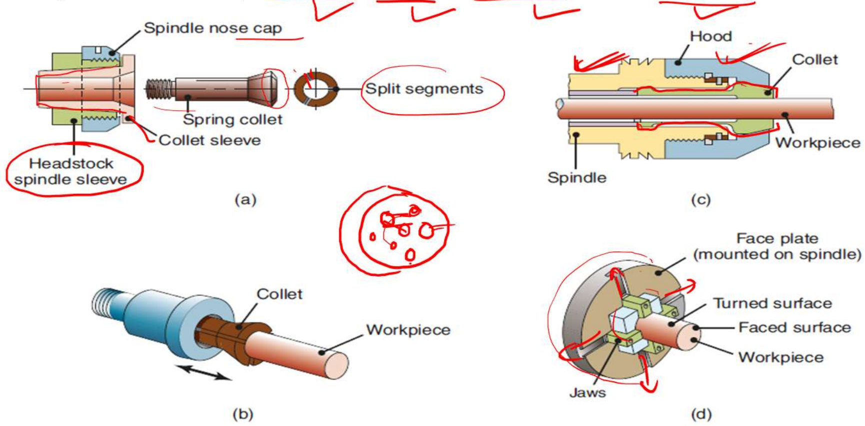
WORK HOLDING DEVICES AND ACCESSORIES

- Workholding devices are important, since they must hold the work piece securely in place while machining. As shown in Fig., one end of the work piece is clamped to the lathe spindle either by a chuck, collet, face plate, or a mandrel.



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CHUCK

- A **chuck** is usually equipped with three or four *jaws*.
- *Three-jaw* chucks generally have a geared-scroll design which makes the jaws self-centering. They are used for round workpieces, such as bar stock, pipes, and tubing, and typically can be centered to within 0.025 mm.
- *Four-jaw* chucks have jaws that can be moved and adjusted independently of each other; thus, they can be used for square, rectangular, or odd-shaped workpieces
- The jaws in some types of chucks can be reversed to permit clamping of hollow workpieces, such as pipes and tubing, either on their outside or inside surfaces.
- Also available are jaws made of lowcarbon steel (called *soft jaws*) that can be machined into desired shapes. Because of their low strength and hardness, soft jaws also conform to small irregularities on workpieces, thus ensuring better clamping.
- Chucks can be *power* or *manually actuated*, using a chuck wrench.

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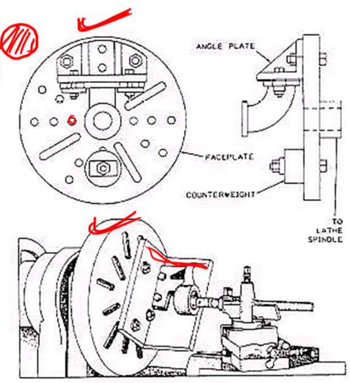
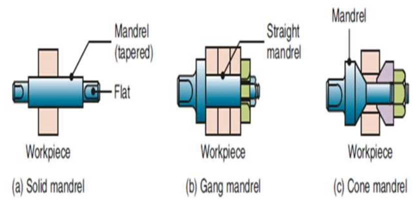
COLLET & FACE PLATE

- A **collet** is basically a longitudinally split, tapered bushing. The workpiece, generally with a maximum diameter of 25 mm, is placed inside the collet, and the collet is pulled (*draw-in collet*; slide 15.Fig. a and b) or pushed (push-out collet; slide 15.Fig.c) mechanically into the spindle.
- The tapered surfaces shrink the segments of the collet radially, tightening them onto the workpiece.
- Collets are used for round or other shapes. An advantage to using a collet, rather than a three- or four-jaw chuck, is that the collet grips nearly the entire circumference of the part, making it well suited particularly for parts with small cross sections.
- **Face plates** are used for clamping irregularly shaped workpieces; they are round and have several slots and holes through which the workpiece is bolted or clamped (slide 15.Fig. d).
- **Mandrels** (Fig.) are placed inside hollow or tubular workpieces, and are used to hold workpieces that require machining on both ends or on their cylindrical surfaces.





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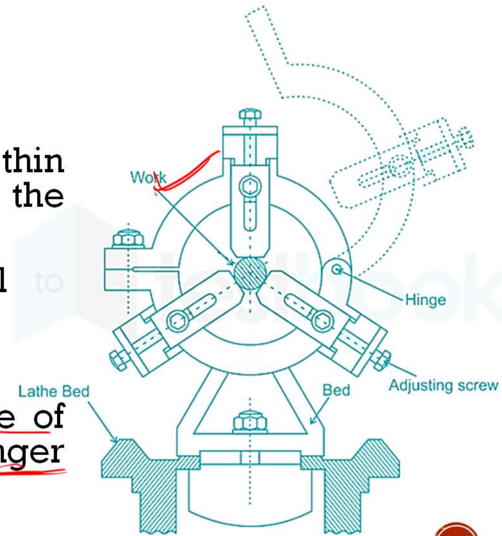
MANDREL & STEADY REST

- Mandrel:
- Mandrel is used during machining of thin walled tubes because to avoid the bending of the tubes.
- The diameter of mandrel is equal inside diameter of the workpiece.
- . Steady rest:
- It is used to supported at the centre of workpiece to avoid bending of longer workpiece due to its self weight.



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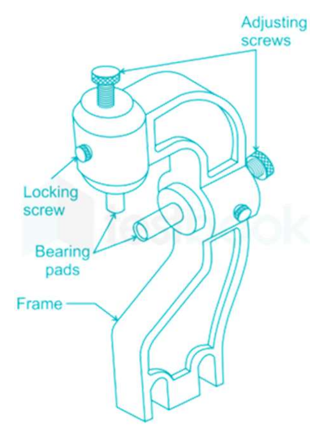
FOLLOWER REST

- Follower rest:
- During machining due to the forces acting by the tool, the workpiece may get bend to avoid this bending a support must be provided opposite to the tool
- and it is moving along with tool called as follower rest.



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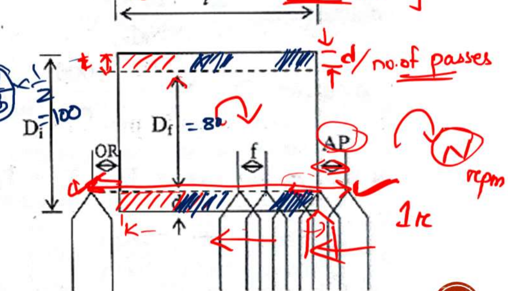
MACHINING OPERATIONS: PLAIN TURNING

- Turning is most commonly used operation to produce cylindrical surfaces.
- In this, the work piece held in the spindle is rotated while the tool is fed past the workpiece in a direction parallel to the axis of rotation. There by diameter of the work piece will be reduced.
- l= Length of workpiece (mm)
- Di = initial diameter of work piece (mm)
- Df = final diameter of work piece (mm)
- d = depth of cut (mm)
- f= feed mm/rev
- OR = Over run
- AP = Approach

Machining time = $\frac{L_e}{\text{feed Velocity}} = \frac{L_e}{fN}$

L_e = Effective length

$L_e = AP + L + OR$



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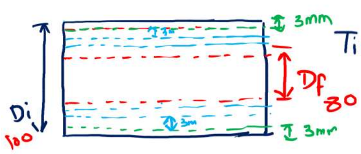
NUMERICALS



Time/Cut = $\frac{\text{Total length of the tool travel}}{\text{feed Velocity}}$

Time/cut = $\frac{L}{fN}$

where $L = l + AP + OR$

- Initial diameter of workpiece is 100 mm is to be turned to final diameter of 80 mm. If maximum depth of cut is 3 mm. Find the number of cuts?

D_i = 100mm D_f = 80mm

d_{max} = 3mm

No. of Cuts = $\frac{\text{Total dia reduced}}{2 \times \text{max DOC}}$ or $\frac{\text{Total radius reduced}}{\text{max of DOC}}$

$= \frac{D_i - D_f}{2 \times d_{max}} = \frac{20}{2 \times 3} = 3.33 \approx 4$ (cuts)

	Initial	Final
1st Cut	D_i 100	D_1 94
2nd Cut	D_1 94	D_2 88
3rd Cut	D_2 88	D_3 82
4th Cut	D_3 82	D_4 80

$N_1 = \frac{1000V}{\pi D_i}$

For Dia D_1: $N_2 = \frac{1000V}{\pi D_1}$

$N_3 = \frac{1000V}{\pi D_2}$

$\frac{\pi D N}{1000} = V$ m/min

Total time $= T_1 + T_2 + T_3 + \dots$

Total $= \frac{L_e}{f}\left[\frac{\pi D_0}{1000V} + \frac{\pi D_1}{1000V} + \frac{\pi D_2}{1000V} + \dots\right]$

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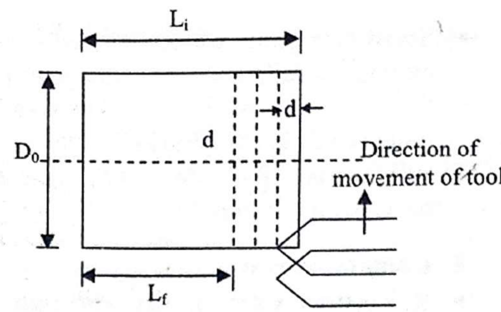
FACE TURNING

- This is used for reducing the length of work piece. In this the feed is given in a direction perpendicular to the axis of revolution.
- In this case the tool has to travel from outside surface to axis of the workpiece and additionally some over run and approach
- $L = \frac{D}{2} + AP + OR$ ----------------- for solid workpiece
- $L = \frac{Do - Di}{2} + AP + OR$ ----------------for hollow workpiece
- $N = \frac{1000V}{\pi Do}$
- Total time = Time/cut x no. of cuts
- No. of cuts = $\frac{li - lf}{dmax}$



$$\text{Time per cut} = \frac{\text{length of tool travel}}{\text{feed velocity}}$$

$$= \frac{L}{fN}$$

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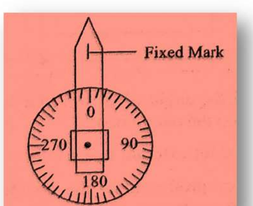
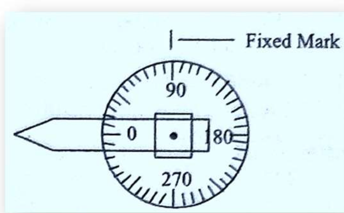
TAPER TURNING:

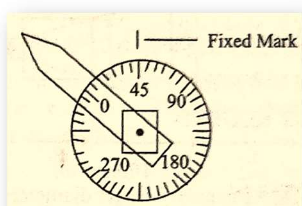
- **Taper turning methods:**
- **1. Compound rest method:**
- **2. Tail stock method**
- **3. Taper turning attachment**
- **4. Form tool method**

Compound rest method:

- In case of plane turning operation 0° of dial indicator coincides with fixed mark
- In case of face turning operation 90° of compound rest is coincides with fixed mark i.e., compound rest is rotated through 90° to do the face turning operation.
- In case of taper turning the compound rest will be swiveled by an angle equal to the required taper angle on the component.







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COMPOUND REST METHOD

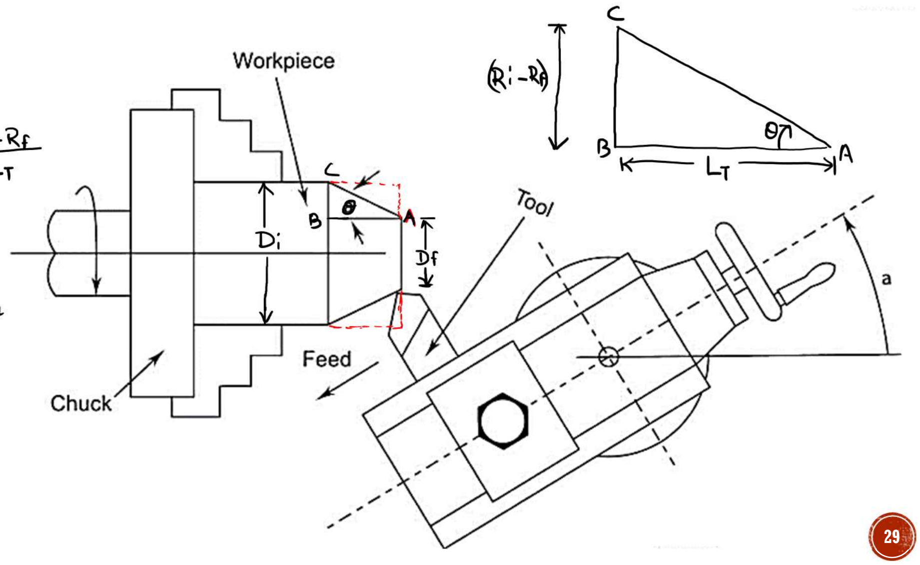
θ = Half Cone Angle

$BC = R_i - R_f$

$\tan\theta = \frac{BC}{AC} = \frac{R_i - R_f}{L_T}$

$\theta = \tan^{-1}\left(\frac{R_i - R_f}{L_T}\right)$

→ Taper Angle = 2θ



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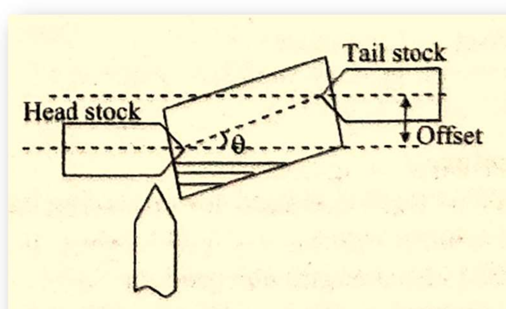
TAIL STOCK SET OVER METHOD

- When the dead centre of tail stock is offset by some amount the workpiece getting tilting so that even though the tool is moving like plane turning operation and produces taper on the workpiece called as "Tail stock offset method'.

Features:

- This method is used for producing only external tapers
- 0.1° taper angles can be produced
- Maximum offset is 10 mm, Therefore any job which requires offset less than 10 mm only can be produced by using this method.



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L = Total Length

L_T = Tapered Length

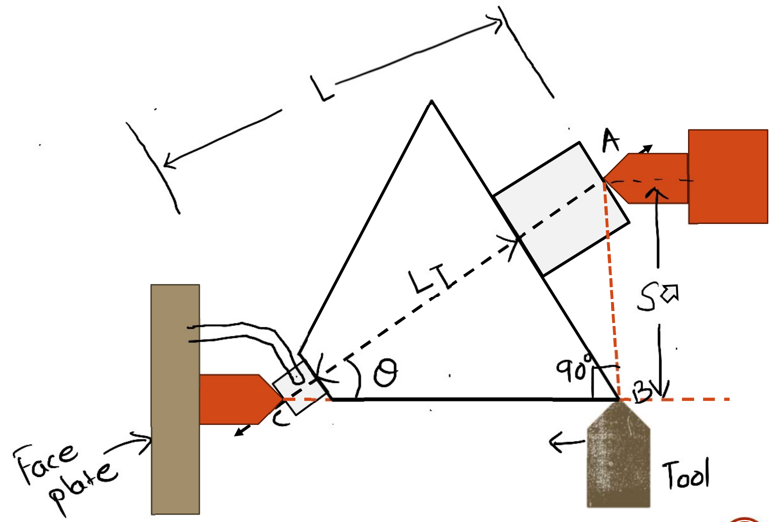
In ΔABC

$\sin\theta = \frac{AB}{AC} = \frac{S}{L}$

$\theta = \sin^{-1}\left(\frac{S}{L}\right)$

θ = Half Cone Angle

S = Set over distance



TAPER ATTACHMENT METHOD

- In normal turning operation the slide ways are kept parallel to the guide ways in taper turning attachment method the slide ways are tilted by an angle equal to taper angle of the component.
- So that the saddle is automatically tilted and when the saddle is moving on the slide ways it produces tapered component.

