# Manufacturing Technology-II

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# UNIT 1: THEORY OF METAL CUTTING

- Mechanism of metal cutting
- Types
- cutting force
- chip formation
- Merchant's circle diagram.
- Calculations
- tool geometry
- machinability
- tool wear
- tool life
- cutting tool materials
- cutting fluids
- types

## MECHANISM OF METAL CUTTING

- **The mechanism of metal cutting involves using a wedge-shaped tool to remove material from a workpiece in the form of a chip. The process involves two motions: primary motion, such as the rotation of a workpiece in a lathe, and secondary motion, such as the feed of a lathe tool.**
- **The two basic methods of metal cutting using a single point tool are orthogonal (2D) and oblique (3D). Orthogonal cutting occurs when the cutting face of the tool is 90 degrees to the line of action of the tool. Oblique cutting occurs when the cutting edge is inclined at an angle less than 90 degrees to the direction of tool travel.**

## TYPES

- **Metal cutting processes remove material from a workpiece. The choice of process depends on the job's requirements, such as the material type, part size and shape, and desired surface finish.**

  **Here are some types of metal cutting:**

  **Orthogonal cutting**

  **The cutting tool moves directly into the workpiece at a right angle. The cutting edge of the tool is perpendicular to the direction of tool travel.**

  **Oblique cutting**

  **The cutting tool engages with the workpiece material at an angle other than 90 degrees.**

  **Waterjet cutting**

  **Uses the force of highly pressurized water for metal particle erosion. It is a cold cutting process that doesn't require physical contact of the waterjet cutting head with the workpiece.**

  **Plasma cutting**

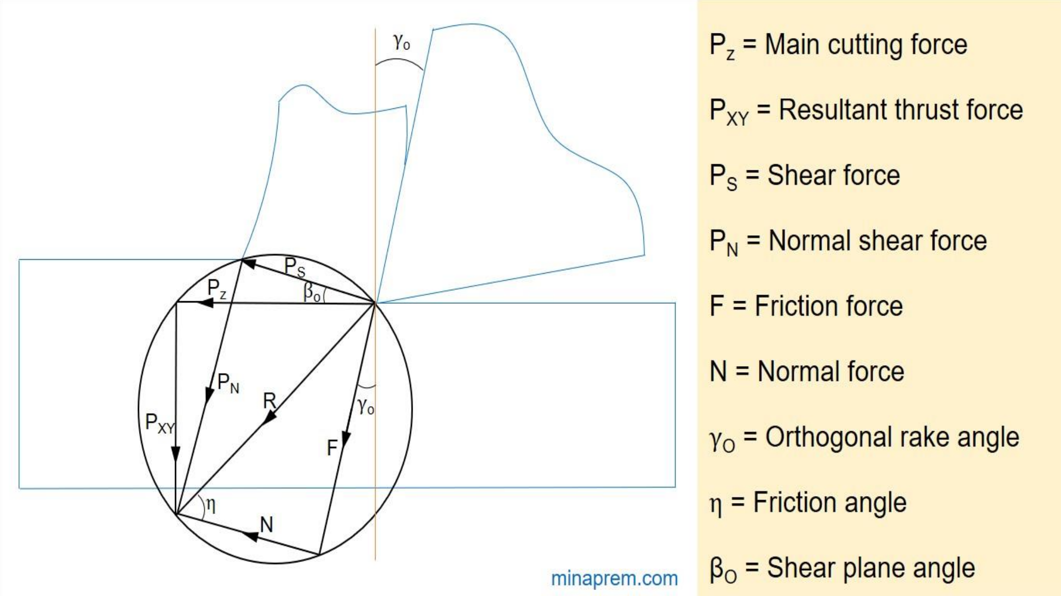
  **Uses an electric arc that passes through the gas which spouts out of a constricted opening. The gases used in plasma cutting can be air, nitrogen, oxygen, and argon.**

- **Other types of metal cutting include: Laser cutting, Flame cutting, Metal turning.**

- **Different types of metal cutting process video link**
  **https://youtu.be/kuPGLUVVkZU?si=p9E1eBn5jtDWnYJo**

## CUTTING FORCE

- **Cutting force is the resistance of a material to a cutting tool's intrusion. It is a key parameter in machining operations, as the power used by the machine to perform the process is always a factor to be optimized.**




