Metal Cutting & Machining

MODULE-3

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Syllabus

Conventional machining process and machine tools: Turning, Drilling, Shaping, Planing, Milling, Grinding. Machine tools used for these processes, their specifications and various techniques used.

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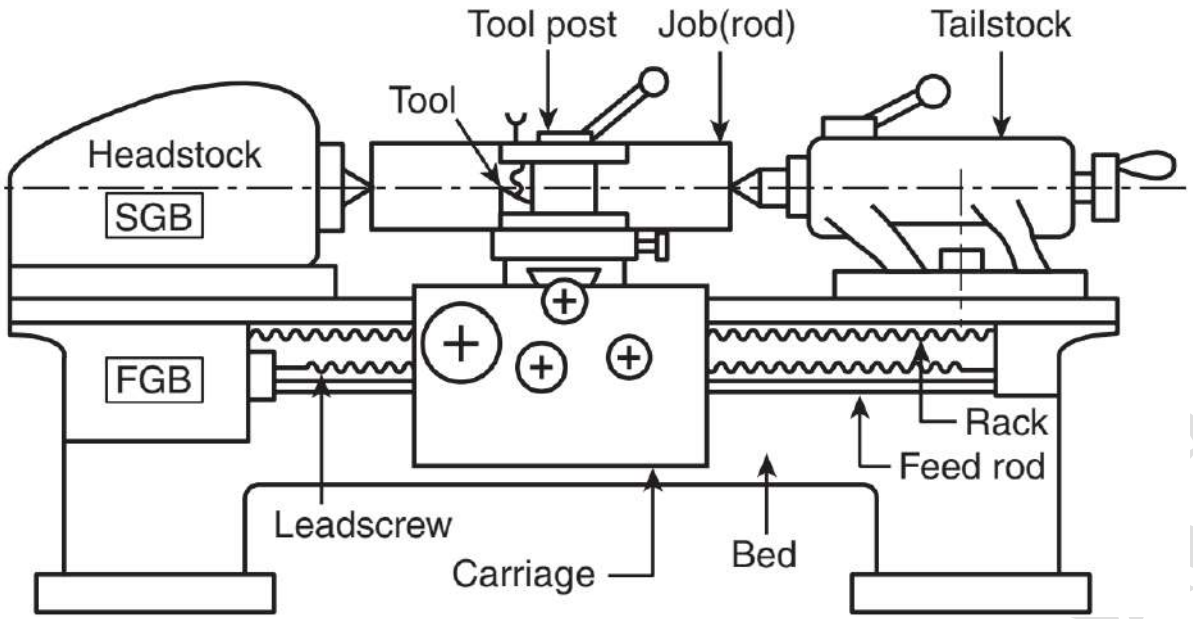
Machine Tools

- A machine tool is a non-portable and power operated device or system of devices in which energy is expended to produce jobs of desired dimension and finish by machining, that is, removing excess material from the preformed blank(s) in the form of chips with the help of cutting tool(s) moved past the work surface at controlled speeds and feeds.
- Any machine tool essentially comprises some major components as common features such as:
    1. Devices for holding the blank and the cutting tool(s) properly and firmly.
    2. Devices for providing motions and power to the tool(s) and the workpiece.
    3. Kinematic system for transforming and transmitting the motions and power from the power source(s) to the tool(s) and workpiece.
    4. Automation and control systems.
    5. Heavy structural body to support and accommodate those systems quite strongly, rigidly and safely.
- Machining in any machine tool needs proper contact and relative motions between the workpiece and the tool.
- The firmly held tool and the workpiece receive the desired motions and the cutting power from the power drive of the machine through a kinematic system comprising various types and number of mechanisms.

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TURNING

Lathe Construction:



Schematic Diagram of Centre Lathe

Major components and their functions in a centre lathe

- **Headstock**
- **Tailstock**
- **Carriage**
- **Bed**
- **Work-tool holding devices**

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❖ **Headstock:** This heavy housing, being mounted on the bed at its left end, receives power and motion from the motor and transmits the same to the workpieces through a clutch, speed gear box (SGB) and the spindle contained in the headstock housing. Thus, the headstock enables rotating the workpiece at different speeds as required.

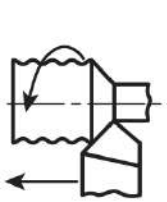
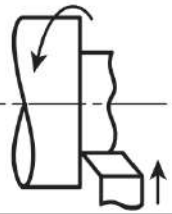
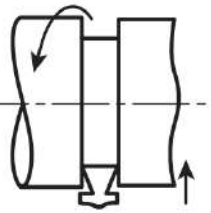
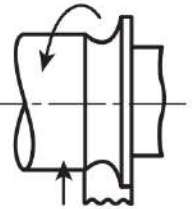
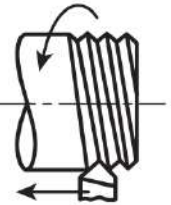
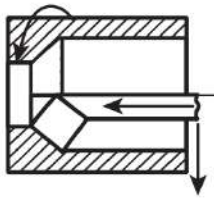
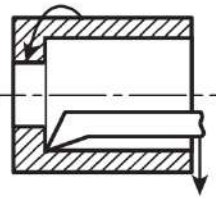
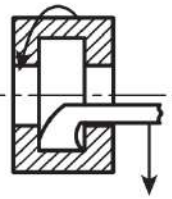
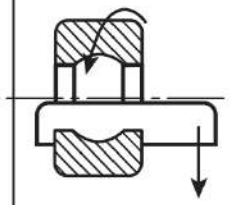
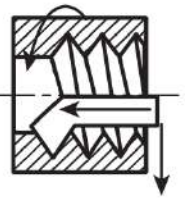
- **Tailstock:** This relatively smaller body can be shifted and fixed at any location on the lathe bed coaxially with the headstock. The main functions of the tailstock are to provide support to long and heavy workpieces and often hold and move some cutting tools for operations like drilling, reaming, etc.
- **Carriage:** This heavy part with a number of mechanisms and parts in it is made to slide along the lathe bed. The carriage firmly holds the tools and moves it at different feed rates. The carriage derives motions usually from the spindle through a feed gear box (FGB) and a feed rod or lead screw.
- **Bed:** This rigid bulky horizontal beam stands firmly on two legs or columns. On the bed, the headstock remains bolted, the tailstock is shifted and clamped and the carriage slides.
- **Work–tool holding devices:** The blanks are usually mounted in between centres or chucks, whereas cutting tools are generally held in the tool post which is mounted on the saddle. Tools are also often held in the tailstock quill.

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Application of Lathe

- **Turning**
  - Both External and Internal;
    - Straight
    - Taper
    - Stepped
    - Any other form
- Facing, Chamfering, Grooving, Recessing, etc.
- Centering, Drilling, Boring, and Reaming
- **Threading**
  - Both External, Internal and also Radial (scroll), if required.
- **Knurling**
  - For roughing handles, etc. to facilitate stronger grip.
- **Parting**

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	Turning	Facing	Grooving	Forming	Threading
External					
Internal					

Classification of Lathe

Centre Lathe: All Horizontal

- Micro (size) lathe
- Table top small lathes
- Medium duty lathes
- Heavy duty lathes

Single-purpose lathes

- Facing lathe
- Multi-tooling lathe
- Roll turning lathe
- Relieving lathe

Semi-automatic lathes

- Capstan lathe of various size
- Turret lathes of various sizes
  - ❖Horizontal
  - ❖Vertical axis type
  - ❖Vertical axis and multiple spindle type
- Copying lathes
  - ❖Mechanical type
  - ❖Hydraulic drive type

Automatic lathes of varying sizes

- Automatic cutting off lathe
- Single spindle automatic lathe
- Swiss type automatic lathe
- Multiple spindle automatic lathe

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Specification of Lathes

Centre lathes are generally specified by

1. Maximum diameter of the workpiece that can be accommodated. Often centre height or swing (double the centre height) is also used.
2. Maximum length of workpiece that can be accommodated in the lathe. Often this aspect is specified by maximum possible distance between the headstock centre and the tailstock centre. In some cases, length of the bed is mentioned.
3. Power, in kW.
4. Spindle speeds:
    (a) Stepped or stepless.
    (b) Range (min. rpm and max. rpm).
    (c) Number of speeds in case of stepped drive.
5. Feeds: range, number and values.
6. Floor space (or foot print) required. Often total weight of the machine is mentioned.

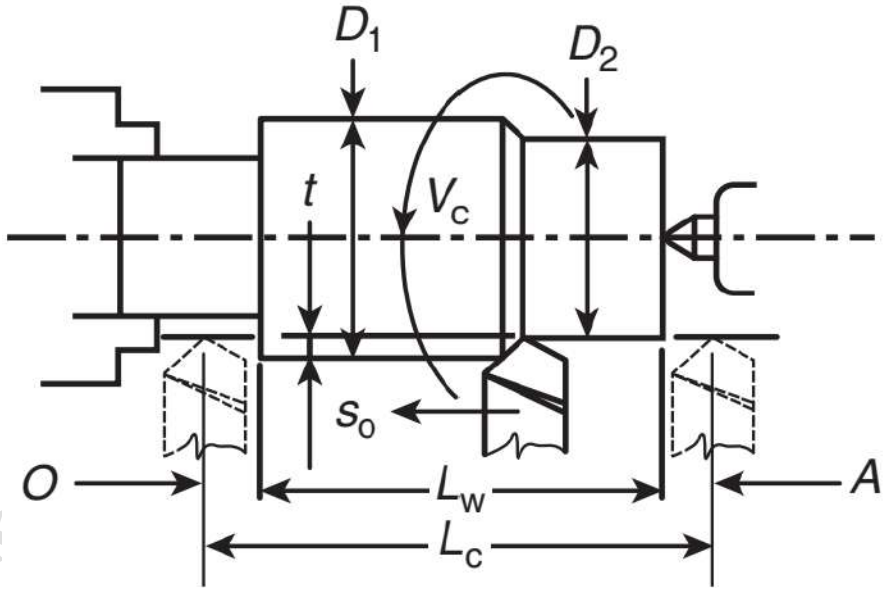
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- Detail specification of centre lathe may include mention of
    1. The spindle; diameter of the hole, taper angle at the front of the hole and the thread at its nose.
    2. Type of tool holder or register.
    3. With or without gap bed.
    4. Coolant system, chip collector, etc.
- Example of specification of a 5.5 kW (say) centre lathe may be as follows:
    1. Max. diameter of workpiece: 160 mm
    2. Max. length of workpiece: 1000 mm
    3. Power: 5.5 kW
    4. Spindle speeds: 40−2000 rpm, 12 steps (GP)
    5. Feeds: for turning, etc.: 0.05−2.00 mm/rev for threading: all standard metric threads
    6. Gap bed: not required
    7. Floor space: 1.2 m × 3 m

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Machining Time in Turning Operation

Let the diameter of a steel rod be reduced from D_1 to D_2 over a length L_w by straight turning in a centre lathe. Here, machining time is



$$T_c = \frac{L_c}{N s_o} \times n_p$$

Here, N is the spindle speed (rpm), s_o is the feed (tool, mm/rev), n_p is the number of passes required, L_c is the actual length of cut given by

$$L_c = L_w + A + O$$

Here, A and O are approach and overrun respectively.

The speed N is determined by $V_c = \frac{\pi D N}{1000}\left(\frac{m}{min}\right) \Rightarrow N = \frac{1000 V_c}{\pi D}$, where D is the diameter of the job before any cut.

Again, $n_p = \frac{D_1 - D_2}{2t}$, where, t is the depth of cut in mm.

- The value of t and hence of n_p are decided by the machining allowance left in the preformed blanks.
- Usually, for saving time and material, very less machining allowance is left, especially in near-net-shape principle.
- Hence, number of passes used is generally one or maximum two: one for roughing and one for finishing.

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Combining those equations we can write, $T_c = \frac{\pi D L_c (D_1 - D_2)}{2000 V_c s_o}$

For single pass turning; $T_c = \frac{\pi D L_c}{1000 V_c s_o}$

Procedural Steps

1. Determine the length of cut by proper selection of amount of approach A (2-5 mm) and overrun O (1-3 mm), as and when required.
2. Select the proper values of V_c and s_o based on the tool–work materials and other factors previously mentioned.
3. Determine the spindle speed N and then fix N as well as s_o from the chart giving the lists of N and s_o available in that lathe.
4. Finally determine T_c using, $T_c = \frac{\pi D\ (L_w + A + O)}{1000 V_c s_o}$

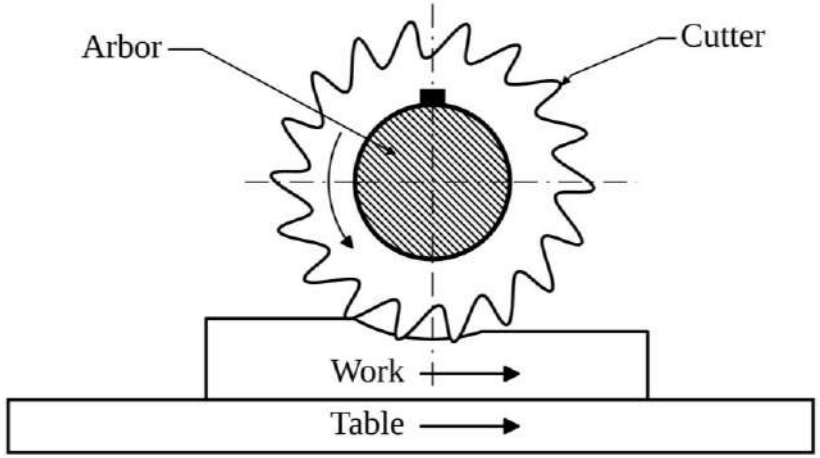
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MILLING

- Milling machine is the machining process in which the removal of material takes place due to the cutting action of a revolving cutter when the work is fed past it.
- The revolving cutter is held on a spindle or arbour and the work, clamped on the machine table, fed past the same.
- In doing so, the teeth of the cutter remove the metal, in the form of chips, from the surface of the work to produce the desired shape.
- Milling machine has the capability to perform a large number of operations which no other single machine tool can perform. At the same time, it gives production at a fairly high rate and within very close limits of dimensions.
- However it only has advantage for small and medium size jobs only; as it will prove to be too slow for machining very long jobs. For small and medium jobs, the milling machine gives probably the fastest production with very high accuracy.

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Working Principle in Milling



- The work is rigidly clamped on the table of the machine, or held between centres, and revolving multiteeth cutter mounted either on a spindle or an arbour.
- The cutter revolves at a fairly high speed and fed slowly past the cutter.
- The 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 the desired shape.

Size and Specifications

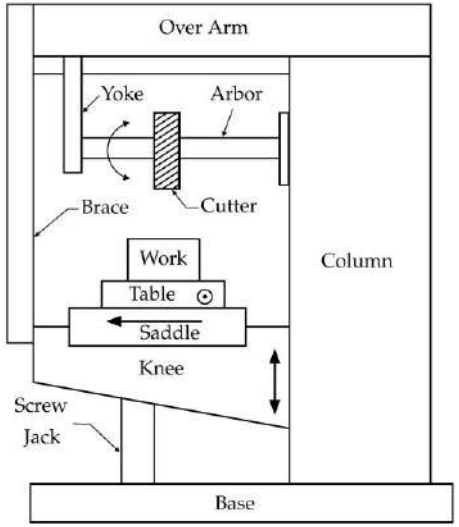
- Size of a milling machine is usually denoted by the dimensions (length and breadth) of the table of the machine.
- Different manufacturers denote these sizes by different numbers 0, 1, 2, 3, 4, 5, 6, etc. Each numbers indicates a particular standard size adopted by the manufacturer.
- Other main specifications of the machine to be considered at the time of placing orders are the horse power, of the driving motor, number od spindle speeds, feeds, drive, taper of spindle nose, required floor area, gross weight, etc.

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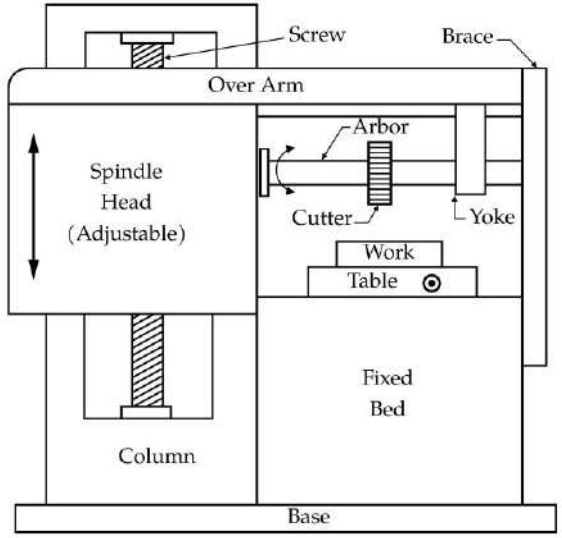
Types of Milling Machine

- **Column and Knee type**
  - Hand milling
  - Plain or horizontal milling
  - Vertical milling
  - Universal milling
  - Omniversal milling
- **Fixed bed type or Manufacturing type**
  - Plain type
  - Duplex type
  - Triplex type
  - Rise and fall type
- **Planer type**
- **Production milling machine**
  - Rotary table or Continuous type
  - Drum type
  - Tracer controlled
- **Special purposed machines**
  - Thread milling machine
  - Profile milling machine
  - Gear milling
  - Cam milling
  - Planetary milling
  - Double end milling
  - Skin milling
  - Spar milling

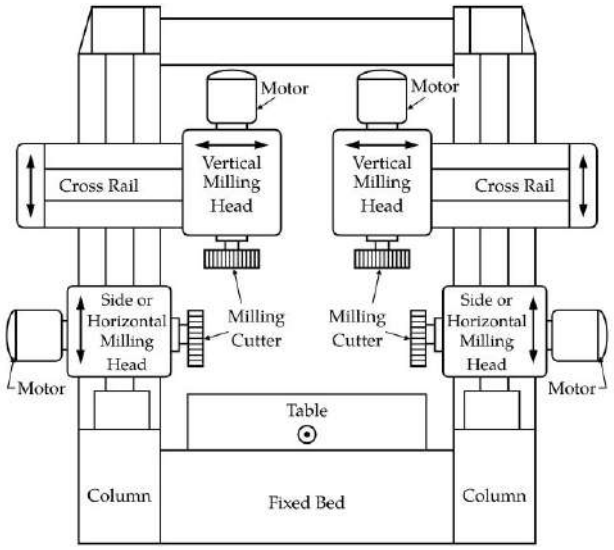
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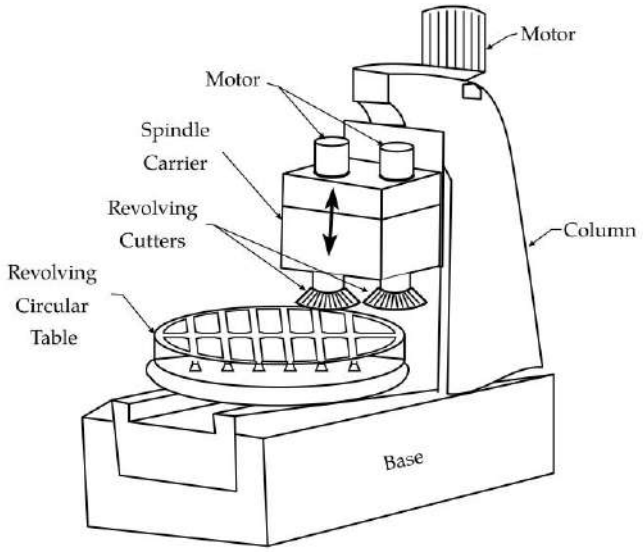
Plain Milling Machine