Features:

- It can be used for both internal, external operation,
- Up to 0.1° accuracy can be produced.
- Maximum taper angle can produced is 8°, included angle “16°”.
- Maximum movement of the saddle possible on the slide ways is 235 mm. Hence in one setting maximum length of the component can be taper turn is 235 mm.

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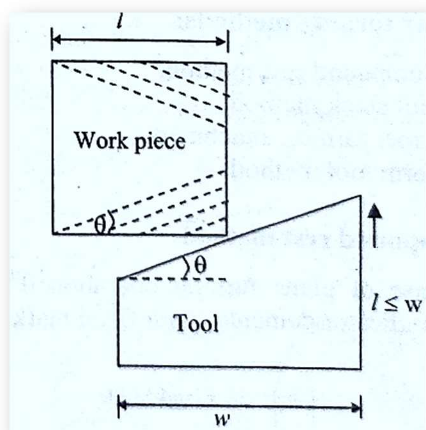
FORM TOOL METHOD

- If the shape of the tool is remains same as the shape of the component to be produced is called as "form tool method".
- What ever the angle is on tool that can be produced on the component
- This is used for external tapers only
- Accuracy produced on the component depends on the accuracy present on the tool.
- Angle of taper is depends on the angle of tool
- For every taper angle separate tool must be used.
- Maximum width of the tool is 20 mm
- Maximum length of the component to produce taper turn is 20 mm.



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THREAD CUTTING OPERATION

- The turning operation used for producing the threads on the component is called "thread cutting operation".
- Low speed required for thread cutting operation is obtained by using back gear arrangement in head stock of lathe machine.
- Even though total depth of the threads is less than maximum depth of cut possible in lathe machine.
- It is always recommended to use. Multiple cuts of threads. For avoiding weakening of threads due to sideward thrust force acting by tool.
- In thread cut operation the feed required for the tool must be given only automatic feed.
- The automatic feed required for thread cutting operation is obtained by using lead screw with split nut mechanism driven through feed gear box.
- Gear 20 to 120 teeth in steps of 5 teeth and 127 teeth.

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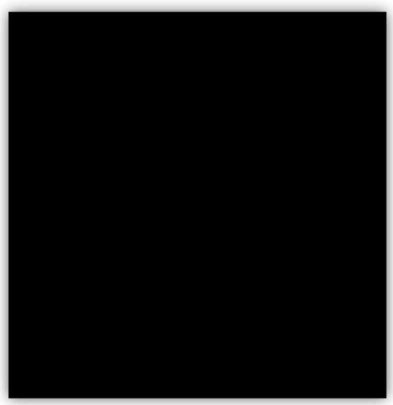
SPLIT NUT MECHANISM

- First bring the tool away from the workpiece, set the depth of cut for the first cut and engage the lever of split nut mechanism when selected position TCD is coinciding fixed mark, with this first cut of the thread cut is produced.
- Now disengage lever of split nut mechanism and bring the tool backward and take it away from the workpiece.
- Now set the depth of cut for the 2nd, cut and engage lever of split nut mechanism when selected position of PCD coincide with fixed mark repeat this procedure with required no. of cuts completed.
- For easy disengagement of tool at the end of length of threads to be produced a grove is produced at the end length of threads, called as grooving or necking or under cutting.
- So that machine operator is finding certain amount of time for disengagement of lever when tool is coming to groove zone.



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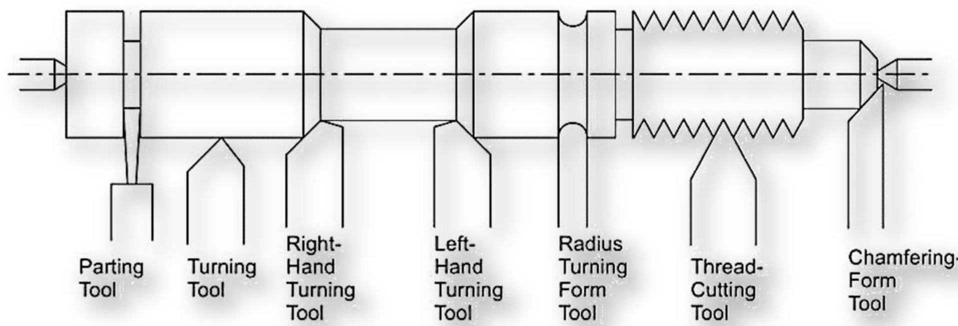
DIFFERENT TYPES OF TOOLS



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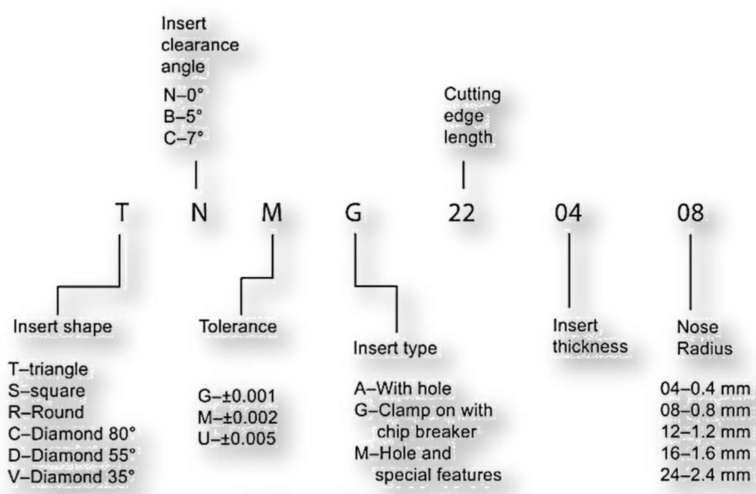
TOOL SPECIFICATION



The ISO coding system for tungsten carbide inserts used in turning

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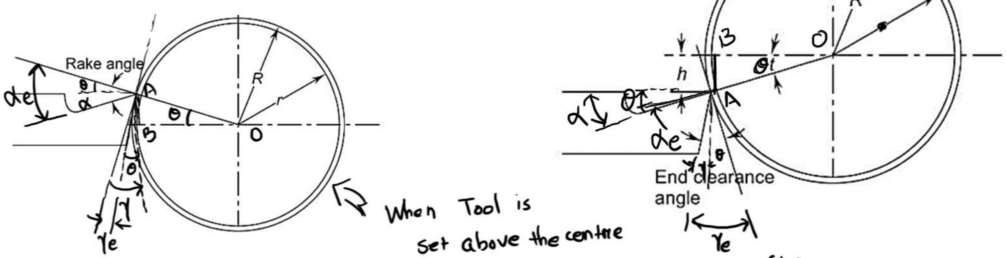
ERROR IN TOOL SETTING

- The tool should be set exactly at the centre of the workpicce for proper cutting. If the tool is kept below or above the workpiece, the tool geometry gets affected as shown in Fig. For example, if the tool is sei at a position below the workpiece centre by a distance h then the expected changes are

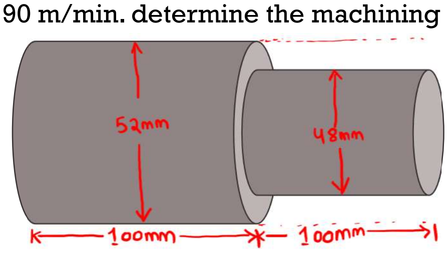
Here $\alpha_e = \alpha - \theta$, $\gamma_e = \gamma + \theta$ } $\theta = \sin^{-1}\left(\frac{h}{R}\right)$



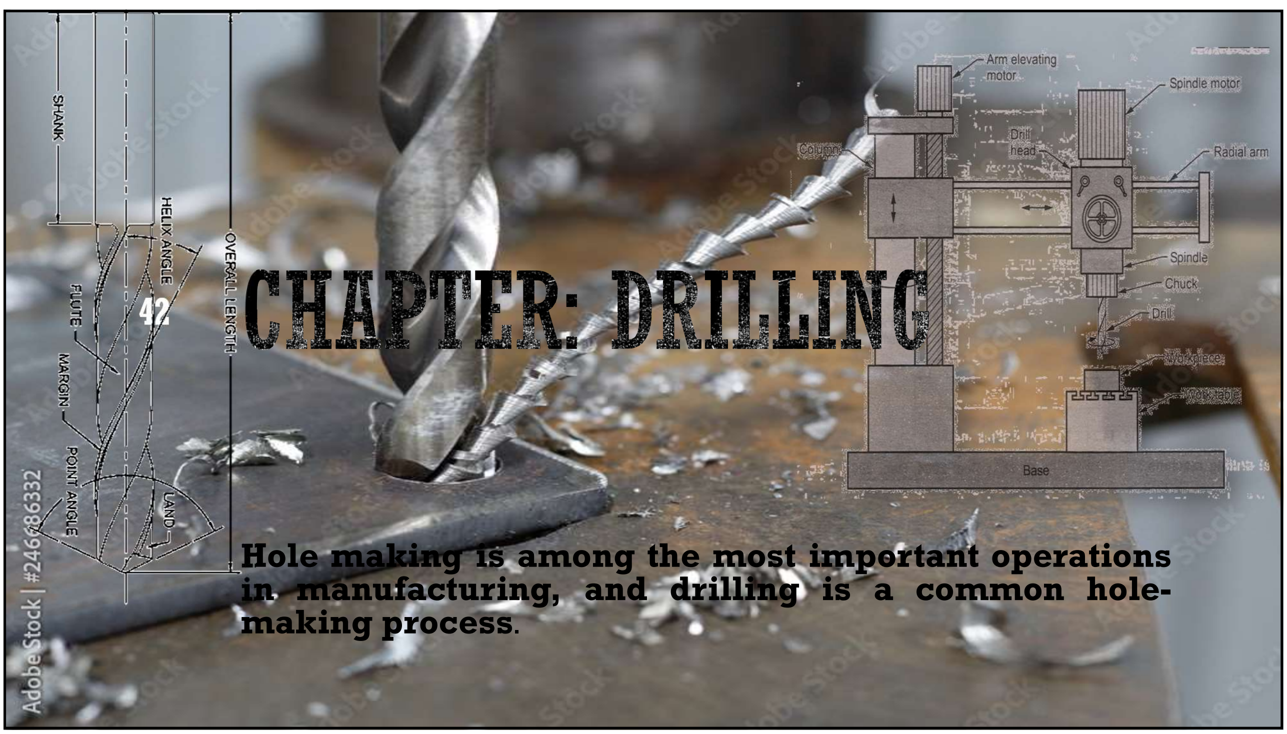
When Tool is set above the centre line $\alpha_e = \alpha + \theta$, $\gamma_e = \gamma - \theta$ } $\theta = \sin^{-1}\left(\frac{h}{R}\right)$

NUMERICALS

- A rod of dia 60mm and length 200mm is to be made 52mm and 48mm dia for 100mm length each. depth of cut is given 2mm ; feed= 0.25mm/rev ; cutting speed = 90 m/min. determine the machining time ?



- A 150-mm-long, 10-mm-diameter, 304 stainless-steel rod is being reduced in diameter to 8 mm by turning on a lathe. The spindle rotates at N = 400 rpm, and the tool is traveling at an axial speed of 200 mm/min.
- Find: Calculate the cutting speed, material-removal rate, cutting time, power dissipated, and cutting force.



CHAPTER: DRILLING

Hole making is among the most important operations in manufacturing, and drilling is a common hole-making process.

HOLE MAKING PROCESS

- **Drilling**
- **Boring**
- **Reaming**
- **Counter Boring**
- **Counter Sinking**
- **Tapping**
- **Trepanning**

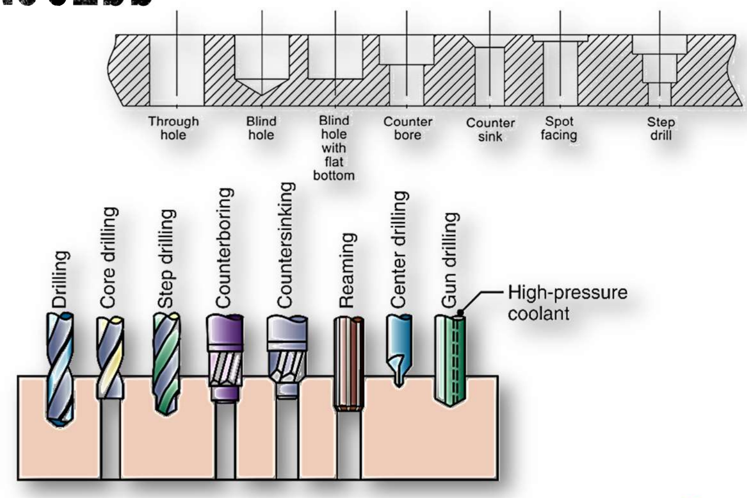


Figure . Various types of drills and drilling and reaming operations.

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DRILLS

- Drills typically have high length-to-diameter ratios , hence they are capable of producing relatively deep holes. However, high ratios make drills somewhat flexible and prone to fracture or making inaccurate holes. Moreover, the chips produced can present significant difficulties in their disposal from the hole being drilled.
- Drills generally leave a burr on the bottom surface of the part upon their breakthrough.
- drilling produces holes with walls with circumferential marks; in contrast, punched holes have longitudinal marks. This difference can be significant in terms of the hole's fatigue properties.
- The diameter of a hole produced by drilling is slightly larger than the drill diameter (oversize), as one can note by observing that a drill can easily be removed from the hole it has just produced, assuming temperature effects are not present.

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TWIST DRILLING

- The most common drill is the conventional standard-point twist drill Fig.. The geometry of the drill point is such that the normal rake angle and velocity of the cutting edge vary with the distance from the center of the drill.
- The main features of this drill are, with typical ranges given in parentheses: **(a) point angle (118◦ to 135◦), (b) lip-relief angle (7◦ to 15◦), (c) chisel-edge angle (125◦ to 135◦), and (d) helix angle (15◦ to 30◦).**
- Two spiral grooves, called flutes, run the length of the drill, and the chips produced are guided upward through these grooves.
- The grooves also serve as passageways to enable the cutting fluid to reach the cutting edges.