Typical Merchant Circle Diagram (MCD) for positive rake angle

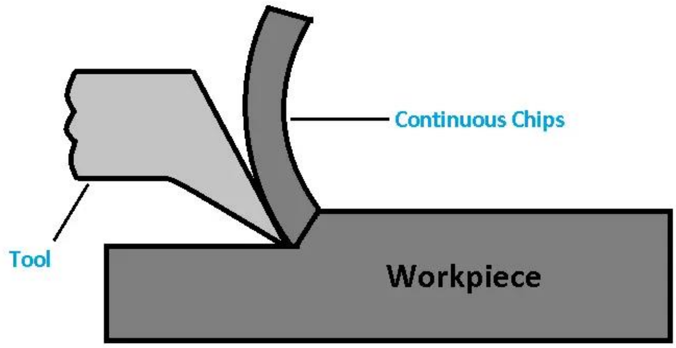
- **Cutting force video link**
  **https://youtu.be/x_4Feo_ETWk?si=NdasjnLD8Gq-l53n**

## CHIP FORMATION

- **Chip formation is a process that occurs when material is cut mechanically using tools like saws, milling cutters, and lathes. It happens during machining, when the material is sheared and plastically deformed in the shear plane. The length or shortness of the chip depends on the material of the workpiece.**
- **Types of chip formation –**
  1. **Continuous chips**
  2. **Discontinuous chips**
  3. **Continuous chips with built up edges (BUE)**

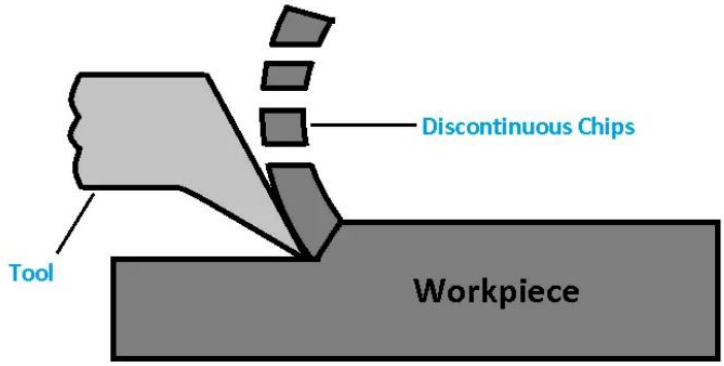
### Continuous chip formation

- **If the metal chips are formed during machining is without segments i.e. without breakage, then it is called as continuous types of chips.**
- **Continuous chips are formed when the ductile material is machined with high cutting speed and minimum friction between the chip and tool face.**



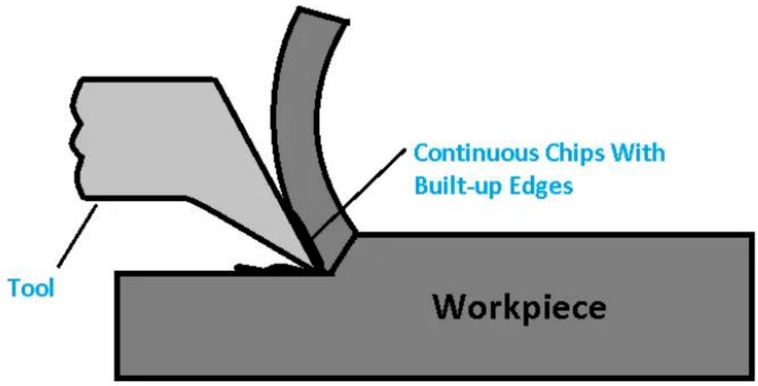

### Discontinuous chips formation

- If the chip is formed during machining is not continuous i.e. formed with breakage is called discontinuous chips. Discontinuous types of chips are formed when hard and brittle metals like brass, bronze and cast iron is machined.