Fixed Bed Type Plain Milling



Planer Type Milling Machine or Plano Mill



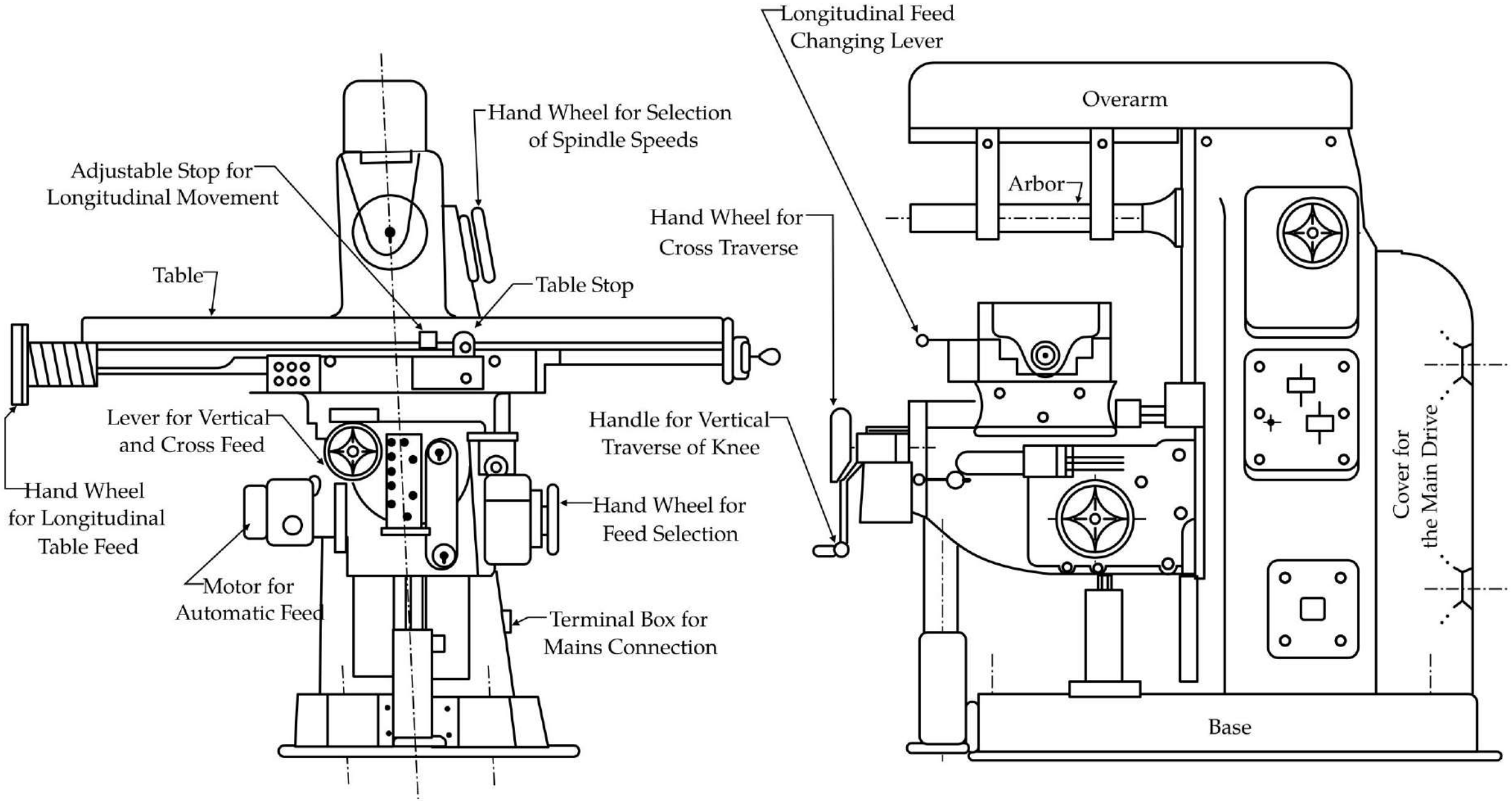
Single Station Rotary Table Milling Machine

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Principal Parts of Milling Machine

1. **Base:**
   - It is a heavy casing provided at the bottom of the machine.
   - It acts as load bearing member for all other parts of the machine.
   - Column of the machine is secured to it.
   - It carries the screw jack which supports and moves the knee.
   - It also serves as a reservoir for the coolant.
2. **Column:**
   - All the various parts and controls of the machine are fitted to this.
   - On the front face of the column, vertical parallel ways are there, in which the knee slides up and down.
   - At its rear side, it carries the enclosed motor drive.
   - Top of the column carries dovetail horizontal ways for the overarm.

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Longitudinal Feed
Changing Lever
Overarm
Arbor
Hand Wheel for Selection
of Spindle Speeds
Adjustable Stop for
Longitudinal Movement
Hand Wheel for
Cross Traverse
Table
Table Stop
Lever for Vertical
and Cross Feed
Handle for Vertical
Traverse of Knee
Hand Wheel
for Longitudinal
Table Feed
Hand Wheel for
Feed Selection
Motor for
Automatic Feed
Terminal Box for
Mains Connection
Cover for
the Main Drive
Base

3. Knee:

- It is a rigid casting, which is capable of sliding up and down along the vertical ways on the front face of the column.
- This enables the adjustment of the table height (distance between the cutter and the job mounted on the table).
- The adjustment is provided by operating the elevating jack, provided below the knee, by means of hand wheel or application of power feed.
- Machine horizontal ways are provided on the top surface of the machine, for cross traverse of the saddle, and hence the table.
- On the front face of the knee two bolts are usually provided for securing the braces to it to ensure greater rigidity under heavy load.

4. Saddle:

- It is the intermediate part between the knee and the table and acts as a support for the latter.
- It can be adjusted crosswise, along the ways provided on the top of the knee, to provide cross feed to the table.
- At its top, it carries horizontal ways, along which moves the table during the longitudinal traverse.

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5. Table:

- It acts as a support for the work.
- The work is mounted on table either directly or held in the dividing head.
- Table is made up of cast iron.
- The top surface of the table carries longitudinal T-slots to accommodate the clamping bolts for fixing the work or securing the fixtures.

6. Overarm:

- It is the heavy support provided on the top of both plain and universal milling machines.
- It can slide horizontally, along the ways provided on the top of the column, and adjusted to a desired position in order to provide support to the projecting arbor by accommodating its free end in the yoke.
- Braces can be employed to connect the overarm and knee.

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Milling Machine Attachments

To hold the cutter

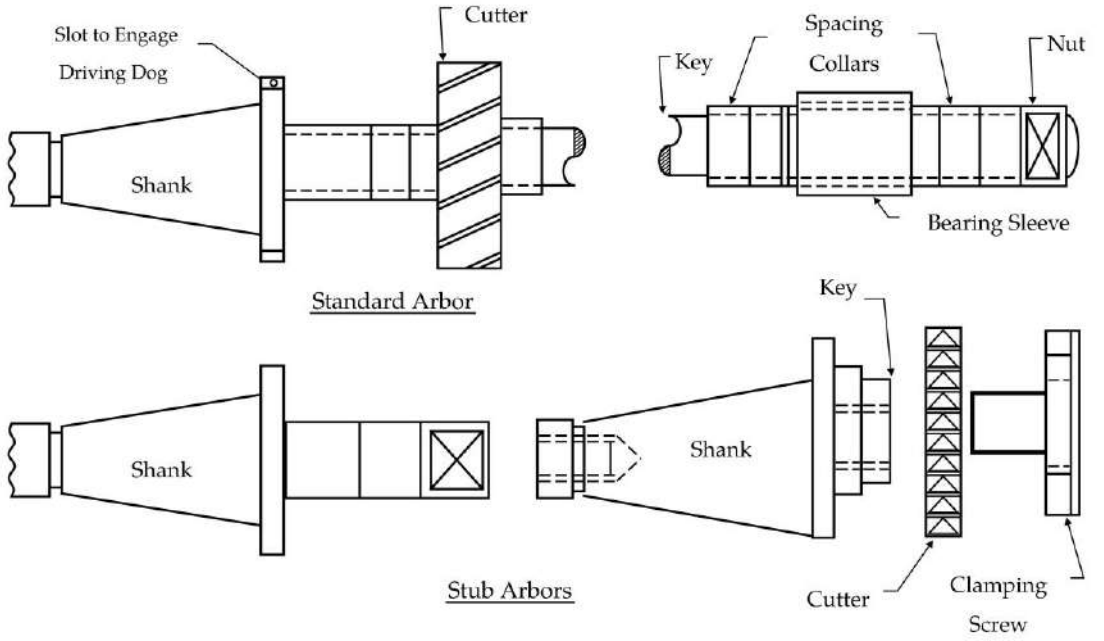
- Arbors
- Collets
- Adaptors, etc.

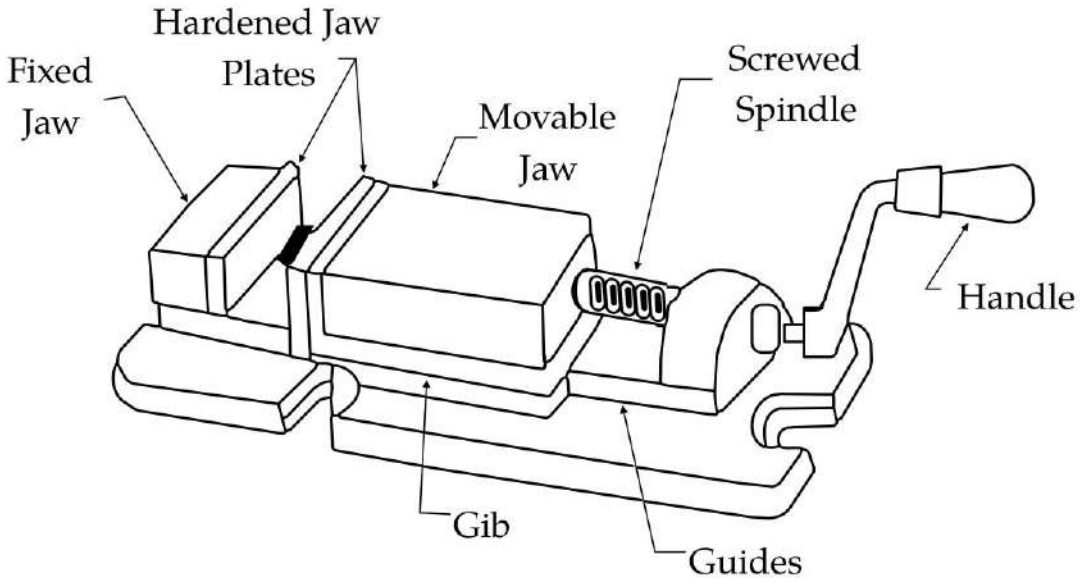
To hold the workpiece on the table

- Vices
- Circular table
- Indexing head
- Tail stock, etc.

To act as auxiliary spindles

- Vertical milling attachment
- Spiral milling attachment
- Slotting attachment, etc.



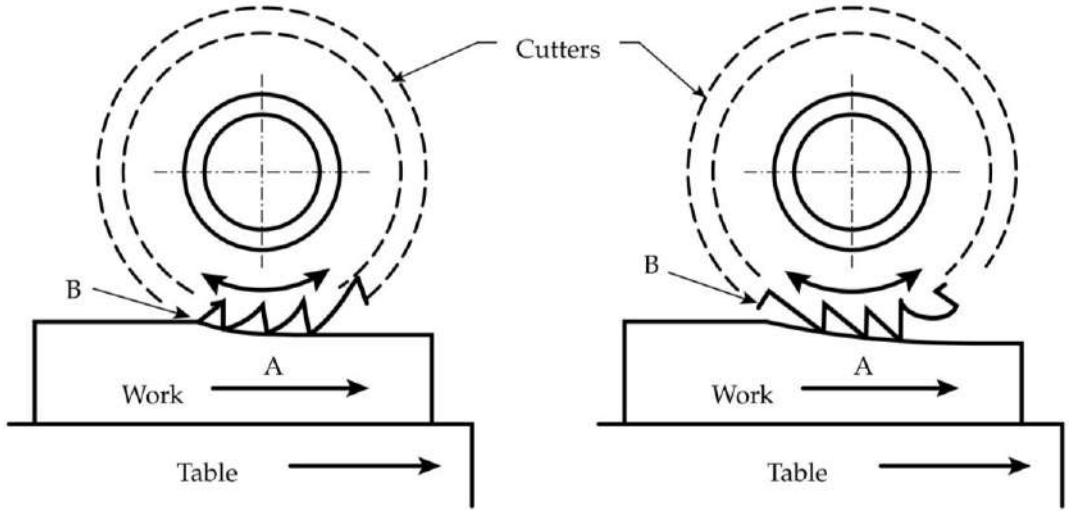


This is for educational purpose only.

Milling Methods

- Milling is a process of metal cutting by means of a multi-teeth rotating tool, called cutter.
- The form of each tooth of the cutter is the same as that of single point tool.
- Each tooth, after taking a cut, comes in operation again after some interval of time. This allows the tooth to cool down before the next cutting operation is done by it. This minimizes the effect of heat developed in cutting on cutting edge.
- With cylindrical cutter, the following two methods are commonly used for performing the operation:
  1. **Up or Conventional Milling:** The cutter rotates in a direction opposite to that in which the work is fed.
  2. **Down or Climb Milling:** The direction of rotation of the cutter coincides with the direction of work feed.

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Up or Conventional Milling **Down or Climbing Milling**

- The relative direction of movement of the cutter and work should be taken at the point of contact between the two.
- The chape of the chip (marked area between points A and B) removed by the cutter in both the cases is same, but in conventional milling, as the cut proceeds, the chip thickness gradually increases; whereas the chip thickness decreases in case of down milling.
- In other words, chip thickness in up milling, is minimum (zero) at the start of the cut and maximum at the end of the cut, whereas in down milling, maximum in the beginning and zero at the end.
- The selection of the method between the above two depends upon the nature of work.
- Up milling is commonly used for machining casting and forging as this method enables the cutter to dig-in and start the cut below the hard upper surface.
- Down milling is useful for finishing operations and small works such as slot cutting, milling grooves, slitting, etc.

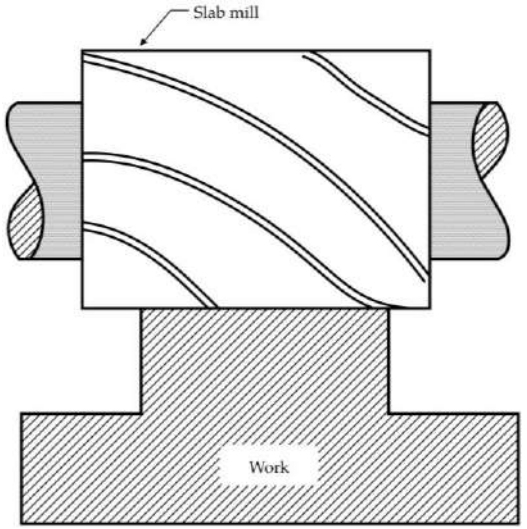
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Milling Operations

- Plain or Slab Milling
- Angular Milling
- Straddle Milling
- Face Milling
- Form Milling
- Gang Milling

Plain or Slab Milling

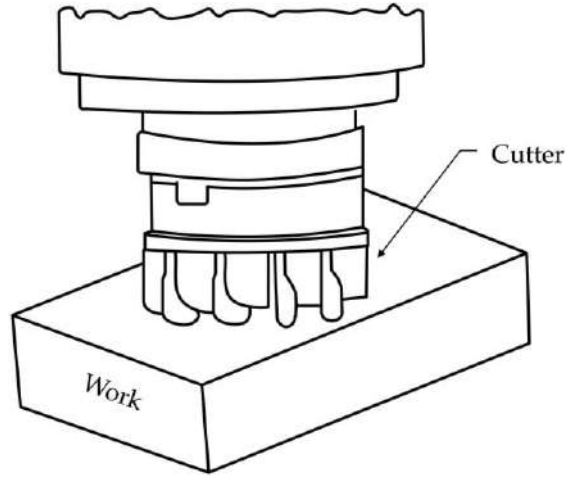
- Employed for machining flat surface, parallel to the axis of the cutter, by using a plain or slab milling cutter.
- When a very wide surface is to be machined, an interlocking teeth plain milling cutter is used instead of simple slab mills.
- They should be arranged in such a way that the axial forces are directed towards each other so that it will force the cutters close as the operation proceeds.



Plain or Slab Milling

Face Milling

- This milling process is employed for machining a flat surface which is at right angles to the axis of the rotating cutter.
- The cutter used in this operation is the face milling cutter.



Face Milling

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Angular Milling

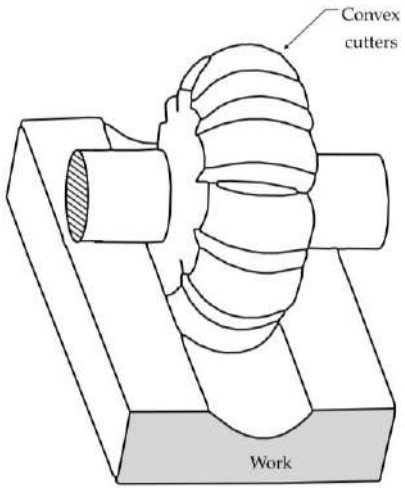
- It is the milling process which is used for machining a flat surface at an angle, other than a right angle to the axis of the revolving cutter.
- The cutter used may be a single or double angle cutter, depending upon whether a single surface is to be machined or two mutually inclined surfaces simultaneously.

Form Milling

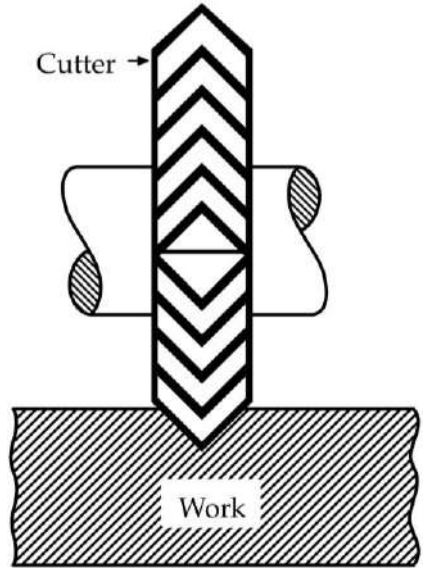
- This milling process is employed for machining those surfaces which are of irregular shapes.
- The cutter used, called form milling cutter, will have the shape of its cutting teeth conforming to the profile of the surface to be produced.

Straddle Milling

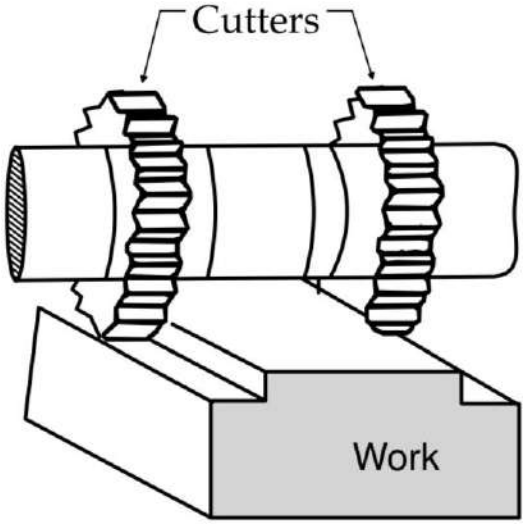
- It is a milling operation in which a pair of side milling cutters is used for machining two parallel vertical surfaces of a work-piece simultaneously.



Form Milling



Angular Milling

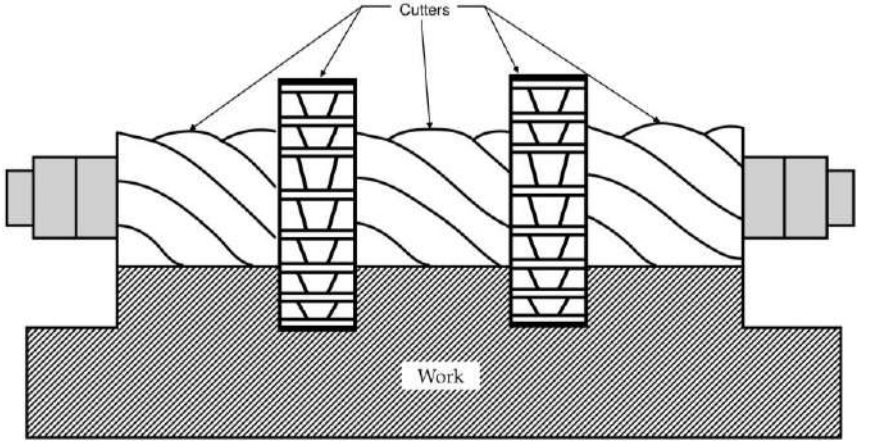


Straddle Milling

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Angular Milling

- It is the milling operation which involves the use of a combination of more than two cutters, mounted on a common arbor, for milling a number of flat horizontal and vertical surfaces of a workpiece simultaneously.
- This combination may consists of only side milling cutters or of plain and side milling cutters both.