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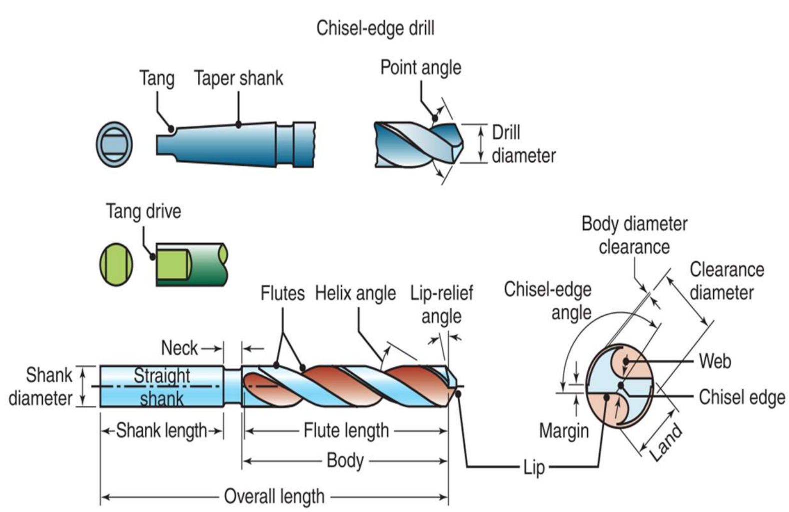

(a)

GEOMETRY

a) **point angle (118◦ to 135◦),**
b) **lip-relief angle (7◦ to 15◦),**
c) **chisel-edge angle (125◦ to 135◦),**
d) **helix angle (15◦ to 30◦).**

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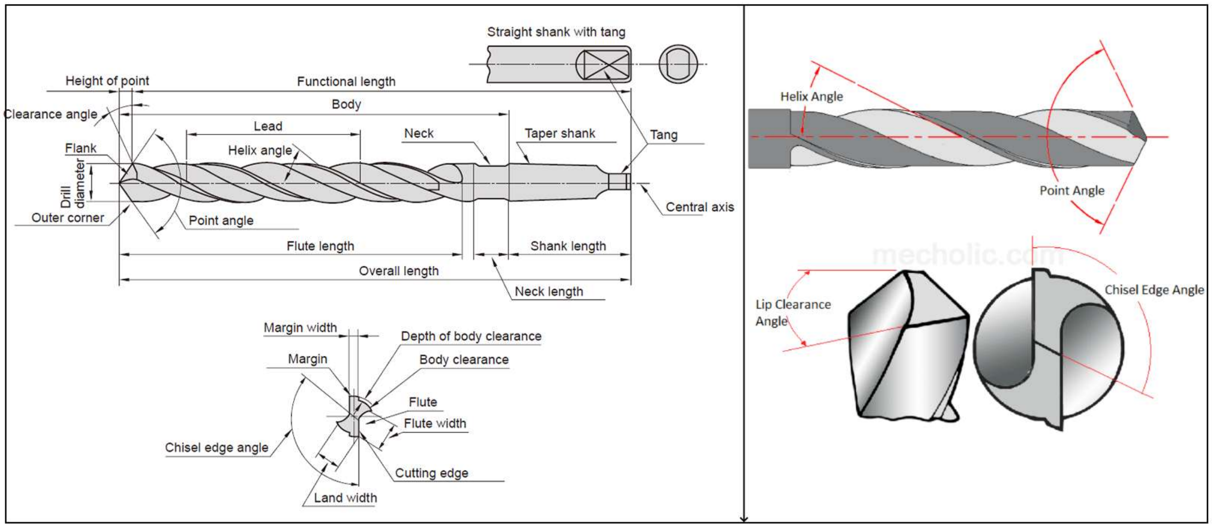
TWIST DRILL GEOMETRY



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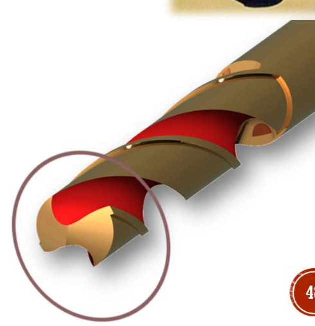
NOMENCLATURE

- **Shank:** Brace Shank, Straight Shank, hex shank, sds shank, Morse taper shank, triangle shank.
- **Flutes:**
  - i- clearance to the chips produced at the cutting edges.
  - ii- Easy passage of the cutting fluid to reach the cutting egdes.
  - iii- length of the flute determines the maximum length of the hole to be produced.
- **Neck:** Separates the main body and the shank. Size and other details are given here.
- **Land:** Drill body between the flutes.
  - provides torsional strength to the drill.

land width ↓ space for chip flow ↑ but strength ↓



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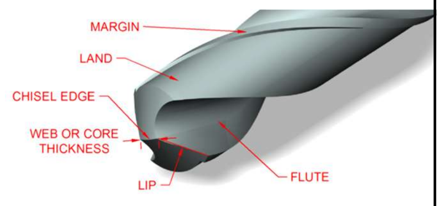
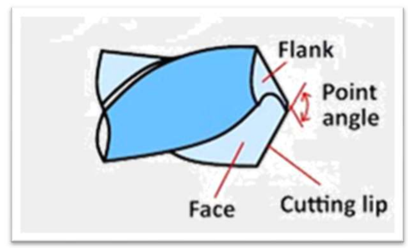
- **Margin:** The cylindrical strip present at the leading edge . It helps in keeping the drill aligned.
- **Lead:** The distance measured from one point on the cutting lip to the next after one revolution of the cutting lip.
- **Back Taper:** Dia of the twist drill reduces towards the shank which is known as the back taper, which provides clearance between drill and workpiece and reduces the heat produced during drilling.
- **Lips:** cutting edges present at the tip of the twist drill.(always of same length.)
- **Flank:** The surface that connects the cutting lip with respective flute is known as flank.
- **Face:** The portion of the flute surface adjacent to the lip is known as face.
- **Point:** Conical shape of the drill consisting of cutting lips, flank and face.





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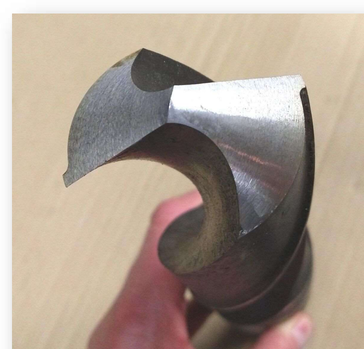
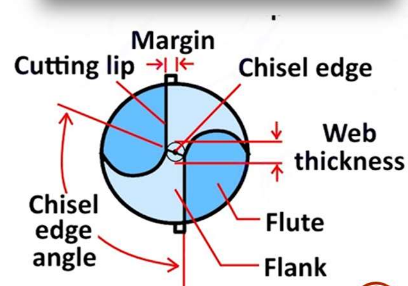
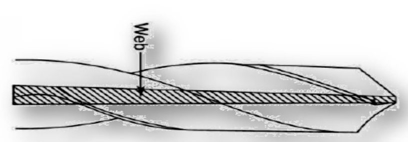
- **Chisel Edge:** Intersection of the flank is known as chisel edge. It only penetrates displacing the workpiece material.
- **Web:** The thickness measured across the base of the flute is web. The web increases through out the length of the body to provide strength and rigidity.
- **Body Clearance:** Diametral Clearance :prevents excessive rubbing and friction.
- **Heel:** Intersection of the flute surface and the body clearance .







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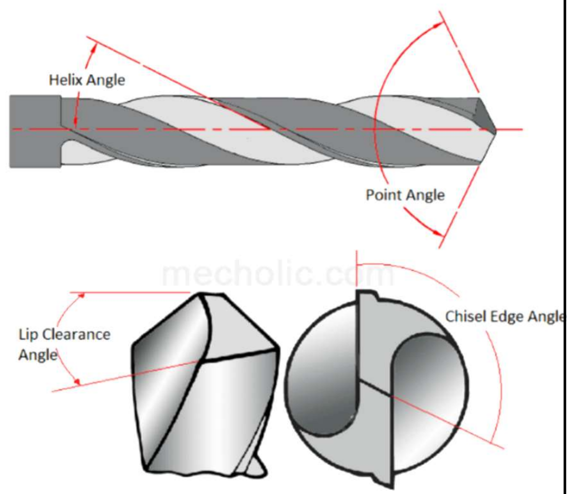
ANGLES

- **Helix Angle:** Angle between the leading edge of the drill and drilling axis.
- **Point Angle:** Angle between both cutting edges .
- **Lip Clearance Angle:** angle between the flank and line normal to the drill axis.
- **Chisel Edge Angle:** Angle between chisel edge and lip or normal to the drill axis.



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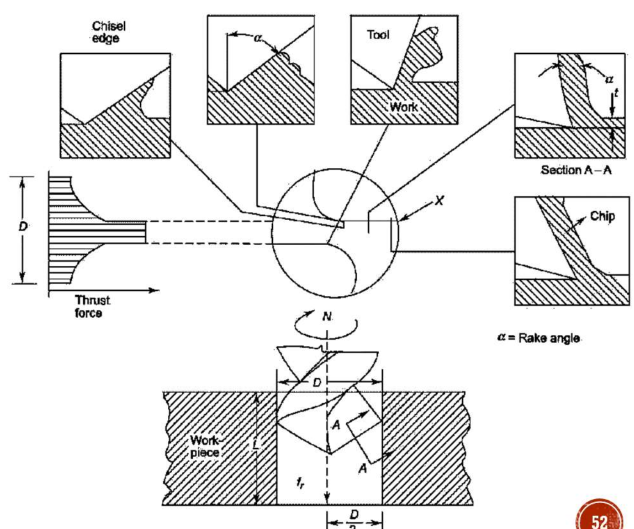
EFFECT OF RAKE ANGLE

- The rake angle in case of drilling is complex since it depends upon the helix angle of the flutes, the point angle and the feed rate.
- The various rake angles possible are shown in Fig. Thus, the thrust force is maximum at the web where the material is compressed and extruded, rather than sheared to the minimum value at the end of the cutting edge.



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COMMMON USED TOOL MATERIAL

- **Low carbon steel**
- **High carbon steel**
- **High speed steel**
- **Cobalt Steel Alloys**
- **Tungsten Carbide**
- **Polycrystaline Diamond**

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DRILLING MACHINE CONSTRUCTION

- **Drill Press**
- **Radial Drill**
- **Muti Spindle Drilling**
- **Gang Drilling**

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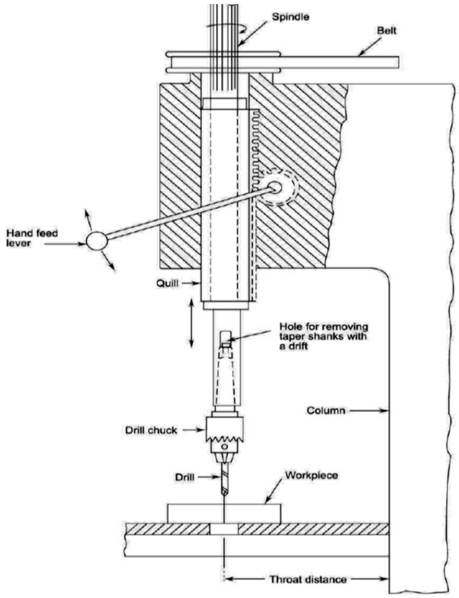
DRILL PRESS



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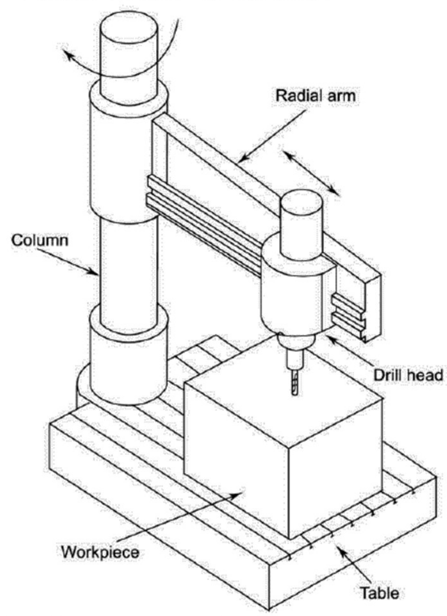
RADIAL DRILL



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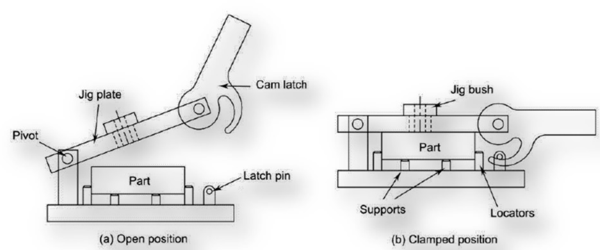
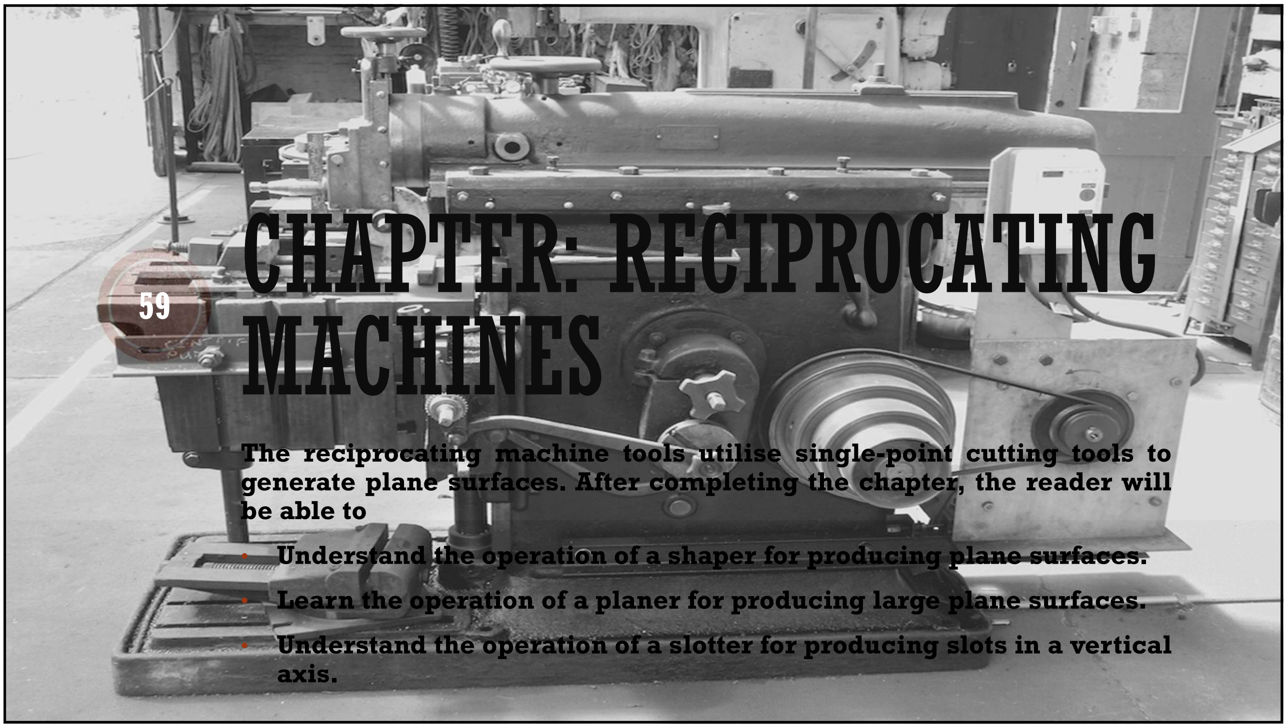
MULTIPLE SPINDLE DRILLING & GANG DRILL

WORK HOLDING

- Work holding in drilling machines is similar to milling. Most of the small components are held in vices for drilling in job shops.
- However, for production operations, it is not only necessary to locate and clamp the workpiece properly, but also to locate and guide the drill.
- Hence jigs are used to serve this function. An example of a drilling jig is shown in Fig.





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CHAPTER: RECIPROCATING MACHINES

The reciprocating machine tools utilise single-point cutting tools to generate plane surfaces. After completing the chapter, the reader will be able to

- **Understand the operation of a shaper for producing plane surfaces.**
- **Learn the operation of a planer for producing large plane surfaces.**
- **Understand the operation of a slotter for producing slots in a vertical axis.**

SHAPER

- Shaping. Machining by shaping is basically the same as by planing, except that it is the tool and not the workpiece that travels; the workpieces are smaller, typically less than 1 m × 2 m of surface area.
- In a horizontal shaper, the cutting tool travels back and forth along a straight path. The tool is attached to the tool head, which is mounted on the ram; the ram has a reciprocating motion. In most machines, cutting is done during the forward movement of the ram (push cut); in others, it is done during the return stroke of the ram (draw cut).
- The shaper is a relatively slow machine tool with very low metal-removal capability. Hence, it is being replaced by the more versatile milling machines in many shops.
- This is low-cost machine tool and hence is used for initial rough machining of the blanks. It is rarely used in production operations.