### Continuous chips with built up edges (BUE) formation

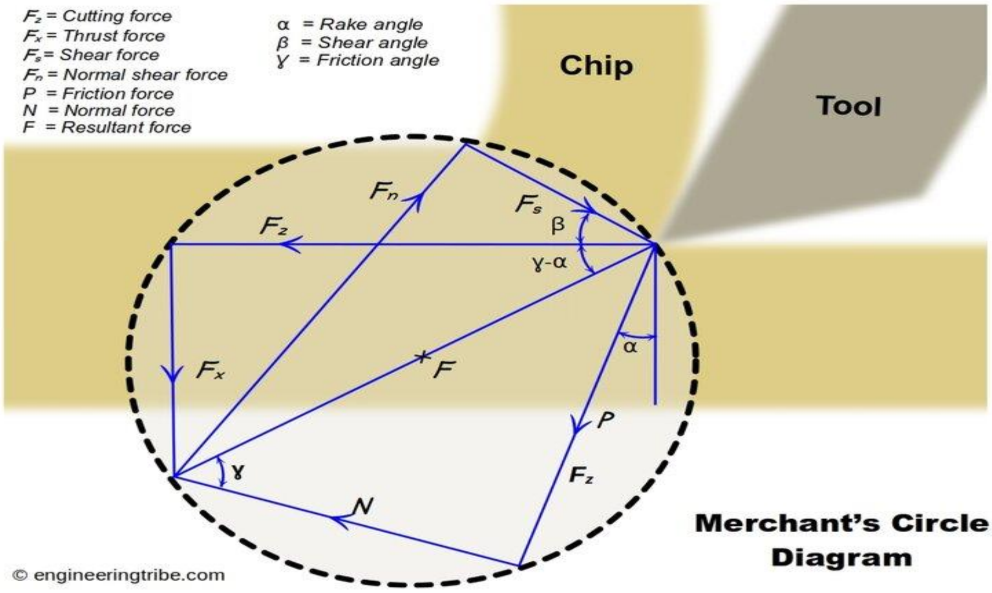
- Continuous chips with built up edge is formed by machining ductile material with high friction at the chip-tool interface.
- It is similar to the continuous types of chips but it is of less smoothness due to the built up edge.



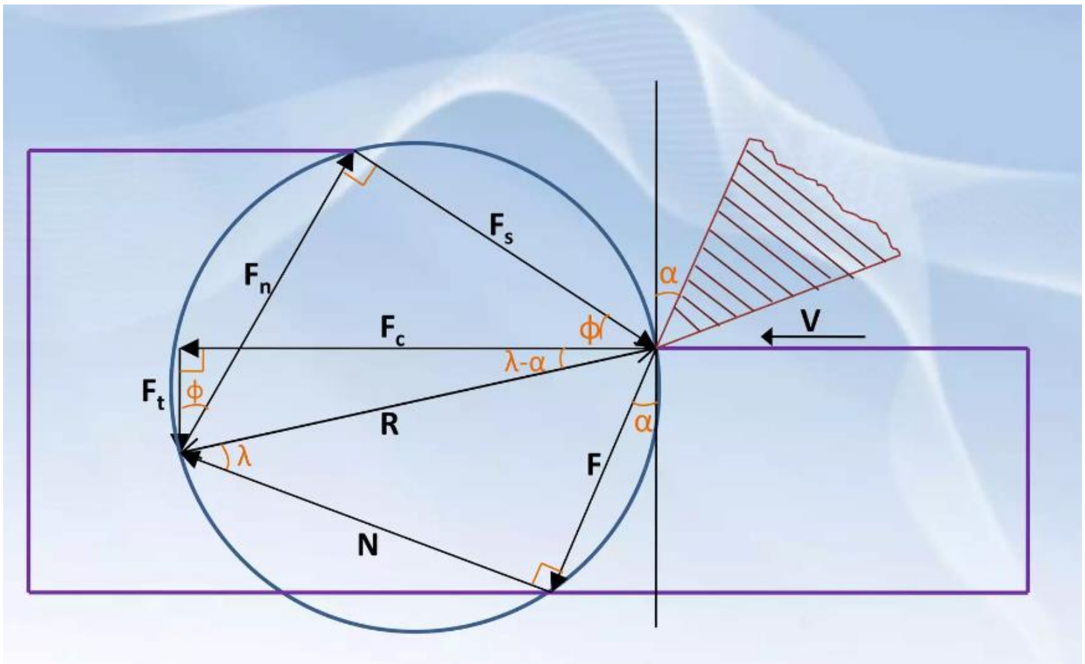

- Type of chip formation video link
  https://youtu.be/huKlcD6N6pc?si=ESEM51fcOOG6dIos

## MERCHANT'S CIRCLE DIAGRAM

- **A merchant circle diagram is made as a graphical representation of the number of forces acting on a workpiece when it is subjected to orthogonal cutting.**