Gang Milling

Prepared by:
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Dr. A.K. Pattanaik

Other Milling Operations

- Slot and Groove Milling
- Slitting or Saw Milling
- End Milling
- Gear Milling
- Thread Milling
- Keyway Milling
- Side Milling
- Profile Milling
- Cam Milling
- Helical Milling

Machining Time in Milling

- The following factors are to be considered in estimating the machining time in any type of milling operation'

1. **Total length** of the job to be machined.
2. **Approach** (the distance through which the cutter has to move before the full depth of cut is acquired)
3. **Over run** (the distance through which the cutter has to move further, after the job length is over, to be clear of the job)
4. **Number of cuts**
5. **Cutting speed**
6. The **amount of feed** per minute

Let

l_1 = Length of the job to be machined in mm.

l_2 = Approach in mm.

l_3 = Overrun of the cutter in mm.

If L be the total distance of table or cutter trave, then: $L = l_1 + l_2 + l_3$

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- In plain milling, if D mm be the diameter of the cutter and d mm be the total depth of cut, then the approach l_2 is given by:

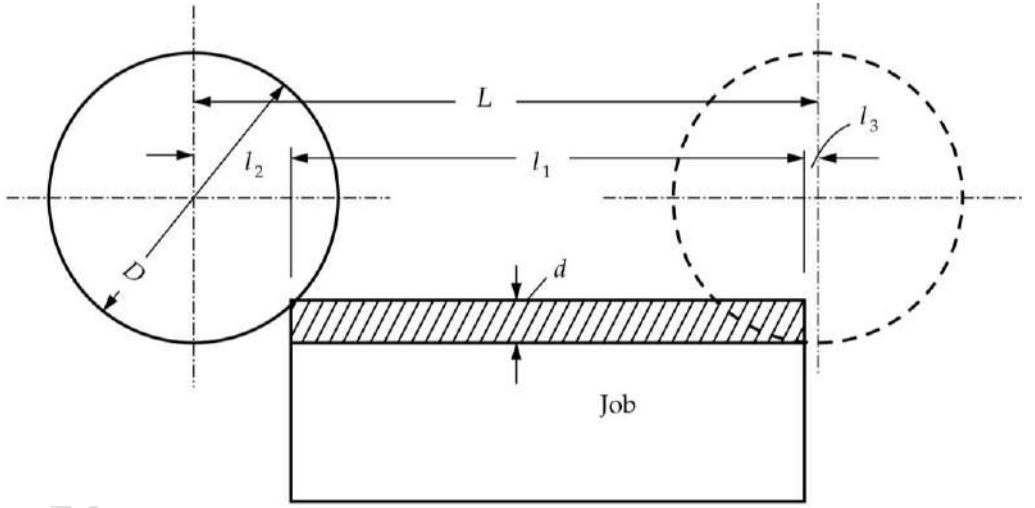
$$l_2 = \sqrt{d(D-d)}\ mm$$

- In face milling, let b mm be the width of the job, D mm be the diameter of the cutter, then approach is given by:

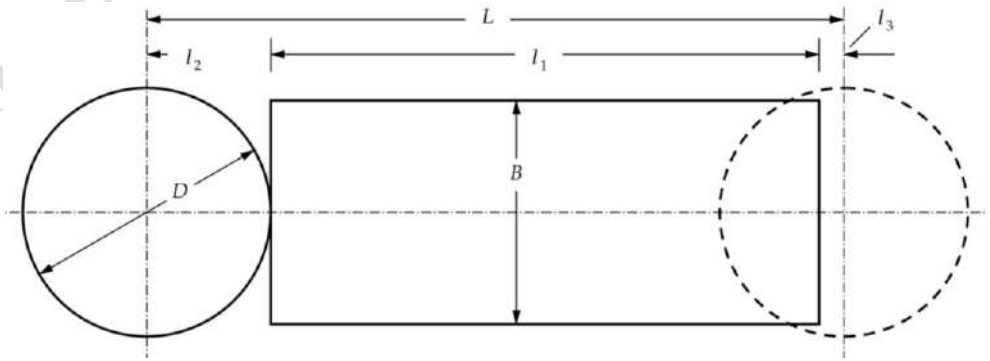
$$l_2 = 0.5\left(D - \sqrt{D^2 - b^2}\right)\ mm$$

- The overrun of the cutter, depending upon the size of the machined surface, can be taken from 1 to 6 mm.
- If n be the number of cuts, N is the speed in rpm and s_o is the feed in mm per revolution, then the machining time T in minutes can be calculated from:

$$T = \frac{L \times n}{s_o \times N}\ minutes$$



Plain Milling

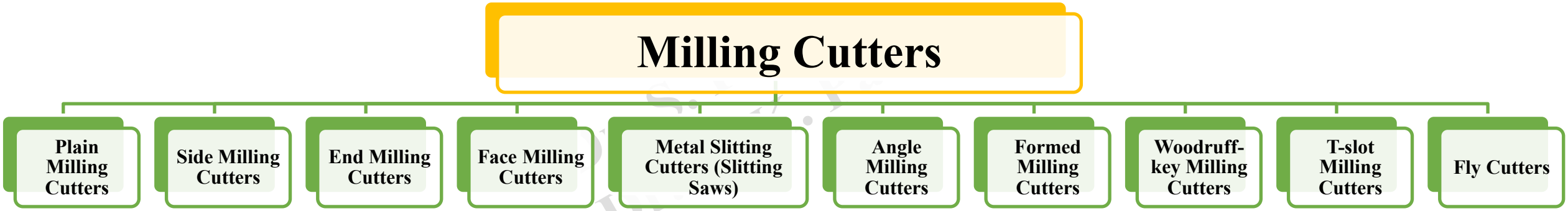


Face Milling

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Different Milling Cutters

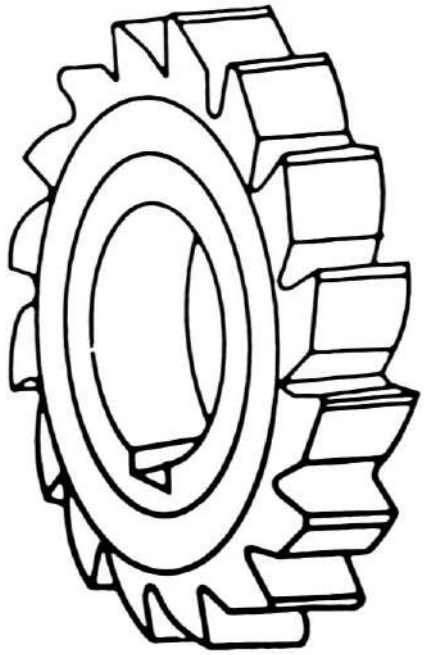
- The milling cutter may have either **straight teeth** (parallel to the axis of rotation) or in **helical shape**.
- The helix angle may be **right hand** or **left hand**. This will decide the direction of rotation of the cutter for performing the cutting operation.
- The broad classification of milling cutter is according to the **shape of the teeth** they carry, like **plain, inserted, formed or sawteeth** etc.



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Plain Milling Cutters

- These milling cutters may have the cutting teeth on their periphery.
- The teeth may be either straight (parallel to the axis) or helical.
- Their end faces are either ground square with the axis or slightly concave to reduce friction.
- These cutters are employed for milling flat surfaces parallel to the axis of rotation.
- The cutters included in plain milling are;
  1. **Plain milling cutter or key way cutter:** Usually employed for key way and slot cutting.
  2. **Helical or slab milling cutters:** commonly used where very heavy cuts are to be employed, as they are capable of removing more material with less power consumption.



Plain Milling Cutter

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Side Milling Cutters

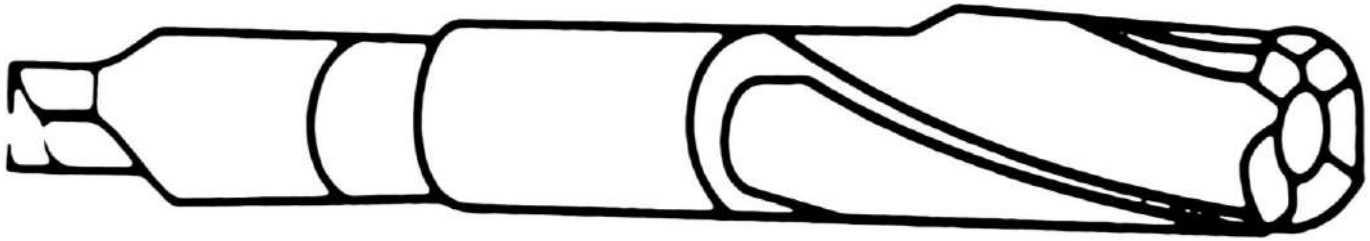
- These cutters have teeth on the periphery as well as one or both sides.
- They are always provided with a central hole for the purpose of mounting them on the arbour.
- They are also called straddle mills when used in pairs.
- These cutters can be classified in to (a) Plain side milling cutter; (b) Half side milling cutters; (c) Staggered teeth side milling cutters; (d) Interlocking side milling cutters

End Milling Cutters

- These are solid circular cutters which are manufactured in two different varieties; those having the shank and the others which do not have the shank.
- They carry teeth on the periphery as well as on the end.
- These teeth may be straight or helical.
- End milling cutters are used for milling slots, keyways, grooves and irregular shaped surfaces.
- The cutters included in end milling are classified into;

1. **Common type:** These carry teeth on the periphery as well as on the end.
2. **Two-lipped end mill:** These cutters are also known as slotting mills. These cutters have two straight or helical teeth on the periphery and the corresponding two teeth on the end, which meet at the end centre. The main advantage of these cutters is that they can be fed straight into the metal like a drill and then fed longitudinally to produce a groove of desired length and depth.
3. **shell end milling cutters:** These cutters are larger and heavier than most of the other types of end mills. They have teeth on the periphery and the end both.

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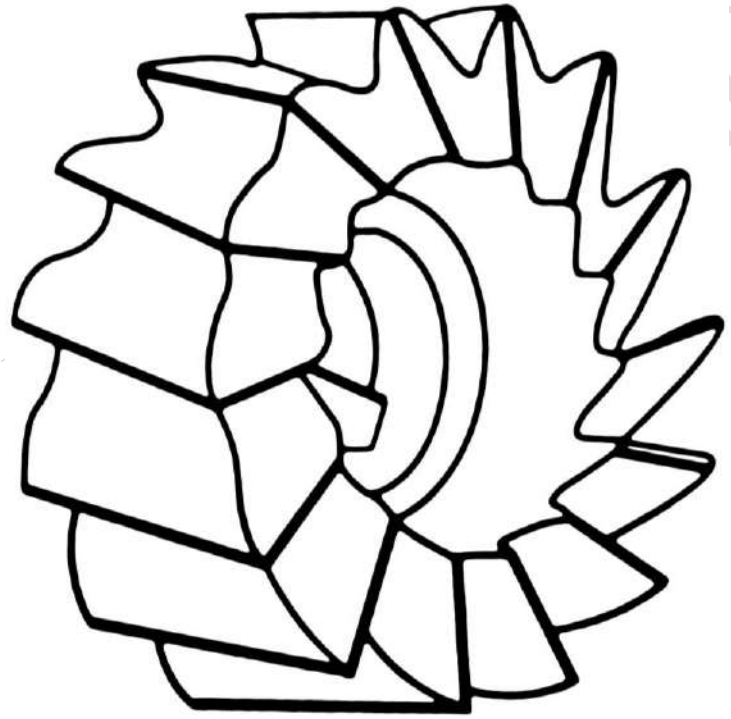


Common type end milling cutter

Face Milling Cutters

- These cutters are made in two common forms;

1. **Shell-type (smaller type) face milling cutter:** It carries teeth on the periphery as well as on the end face. Maximum cutting is done by the teeth on the periphery and the end face teeth perform finishing operation. It is used for small work.
2. **Built-up type (larger type) face milling cutter:** These cutters consist of a steel body, along the periphery of which are inserted the cutting teeth. It is used for larger surfaces.

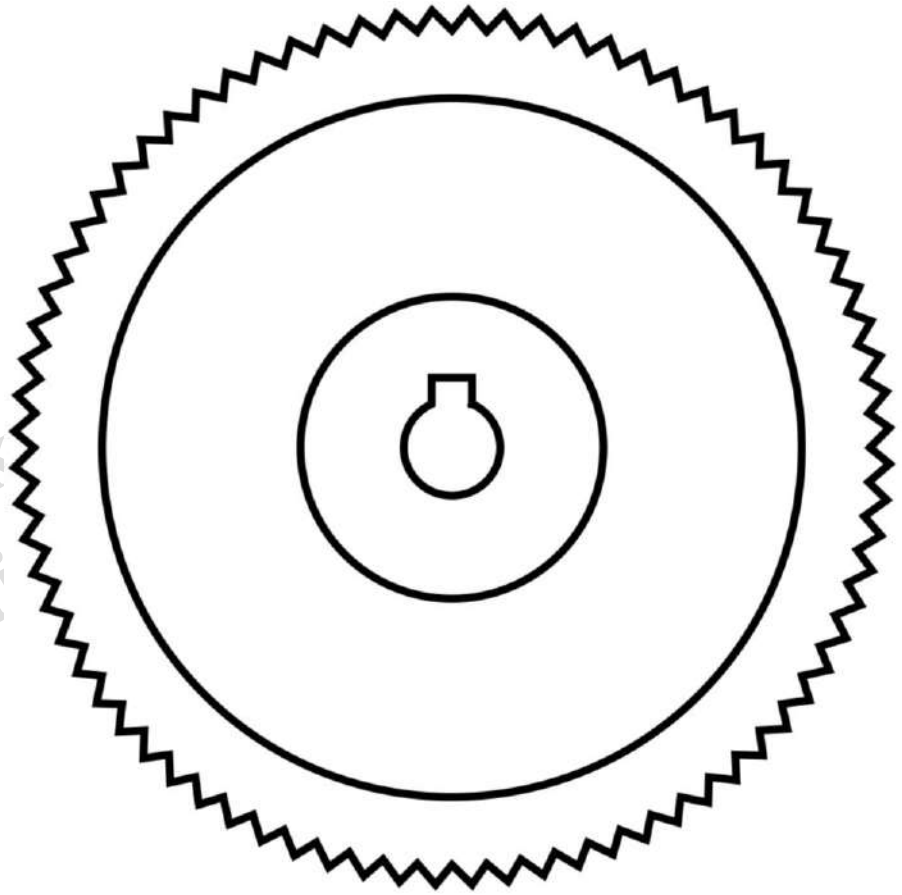


Shell type Face Milling Cutter

Metal Slitting Cutters

- These cutters are also called metal slitting saws.
- They are used for cutting thin slots or for parting off.
- They are commonly manufactured in the following two varieties;

1. **Plain slitting saw:** They are plain milling cutters which are very thin as compared to other types of milling cutters. Their teeth are provided with some side relief in order to prevent rubbing. They are made in different widths, ranging between approximately 1mm and 5mm.
2. **Staggered teeth milling cutter (saw):** These saws are used for comparatively heavier work. They have teeth staggered alternatively and have side teeth. These saws are generally made in different widths, ranging between 4mm and 10mm.



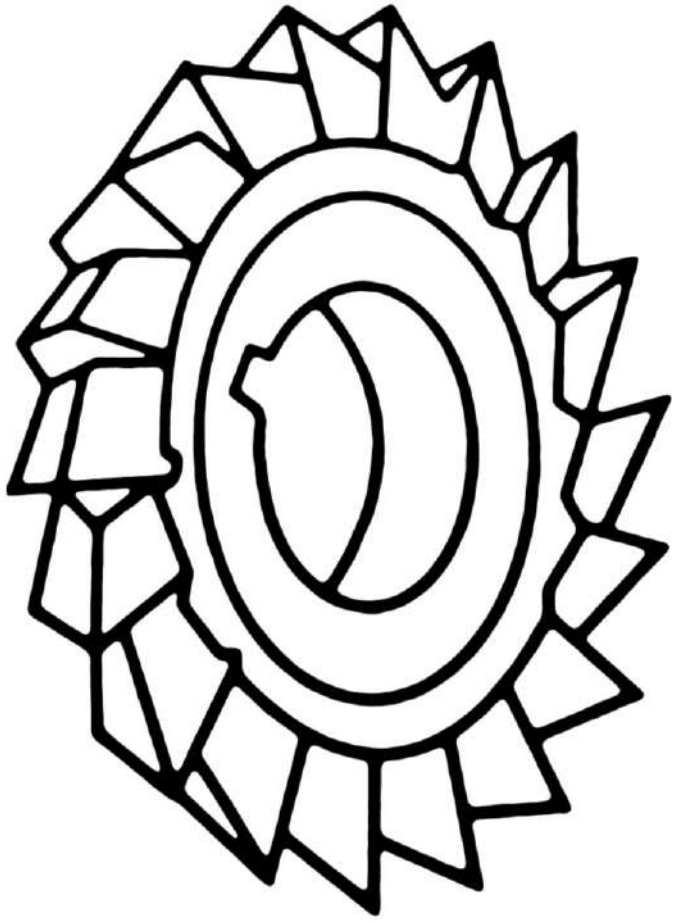
Metal Slitting Saw

Prepared by:
Dr. S. R. Parimanik
Dr. A. K. Pattanai

Angle Milling Cutters

- These cutters carry very sharp angular teeth, which are neither parallel nor normal to their axes.
- Their specific use is in milling V-grooves, notches, dovetail slots, reamer teeth and other angular surfaces.
- They are commonly in following types;

1. **Single Angle Cutters:** These cutters may have their teeth either only on the angular face or on both, angular face and the side. The side teeth type enables milling of both flanks of the inclined angular groove simultaneously. Their teeth may have inclined angle of 45° or 60°.
2. **Double-angle Cutters:** These cutters have two angular faces which join together to form V-shaped teeth. The inclined angle of this 'V' is either 45°, 60° or 90°, though it is not necessary that the angle of both the faces should be equal.



Metal Slitting Saw

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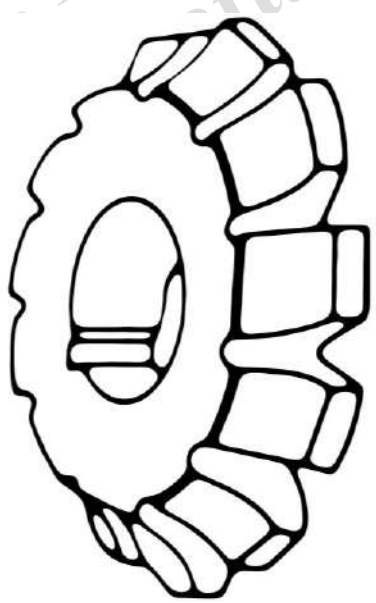
Form Milling Cutters

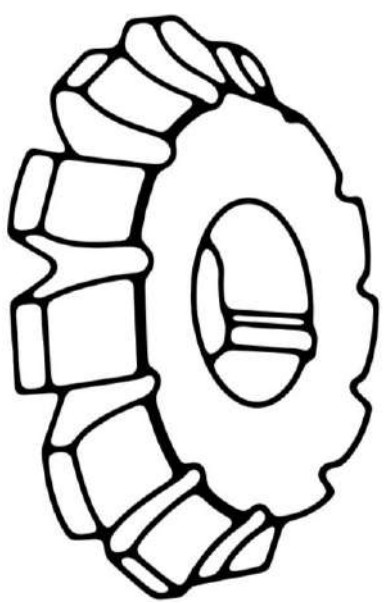
- They are also known as form relieved milling cutters or radius cutters and used for producing different shaped contours.
- They are commonly in following types;

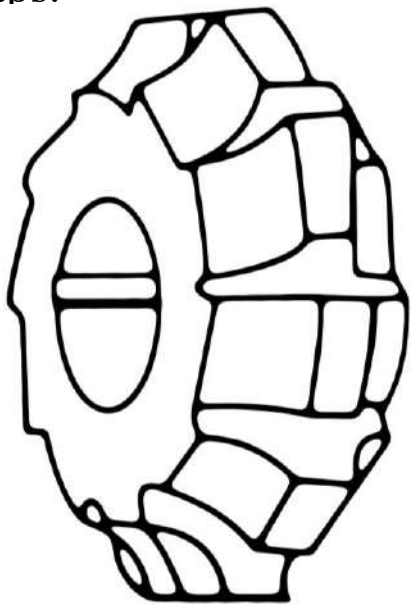
1. **Corner Rounding Cutters:** These cutters are used for milling the edges and corners of the jobs to a required radius.
2. **Concave and Convex Cutters:** These cutters are used for milling convex and concave surfaces or circular contours of half circle or less.
3. **Gear Cutters:** They are also designed as involute gear cutters. They are used for milling gear teeth on a milling machine. Two common grades are roughing and finishing.
4. **Tap and Reamer Fluting Cutters:** These formed cutters are used for milling flutes on a reamer and taps.
5. **Gear hobs:** Carries helical cutting teeth on periphery.
6. **Thread milling Cutters:**

   Used for milling different types of threads.