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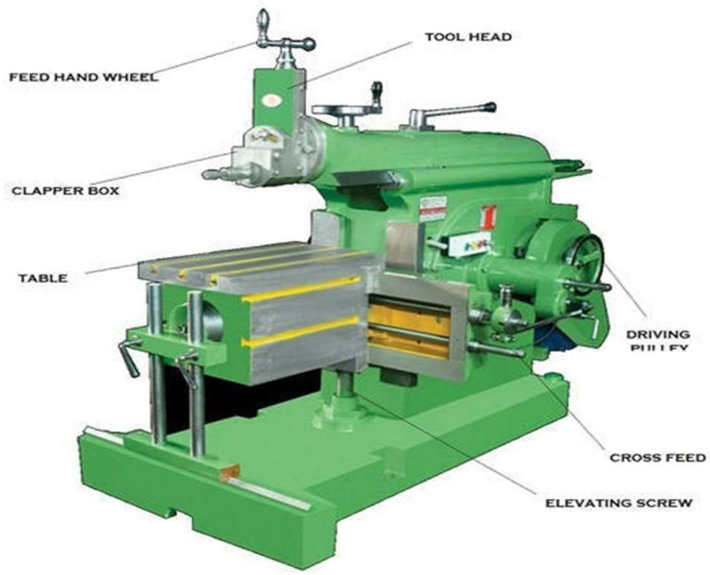

PARTS OF SHAPER MACHINE

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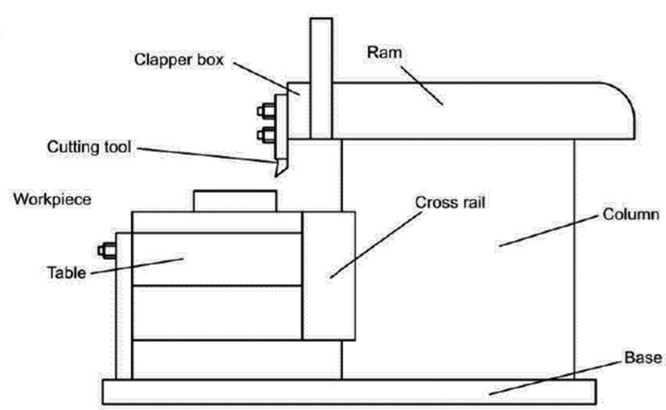
SHAPER CONSTRUCTION

The main constructional pieces of a mechanical shaper are

- Base
- Column
- Ram
- Tool head (clapper box)
- Cross rail
- Table



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1. Base

- The base provides stability for the shaper as it supports all other equipment present as well as absorbs the forces coming due to the cutting. Generally, it is made of grey cast iron and will have the necessary arrangement of bolts so that it can be bolted to the factory floor with proper levelling.

2. Housing (Column)

- The housing is a boxlike structure to provide the necessary rigidity and also houses all the motors and power transmission equipment. On top of the housing, necessary guideways are provided for the linear motion of the ram for the cutting stroke.

3. Ram

- It is a part of the shaper that provides the reciprocating motion for the cutting tool. It gets the motions directly from the quick-return mechanism present in the housing.

4. Table

- A heavy table is present at the front end of the shaper.
- The table is provided with T-slots for mounting the workpieces or work-holding fixtures.
- The table can be moved up and down along the guideways provided on the cross rail attached to the housing.

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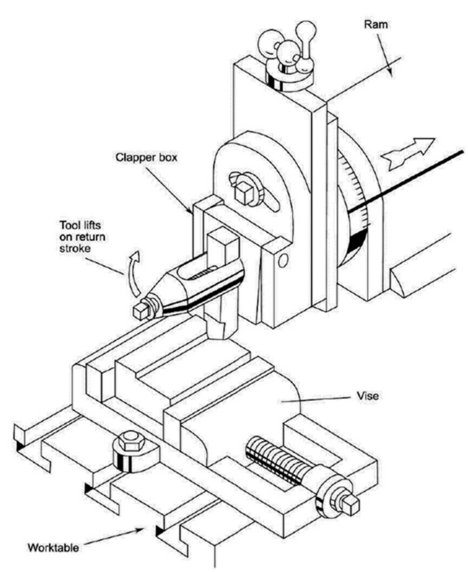
4. Tool Head (Clapper Box)

- The single-point cutting tool is clamped in the tool head as shown in Fig. The tool head has the ability to swivel the cutting tool in any angle while being able to clamp the tool with any overhang depending upon the requirement.
- The swivelling ability is important for the tool to machine surfaces that are not in the horizontal plane. Further, the tool should be firmly supported during forward motion to carry out the material removal.
- During the return stroke, the cutting tool will not be doing the cutting and hence will be an idle stroke.
- If the tool is held firmly as in the cutting stroke, the tool will be rubbing the already machined workpiece and also the flank surface of the tool will wear out quickly.
- To reduce this, the tool is lifted during the return stroke by the clapper-box arrangement as shown in Fig.



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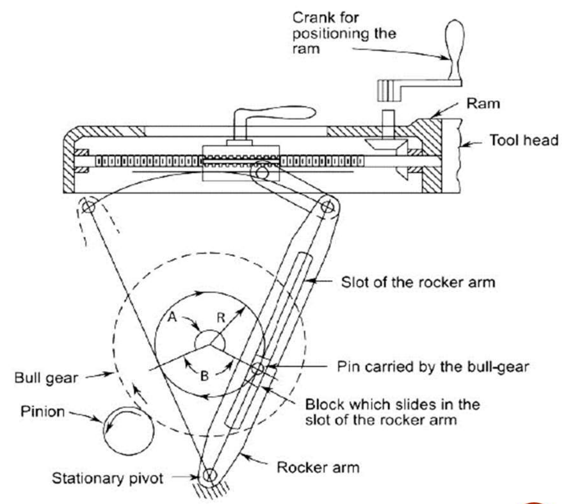
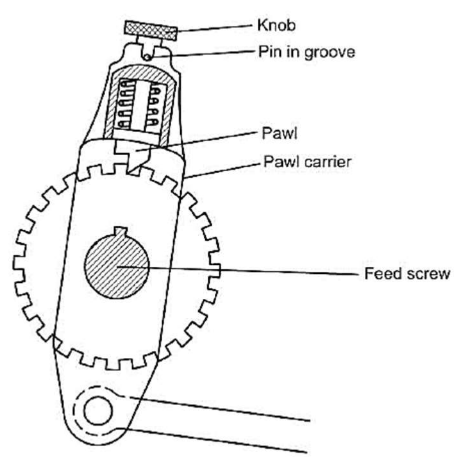
QUICK RETURN MOTION MECHANISM

- During the return stroke, the tool will simply be sliding. Hence, it is necessary to reduce the idle time of the machine to make the return stroke faster compared to the forward motion This is generally accomplished by means of a quick-return mechanism.
- The motor drives the bull gear, which carries a pin in a circular motion.
- This pin fits into the slot of the rocker and is free to slide in a straight-line path.
- As the bull gear rotates, the rocker arm oscillates about its pivot point.
- The end of the rocker arm is connected to the ram of the shaper through a link arm. The length of the stroke is changed by changing the radius of the circle in which the pin on the bull gear rotates. The length of travel should be a little longer than the actual length of the work-picce. This allows sufficient time for the tool block of the clapper box to swing back to its position for cutting.



MECHANICAL FEED DRIVE

- Automatic feeding(intermittent feeding) of the workpiece at the end of the cutting stroke is obtained by moving the feed screw as shown in Fig. through a part of a revolution.
- The feed screw is engaged by a pawl that sits in a notched wheel attached to the feed screw.
- The pawl operates once for each rotation of the bull gear. During one revolution of the bull gear, the oscillating motion of the pawl carrier moves the pawl forward and then back by one or more teeth depending upon the feed rate that was set.
- The oscillating motion is generally obtained by means of a crank pin arranged to make one cycle per one revolution of the bull gear. The feed is normally given during the return stroke.
- The amount of feed is controlled by the number of teeth in the notched wheel that are moved during the return stroke.



SHAPER SPECIFICATION

- Maximum length of stroke, mm
- Maximum table size, length, mm x width, mm x height, mm
- Maximum table travel, length, mm x width, mm
- Maximum power of the drive motor used in the machine, kW
- Range of cutting speeds, strokes/min
- Range of feeds, mm/stroke
- Maximum weight of the machine
- Maximum dimensions of the machine for installation (floor space)

TYPES OF SHAPER

- **Universal Shaper**
- **draw cut shaper**
- **Vertical Shaper**
- **Hydraulic shaper**
  - In a hydraulic shaper Ram is connected to a hydraulic cylinder which is controlled by means of a 4 way valve.
  - The hydraulic fluid is pumped to the hydraulic cylinder through the 4 way valve the 4 way valve is also connected to the sump.
  - A four way valve controls the direction of high pressure fluid into the cylinder thereby controlling the direction of the motion ,either the cutting stroke or return stroke. The flow control valve controls the flow rate of the hydraulic fluid thereby controlling the speed with which the ram will be moving.
  - A finger operated lever serves the purpose of static and stopping the machine an adjustable trip dog operated lever controls the operation of the 4 way valve to control reversal of the ram.

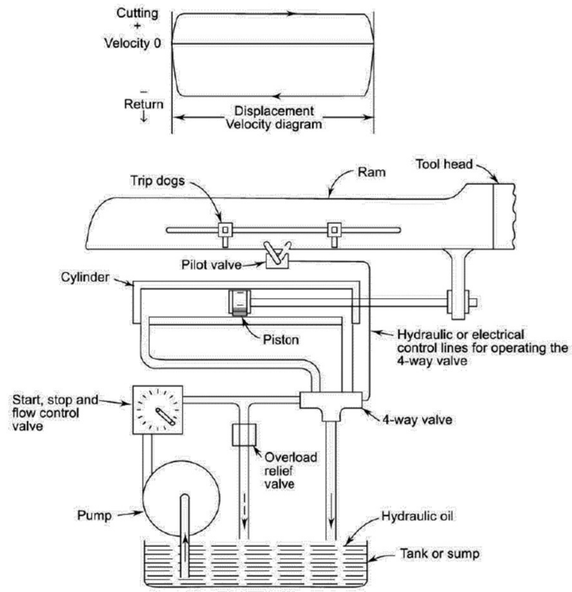
HYDRAULIC SHAPER

Advantages

- Cutting speed remains constant throughout most of the cutting stroke unlike the crank shaper where the speed changes continuously next slide
- Since the power available remains constant throughout it is possible to utilise the full capacity of the cutting tool during the cutting stroke
- The Ram reverses quickly without any shock due to the hydraulic cylinder utilised the inertia of the moving parts is relatively small
- The range and the number of cutting speeds possible are relatively large in a hydraulic shaper.
- More strokes per minute can be achieved by consuming less time of reversal and return stroke.

Disadvantages

- It is more expensive compared to the mechanical shaper the stopping point of the cutting stroke in a hydraulic shaper can vary depending upon the resistance offered to cutting by the work material



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WORK-HOLDING AND SHAPING

- The workpiece which are small are normally hailed in a vice fixed to the shaper table.
- Some other work holding arrangements such as angle blades strap clamps support elements can also be used.

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CUTTING TOOLS USED

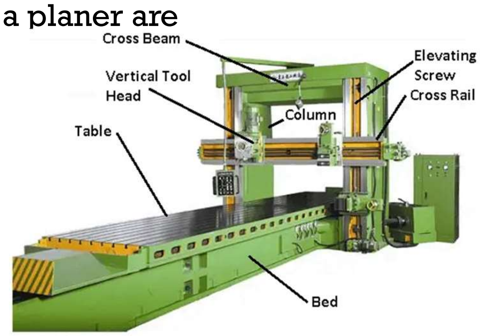
- Large variety of single pond cutting tools with various approaches and edge geometries can be used in the Shaper .
- Single point cutting tools similar to the types used in a lathe are used in shaper too.
- The main difference is that the clearance angle required will have to be properly ground into the tool, as there is no adjustment possible in a shaper's clapper-box arrangement.
- Both the right-hand and left-hand tools are used in shapers. Since the cutting speeds used are relatively low, high-speed steel is the most widely used cutting-tool material for shaping tools.

SHAPING TIME & POWER ESTIMATION

- A shaper is operated at 120 cutting strokes per minute and is used to machine workpeiece of 250 mm length and 120 mm width. Use a feed of 0.6 mm per stroke and a depth of cut of 6 mm. Calculate the total machining time for machining the component. If the forward stroke is completed in 230°, calculate the percentage of the time when the tool is not contacting the workpiece.

PLANNING MACHINE(PLANER)

- Generally, a planer is used for machining large workpieces, which cannot be held in the shaper. In the shaper, the cutting tool reciprocates during the cutting motion, while in the case of a planer, the work table reciprocates. Feeding motion in the planer is given to the cutting tool, which remains stationary during the cutting motion.
- The main constructional pieces of a planer are
- Bed
- Table
- Column
- Cross rail
- Tool head



DOUBLE HOUSING PLANER

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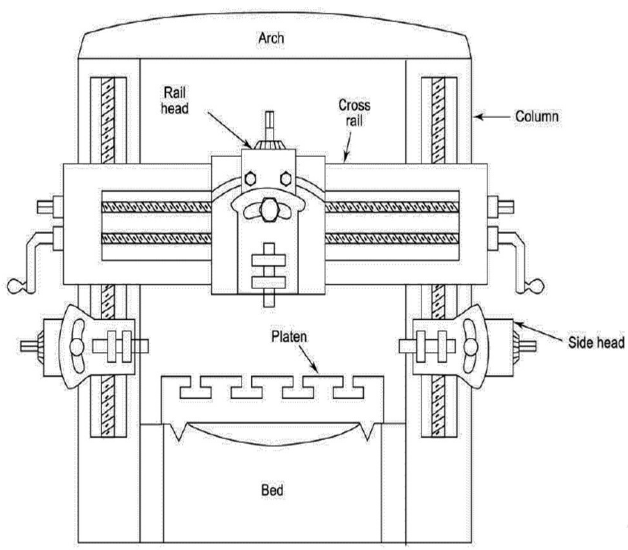
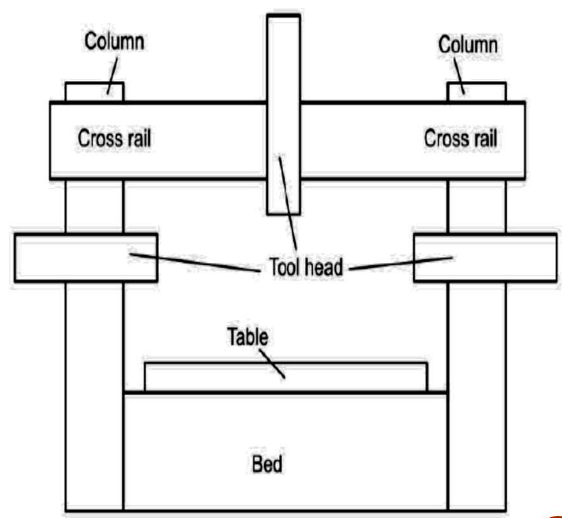
SCHEMATIC DIAGRAM