## CALCULATIONS



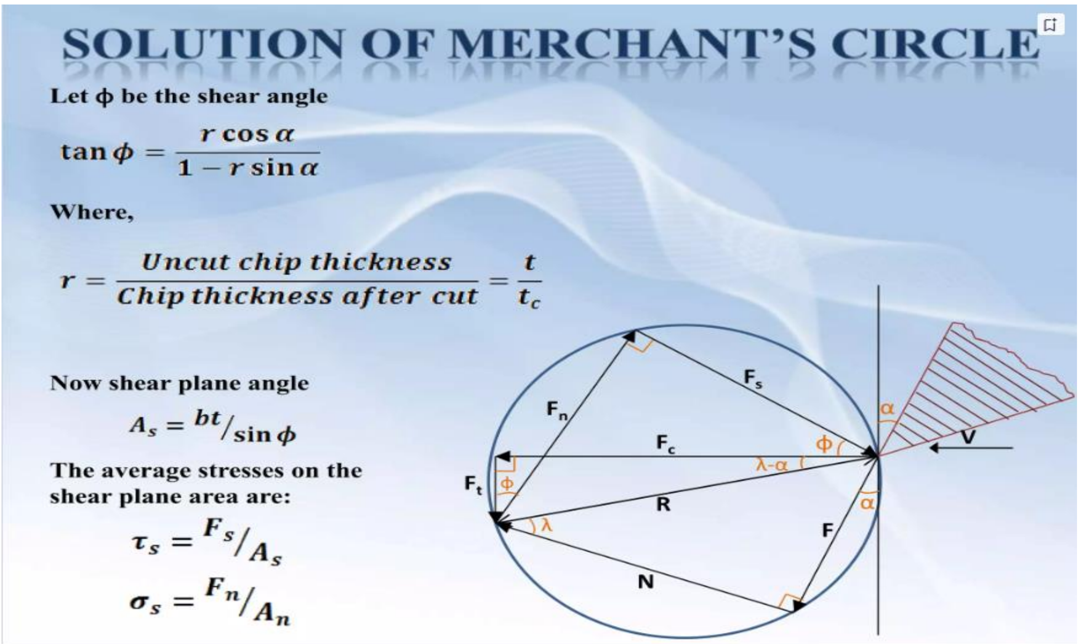

### ASSUMPTIONS FOR MERCHANT'S CIRCLE DIAGRAM

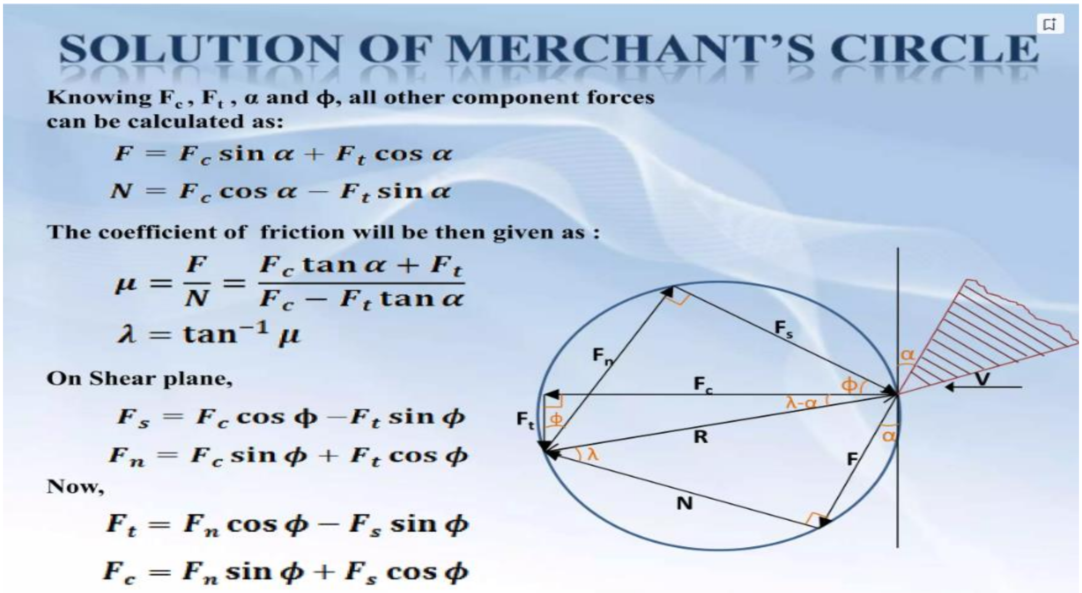
- **Tool edge is sharp.**
- **The work material undergoes deformation across a thin shear plane.**
- **There is uniform distribution of normal and shear stress on shear plane.**
- **The work material is rigid and perfectly plastic.**
- **The shear angle o adjusts itself to minimum work.**
- **The friction angle remains constant and is independent.**