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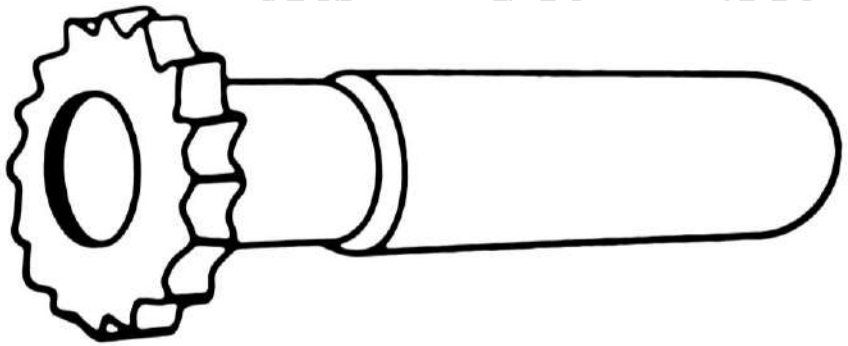






Woodruff-key Milling Cutters

- It is a small type end milling cutter which resembles with plain and side mills.
- Smaller sizes (upto 50mm diameter) are made to have solid shank, to be fitted in the machine spindle.
- Larger sizes are provided with a hole for mounting the same on an arbour.
- Smaller sizes generally have straight teeth on the periphery with sides having a little clearance.
- Larger sizes are usually made to have staggered teeth both on the periphery as well as the sides.

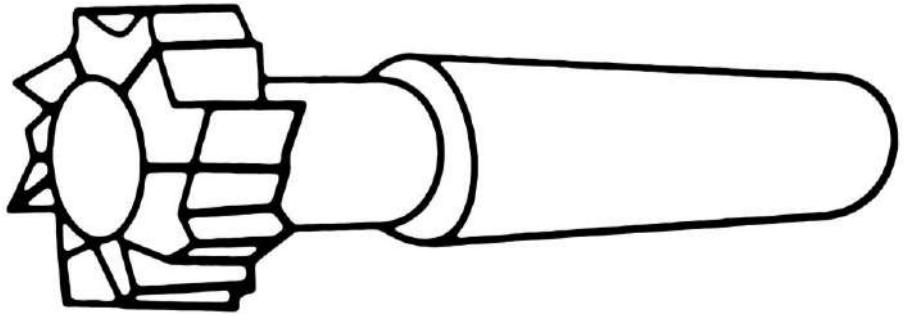


Woodruff key-seat Cutter

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T-slot Milling Cutters

- It is a single operation cutter which is used only for cutting T-slots.
- In smaller sizes it is made to have the shank integral with cutter.
- Large size cutters are mounted on a separate shank.



T-slot Milling Cutter

Fly Cutters

- It is actually a single point tool.
- It is either mounted on a cylindrical body, held in a stub arbour or held in a bar.
- Screws are used for tightly holding the tool in the holders.
- Cutting edge of the tool can be grounded to any desired shape. Therefore, it can be considered as a formed tool.
- It is generally used for experimental purposes since this type of cutter, if properly designed, is capable of producing a very accurate surface.

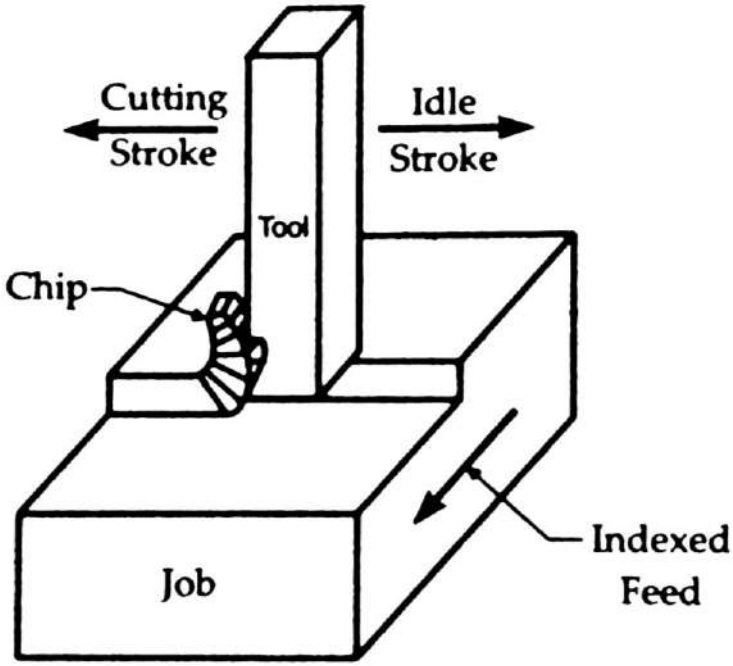
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SHAPING

- Shaper is a versatile machine which is primarily used for producing flat surfaces.
- These surfaces may be horizontal, vertical or inclined.
- It involves the use of a single point tool held in a properly designed tool box mounted on a reciprocating ram.
- The main significance of this machine lies in its greater flexibility on account of ease in work holding, quick adjustment and use of tools of relatively simple design.

Working Principal of a Shaper

- The job is rigidly held in a suitable device like vice or clamped directly on the machine table.
- The tool is held in the tool post mounted on the ram of the machine.
- This ram reciprocates to and fro and, in doing so, makes the tool to cut the material in forward stroke.
- No cutting of material takes place during the return stroke of the ram. Hence the term idle stroke.
- The job is given as indexed feed in a direction normal to the line of action of the cutting tool.

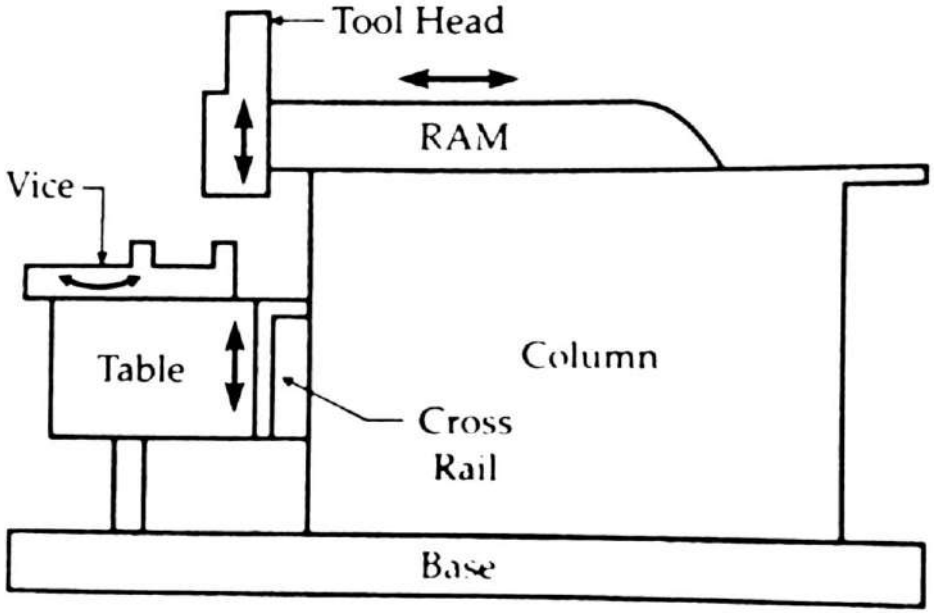


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Principal Parts of a Shaper

Principal parts of a shaper is as following:

1. **Base:**
   - It is a heavy and robust cast iron body acts as a support for all the other parts of the machine which are mounted over it.
2. **Column:**
   - It is a box typecast iron body, mounted on the base and acts as a housing for the operating mechanism of the machine and the electricals.
   - It also acts as a support for other parts of the machine such as cross rail and ram, etc.
   - In case of a hydraulic shaper, it carries the hydraulic drive mechanism inside it.
   - On its top it carries machined ways, in which the ram reciprocates and vertical guideways at its front.



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3. **Cross-rail:**
   - It is a heavy cast iron construction, attached to the column at its front on the vertical guideways.
   - It carries two mechanisms; one for elevating the table and the other for cross traverse of the table.
4. **Table:**
   - It is made of cast iron and has box type construction.
   - It holds and supports the work during the operation and slides along the cross-rail to provide feed to work.
   - T-slots are provided on its top and slides for securing the work to it.
5. **Ram:**
   - It is also an iron casing, semi-circular in shape and provided with a ribbed construction inside for rigidity and strength.
   - It carries the tool head and travels in dovetail guideways to provide a straight line motion to the tool.
   - It carries the mechanism for adjustment of ram position inside it.
6. **Tool head:**
   - It is the device in which it held the tool.
   - It can slide up and down and can swing to a desired angle to set the tool at a desired position for the operation.
7. **Vice:**
   - It is a job holding device and is mounted on the table.
   - It holds and supports the work during the operation.
   - Alternatively, the job can be directly clamped to the machine table.

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Size and Specification of a Shaper

- The size of a shaper us determined by the maximum length of cut or stroke it can make.
- It is reckoned that a standard shaper is usually capable of holding and machining a cube of the same dimensions as the length of stroke.
- The details of the specifications are listed below to specify a shaper:

1. Length of stroke
2. Maximum horizontal travel of table
3. Maximum vertical travel of table
4. Maximum distance from table to ram
5. Maximum vertical travel of tool slide
6. Length and width of table top
7. Length and width of table slide
8. Poer of motor 2/2 H.P. or kW
9. Number of ram cycle per minute
10. Range of ram cycles per minute
11. Tool box takes tool of size
12. Maximum vice opening
13. Approximate net weight
14. Approximate gross weight
15. Floor space

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Classification of Shapers

1	Standard shaper
2	Draw-cut shaper
3	Horizontal shaper
4	Universal shaper
5	Vertical shaper
6	Geared shaper
7	Crank shaper
8	Hydraulic shaper
9	Contour shaper
10	Travelling head shaper

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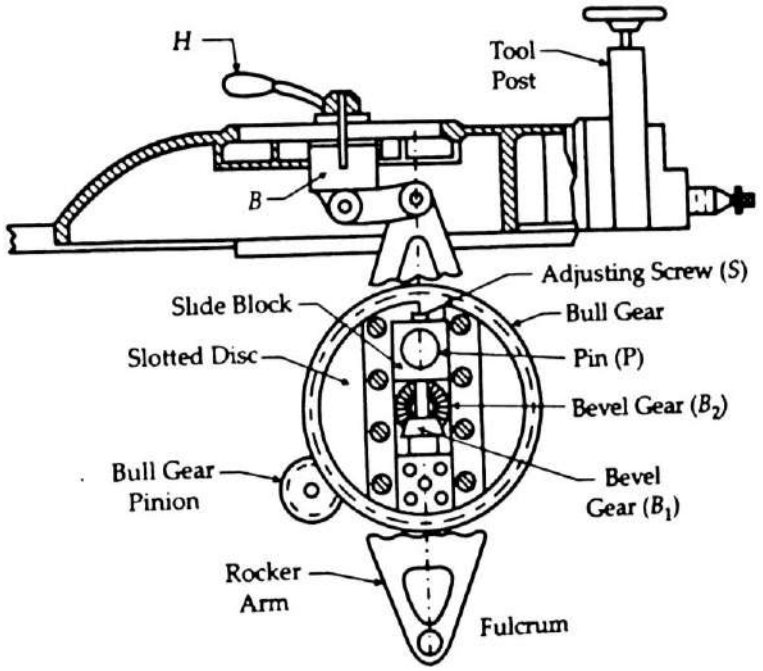
Quick Return Mechanisms

- During machining in shaper machine, the material is cut in the forward stroke only and the return stroke is idle. Therefore, time spent in the idle stroke is a waste.
- However fast this idle stroke is made it will definitely take some time and it is not possible to reduce it to zero value.
- Hence our goal is to use some such mechanism that will reduce this idle time to minimum. Such mechanism is ca known as quick return mechanism.
- There are two common mechanisms used for this purpose;
    1. Crank and slotted link mechanism
    2. Hydraulic mechanism

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1. Crank and slotted link mechanism

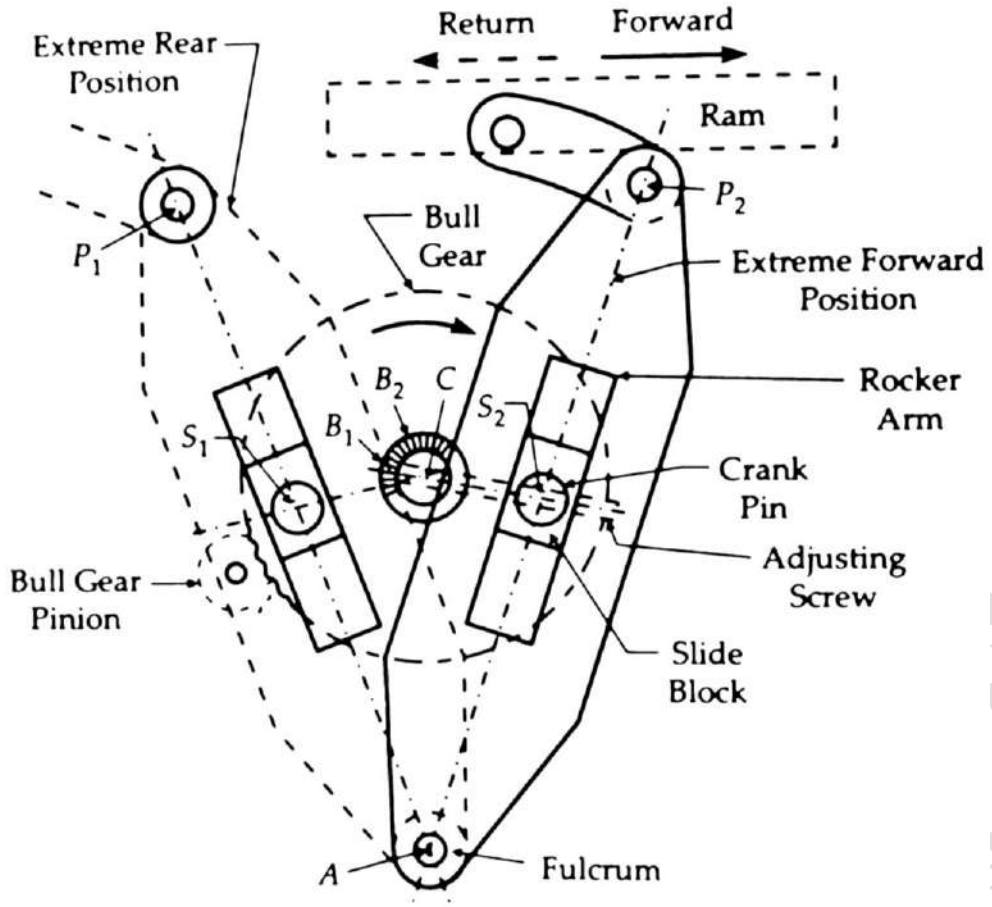
- The crank and slotted link mechanism consists of a slotted link called rocker arm, pivoted at its bottom end which forms the fulcrum.
- At its upper end it carries another short link which is attached to the bock B.
- Block B can be clamped at the desired position by means of the head lever H.



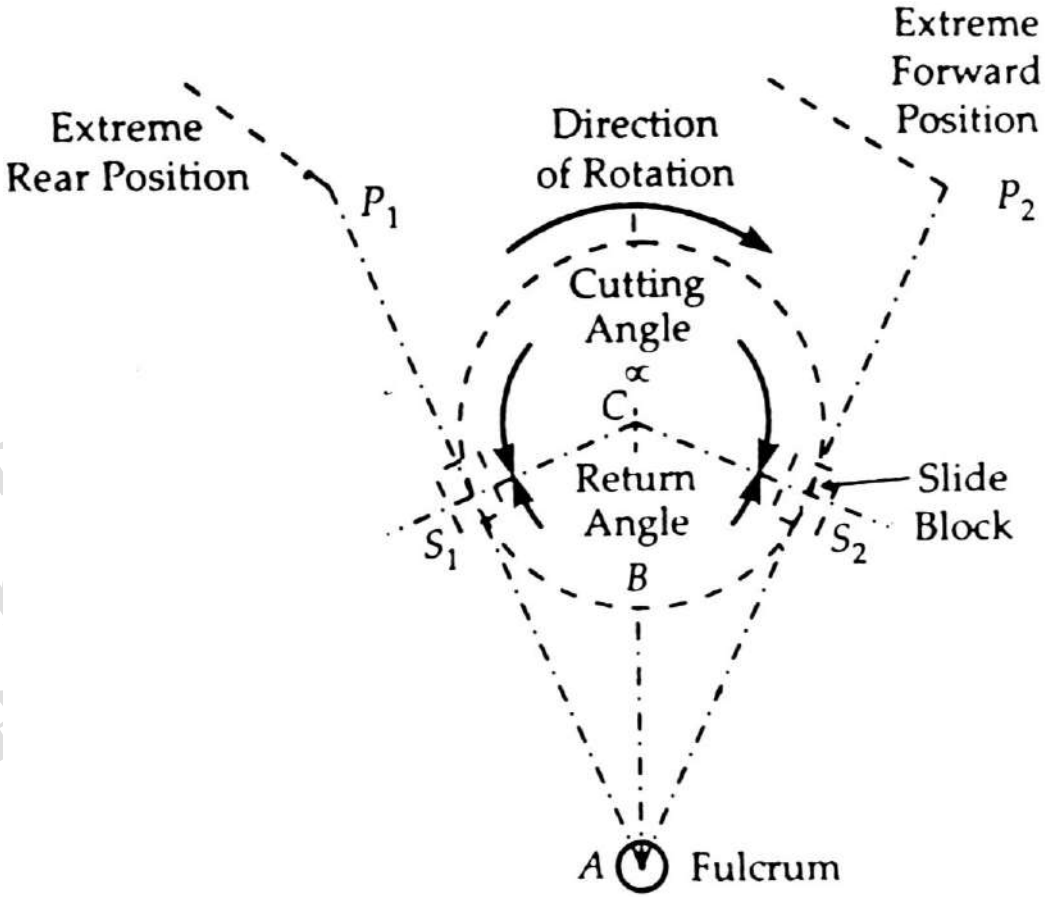
Crank and slotted link mechanism

- The rocker arm is provided with a slide block, in which revolves the crank pin P.
- The slide block can freely slide in the slot provided in the rocker arm.
- At the back of the rocker arm a large cast steel gear, called bull gear, is provided, which is mounted on a pin attached to the frame of the machine.
- A slotted disc, carrying a T-slot, is secured to the bull gear at its front.
- The crank pin P is fitted in this slot and can be moved to any desired position along the same by means of bevel gears B_1 and B_2 and the adjusting screw S.
- Bevel gear B_2 is concentric with the bull gear and the other bevel gear B_1 is attached to the adjusting screw at its one end, the axes of B_1 and B_2 being at right angles to each other.
- The bull gear pinion is mounted on the power shaft and is actuated by the speed control mechanism.
- This pinion drives the bull gear which, while rotating, on account of the eccentricity between its centre and that of the crank pin, makes the rocker arm swing about the fulcrum.
- This, in return, moves the ram to and fro.