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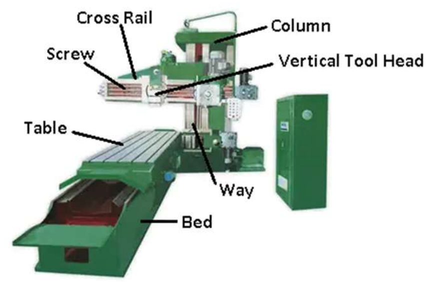
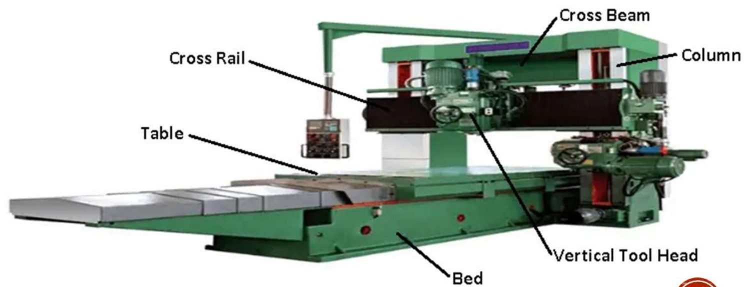
TYPES OF PLANERS

- **Open side planer**
- **Planer Miller**
- **Pit planer**
- **Divided Table Planer**
- **Plate Planer**



OPEN SIDE PLANER



PIT PLANER

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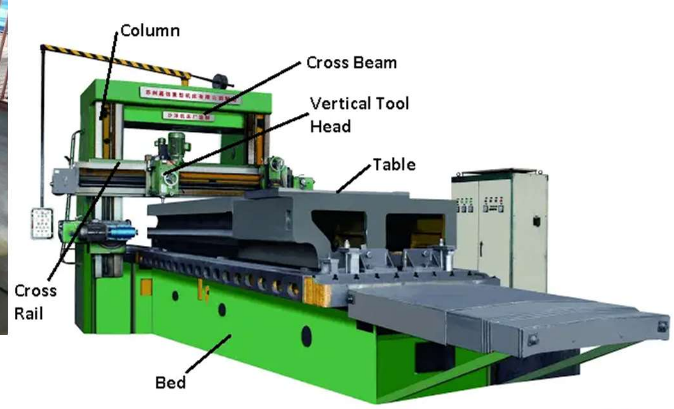
PLATE PLANER & DIVIDED TABLE PLANER



DIVIDED TABLE PLANER

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PLANNING-TIME ESTIMATION

$$\text{Planing time, } t = \frac{W}{f}\left(\frac{l}{V_c} + \frac{l}{V_r} + a\right)$$

where, l = Length of the planer stroke, m

W = Width of surface to be cut, mm

f = Feed rate, mm/stroke

V_c = Cutting speed, m/min

V_r = Table return speed, m/min

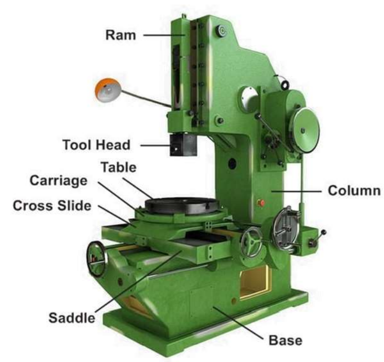
a = Time for reversal of table, min which is about 0.015 to 0.040 minutes

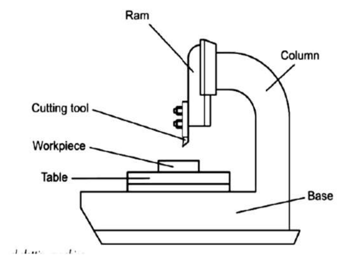
NUMERICALS

- The flat surface of a large cast-iron part measuring 2 m x 1 m x 300 mm is to be machined using a planer along its face (2 m x 1 m). Estimate the machining time, taking approach as well as over travel as 20 mm each. Take cutting speed as 20 m/min, return speed is 40 m/min and a machining allowance on cither side of plate width is 5 mm and feed is 1 mm/stroke.

SLOTTING MACHINE

- Slotting machine is basically a vertical-axis shaper with the differences as mentioned earlier. This is a larger version of the vertical shaper with ram strokes up to 1800 mm long. Thus the workpieces, which cannot be conveniently held in shaper, can be machined in a slotter. Generally, keyways, splines, serrations, rectangular grooves and similar shapes are machined in a slotting machine. The stroke of the ram is smaller in slotting machines than in shapers to account for the type of the work that is handled in them.
- A typical slotter is shown in Fig. The main constructional pieces of a slotter are
  - Base
  - Table
  - Column
  - Ram





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1 Base

- Similar to a shaper and planer, the base of the slotter is a heavy structure to support all the weight of the machine tool and the cutting forces that come against it. Since the cutting force in slotting is directed against the table, the base of the machine is rigidly built.
- Precision guideways are provided on top of the base for the cross-slide to move.

2. Table

- Table is generally a circular one similar to a rotary table of a milling machine. T-slots are cut on the table to facilitate the fixing of workpicces utilising various fixturing elements such as T-bolts, clamps, etc.
- Tables on slotters can be rotated as well as moved longitudinally or transversely. With such flexibility in the feed direction, a slotter can cut any type of groove, slot or keyway.

3. Column

- The column of a slotter is a support structure to the cutting tool and its reciprocating motion. It is also massive and houses the power and drive mechanism used for the reciprocation of the cutting tool.

4. Ram

- The ram holds and supports the tool head during the cutting action. Since gravity acts on the ram during its upward travel, a counterweight is added to equalise the power requirements on the upward and downward strokes. This will provide a smooth action of the machine.
- The actual cutting takes place during the downward motion of the tool. The stroke length can be adjusted suitably depending upon the part.
- The types of tools used in slotter are very similar to that of a shaper except that the cutting actually takes place in the direction of cutting. However, in view of the type of surfaces that are possible in the case of slotter, a large variety of boring bars or single-point tools with long shanks will be used.

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COMPARISON OF RECIPROCATING MACHINE TOOLS

		Shaper	Planer	Slotter
1.	Work-tool motion	Tool reciprocates in horizontal axis and work feeds intermittently	Work reciprocates in horizontal axis and tool feeds intermittently	Tool reciprocates in vertical axis and work feeds intermittently
2	Construction and rigidity	Lighter in construction and less rigid	Heavier in construction and more rigid	Lighter in construction and less rigid
3	Motor power required	Relatively less power	Higher power compared to shaper	Relatively less power
4	Typical work size and set-up time	Relatively small parts. Typical work envelope is: 450 × 450 × 600 mm. Quick set-up time.	Bigger parts require lengthy set-up time. Typical work envelope is 3 × 3 × 15 m	Relatively small parts. Typical work envelope is 450 × 450 × 300 mm. Quick set-up time.
5	Number of surfaces that can be machined at a time	Only one surface at a time	Three surfaces can be machined at a time	Only one surface at a time
6	Material-removal rate (MRR)	Low MRR	High since multiple tools can work at a time	Low MRR
7	Tool size	Regular size similar to lathe	Bigger size tools that can take higher depth of cut and feed	Regular size similar to lathe
8	Range of speeds and feeds	Smaller range and smaller number of speeds and feeds	Wide range and more number of speeds and feeds available	Smaller range and smaller number of speeds and feeds

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CHAPTER: MILLING

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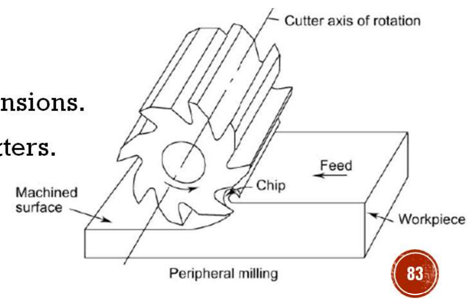
Milling is a versatile machine tool that uses a rotating milling cutter while the workpiece reciprocates in contact with the cutting tool. After completing this chapter the reader will be able to

- **Understand the characteristic features of the milling process**
- **No the various types of milling machines and their applications**
- **Select the various types of milling cutters based on the application**
- **Understand different types of milling operation that can be done in milling machines**
- **Understand the mechanics of milling operations to appreciate the effect of different process variables on the performance.**

INTRODUCTION

- After the class of lathe, milling machines are the most widely used machine tools for manufacturing applications.
- In milling the work piece is fed into rotating milling cutter which is a multi point tool as shown in the figure.
- It is unlike a lathe which uses a single point cutting tool the tool is you is in milling is called milling cutter .
- Capability to perform large no of operations.
- High production rate with in very closed limits of dimensions.
- Replaced other machine tools like shaper, planers, slotters.



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WORKING PRINCIPLE

- Work is rigidly clamped on the table of the machine and revolving multi teeth cutter either on a spindle or on arbor.
- The work can be fed in a vertical, longitudinal, or cross direction. As the work advances the cutter-teeth remove the metal from the work surface to produce desired shape.

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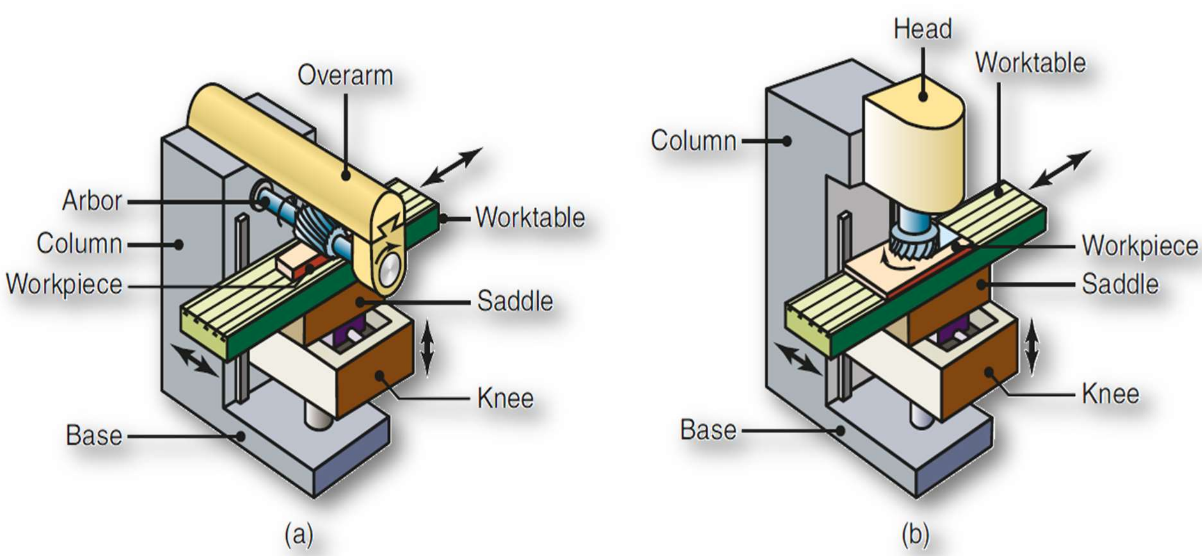
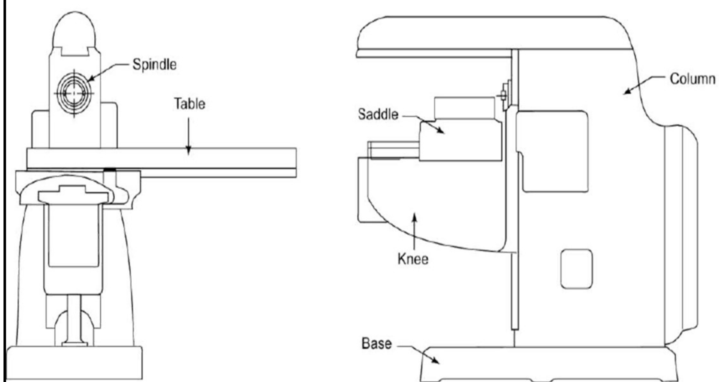
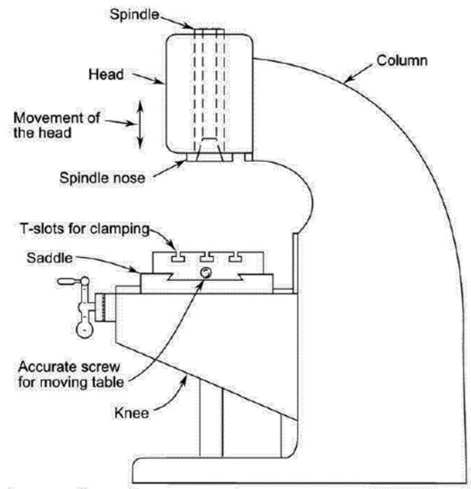
TYPES OF MILLING MACHINES

- **Knee and column type**
- **Production type**
- **Plano Millers**
- **Special type**



KNEE AND COLUMN TYPE





Vertical knee and column-type milling machine

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- The knee houses the feed mechanism and mounts the saddle and table. The table basically has the T-slots running along the X-axis for the purpose of work holding. The table moves along the X-axis on the saddle, while the saddle moves along the Y-axis on the guideways provided on the knee.
- The knee can move up and down (Z-axis) on a dovetail provided on the column.
- The massive column at the back of the machine houses all the power train including the motor and the spindle gearbox. The power for feeding the table lead screw is taken from the main motor through a separate feed gearbox.
- The spindle is located at the top end of the column. Arbour used to mount the milling cutters is mounted in the spindle, and is provided with a support on the other end to take care of the heavy cutting forces by means of an over-arm with bearing.
- Another type of knee and column milling machine possible is the vertical-axis type (Fig. Most of the construction is very similar to the horizontal-axis type except the spindle type and location. The spindle is located in the vertical direction and is suitable for using the shank-mounted milling-cutters such as end mills.
- Relatively the vertical-axis milling machine is more flexible and suitable for machining complex cavities, such as in-die cavities in toolrooms. Also, the vertical head is provided with swivelling facility in horizontal direction, whereby the cutter axis can be swivelled. This is useful for toolrooms where more complex milling operations are carried out.

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MILLING MACHINE SPECIFICATION

Milling machines are generally specified based on the following:

- Size of the table, which specifies the actual working area on the table and relates to the maximum size of the workpiece that can be accommodated.
- Amount of table travel, which gives the maximum axis movement that is possible.
- Horsepower of the spindle, which actually specifies the power of the spindle motor used. Smaller machines may come with 1 to 3 hp while the production machines may go from 10 to 50 hp.

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TYPES OF MILLING CUTTERS

- End mill cutters
- Peripheral mill cutters
- Side mill cutters
- Straddle mill cutter
- Gang mill cutter

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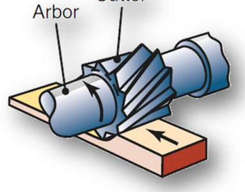

Figure Schematic illustration of peripheral milling.

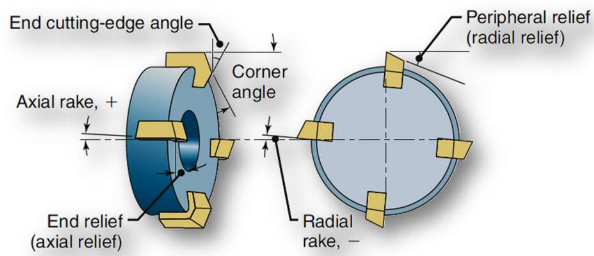

Figure . Terminology for a face-milling cutter.