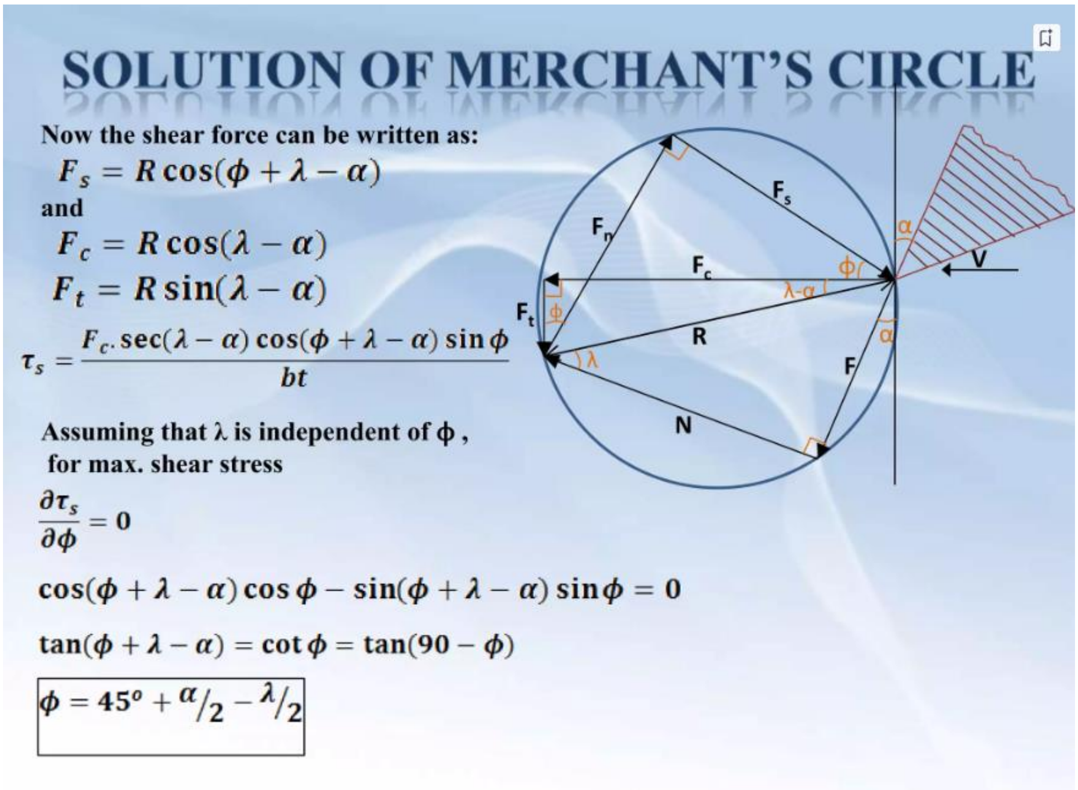
❖ The chip width remains constant.
❖ The chip does not flow to side, or there is no side spread.

## FORCES INCLUDED IN METAL CUTTING

❖ F(s), Resistance to shear of the metal in forming the chip. It acts along the shear plane.
❖ F(n), Backing up' force on the chip provided by the workpiece. Acts normal to the shear plane.
❖ N, It at the tool chip interface normal to the cutting face of the tool and is provided by the tool.
❖ F, It is the frictional resistance of the tool acting on the chip. It acts downward against the motion of the chip as it glides upwards along the tool face.






**ADVANTAGES OF MERCHANT'S CIRCLE**

- **Proper use of MCD enables the followings:-**
- **Easy, quick and reasonably accurate determination of several other forces from a few forces involved in machining.**
- **Friction at chip-tool interface and dynamic yield shear strength can be easily determined.**
- **Equations relating the different forces are easily developed.**