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Working of the crank and slotted link mechanism

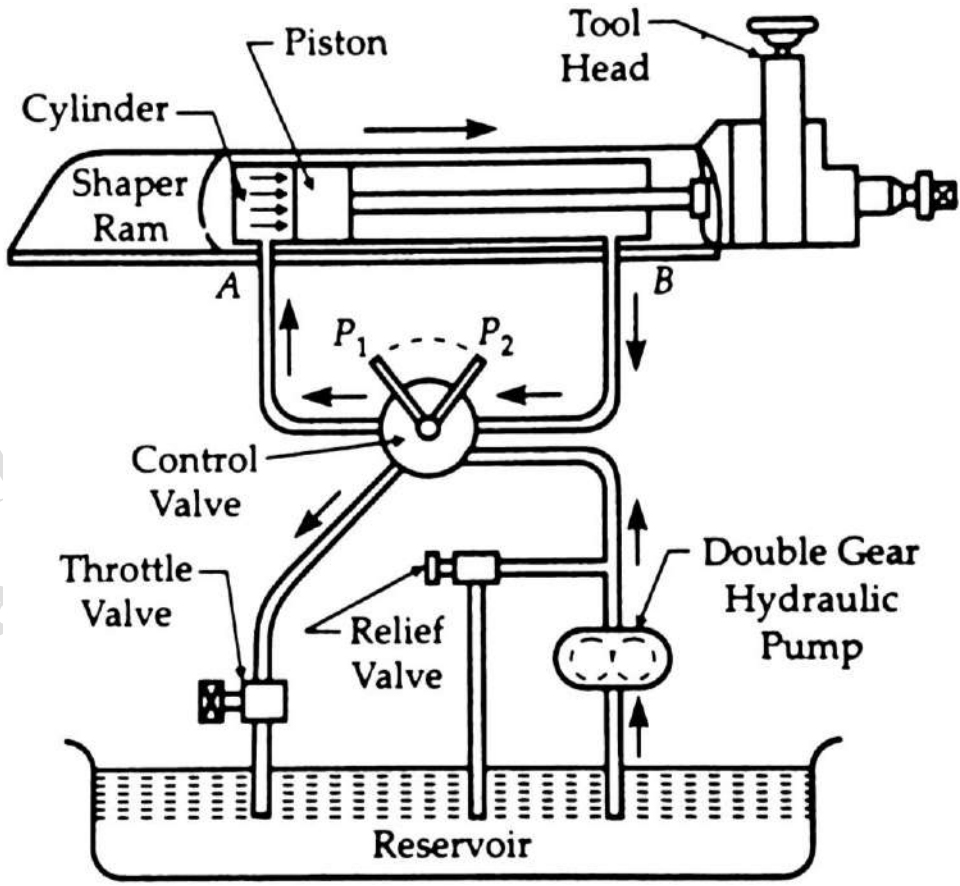


Quick Return Motion

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2. Hydraulic Mechanism

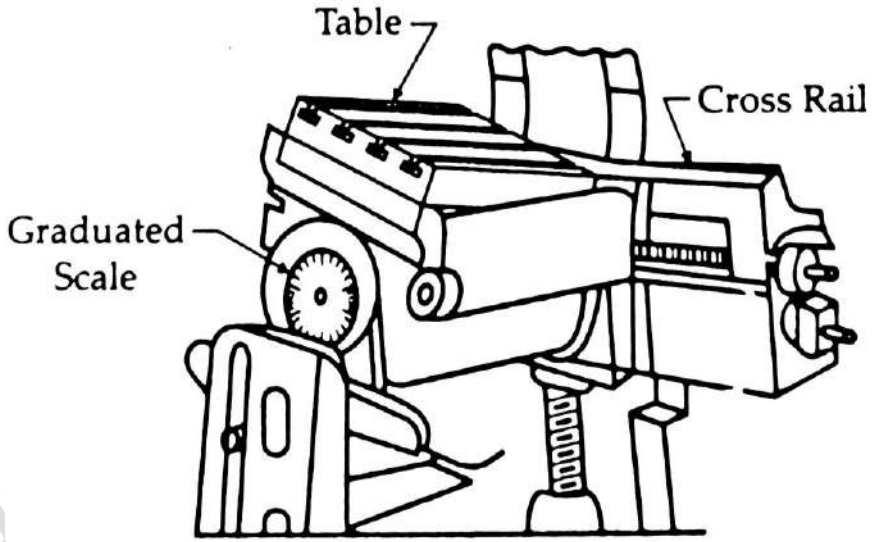
- The oil from the reservoir is drawn through an oil filter by the double gear hydraulic pump which is driven by an electric motor.
- The reservoir is kept open to atmospheric pressure.
- Pump delivers a constant quantity of oil to the control valve at a moderate pressure.
- From the control valve, the oil is delivered to either side of piston in the feed control cylinder situated under the ram.
- Position of control lever of the control valve determines as to which side of the piston the oil will be delivered.



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Shaping Machine Attachments

- The common attachments used on a shaper are the followings;
  1. Universal Table
  2. Shaper Centres and Dividing Head
  3. Curvilinear Motion Head
  4. Keyway Cutting Attachment



Universal Table

1. Universal Table

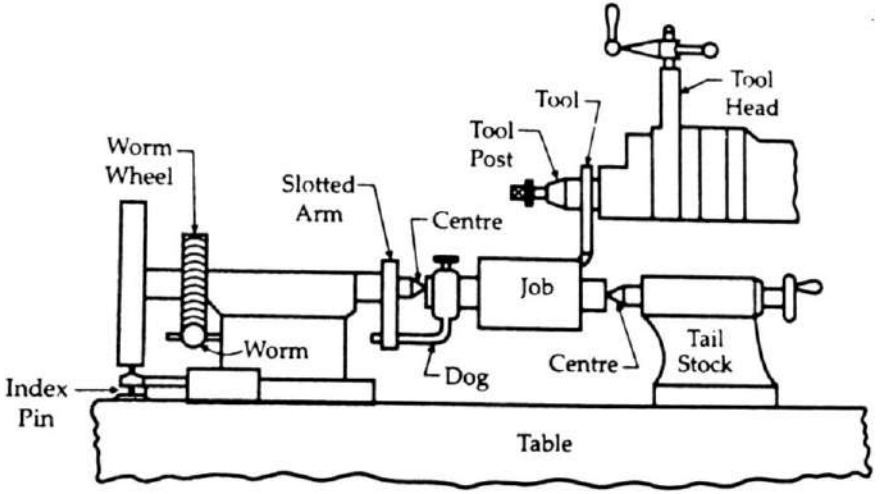
- It is mounted in place of the ordinary table of the machine. Its specific use is in machining angular and oblique surface.
- This table can be swivelled to a desired angle by means of a circular back and pinion mechanism provided with it. The table top can also be tilted to a desired angle in the vertical direction.

2. Shaper Centres and Dividing Head

- It consists of a tailstock and an index head. The workpiece is held between two centres exactly in the same way as in centre lathe.
- The tailstock is of the same type as used on a lathe. The index head consists of a simple circular disc carrying equispaced holes along its periphery.

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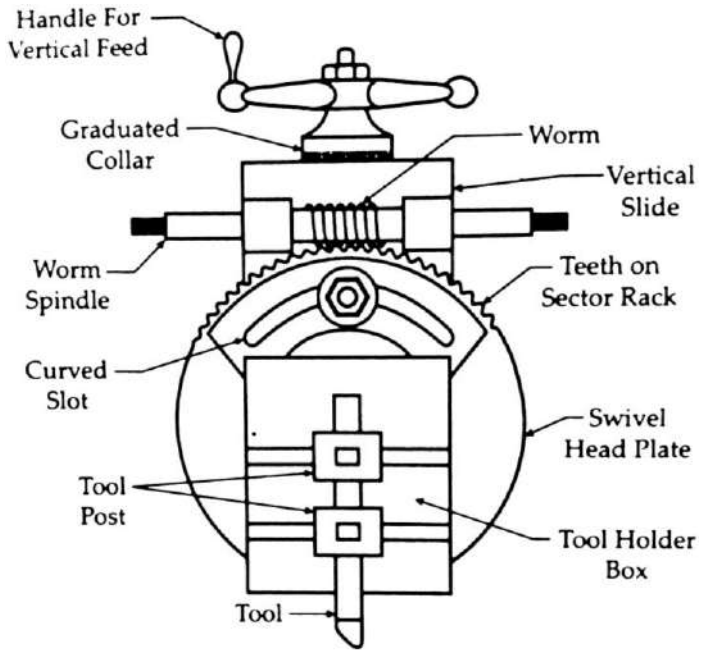
- A worm wheel is mounted on the spindle of the index head and is driven by means of a worm attached at its bottom.
- The attachment may either be mounted on a base plate, which is later on clamped to the machine table or alternatively the index head and tailstock both may carry T-shaped projections at the bottom to fit in the slots on the table.



Shaper Centre and Dividing Head

3. Curvilinear Motion Head

- This type of tool head is a separate attachment, which can be fitted on the shaper ram in place of the regular tool head when a curvilinear motion is required.
- It consists of a vertical slide, which can be moved up and down by means of the handle provided at the top of the tool head.
- At the front of the vertical slide is provided a tool holder box carrying two tool-posts.
- The tool is held vertically between these tool posts.
- They can be adjusted horizontally, and so the tool, by moving in T-slots provided on the tool-holder box.

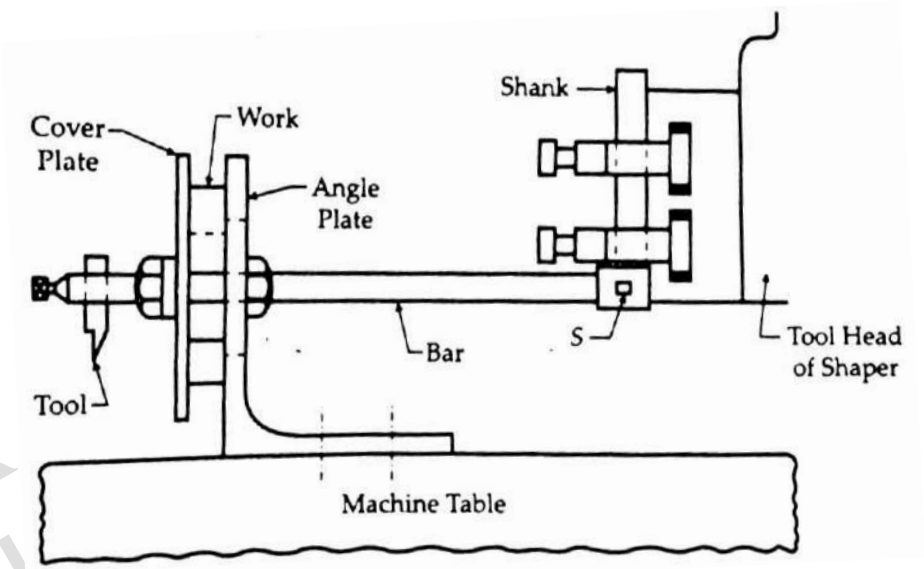


Curvilinear Motion Head

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4. Keyway Cutting Attachment

- The shaping machine may quite often be required to cut keyways in many components like pulleys, gears, etc. For this purpose a keyway cutting attachment can be mounted on the tool-head of this machine.
- The attachment consists of a solid shank and a bar.
- The shank is held in the shaper tool-head.
- At its bottom the shank is provided with a housing, in which the bar is inserted and secured by means of the set screw S.
- The other end of the bar carries the cutting tool.
- The work is held on a suitable angle plate at its back by means of two or more bolts and a cover plate, the axis of the work being horizontal, i.e., parallel to the bar.



Keyway Cutting Attachment

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Shaping Operations

- The basic operations done on a shaper can be broadly classified is follows;
    1. Horizontal Cutting
    2. Vertical Cutting
    3. Angular Cutting
    4. Irregular Cutting

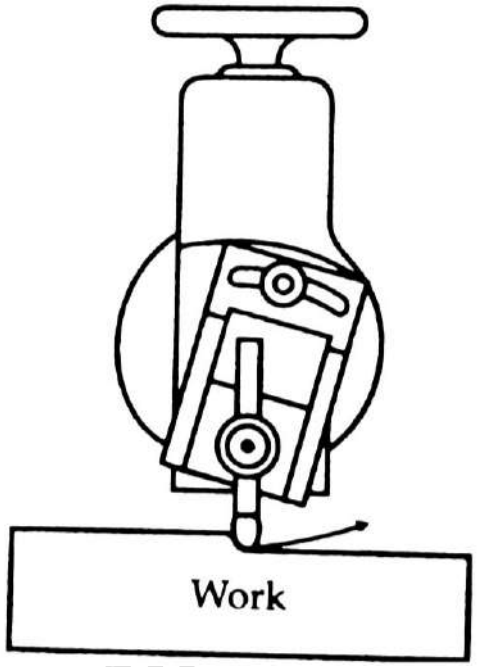
1. Horizontal Cutting

- In this, the work is fed in a horizontal direction under the reciprocating tool and the surface produced is horizontal and flat.
- For this, the work is either held in a vice or clamped directly on the machine table, depending upon its size. Parallels are used for clamping the work.
- The tool is held in a proper tool holder. It is set at proper inclination and at correct height above the work.
- The depth of cut is adjusted and the machine started.
- Cross feed to the table is given initially by hand, till the cut starts. After that power feed can be employed.
- After the cut is finished, the machine is stopped and the work inspected. If more material is to be removed, the procedure is repeated till the desired surface is obtained.

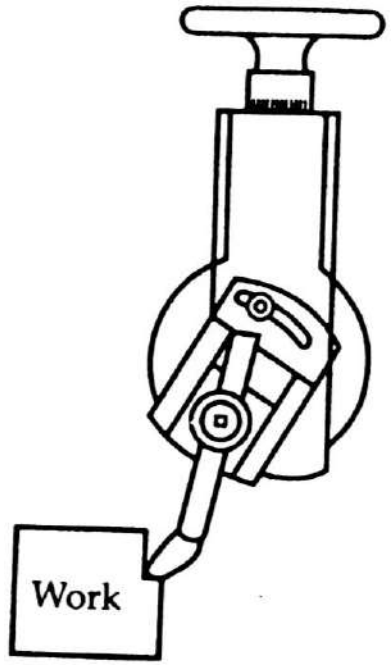
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2. Vertical Cutting

- The tool is fed downward in vertical cutting.
- This sort of tool feed is commonly employed in cutting grooves, key-ways, parting off and squaring ends and shoulders.
- When the down feed of the tool is used, except in parting off, the apron top is swivelled in a direction away from the surface to be machined.
- The down feed to the tool is given by rotating down feed screw of the tool head.



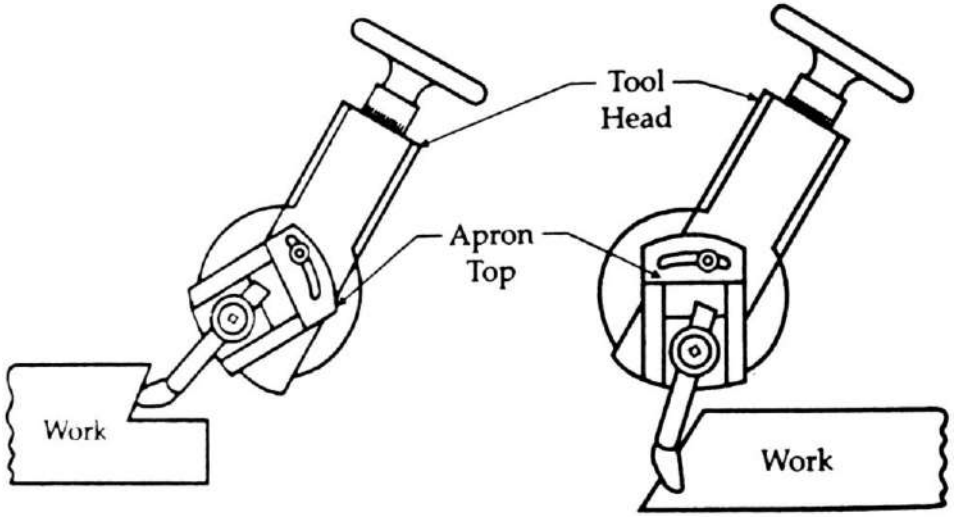
Tool Setting in Horizontal Cutting



Tool Setting in Vertical Cutting

3. Angular Cutting

- The operation of angular cutting is employed for machining inclined surfaces, bevelled surfaces and dovetail, etc.
- The down feed of the tool is used.
- Alternatively, sometimes an inclined surface is obtained by setting the job in inclined position by setting it on tapered parallels or by other suitable means.



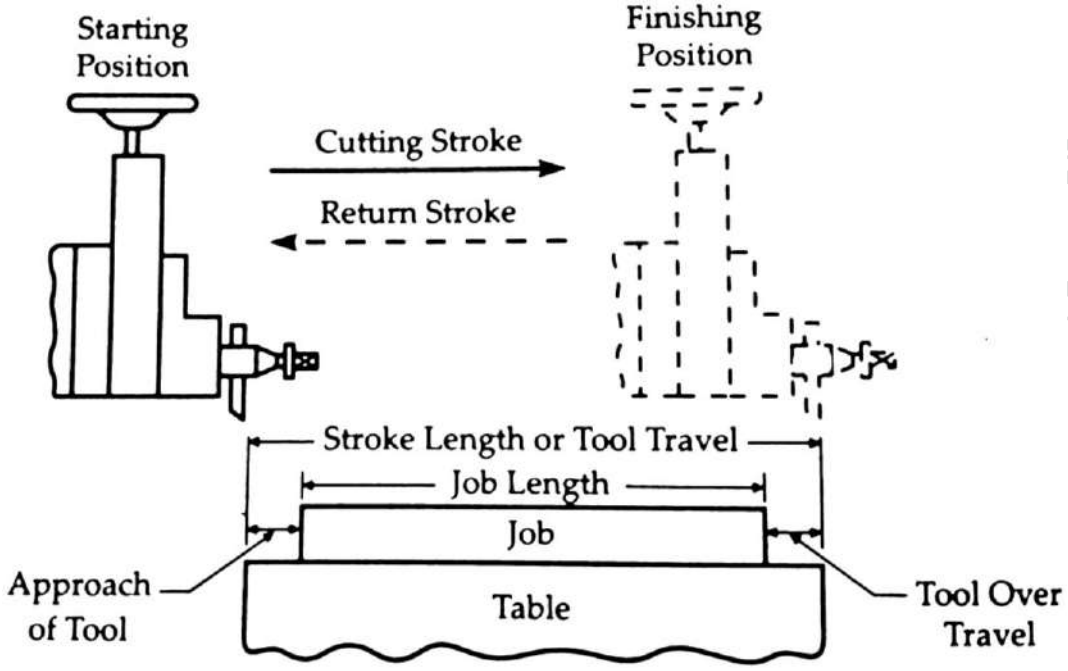
Tool Setting for Angular Cutting

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Dr. A. K. Pattanay

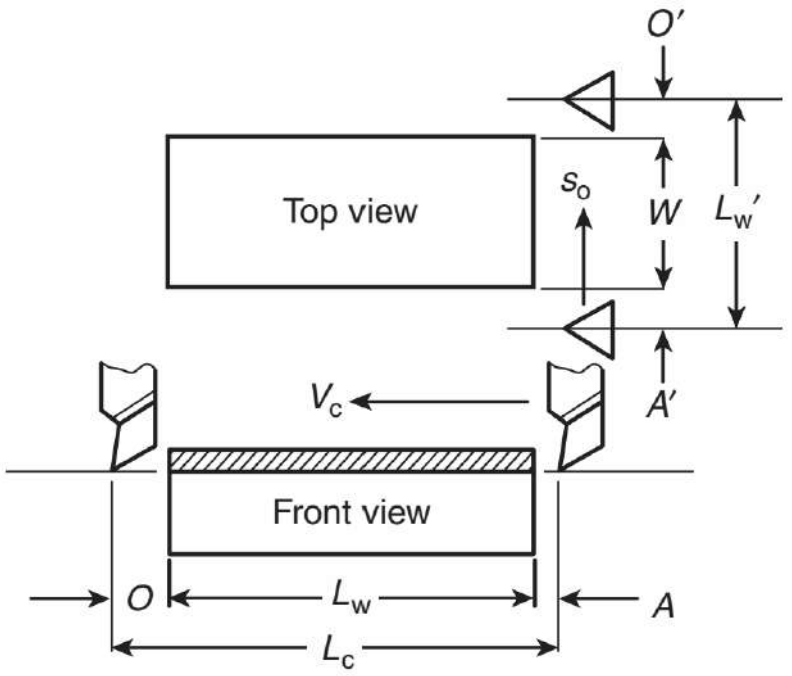
4. Irregular Cutting

- If an irregular surface is to be machined and It is appreciably narrow, a form tool can easily be used for machining the same.
- If a wide irregular surface is to be machined the shape ia marked on the side of the job.
- For machining irregular surfaces, a combination of vertical hand feed to the tool and horizontal power cross feed to the table is to be used.