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TYPES OF MILLING OPERATIONS

- **Face milling operation**
- **Slot or slab milling operation**
- **Up milling operation**
- **Down milling operation**

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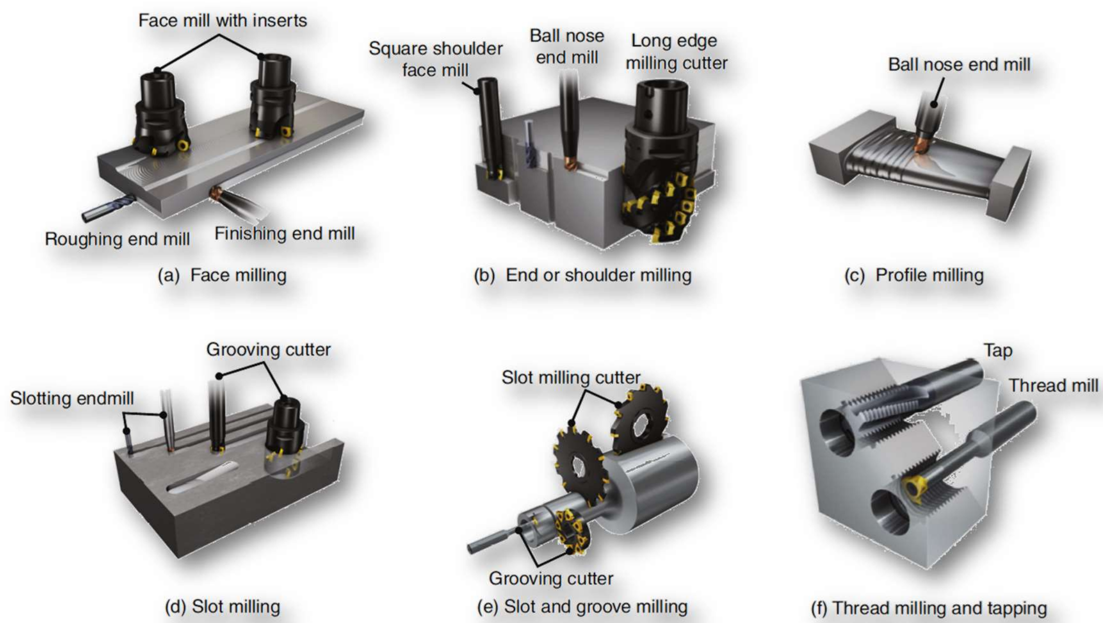

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- **Face milling operation**: the method of removing a layer of material from surface of work piece is called as face milling operation.
- **Slab milling operation**: The method of producing slots in the component using milling is called slab or slot milling operation.
- **Face milling operation** is preferable to perform by using end mill cutter and slab milling operation is preferable to perform by using peripheral mill cutter.
- **Up milling**: in this method of milling the cutter rotates in a direction opposite to that in which the work is fed.
- **Down milling**: In this method the direction of rotation of the cutter coincides with the direction of work feed.

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PERIPHERAL MILLING

- In peripheral milling, also called **plain milling**, the axis of cutter rotation is parallel to the workpiece surface, as shown in Fig. The cutter body, which generally is made of high-speed steel has anumber of teeth along its circumference; each tooth acts like a single-point cutting tool.
- When the cutter is longer than the width of the cut, the operation is called **slab milling**.
- Cutters for peripheral milling may have either straight or helical teeth, resulting in an orthogonal or oblique cutting action, respectively. Helical teeth generally are preferred over straight teeth, because each tooth is always partially engaged with the workpiece as the cutter rotates.
- Consequently, the cutting force and the torque on the cutter are lower, resulting in a smoother milling operation and reduced chatter.

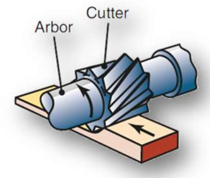
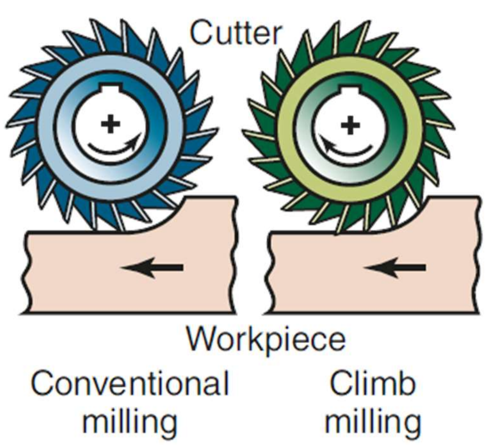


Figure Schematic illustration of peripheral milling.

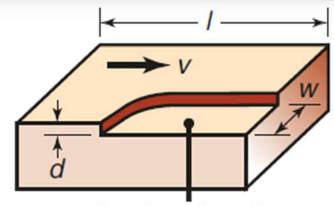
UP MILLING & DOWN(CLIMBING) MILLING



- An important difference is that in conventional milling has cut proceeds the chief thickness increases gradually against this the chief thickness decreases in place of climbing milling.
- In other words we can say that the chip thickness in conventional milling is minimum at the start of the cut and maximum at the end of the cut whereas in climb or down milling it is a reverse case that is maximum in the beginning and zero at the end.
- Conventional milling is commonly used for machining castings and forging works.
- Down milling is used for finishing operations such as slot cutting groove cutting etc.

FACE MILLING

- In *face milling*, the cutter is mounted on a spindle having an axis of rotation perpendicular to the workpiece surface (Fig.);
- it removes material in the manner shown in Fig. The cutter rotates at a rotational speed, *N*, and the workpiece moves along a straight path, at a linear speed, *v*.
- When the direction of cutter rotation is as shown in Fig. the operation is *climb milling*; when it is in the opposite direction (Fig.), it is *conventional milling*. The cutting teeth, such as carbide inserts, are mounted on the cutter body, as shown in Fig.



Machined surface

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END MILLING

- *End milling* is an important and common machining operation, because of its versatility and capability to produce various profiles and curved surfaces. The cutter, called an **endmill** , has either a straight shank (for small cutter sizes) or a tapered shank (for larger sizes), and is mounted into the spindle of the milling machine.
- End mills may be made of high-speed steels, solid carbide, or with coated or uncoated carbide inserts, similar to those for face milling.
- The cutter usually rotates on an axis perpendicular to the workpiece surface, but it can be tilted to conform to machine-tapered or curved surfaces.
- End milling can produce a variety of surfaces at any depth, such as curved, stepped, and pocketed (Fig.). The cutter can remove material on both its end and on its cylindrical cutting edges, as can be seen in Fig.

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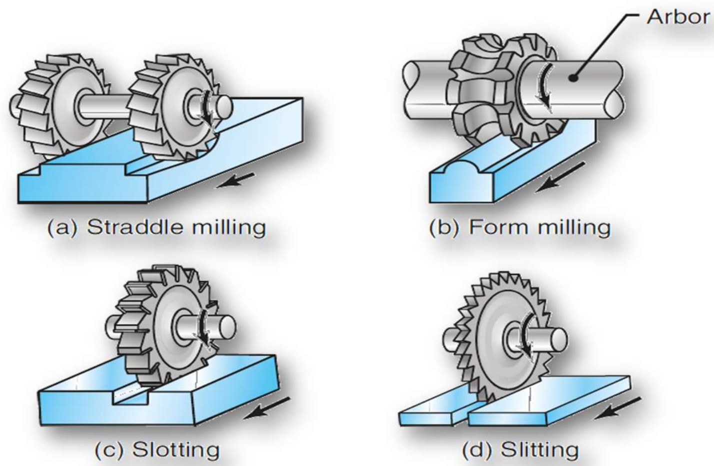
OTHER MILLING OPERATIONS

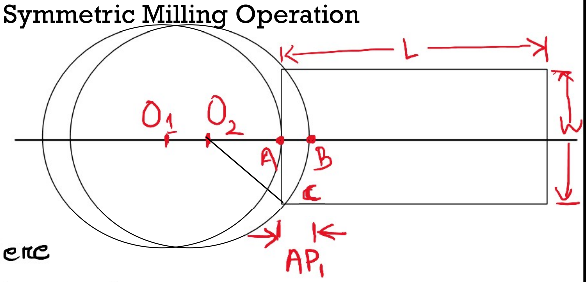
- Cutters for (a) straddle milling, (b) form milling, (c) slotting, and (d) slitting with a milling cutter.



MACHINING TIME

- Time/cut $= \frac{L}{f_m} = \frac{L}{fN} = \frac{L}{f_t zN}$
- $f_m = fN = f_t z\mathbb{N} = \frac{feed}{\min}$
- f= feed per rev.
- Ft = feed per tooth
- Z = number of teeth.
- Le = L+AP1+AP+OR

- Symmetric Milling Operation



Here

$AP_1 = AB$

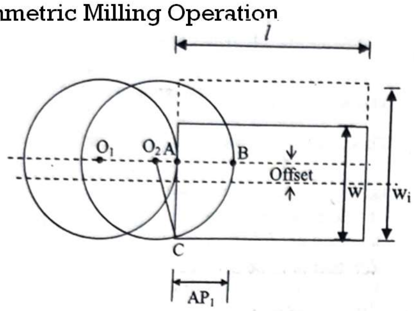
$= O_2B - O_2A$

$= \frac{D}{2} - \sqrt{O_2C^2 - AC^2}$

$$AP_1 = AB = O_1O_2$$
$$= O_2B - O_2A$$
$$= O_2B - \sqrt{O_2C^2 - AC^2}$$
$$= \frac{D}{2} - \sqrt{\left(\frac{D}{2}\right)^2 - \left(\frac{W}{2} + offset\right)^2}$$
$$= \frac{1}{2}\left(D - \sqrt{D^2 - W_i^2}\right)$$

$$= \frac{D}{2} - \sqrt{\left(\frac{D}{2}\right)^2 - \left(\frac{W}{2}\right)^2}$$
$$AP_1 = \frac{1}{2}\left(D - \sqrt{D^2 - W^2}\right)$$

Asymmetric Milling Operation



* Approach for Asymmetric milling is always greater than symmetric milling.

→

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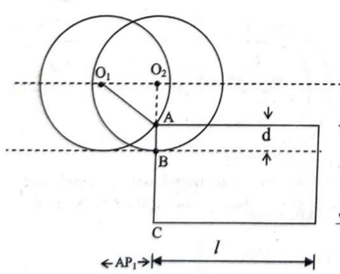
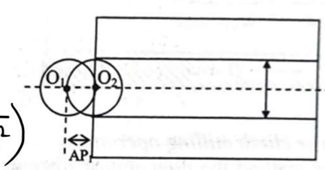
2. Face Milling with Peripheral Milling Cutter :-



$$AP_1 = O_1O_2 = \sqrt{O_1A^2 - O_2A^2}$$
$$= \sqrt{\left(\frac{D}{2}\right)^2 - (O_2B - AB)^2}$$
$$= \sqrt{\left(\frac{D}{2}\right)^2 - \left[\left(\frac{D}{2}\right) - d\right]^2}$$
$$= \sqrt{Dd - d^2} = \sqrt{d(D-d)} \approx dD$$
$$AP_1 = \sqrt{d(D-d)} \approx \sqrt{dD}$$

3. Slab Milling with end mill Cutter



$$AP_1 = O_1O_2$$
$$AP_1 = D/2$$
$$AP_1 = \frac{1}{2}\left(D - \sqrt{D^2 - W^2}\right)$$

When $D = W$

$$\boxed{AP_1 = D/2}$$

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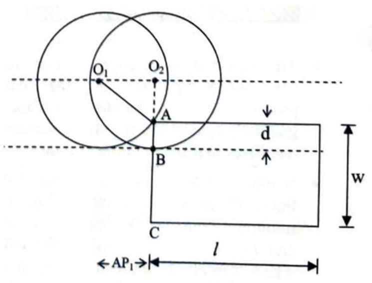
4. Slab Milling with Peripheral Milling Cutter



$$AP_1 = O_1O_2 = \sqrt{(O_1A)^2 - (O_2A)^2}$$
$$= \sqrt{Dd - d^2}$$
$$= \sqrt{d(D-d)}$$
$$= \sqrt{dD}$$

*Note - Whenever end mill cutter is used

$$AP_1 = \frac{1}{2}\left(D - \sqrt{D^2 - W^2}\right)$$

Whenever peripheral mill cutter is used

$$AP_1 = \sqrt{d(D-d)}$$

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MATERIAL-REMOVAL RATE, POWER, TORQUE, AND CUTTING TIME IN SLAB MILLING

A slab-milling operation is being carried out on a 300 mm-long, 100-mm-wide annealed mild steel block at a feed f = 0.25 mm/tooth and a depth of cut d = 3 mm. The cutter is D = 50 mm in diameter, has 20 straight teeth, rotates at N = 100 rpm, and, by definition, is wider than the block to be machined.

*Since the workpiece is annealed mild steel, the unit power is estimated as 5.5W-s/mm3

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- Given: Refer to and assume that D = 150 mm, w = 60 mm, l = 500 mm, d = 3 mm, v = 0.6 m/min, and N = 100 rpm. The cutter has 10 inserts, and the workpiece material is a high-strength aluminum alloy.
- Find: Calculate the material-removal rate, cutting time, and feed per tooth, and estimate the power required.

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INDEXING IN MILLING

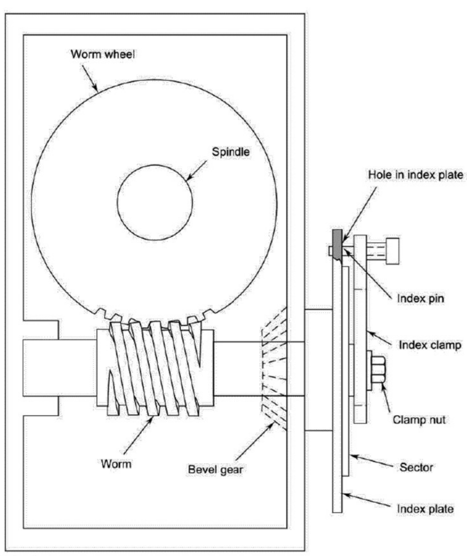

Fig. Dividing-head construction

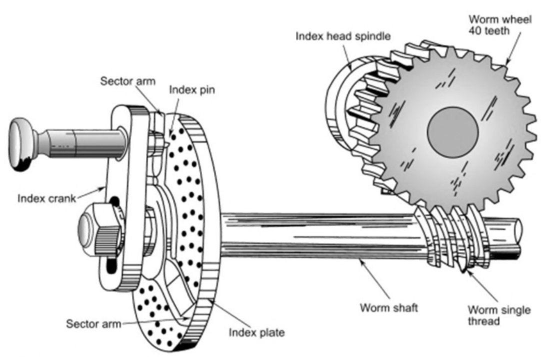

Fig. Indexing method of the dividing head

- **The operation of rotating the job through required angle in between the two successive cuts is called as indexing in milling operation.**

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MAJOR COMPONENTS

Indexing requires basically two devices.

- A device which can rotate the job through required angle that is **indexing crank**.
- A device which can ensure that the given rotation is correct that is **indexing plate.** Indexing plate means it is a circular disc with many number of holes in a circle at equally spaced drill.