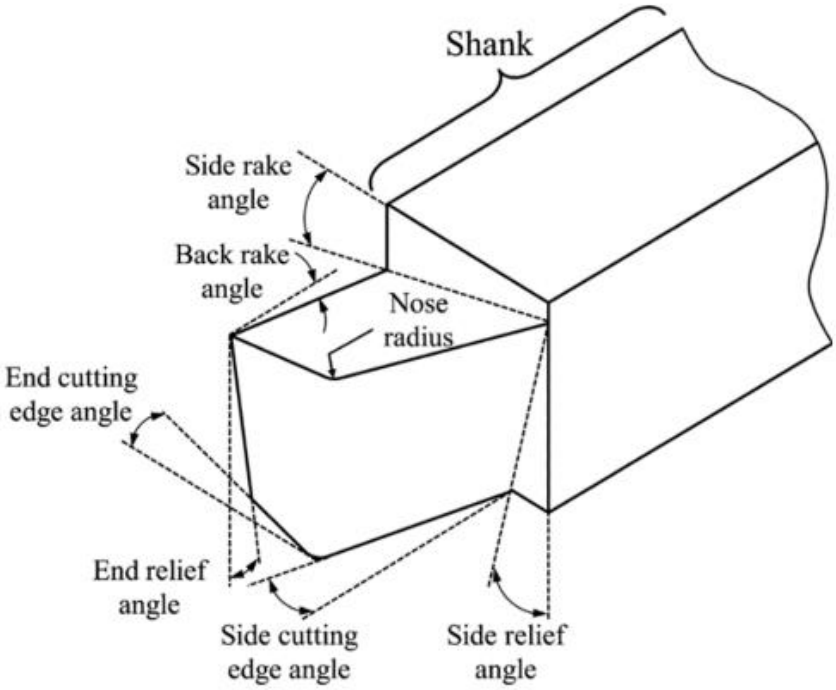
**LIMITATIONS OF MERCHANT'S CIRCLE**

- **Some limitations of use of MCD are :-**
- **Merchant's Circle Diagram (MCD) is valid only for orthogonal cutting.**
- **By the ratio, F/N, the MCD gives apparent (not actual) coefficient of friction.**
- **It is based on single shear plane theory.**
- **Merchant's Circle Diagram video link**

  https://youtu.be/YCLZMx_nhsM

## TOOL GEOMETRY

- Tool geometry has been around since ancient times as it helps to understand how machines work by describing their functions, sizes, shapes and features.




**Tool geometry video link-**

https://youtu.be/BHEYrGrvp6U?si=gNZdQ9aKJmevzKED

## GEOMETRY OF CUTTING TOOL – ASA and ORS –

## SINGLE POINT TURNING TOOLS

- Cutting tools may be classified according to the number of major cutting edges (points) involved as follows:
- Single point: e.g., turning tools, shaping, planning and slotting tools and boring tools
- Double (two) point: e.g., drills
- Multipoint (more than two): e.g., milling cutters, broaching tools, hobs, gear shaping cutters etc.

**Concept of rake and clearance angles of cutting tools.**

- The word tool geometry is basically referred to some specific angles or slope of the salient faces and edges of the tools at their cutting point. Rake angle and clearance angle are the most significant for all the cutting tools. The concept of rake angle and clearance angle will be clear from some simple operations shown in Fig. below :