Machining Time for Shaping Operations



Tool travel in shaping operation



Machining in Shaping Machine

In the front view the tool moves along the length of the job. It starts a distance A before the job (approach), crosses the job length L_w and runs a distance O past the far end (overrun). So every stroke covers

$$L_c = L_w + A + O\ (mm)$$

This is the stroke length for the ram.

Each cycle has two parts: **(i) Cutting stroke:** The tool moves at V_c (m/min) and removes metal; **(ii) Return stroke:** The tool comes back idle, at a higher speed because of the quick return mechanism.

Time for the cutting stroke:

$$T_{cut} = \frac{L_c}{1000V_c}\ min$$

The factor 1000 is there because L_c is in mm and V_c is in m/min.

The quick return ratio (Q) is defined as; $Q = \frac{Time\ of\ Return\ Stroke}{Time\ of\ Cutting\ Stroke} = \frac{T_{return}}{T_{cut}} \Longrightarrow T_{return} = Q \times T_{cut}$

Q is less than 1 because the return is faster.

Time for one full cycle:

$$T_{cycle} = T_{cut} + T_{return} = T_{cut} + Q \times T_{cut} = T_{cut}(1+Q) \Longrightarrow T_{cut} = \frac{L_c}{1000V_c}(1+Q)\ min$$

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If one cycle takes $T_{cycle}\ mins$, the machine makes $\frac{1}{T_{cycle}}$ cycles per minute.

Therefore, $Number\ of\ strokes\ per\ minute\ (N_s) = \frac{1}{T_{cycle}} = \frac{1000V_c}{L_c(1+Q)} \Longrightarrow V_c = \frac{N_s L_c(1+Q)}{1000}$

That means N_s cycles per minute, each with a cutting part of $L_c\ mm$, give the cutting speed after allowing for the lost time in the return.

In the top view, the job is fed sideways by $s_0 mm$ after every stroke. The surface is finished only when the tool has crossed the full width W, plus the approach A' on the starting side and overrun O' on the far side. So the total cross travel is:

$$L_w' = W + A' + O'\ (mm)$$

At $s_0 mm$ per stroke, the number of strokes needed is;

$$Number\ of\ strokes = \frac{L_w'}{s_0}$$

Therefore, the total machining time is:

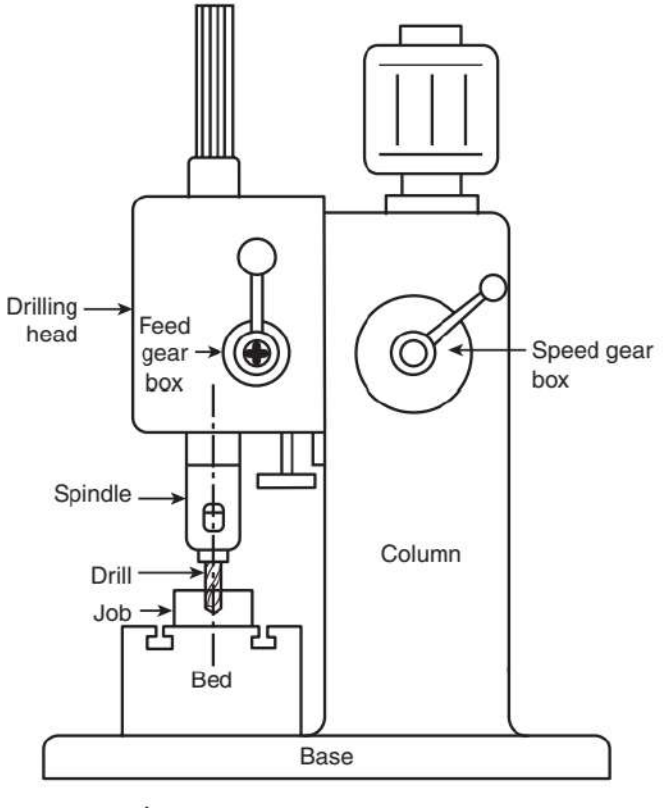
$$Machining\ Time, T_c = \frac{Strokes\ needed}{Strokes\ per\ minute} = \frac{L_w'}{N_s s_0}$$

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DRILLING

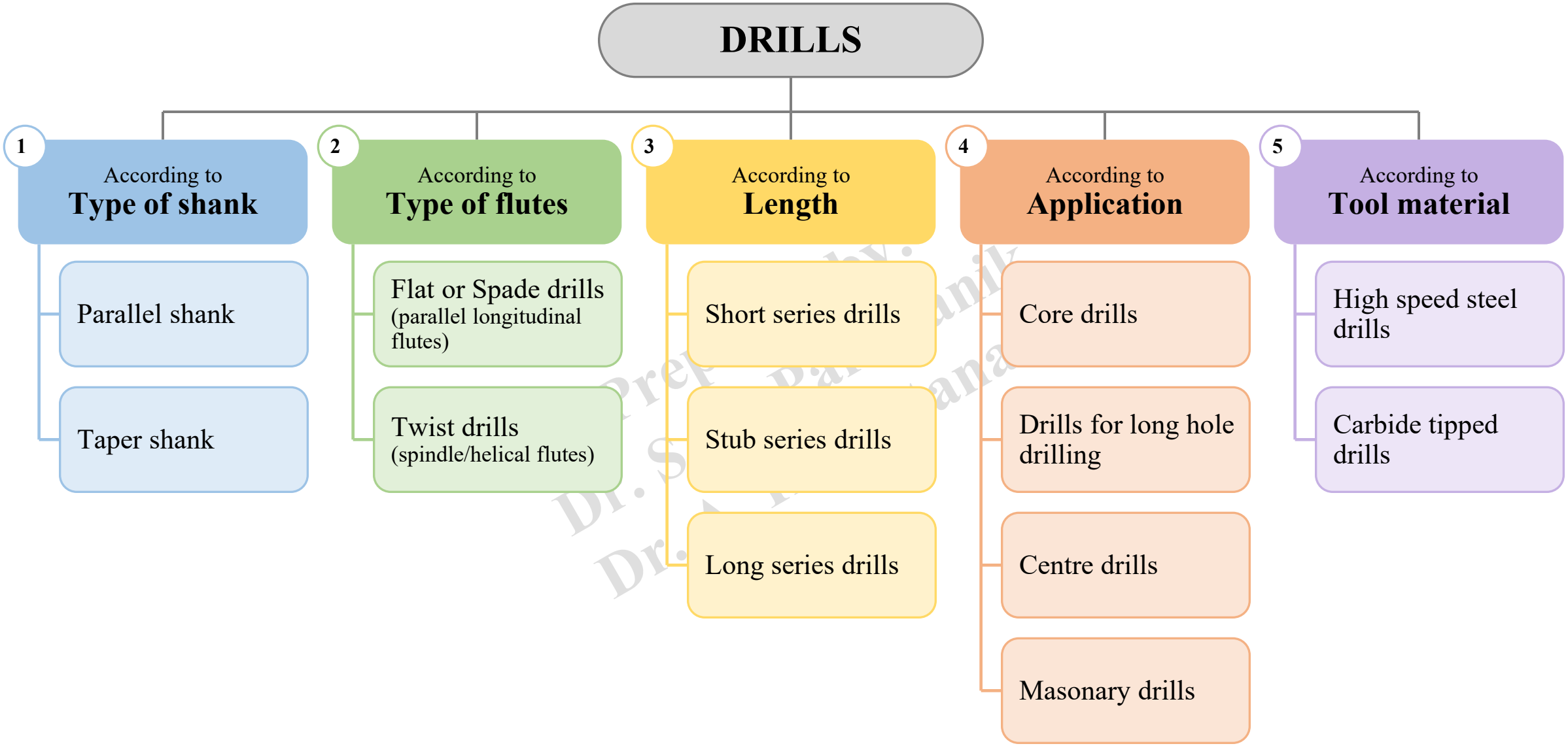
- Drilling is an operation through which holes are produced in a solid metal by means of a revolving toll called drill.
- Since it is not possible to produce a perfectly true hole by drilling, it is considered as a roughing operation.
- Where a very close dimensional accuracy is to be maintained, drilling is followed by another operation called reaming, in which the required dimensional accuracy and fine surface finish are obtained by means of a multi-tooth revolving tool called reamer.
- Boring is the operation employed for enlarging an exiting hole.
- Drilling machine (column type) comprises the following:

1. **Column:** A long hollow but rigid vertical structure which stands on its base and provides support to the other components.
2. **Drilling head:** This box type body accommodates the power drive and the gear boxes to adjust speed and feed.
3. **Spindle:** This rod-like component is rotated and axially moved along with the coaxially mounted drill to impart both cutting motion and feed motion to the tool.



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Classification of Drills



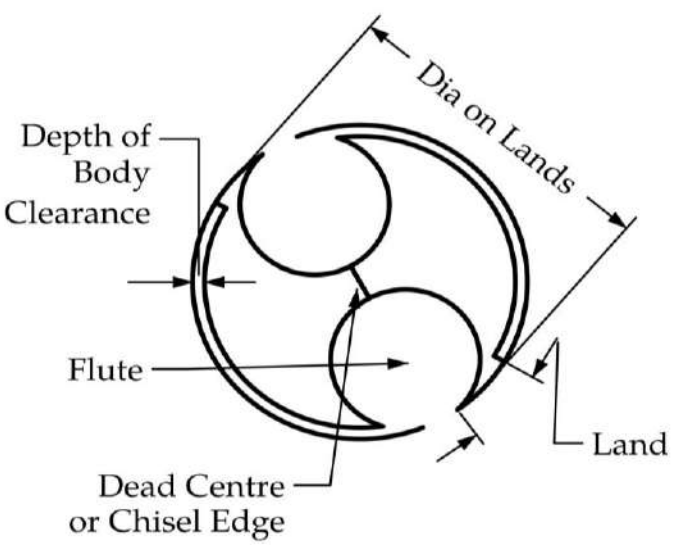
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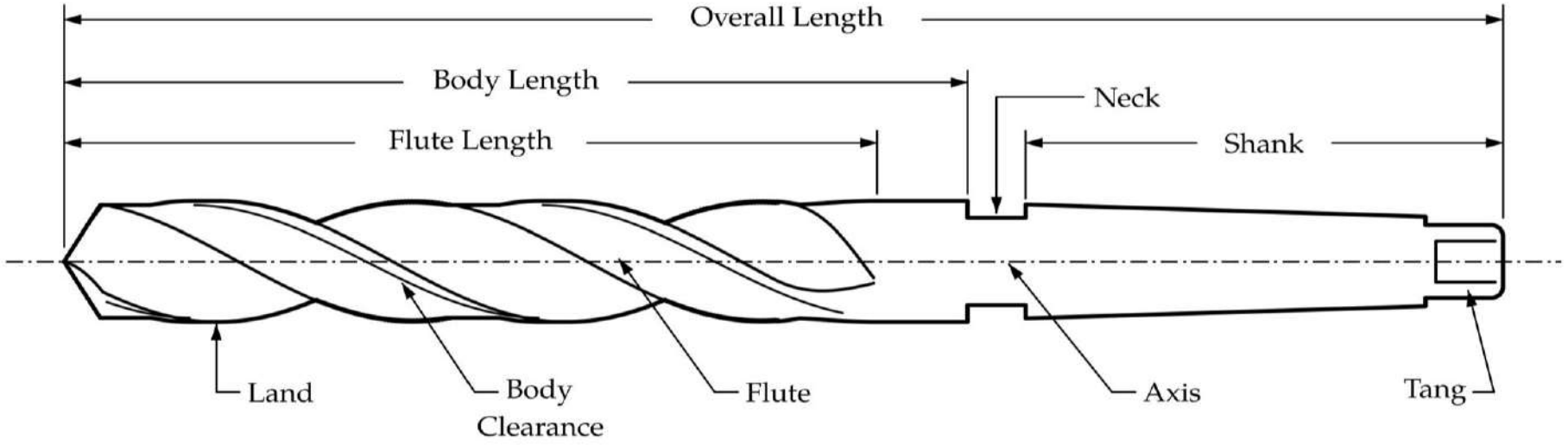
Twist Drills

- Twist drill is the most widely used tool in modern drilling operations.
- These are made up of high speed steel, high carbon steel, etc.
- The twist drills consists of two main parts, i.e.,
  1. **Shank:** It is gripped in drill chuck or sleeve.
  2. **Body:** It forms the main cutting unit.
- The advantages of using twist drills are:
  - The chip and cutting of the metal are automatically driven out of the hole through the flutes.
  - Cutting edges are retained in good condition for a fairly long time, thus avoiding the frequent regrinding of the drill.
  - Heavier feeds and speeds can be employed quite safely, resulting in a considerable saving of time.
  - For the same size and depth of the hole they need less power in comparison to other forms of drills.

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Twist Drill Parts and Terminology





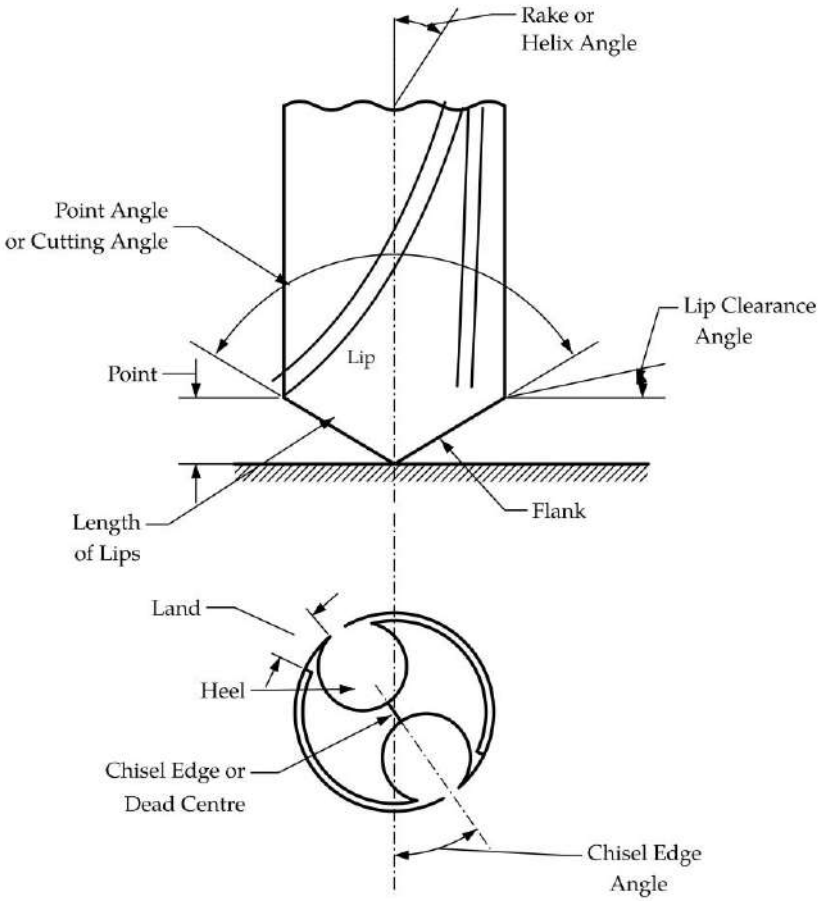
- **Body:** It is the part of the drill which carries flutes and extends from the dead centre upto almost start of the neck. This part of the drill is always relieved.
- **Axis:** The longitudinal centre line of the drill, along which the whole body , neck and shank of the drill are concentric, is called the axis of the drill.
- **Chisel edge or Dead Centre:** The short edge formed at the extreme tip end of the drill, due to the intersection of the flanks, is called chisel edge or dead centre. It coincides with the axis od the drill.
- **Shank:** The portion of the drill beyond the neck, which is gripped in the holding device, is called shank. It may be parallel or tapered.

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- **Point:** The cone shaped surface at the end of the flutes, formed by grinding, and containing the dead centre, lip and flanks, etc. is known as point.
- **Lip or Cutting Edge:** It is the main cutting part of the drill and is formed by the intersection of each flank and face. Therefore, there will be so many lips in a drill as the number of flutes and the faces. In a commonly used twist drill there are two lips because it carries two flutes and two corresponding flanks.
- **Body Clearance:** A small reduction I the diameter of the body is provided on a drill adjacent to the Land. This is called Body clearance. It helps in reducing friction between the drill and the walls of the hole and, thus, helps in both Metal cutting and increasing Tool life.
- **Land or Margin:** It is a narrow flat surface which runs all along the flutes of the drill on its leading edges. The diameter of the drill measured across its lands determines its correct size. The functions of the lands are to keep the drill aligned during the operation and produce the correct size hole.
- **Lip clearance:** That part of the conical surface of point, which is ground to provide relief near the cutting edge, is called Lip Clearance.
- **Face:** The curved surface of the flute near the lip is called Face. The chips cut from the material slide upward along this surface.

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- **Flutes:** The helical grooves in the body of the drill are known as Flutes. Commonly used drills carry two flutes, while special drills may carry four. These flutes make the chips curl and provide passage for their exit. Also, Cutting edges are formed on the point due to machining of these flutes and the cutting fluid reaches the cutting area through these flutes only.
- **Flank:** It is the curved surface, on either side of the dead centre, which is confined between the cutting edge on its one side and the face of the other flute on the other side.
- **Web:** The central metal column of the drill body, that separates the flutes from one another, is known as Web. Its thickness gradually increases from the tip side towards shank side, where it is maximum. It is this part of the drill which is largely responsible for providing strength and rigidity to the drill.
- **Chisel edge corner:** The point of intersection of the chisel edge and the lip is known as Chisel edge Corner.



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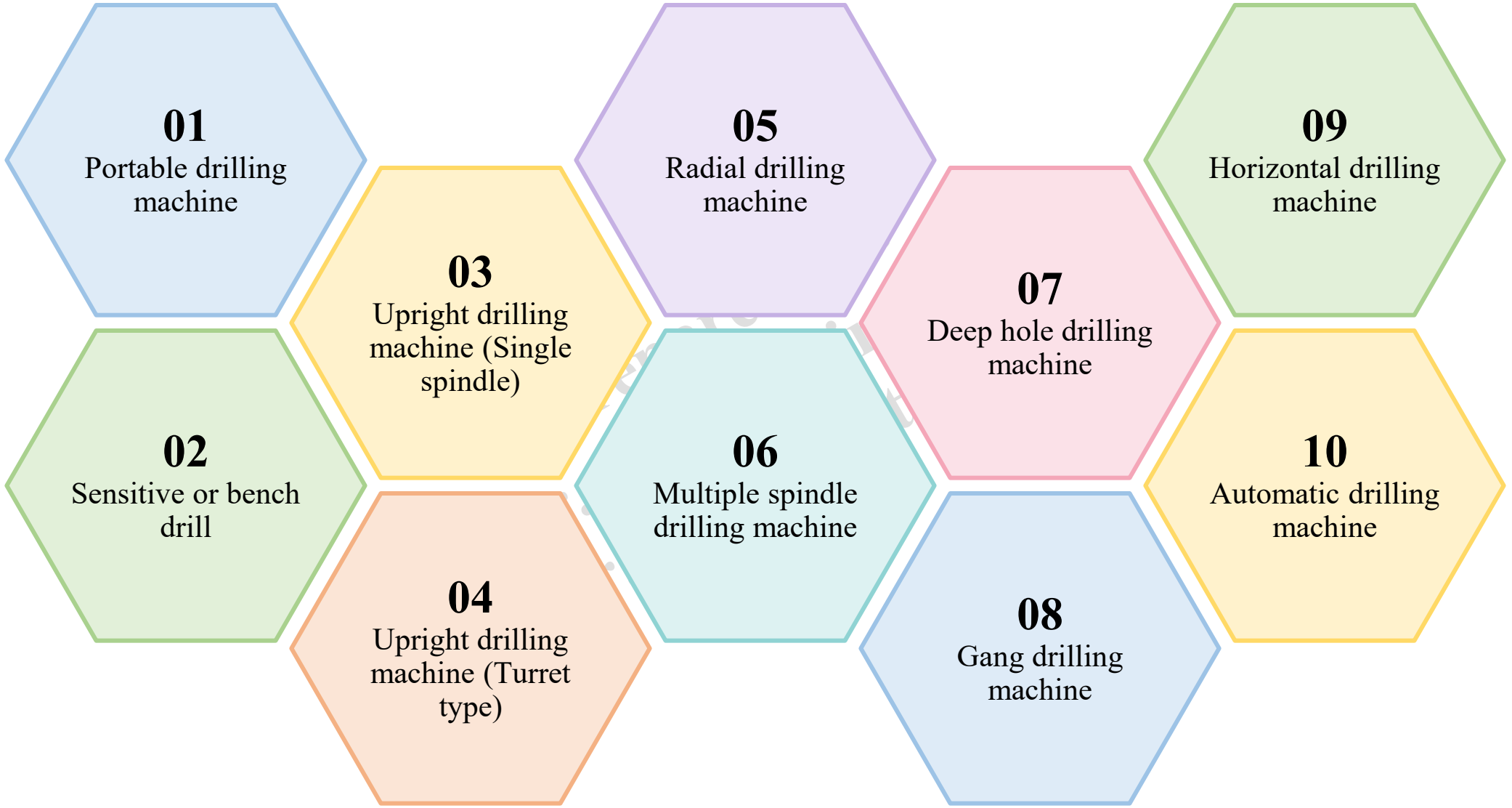
- **Outer corner:** That extreme of the dead centre, where the face and flank intersect to form a corner, is called Outer corner.
- **Neck:** The smaller diameter cylindrical portion which separates the body and shank of a drill is called Neck. All necessary particulars of the drills are engraved on this portion.
- **Tang:** The flat portion of rectangular cross-section provided at the end of the tapered shank is known as Tang. This fits into a matching slot in the Holding device, such as a Socket, Sleeve or Spindle, to provide a positive drive. Also, for driving the drill out of the sleeve or spindle, a drift is applied over this part of the drill.
- **Heel:** An edge is formed where the Body clearance and Flute of the drill intersect. This edge is known as Heel.