The index plates available with the Brown and Sharpe milling machines are

- Plate no. 1: 15,16, 17, 18, 19, and 20 holes
- Plate no. 2: 21, 23,27, 29,31, and 33 holes
- Plate no. 3: 37,39, 41, 43,47, and 49 holes

The index plate used on Cincinnati and Parkinson dividing heads is

- Plate 1: Side | 24, 25,28, 30, 34, 37, 38, 39, 41, 42 and 43 holes
- Side2 46,47,49, 51, 53, 57, 58, 59, 62 and 66 holes

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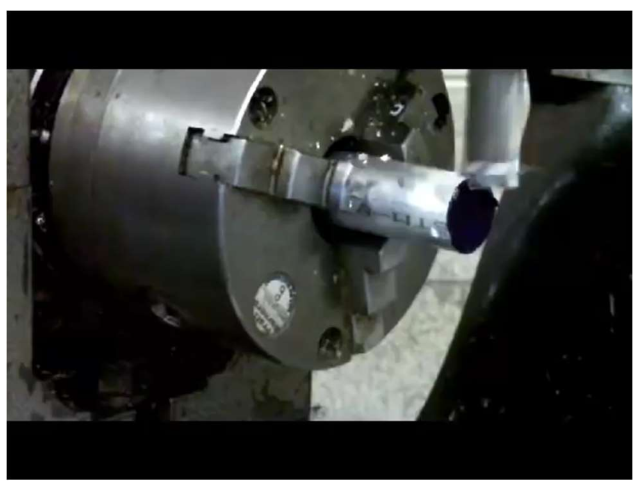
TYPES OF INDEXING

- **Direct indexing**
- **Simple or plain indexing**
- **Angular indexing**
- **Compound indexing**
- **Differential indexing**



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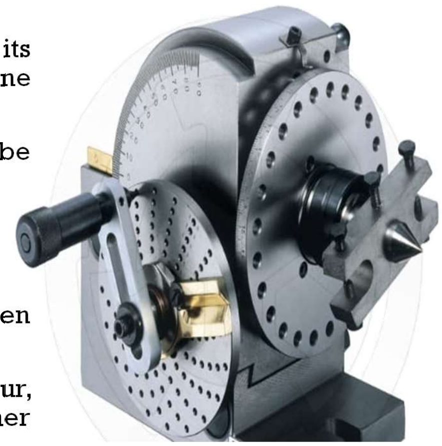
DIRECT INDEXING

- The job at Crank are rotating on a single shaft therefore its name named as direct indexing so that for empree one revolution of crank is equal to one revolution of job.
- Let N = Number of division of circumference of job that is to be divided
- Crank rotation CR = 24/N
- Cr = 24/6 = 4 holes
- To get six division the crank has to rotate four holes in given circle of holes after every cut.
- Direct indexing can be used for producing to two, three, four, six, eight, twelve,twenty four divisions only but for all other division impossible.



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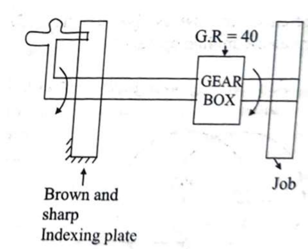
PLAIN INDEXING

- In this indexing to get gear ratio 40 worm and worm wheel be employed and brown and sharpen plate will be used.
- One revolution of crank = (1/40) revolution of job
- = 360°/40 = 9° of job will rotate.
- CR = 40/N
- Where N = no of Division by which the circumference of the job is to be divided.



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COMPOUND INDEXING

- Using the above method, a majority of the indexing jobs could be completed. However, when the available capacity of the index plates is not sufficient to do a given indexing job, the compound indexing method could be used.
- In order to obtain more complex indexing, the following method is used. First the crank is moved in the usual fashion in the forward direction.
- Then a further motion is added or subtracted by rotating the index plate after locking the plate with the plunger. This is termed compound indexing.

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- **Indexing for 69 divisions.**

Follow the steps given below :

(a) Factor the divisions to be make (69 = 3 *23) N = 69.

(b) Select two hole circles at random (These are 27 and 33 in this case, both of the hole circles should be from same plate).

(c) Subtract smaller number of holes from larger number and factor it as (33 – 27 = 6 = 2 * 3).

(d) Factor the number of turns of the crank required for one revolution of the spindle (40). Also factorize the selected hole circles.

(e) Place the factors of N and difference above the horizontal line and factors of 40 and selected both the hole circles below the horizontal line as given below. Cancel the common values.

$$69 = 23 \times 3$$
$$6 = 2 \times 3$$
$$\overline{}$$
$$40 = 2 \times 2 \times 2 \times 5$$
$$27 = 3 \times 3 \times 3$$
$$33 = 3 \times 11$$

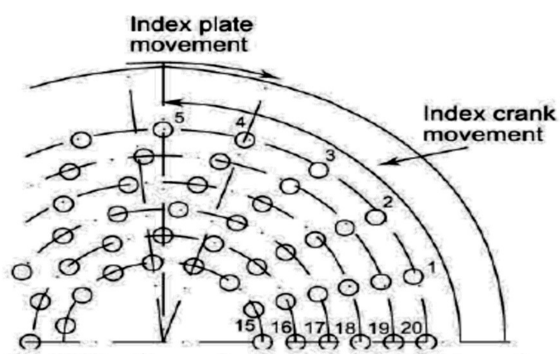

Fig. 7.23 *Compound indexing using the index plate no. 1 of Brown and Sharpe dividing head with 5 holes in the 20-hole circle minus 1 hole in the 15-hole circle*

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f) (f) If all the factors above the line are cancelled by those which are below the line, then the selected hole circles can be used for indexing otherwise select another two hole circles. In this case there is need to select another hole circles. Let us select 23 and 33 this time and repeat the step 5 as indicated below. Encircled numbers below the line are the left out numbers after canceling the common factors. All the factors above the horizontal line are cancelled so selected hole circles with 22 and 33 holes can used for indexing.

$$69 = 23 \times 3$$
$$10 = 2 \times 5$$
$$\overline{40 = 2 \times \textcircled{2} \times \textcircled{2} \times 5}$$
$$22 = 23 \times 1$$
$$33 = \textcircled{11} \times 3$$

g) Following formula is used for indexing : In this formula N1 = 23 and N2 = 33 (N_1 is always given smaller value out of two).

$$\frac{40}{69} = \frac{n_1}{N_1} \pm \frac{n_2}{N_2}$$

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(h) Multiply all the remaining factors below the line as $2 \times 2 \times 11 = 44$.
The formula above will turn to

$$\frac{40}{69} = \frac{44}{23} - \frac{44}{33}$$

We will neglect the +ve sign.

$$= 1\frac{21}{23} - 1\frac{11}{33}$$

The –ve sign indicates backward movement.

Action

For indexing of 69 divisions, the indexing crank should be moved by 21 holes circle in forward direction and then crank along with the plate are moved by 11 holes in 33 hole circle is reversed (backward) direction.

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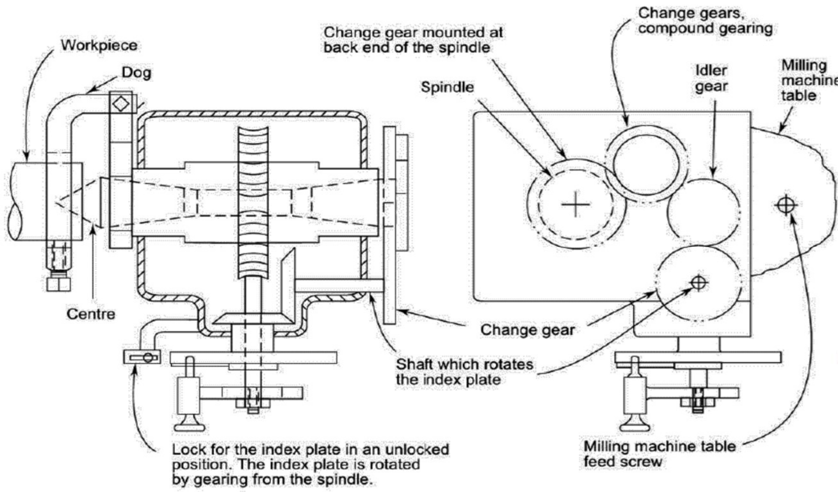
DIFFERENTIAL INDEXING



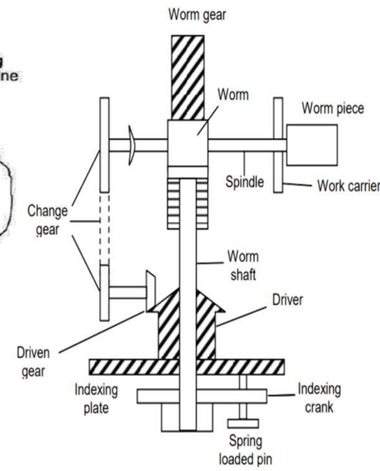


Figure Working Principle of Indexing Mechanism

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- differential indexing is used for that purpose which is exactly an automatic way to carry out the compound indexing method.
- In differential indexing, the index plate is made free to rotate. A gear is connected to the back end of the dividing-head spindle, while another gear mounted on a shaft is connected to the shaft of the index plate through bevel gears as shown in Fig. .
- When the index crank is rotated, the motion is communicated to the workpiece spindle. Since the workpiece spindle is connected to the index plate through the intermediate gearing as explained above, the index plate will also start rotating.
- If the chosen indexing is less than the required one then the index plate will have to be moved in the same direction as the movement of the crank to add the additional motion. If the chosen indexing is more then the plate should move in the opposite direction to subtract the additional motion.
- **The direction of the movement of the index plate depends upon the gear train employed. If an idle gear is added between the spindle gear and the shaft gear in case of simple gear train then the index plate will move in the same direction to that of the indexing crank movement.**
- **In the case of compound gear train, an idler is to be used in the case when the index plate is to move in the opposite direction.**

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CHAPTER- GRINDING

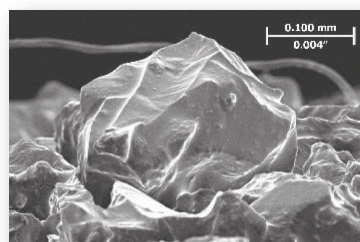
Abrasive machining is among the major finishing operations in the production of parts, and is important because of its capability to impart high dimensional accuracy and surface finish.

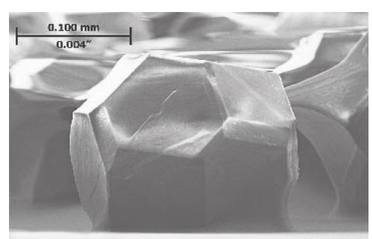
• This chapter opens with a description of the grinding process, the mechanics of material removal, and the types of abrasives and bonds used in grinding wheels.

Grinding is also conventional machining method used for removing small amount of material from the work piece to get good or excellent surface finish on the workpiece.

INTRODUCTION

- Consider the dimensional accuracy and fine surface finish required on ball bearings, pistons, valves, cylinders, cams, gears, molds and dies, and the precision components in instrumentation.
- One of the most common and economical methods for producing such demanding characteristics on parts is abrasive machining.
- An abrasive is a very small, hard particle having sharp edges and an irregular shape (Fig.).
- The simplest example is sand, which is capable of removing small amounts of material from a surface by scratching it, producing tiny chips. Familiar applications of abrasives are sandpaper or emery cloth, used to smoothen surfaces and remove sharp corners, and grinding wheels, as shown in Figs., to sharpen knives, tools, or to impart good dimensional accuracy and surface finish. Abrasives also are used to hone, lap, buff, and polish workpieces.





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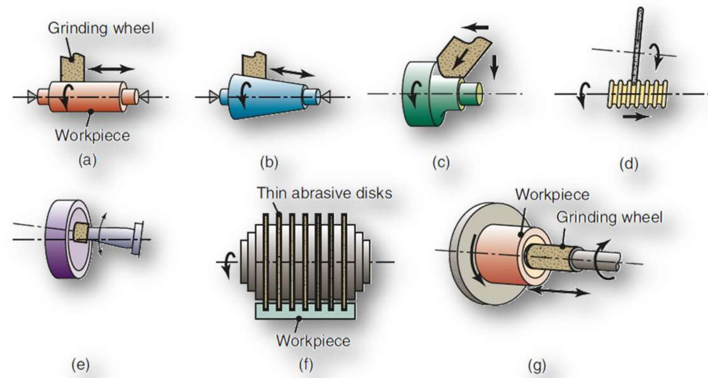
APPLICATION

- The types of workpieces and operations typical of grinding: (a) cylindrical surfaces, (b) conical surfaces, (c) fillets on a shaft, (d) helical profiles, (e) concave shape, (f) cutting off or slotting with thin wheels, and (g) internal grinding.



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WORKING PRINCIPLE

- During machining operation the abrasive present on the surface of grinding wheel will be acting as a single point cutting tool for removing the material from the work piece.
- Abrasive particle looks like cubicle cross section.
- During removal of material from the workpiece using cubical shape abrasive particle the cross section of the chip produced is approximately circular.
- As the machining is continuing the abrasive particle will be wearing out slowly, when the wear on the abrasive particle is considerable it is started rubbing onto the work piece, produces rubbing forces.
- These rubbing forces will pull out the worn out abrasive particle so that the fresh and new abrasive particle will present and come in contact with work piece and start removing material from work piece .This is called as **self sharpening of grinding wheel.**

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IMPORTANT POINTS

- Out of all conventional machining operation the grinding requires largest specific cutting energy.
- Even though abrasive particle has the capability to penetrate more into the workpiece and remove larger amount of material but because of presence of bonding material side by the abrasive particle is not allowing the abrasive particle to penetrate more hence the size of the chip produced is reduced and MRR is also reducing.
- This is called size effect of chip formation.
- Out of all conventional machining method the grinding done at high velocity whereas Broaching will be done at slow velocity.(V_c= 18000 -30000 m/min).

GRINDING RATIO

- Machining ratio = Grinding Ratio= $\frac{volume\ of\ the\ material\ removed\ on\ the\ workpiece}{volume\ of\ material\ wore\ on\ tool}$

$$= \frac{L * b * t}{\left(\frac{\Pi}{4}\right) * (Di^2 - Df^2) * w}$$

- Work piece of size 200 X 2.5 mm^2 have to be machined into a thickness 5 mm by using a grinding wheel of initial diameter 500 mm tool has worn 20 micrometre depth radially and width of tool is 25 millimetre then find grinding ratio of the machining?

SPECIFICATION OF GRINDING WHEEL

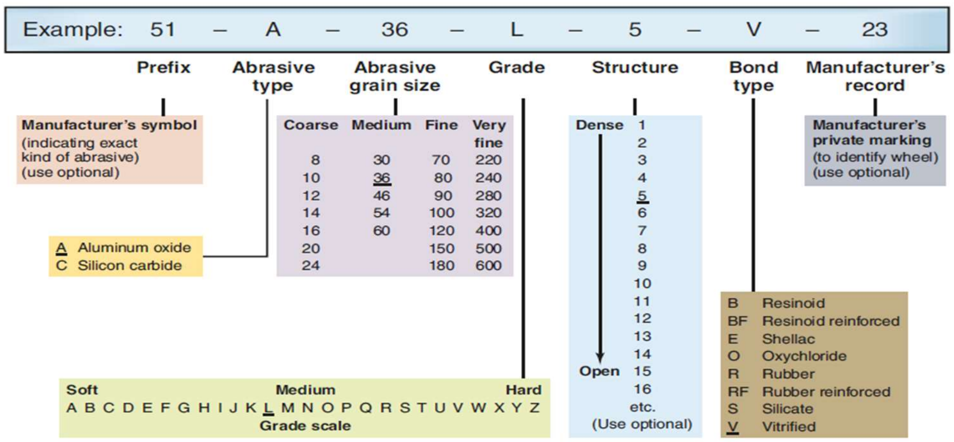

Figure Standard marking system for aluminum-oxide and silicon-carbide bonded abrasives.