Drill Size and Specification

- According to Indian Standards the drills are specified by their diameters, series they belong to, the material they are made of and the I.S. numbers.
- They are made in three types:
  - **Type N:** For normal low carbon steel
  - **Type H:** For hard materials
  - **Type S:** For soft and tough materials
- For example, a twist drill specified as "**9.50 IS : 5101 HS**", means a twist drill of 9.50mm diameter, conforming to IS: 5101, made from high speed steel.

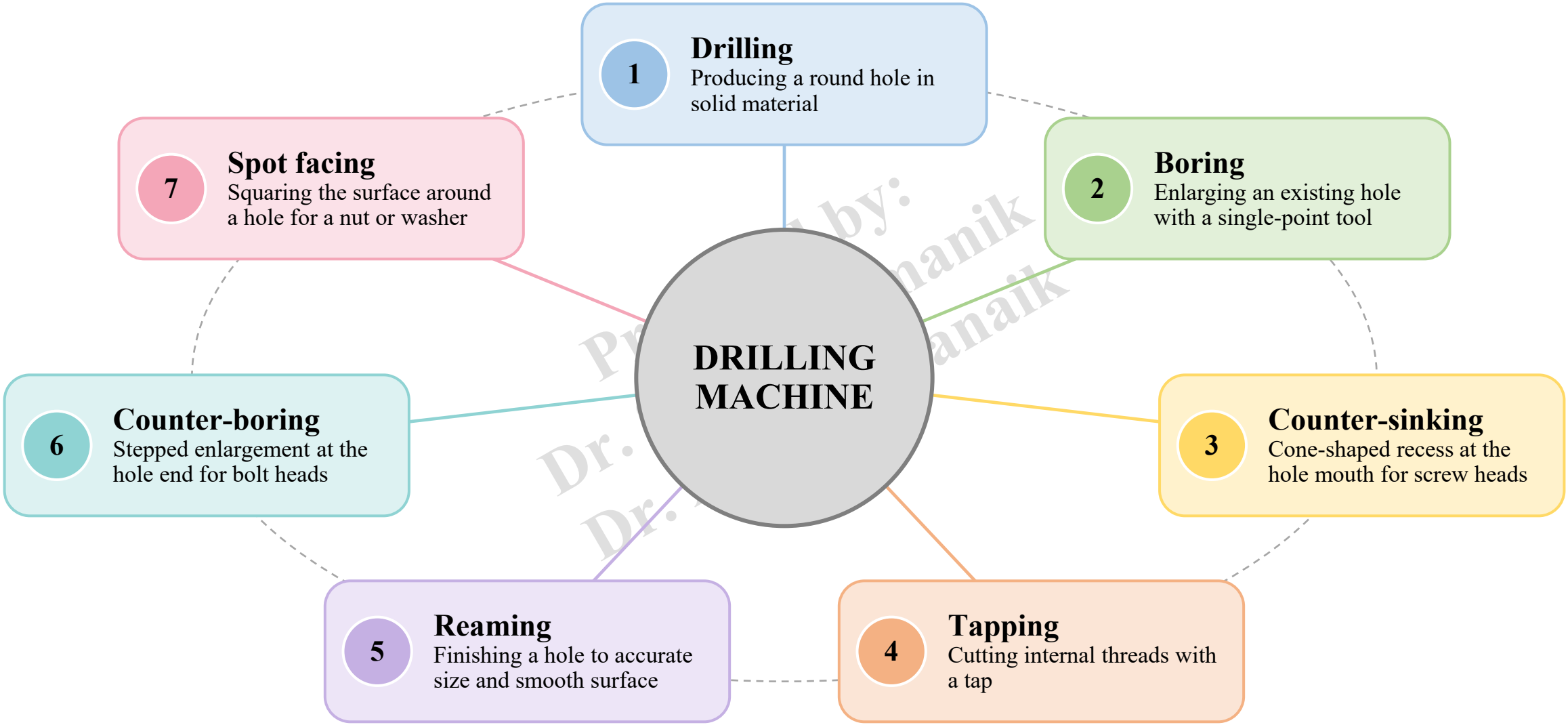
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Dr. A. K. Pattanaik

Classification of Drilling Machines



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Operations Done on a Drilling Machine



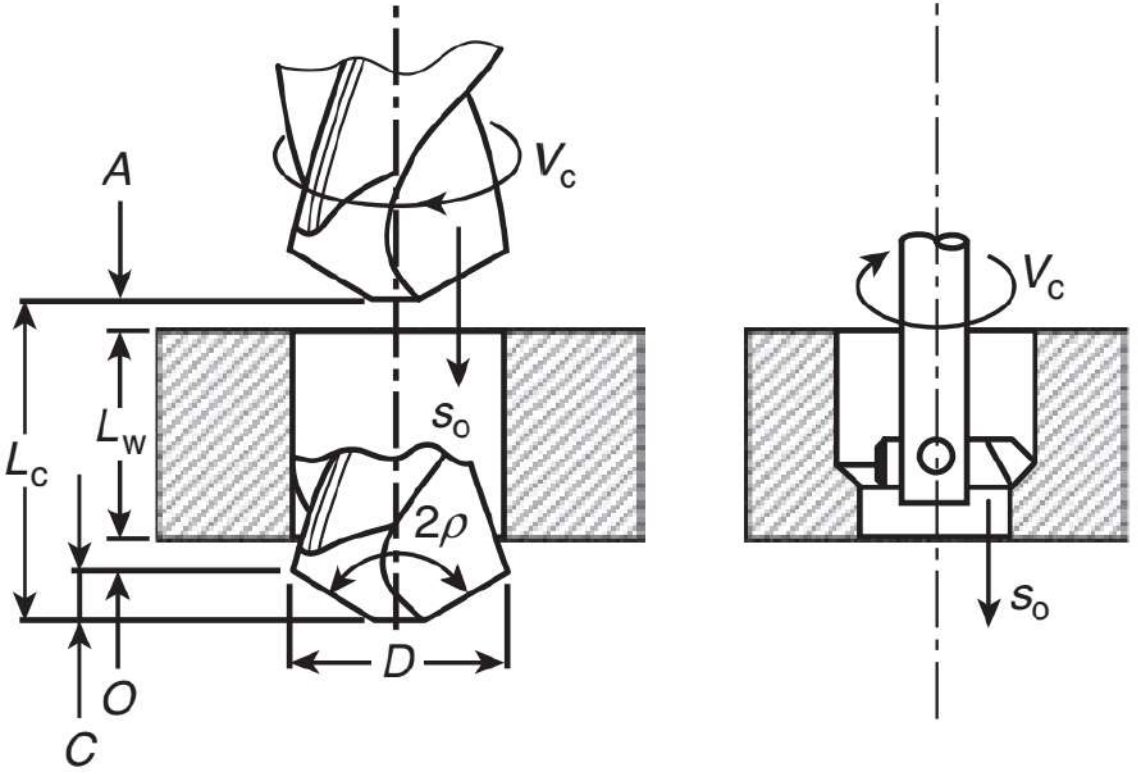
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Estimation of Machining Time in Drilling

The drill turns at N rpm and advances $s_o mm$ every revolution.

In one minute it moves forward $N \times s_o\ mm$. Therefore, if we can calculate the total distance travelled by the drill along its axis, the time can be calculated by;

$$Time = \frac{Total\ Axial\ Travel}{Distance\ Travelled\ per\ minute}$$



Approach *A:* The drill does not start touching the job. Before cutting it is held a small distance above the top surface, so that it can reach full feed safely. This gap is the approach A. It is usually 2 to 5 mm.

Job Thickness (L_w): This is the length of the hole, the plate thickness for a through hole.

Point allowance, *C*: The drill has a conical point with included angle 2ρ, so the half angle is ρ. When the tip reaches the bottom face, the outer corners of the lips are still inside the job. The hole is not yet full diameter at the bottom. The drill must move a further distance C, equal to the height of the cone, before the full diameter D breaks through.

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The height of the cone comes from the right-angled triangle formed by the drill axis, the lip and the radius:

$$\text{Base} = D/2;\ \text{Angle at the tip} = \rho;\ \tan\rho = \frac{D/2}{C} \Longrightarrow C = \frac{(D/2)}{\tan\rho}$$

Overrun, *O*: After the full diameter has broken through, the drill is fed a little further, so that no burr or uncut ring is left at the bottom edge. This extra travel is the overrun *O*, usually 1 to 3 mm.

So, the total drill travel is $\boldsymbol{L_c = L_w + A + O + C}$

Spindle speed (N): Cutting Speed, $V_c(m/min) = \frac{\pi DN}{1000} \Longrightarrow N = \frac{1000V_c}{\pi D} rpm$

Machining Time is $T_c = \frac{L_c}{Ns_o}\ min = \frac{L_w+A+O+C}{\left[\left(\frac{1000V_c}{\pi D}\right)\times s_o\right]} \Longrightarrow T_c = \frac{\pi D(L_w+A+O+C)}{1000V_c s_o}$

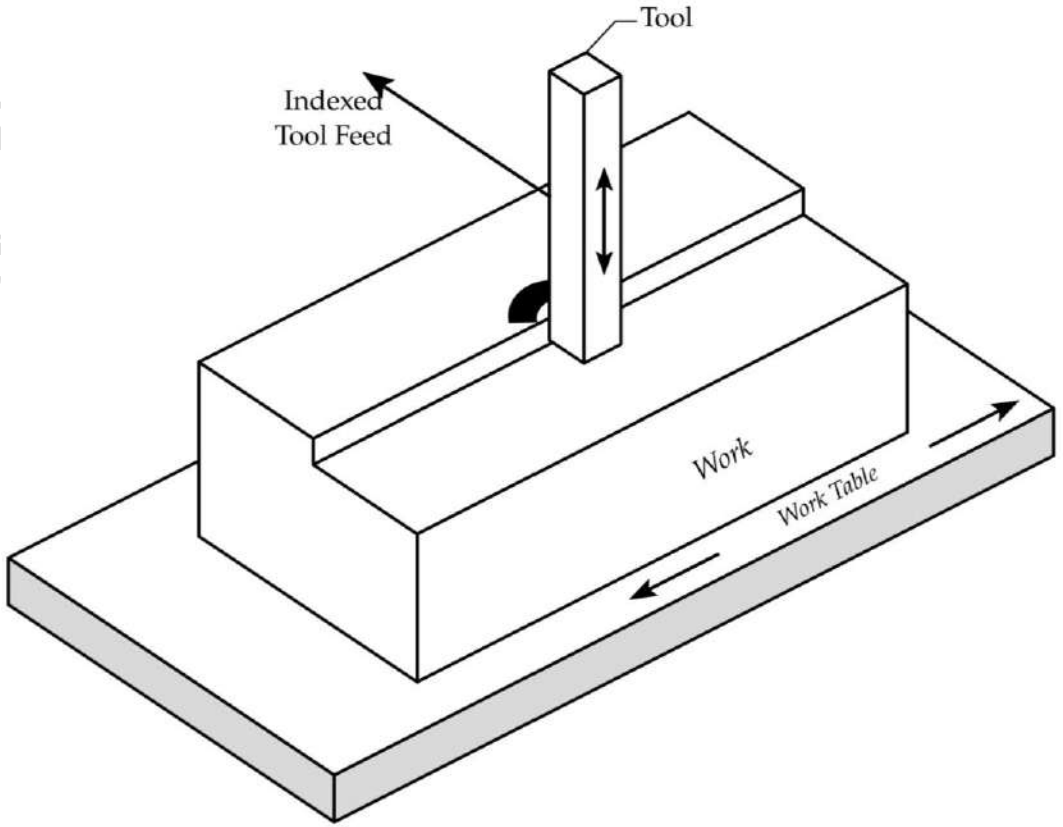
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Dr. S. R. Parimanik
Dr. A. K. Pattanaik

PLANING

- Planing is one of the basic operations performed in machining work and is primarily intended for machining large flat surfaces.
- These surfaces may be Horizontal, Vertical or Inclined. In this way, the function of a Planing Machine is quite similar to that of a Shaper except that the former is basically designed to undertake machining of such large and heavy Jobs which are almost impracticable to be machined on a Shaper or Milling machine, etc.

Working Principle of a Planer

- The work is rigidly held on the Work table or Platen of the machine. The tool is held vertically in the Tool-head mounted on the Cross-rail. The Work table, together with the Job, is made to reciprocate past the vertically held tool. The indexed feed, after each cut, is given to the tool during the idle stroke of the Table.



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Dr. A. K. Patt

Machine Size and Specifications

- Planers are made in different sizes and they are specified by the following main dimensions:
  1. **Horizontal distance:** Between the two vertical housings
  2. **Vertical distance:** Between the table top and the cross-rail, when the later is in its topmost position
  3. **Maximum length:** Of the table travel or length of stroke.
- In addition to these, in order to specify the planer fully, the following particulars are also required:
  1. Length of the bed
  2. Length of table
  3. Method of driving: common or individual
  4. Method of driving the table: geared or hydraulic etc.
  5. H.P. (or kW) of motor
  6. Number of additional tool heads required

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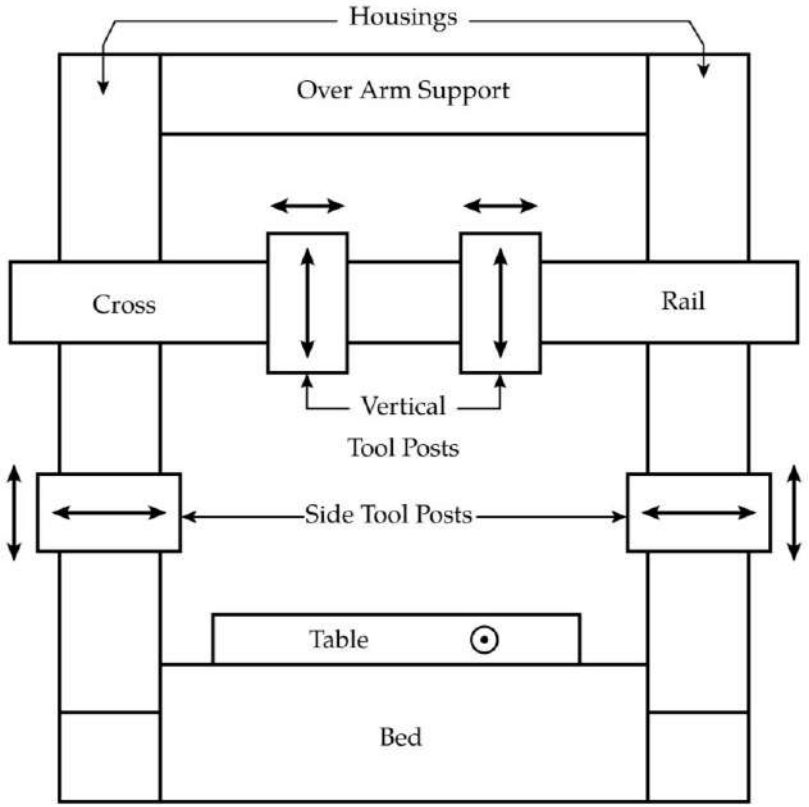
Main Parts of a Planer

1. Bed

- It is very large and heavy Cast iron Structure, which is provided with cross ribs for additional strength and stiffness, as the same supports the whole Structure of the Machine over it.
- At its top, it carries either V-ways, or Flat ways (only in case of large planers), to support and guide the table. All small and medium-size Planer Beds carry two V-ways, one on each side.
- All the ways are Straight, Parallel, accurately machined and scraped.

2. Table

- The Table or Platen (as it is frequently called) is also made of cast iron with an accurately machined top.
- It may be a single piece Casting or made in two pieces, bolted together in the same ways as the two-piece bed.
- It carries a Box type construction, provided with strengthening ribs under it in order to make it strong enough to support the heavy work over it.



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3. Housings or Columns

- They are also sometimes called Columns or Uprights.
- These vertical members are situated on both sides in case of a Double Housing Planer and on one side only in case of an Open side Planer.
- Inside them, they carry the different mechanisms for transmission of power to the upper parts of the machine, from the main drive viz., Cross-rail Elevating screws, Vertical feed shaft and Cross feed bar, etc.
- At their front, they are very accurately machined to form Vertical ways along which the cross rail slides up and down. Where Side Tool-heads are used, they also slide vertically along the same guideways.

4. Cross-rail

- It is a horizontal member of heavy structure which connects the two Vertical housings of the machine. It provides additional rigidity to the machine. By means of the Elevating screws it can be moved up and down along the ways provided on the housings. Clamps are provided to lock the Cross-rail in any desired position along the columns.
- Accurately finished ways are provided at the front of the Cross-rail for the two Vertical Toolheads.

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5. Toolheads

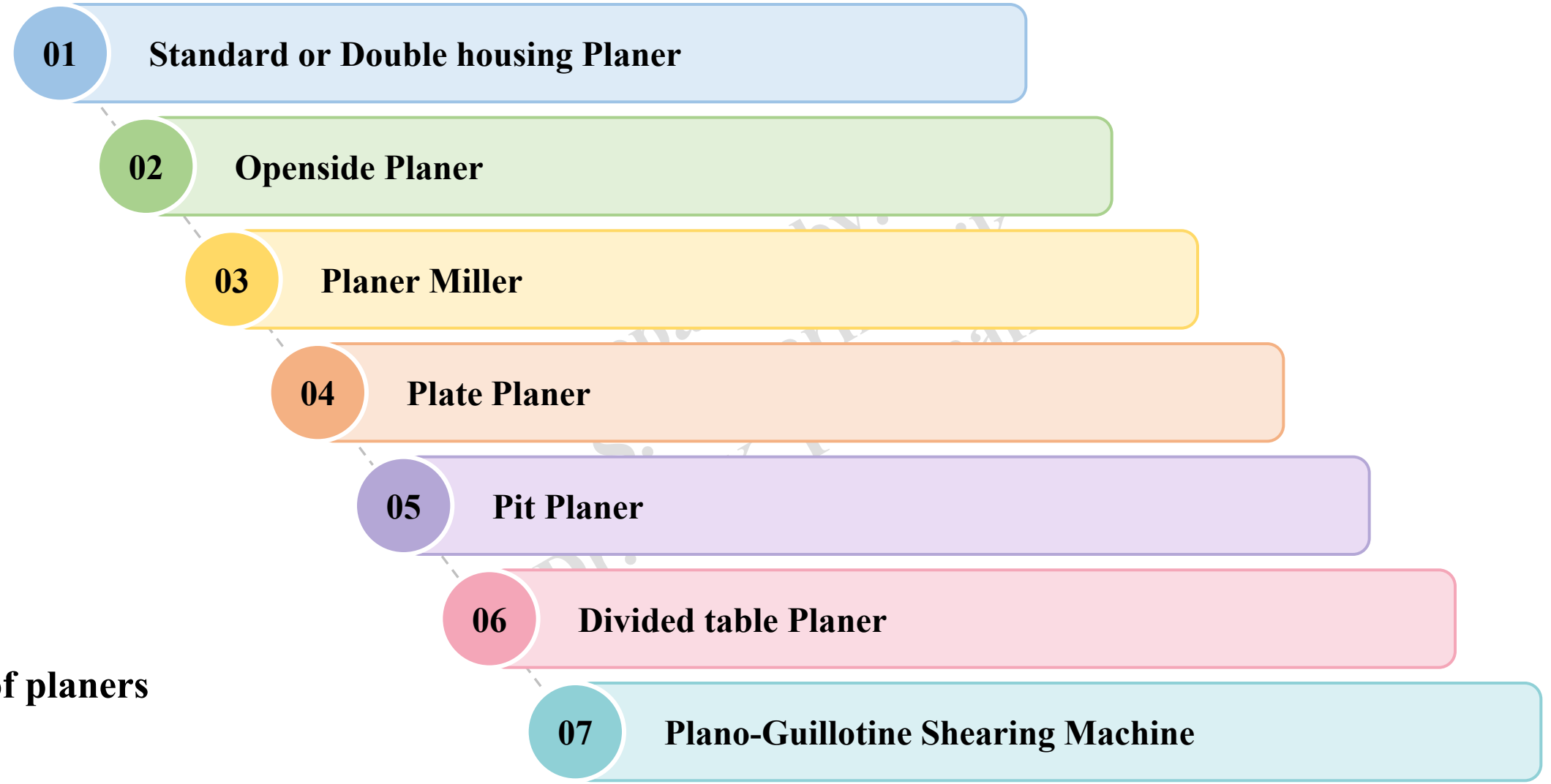
- The Planer Toolheads, both in construction as well as operation, resemble very much with the Shaper Toolheads.
- At the most four Toolheads can be fitted in a planer and any or all of them can be used at a time.
- Two Toolheads can be fitted in vertical position on the Cross-rail and the other two on the Vertical Columns.
- Each Column carries one Side Toolhead.

6. Controls

- Various Controls for starting, operating and stopping the various mechanisms, automatic cutting off speed and feed regulation and similar other functions are usually provided within a quick approach of the operator of the machine.
- A good number of these are usually provided on a Suspended Pendant so that the operator can take them to any convenient position according to his needs.

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Types of Planers



7

types of planers

Planer and Shaper: Similarities and Dissimilarities

	PLANER	VS	SHAPER
01	It is a heavier, more rigid and costlier machine.		It is a comparatively lighter and cheaper machine.
02	It requires more floor area.		It requires less floor area.
03	It is used for machining large flat surfaces: horizontal, vertical and inclined.		It is also used for the same purposes but for relatively smaller surfaces.
04	The work is usually clamped directly on the machine table by means of suitable fixtures or clamping devices.		The work may be clamped directly on the table or held in a vice or chuck.
05	Cutting takes place by reciprocating the work under the tool.		Cutting takes place by moving the cutting tool over the job.
06	Indexed feed is given to the tool during the idle stroke of the work table.		Indexed feed is given to the work during the idle stroke of the ram.
07	Heavier cuts and coarse feeds can be employed.		Very heavy cuts and coarse feeds cannot be employed.
08	Several tools (usually four as a maximum) can be mounted and employed simultaneously, giving a faster rate of production.		Usually only one tool is used on a shaper.
09	With its large stroke length and table size, several identical jobs can be held in series and machined in a single setting.		This is not possible on a shaper unless the jobs are small enough to be conveniently held on the table, say in a vice.
10	The tools used on a planer are larger, heavier and stronger than those used on a shaper.		The tools used on a shaper are smaller and lighter.

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GRINDING

- Grinding is a process of removing material by the abrasive action of a revolving wheel on the surface of a workpiece, in order to bring it to the required shape and size.
- The wheel used for performing the grinding operation is known as 'Grinding Wheel'. It consists of sharp crystals, called abrasives, held together by a binding material or bond. The wheel may be a single piece or solid type or may be composed of several segments of abrasive blocks joined together.

Common Forms of Abrasive Tools (four types in common use)

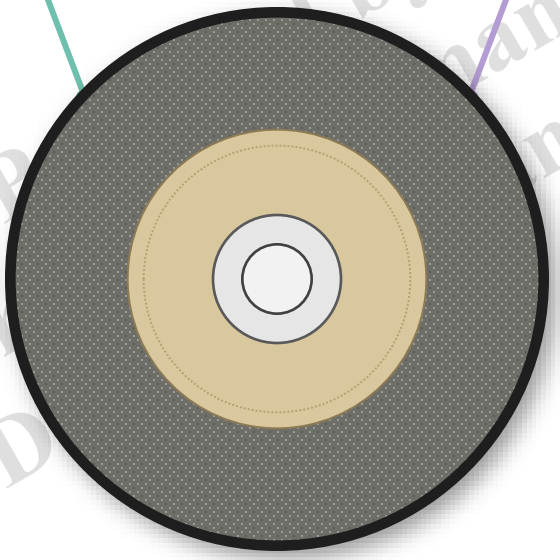
Prepared by: Prof. Primanik Kundu

1 Stones and sticks	2 Coated abrasives	3 Polishing grains	4 Grinding wheels
Form: abrasive grains bonded into stones and sticks of various shapes and sizes. **Use:** hand sharpening of tools, cleaning, polishing and hand finishing of dies, jigs, moulds, etc.	**Form:** a single layer of grains bonded with glue or resin to a flexible paper or cloth backing. **Shapes:** sheets, strips (by hand); belts, cones, sleeves, discs (on machines). **Use:** polishing surfaces, deburring castings.	**Form:** loose grains coated with adhesive on the rim of flexible cloth or leather wheels. **Use:** lapping. **Note:** worn grains are cleaned off and the wheel recoated.	**Form:** abrasive grains held together by a binding material called 'bond'. **Use:** the machining operation called grinding. **Note:** studied in detail in this chapter.

Grinding Wheel Materials

ABRASIVES
Material that does the cutting action

Natural	Artificial / manufactured
Sand stone	Silicon carbide (SiC)
Emery	Aluminium oxide (Al_2O_3)
Corundum	Artificial diamond
Quartz	
Diamond	



Grinding Wheel
= Abrasive + Bond

BONDS
Binder that holds the abrasive grains together

Bond types
Vitrified
Silicate
Oxychloride
Resinoid
Shellac
Rubber

This is for educational purpose only.

Method of Specifying a Grinding Wheel

- Methods of specifying a grinding wheel differ slightly between countries. For uniformity, the **Bureau of Indian Standards** devised a standard marking system (IS: 551-1954) to be followed by all manufacturers.
- Every wheel carries its elements in a fixed sequence. A manufacturer may add an optional **prefix** (own abrasive brand) and **suffix** (own wheel type notation).

Standard marking sequence

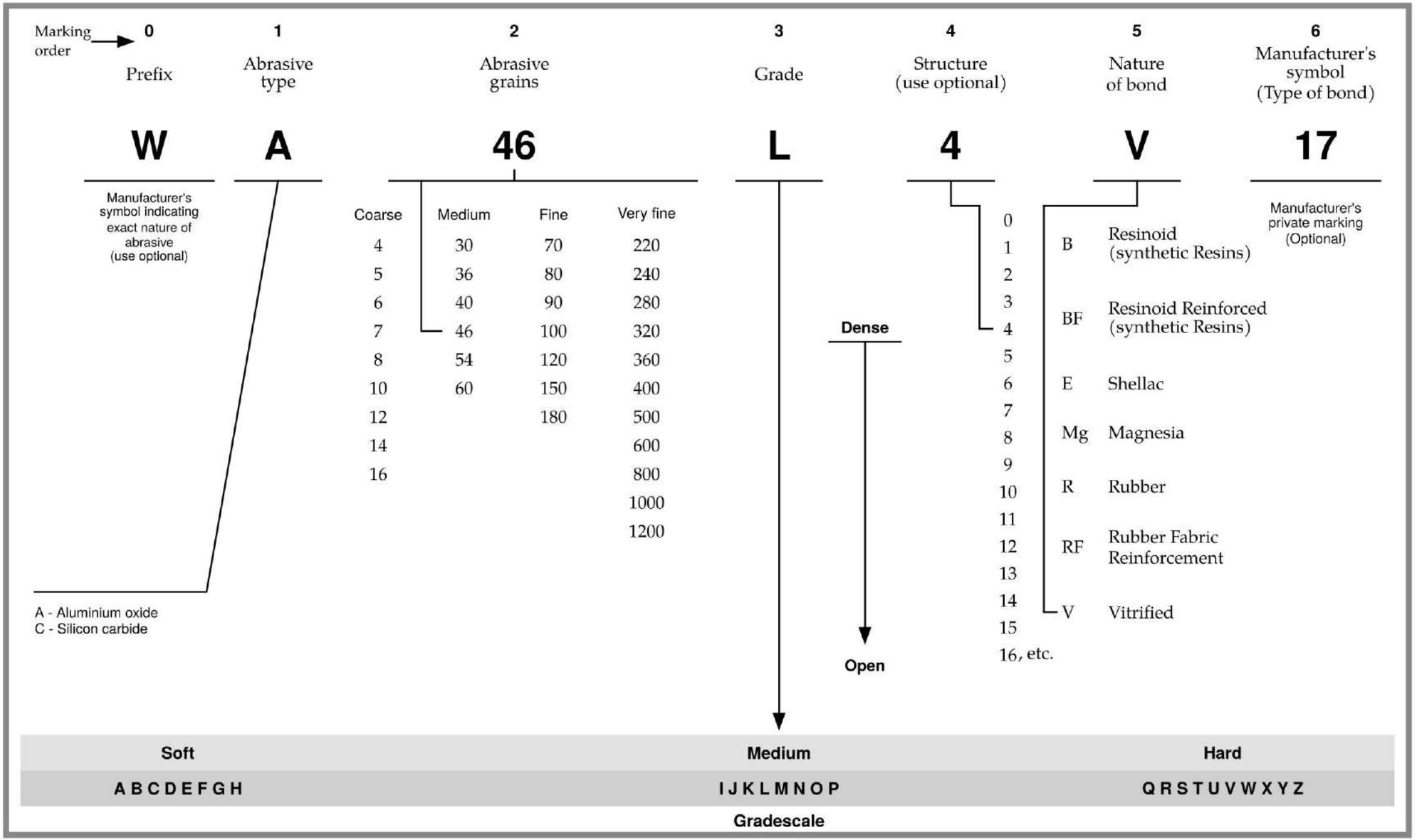


Example: 250 × 25 × 32 W A 46 L 4 V 17

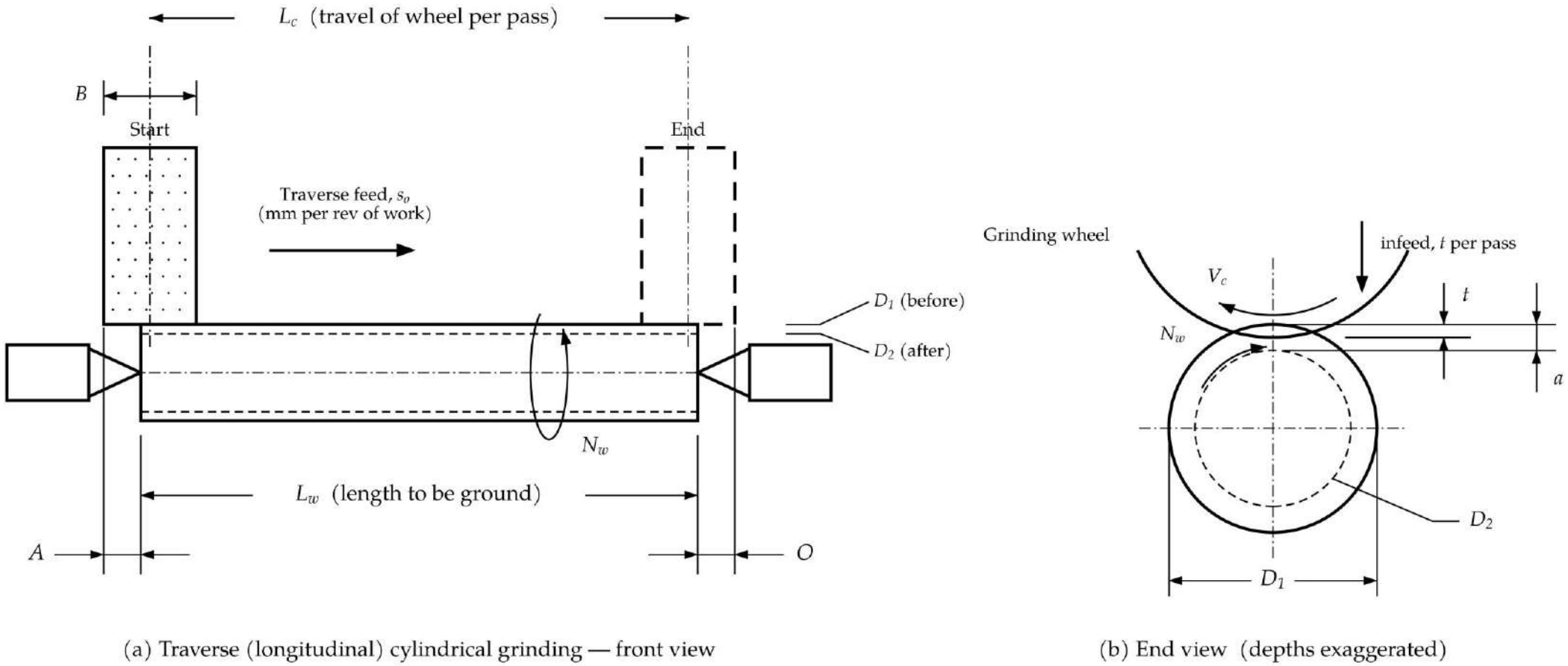
Wheel size			*Wheel specification*						
250	**25**	**32**	**W**	**A**	**46**	**L**	**4**	**V**	**17**
Wheel dia. 250 mm	**Thickness** 25 mm	**Bore dia.** 32 mm	**Prefix** 'white'	**Abrasive** Al_2O_3	**Grain size** medium	**Grade** medium	**Structure** dense	**Bond** vitrified	**Suffix** bond type

Code values for grain size, grade and structure are given in Tables 12.2, 12.3 and 12.4.

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Marking order
0
Prefix
1
Abrasive type
2
Abrasive grains
3
Grade
4
Structure (use optional)
5
Nature of bond
6
Manufacturer's symbol (Type of bond)
W
A
46
L
4
V
17
Manufacturer's symbol indicating exact nature of abrasive (use optional)
A - Aluminium oxide
C - Silicon carbide
Coarse
Medium
Fine
Very fine
4
5
6
7
8
10
12
14
16
30
36
40
46
54
60
70
80
90
100
120
150
180
220
240
280
320
360
400
500
600
800
1000
1200
Dense
Open
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16, etc.
B
Resinoid (synthetic Resins)
BF
Resinoid Reinforced (synthetic Resins)
E
Shellac
Mg
Magnesia
R
Rubber
RF
Rubber Fabric Reinforcement
V
Vitrified
Manufacturer's private marking (Optional)
Soft
Medium
Hard
A B C D E F G H
I J K L M N O P
Q R S T U V W X Y Z
Gradescale

Estimation of Machining Time in Grinding



(a) Traverse (longitudinal) cylindrical grinding — front view

(b) End view (depths exaggerated)

View (a): wheel moves from start (solid) to end (dashed) along the work, which turns at N_w. View (b): each pass cuts depth t until diameter D_1 is reduced to D_2.

Symbols Used in the Derivation

Symbol	Meaning
L_w	Length of the work surface to be ground (mm)
A, O	Approach and overrun: wheel face run past the start and end of the job (mm)
B	Width of the wheel face (mm)
L_c	Travel of the wheel (or table) in one pass (mm)
D_1, D_2	Work diameter before and after grinding (mm)
a	Radial grinding allowance = $(D_1 - D_2)/2$ (mm)
t	Depth of cut (infeed) per pass (mm)
s_o	Traverse feed per revolution of the work (mm/rev)
N_w	Speed of the work (rpm)
V_w	Surface speed of the work (m/min)
V_c	Peripheral speed of the wheel (m/s)
K	Spark-out (accuracy) factor
T_c	Machining time (min)

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Steps 1–2: Length of Pass and Traverse Feed

Step 1: Length of one pass, L_c (Fig. a)

- The wheel need not travel the full job length plus its width B. At each end only part of the face (A or O) runs past the job, so no step is left.
- A and O are usually B/3 to B/2. If A = O = B/2, then $L_c = L_w$.

Following the wheel centre line:

$$\mathbf{L_c = L_w + A + O - B}$$

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Step 2: Traverse feed, s_o

- The feed must be less than the wheel width, so that successive turns of the helical grinding path overlap.
- C = 0.6 to 0.9 for rough grinding; 0.4 to 0.6 for finish grinding.

$$\mathbf{s_o = C \cdot B \ \ mm/rev}$$

Steps 3–4: Work Speed and Time for One Pass

Step 3: Speed of the work, N_w

- The work surface speed V_w is chosen from tables, typically 15 to 30 m/min.
- Wheel speed $V_c = \pi D_g N_g/(1000 \times 60)$ m/s controls cutting action and finish, but does not enter the time: time depends only on the feed motion.

$$N_w = 1000\, V_w / (\pi\, D_1) \ \text{rpm}$$

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Step 4: Time for one pass

- The work makes N_w rev/min and the wheel moves s_o mm per revolution, so the traverse speed is $N_w \cdot s_o$ mm/min.
- One pass covers the length L_c.

Time per pass

$$= L_c / (N_w \cdot s_o) \ \text{min}$$

Steps 5–6: Number of Passes and Spark-out

Step 5: Number of passes, n_p (Fig. b)

- The radial grinding allowance is $a = (D_1 - D_2)/2$.
- Each pass removes a depth t, so the number of passes is a / t.

$$n_p = a / t$$
$$= (D_1 - D_2) / (2t)$$

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Step 6: Spark-out allowance, K

- At the end, extra passes are made with no infeed, so the wheel can "spark out" and the size and finish settle.
- These extra passes are allowed for by multiplying by the factor K.

Rough grinding: K = 1.0 to 1.2 (≈ 1.1)

Finish grinding: K = 1.3 to 1.7 (≈ 1.4)

Machining Time: Traverse and Plunge Grinding

Step 7: Machining time in traverse grinding

- Time per pass × number of passes × spark-out factor (Steps 4, 5 and 6).
- Assumes infeed at every reversal. If infeed is given at one end only, double the time.

$$T_c = L_c \cdot n_p \cdot K / (N_w \cdot s_o)$$

$$T_c = (L_w + A + O - B)(D_1 - D_2)\, K / (2\, t\, N_w\, s_o) \ \text{min}$$

Plunge grinding

- Used when the wheel face is at least as wide as the length to be ground, so there is no traverse.
- The wheel is fed straight in at a radial feed s_r mm per revolution of the work.

$$T_c = a \cdot K / (s_r \cdot N_w)$$

$$T_c = (D_1 - D_2)\, K / (2\, s_r\, N_w) \ \text{min}$$

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Worked Example: Rough Grinding of a Shaft

Given

A shaft is rough-ground from Ø50.4 to Ø50.0 mm.

$L_w = 300$ mm

$D_1 = 50.4$ mm, $D_2 = 50.0$ mm

$B = 40$ mm

$A = O = B/2 = 20$ mm

$C = 0.75$

$V_w = 20$ m/min

$t = 0.02$ mm per pass

$K = 1.1$

Find: T_c

Solution

1. **Length of pass:** $L_c = 300 + 20 + 20 - 40 = 300$ mm
2. **Traverse feed:** $s_o = 0.75 \times 40 = 30$ mm/rev
3. **Work speed:** $N_w = 1000 \times 20 / (\pi \times 50.4) = 126.3 \approx 126$ rpm
4. **Time per pass:** $300 / (126 \times 30) = 0.0794$ min
5. **Number of passes:** $n_p = (50.4 - 50.0) / (2 \times 0.02) = 10$
6. **Machining time:** $T_c = 0.0794 \times 10 \times 1.1$

$T_c \approx 0.87$ min

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