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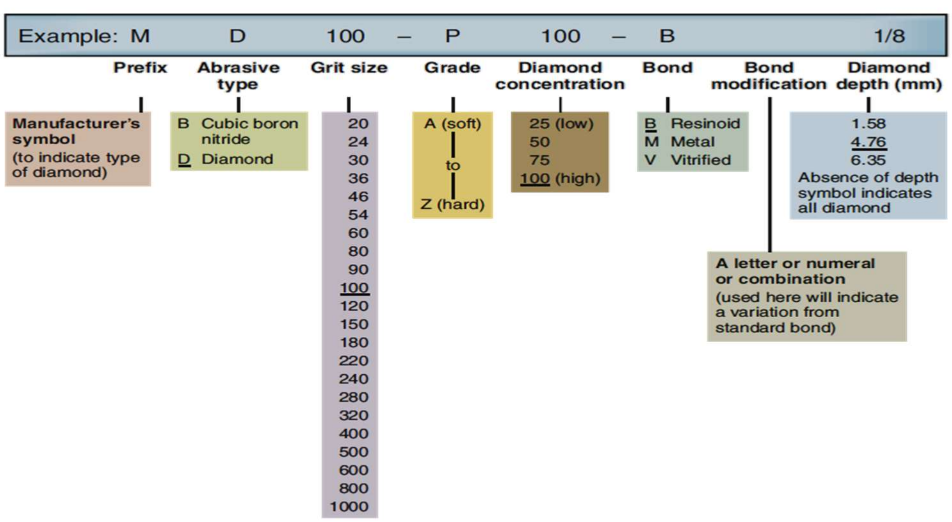

Figure Standard marking system for cubic boron nitride and diamond bonded abrasives.

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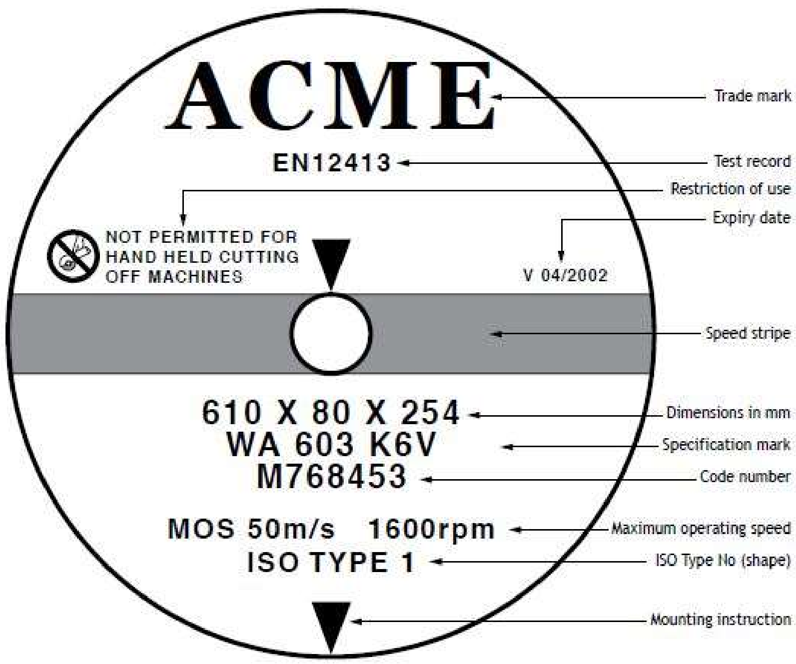

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TYPE OF ABRASIVES

- **A-Aluminum oxide**
  - This is one of the natural abrasives found and is commonly called corundum and emery.
  - However, natural abrasives generally have impurities and as a result, their performance is inconsistent.
  - Hence, the abrasive used in grinding wheels is generally manufactured from the aluminium ore, bauxite.
- **C-Silicon carbide**
  - Silicon carbide is made from silica sand and coke with small amounts of common salt.
- **B-Cubic boron nitride**
  - Cubic Boron Nitride (CBN) is next in hardness only to diamond (Knoop hardness ~ 4700 kg/mm³) .
  - It is not a natural material but produced in the laboratory using a high-temperature/high-pressure process similar to the making of artificial diamond.
  - CBN is less reactive with materials like hardened steels, hard-chill cast iron, and nickel-base and cobalt-based super alloys.
  - This is very expensive, 10 to 20 times that of the conventional abrasive such as aluminium oxide.
- **D-Diamond**
  - Diamond is the hardest known (Knoop hardness ~ 8000 kg/mm?) material that can be used as a cutting-tool material.
  - It has very high chemical resistance along with low coefficient of thermal expansion. Also, it is inert towards iron.

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GRAIN SIZE OR GRIT SIZE

- As used in manufacturing operations, abrasives generally are very small when compared to the size of cutting tools and inserts . They have sharp edges, allowing removal of very small quantities of material from a workpiece surface, resulting in very fine surface finish and dimensional accuracy.
- The size of an abrasive grain is identified by a **grit number**, which is a function of sieve size.
- The smaller the grain size, the larger is the grit number. For example, grit number 10 is typically regarded as very coarse, 100 as fine, and 500 as very fine. Sandpaper and emery cloth also are identified in this manner, as can readily be observed by noting the grit number printed on the backs of abrasive papers or cloth.

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COMPATIBILITY OF ABRASIVE AND WORKPIECE MATERIAL

- **Aluminum oxide:** Carbon steels, ferrous alloys, and alloy steels.
- **Silicon carbide:** Nonferrous metals, cast irons, carbides, ceramics, glass, and marble.
- **Cubic boron nitride:** Steels and cast irons above 50 HRC hardness and high-temperature alloys.
- **Diamond:** Ceramics, carbides, and some hardened steels where the hardness of diamond is more significant than its reactivity with the carbon in steel.

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GRADE

- Tt is also called the hardness of the wheel. This designates the force holding the grains.
- The grade of a wheel depends on the kind of bond, structure of wheel, and amount of abrasive grains.
- Greater bond content and strong bond results in harder grinding wheel. Harder wheels hold the abrasive grains till the grinding force increases to a great extent.
- The grade is denoted by letter grades as indicated

Very soft	**Medium**	**Very hard**
ABCDEFGH	**IJKLMNOP**	**QRSTUVWXYZ**

STRUCTURE

- The structure of a bonded abrasive is a measure of its porosity (the spacing between the grains, as shown in Fig.). The structure ranges from dense to open, as shown in Fig.
- Some porosity is essential to provide clearance for the chips, as otherwise they would interfere with the grinding operation.

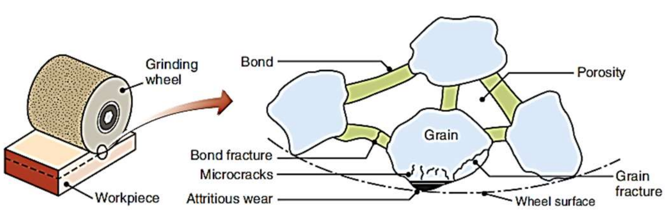

Figure Schematic illustration of a physical model of a grinding wheel, showing its structure and its wear and fracture patterns.

BONDING MATERIAL

- **V -vitrified**
- **B – Bakelite**
- **S- Silicate**
- **F- Shellac**
- **R- rubber**
- **Vitrified.** Also called *ceramic* bond, *vitrified bonds* are the most common and widely used material. The raw materials consist of feldspar (a crystalline mineral) and clays.
- They are mixed with the abrasives, moistened, and molded under pressure into the shape of grinding wheels. These *green* wheels are then fired slowly, up to a temperature of about 1250◦C, to fuse the glass and develop structural strength. The wheels are then cooled slowly (to avoid temperature gradients within the wheels and associated thermal cracking), finished to size, inspected for quality and dimensional accuracy, and tested for any defects.

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GEAR MANUFACTURING

- Several processes for making gears or producing individual gear teeth ; involving such processes as **casting, forging, extrusion, drawing, thread rolling, and powder metallurgy.**
- **Blanking** of sheet metal also can be used for making thin gears, such as those used in mechanical watches, clocks, and similar mechanisms.
- Plastic gears can be made by **casting or injection molding**.

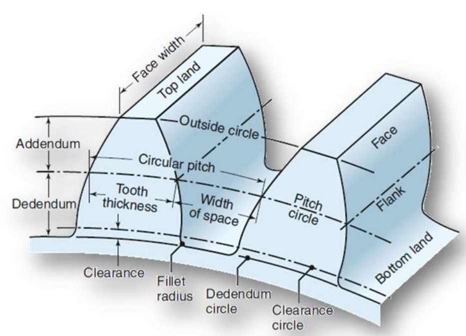

Figure .. Nomenclature for an involute spur gear.

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FORM CUTTING

- In form cutting, the cutting tool is similar to a form-milling cutter made in the shape of the space between the gear teeth (Fig. 24.33a). The gear-tooth shape is reproduced by machining the gear blank around its periphery.
- The cutter travels axially along the length of the gear tooth, and at the appropriate depth to produce the gear-tooth profile. After each tooth is cut, the cutter is withdrawn, the gear blank is rotated (indexed), and the cutter proceeds to cut another tooth. This process continues in a cycle until all of the teeth are machined.
- Each cutter is designed to cut a range of numbers of teeth.
- The precision of a form-cut tooth profile depends on the cutter accuracy and on the machine and its stiffness. Because the cutter has a fixed geometry, form cutting can be used only to produce gear teeth that have a constant width, that is, on spur or helical gears but not on bevel gears. Internal gears and gear teeth on straight surfaces, such as those in a rack and pinion, are form cut with a shaped cutter, on a machine similar to a shaper.

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FORM CUTTING

- **Broaching** can be used to machine gear teeth and is particularly suitable for producing internal teeth. The process is rapid and produces fine surface finish with high dimensional accuracy. However, because a different broach is required for each gear size and broaches are expensive, this method is suitable almost exclusively for high-quantity production.
- form cutting also can be done on **milling machines**, with the cutter mounted on an arbor and the gear blank mounted in a dividing head. Gear teeth also may be cut on special machines, with a single-point cutting tool guided by a template, made in the shape of the gear-tooth profile. Because the template can be made much larger than the gear tooth itself, dimensional accuracy is improved.
- Form cutting is a relatively simple process and can be used for cutting gear teeth with various profiles.
- **Nonetheless, it is a slow operation and some types of machines require skilled labor. Machines with semiautomatic features can be used economically for form cutting on a limited-production basis; generally,**
- **however, form cutting is suitable only for low-quantity production.**

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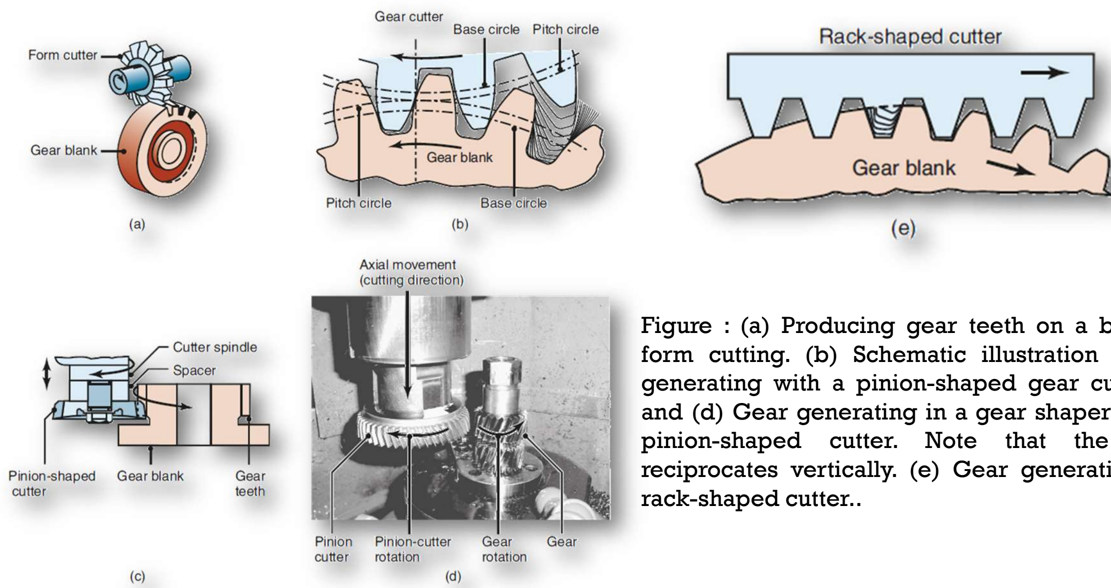

Figure : (a) Producing gear teeth on a blank by form cutting. (b) Schematic illustration of gear generating with a pinion-shaped gear cutter. (c) and (d) Gear generating in a gear shaper using a pinion-shaped cutter. Note that the cutter reciprocates vertically. (e) Gear generating with rack-shaped cutter..

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GEAR HOBBING

- A hob is basically a gear-cutting worm, or screw, made into a gear-generating tool by a series of longitudinal slots or gashes machined into it to form the cutting teeth.
- When hobbing a spur gear, the angle between the hob and gear-blank axes is 90◦ minus the lead angle at the hob threads.
- All motions in hobbing are rotary, and the hob and gear blank rotate continuously, much as two gears mesh, until all of the teeth are cut.
- Hobs are available with one, two, or three threads. For example, if the hob has a single thread and the gear is to have 40 teeth, the hob and the gear spindle must be geared together such that the hob makes 40 revolutions while the gear blank makes 1 revolution.
- Similarly, if a double-threaded hob is used, the hob would make 20 revolutions to the gear blank's 1 revolution. In addition, the hob must be fed parallel to the gear axis, for a distance greater than the face width of the gear tooth (Fig.).
- in order to produce straight teeth on spur gears. The same hobs and machines can be used to cut helical gears, by tilting the axis of the hob spindle.
- **Because it produces a variety of gears at high rates and with good dimensional accuracy, gear hobbing is used extensively in industry. Although the process is suitable also for low-quantity production, it is most economical for medium- to high-quantity production.**

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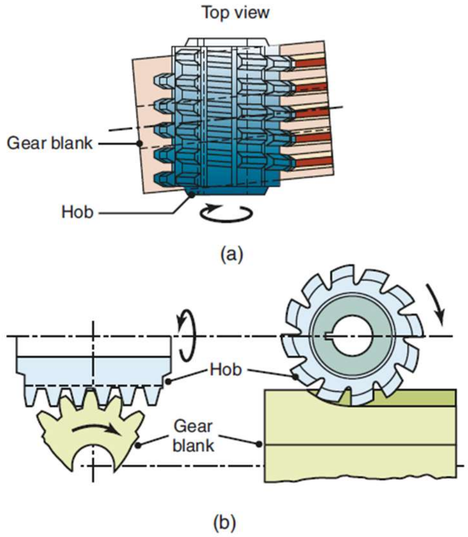

Figure: (a) Hobs, used to machine gear teeth; (b) schematic illustration of gear cutting with a hob.

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GEAR HONING: SURFACE FINISHING

- The honing process is faster than grinding, and is used to improve surface finish.
- The honing tool is a plastic gear impregnated with fine abrasive particles.
- To further improve the finish, ground gear teeth are lapped, using abrasive compounds either with (a) a gear-shaped lapping tool made of cast iron or bronze,
- or (b) a pair of mating gears that are run together.
- Although production rates are lower and costs are higher, these finishing operations are particularly suitable for making hardened gears of very high quality, long life, and quiet operation.

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THANK YOU

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