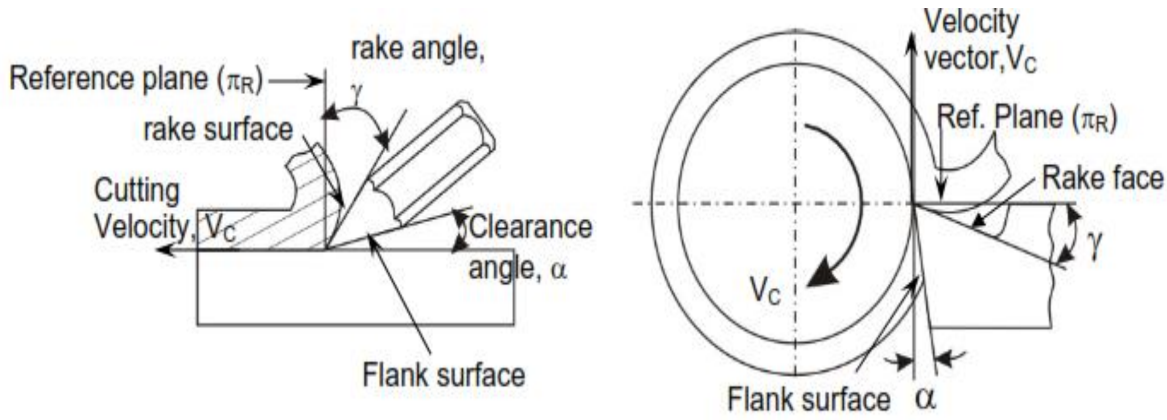
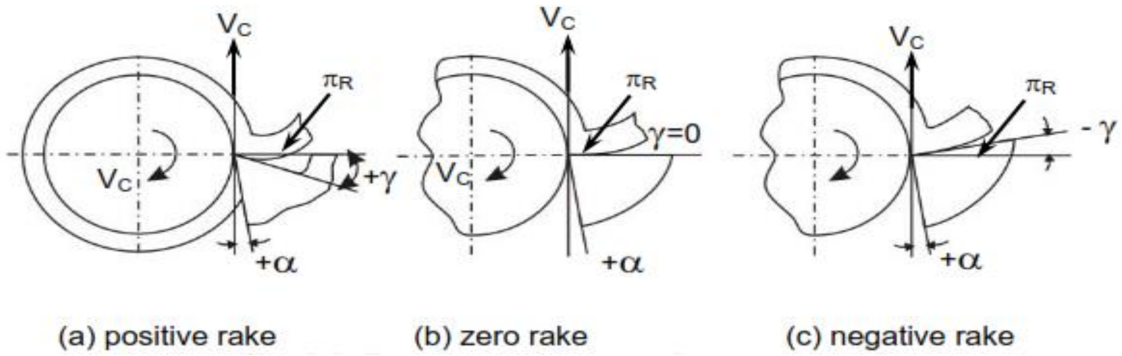



*Fig. Rake and clearance angles of cutting tools.*

***Definition –***

- **Rake angle** ($\gamma$): Angle of inclination of rake surface from reference plane
- **clearance angle** (a): Angle of inclination of clearance or flank surface from the finished surface
- Rake angle is provided for ease of chip flow and overall machining. Rake angle may be positive, or negative or even zero as shown in Fig. below :




Relative advantages of such **rake angles** are:

- Positive rake – helps reduce cutting force and thus cutting power requirement.
- Negative rake – to increase edge-strength and life of the tool
- Zero rake – to simplify design and manufacture of the form tools.

**Clearance angle** is essentially provided to avoid rubbing of the tool (flank) with the machined surface which causes loss of energy and damages of both the tool and the job surface. Hence, clearance angle is a must and must be positive ($3^0$ ~ $15^0$ depending upon tool-work materials and type of the machining operations like turning, drilling, boring etc.)

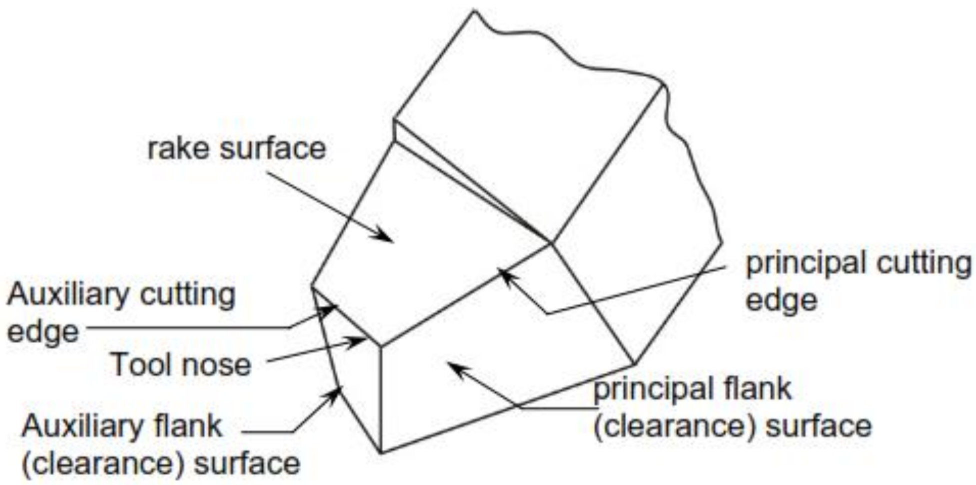
**Systems of description of tool geometry**

- Tool-in-Hand System – where only the salient features of the cutting tool point are identified or visualized as shown in Fig. below. There is no quantitative information, i.e., value of the angles.
- Machine Reference System – **ASA system**
- Tool Reference Systems
  * Orthogonal Rake System – **ORS system**
  * Normal Rake System – NRS system
- Work Reference System – WRS system

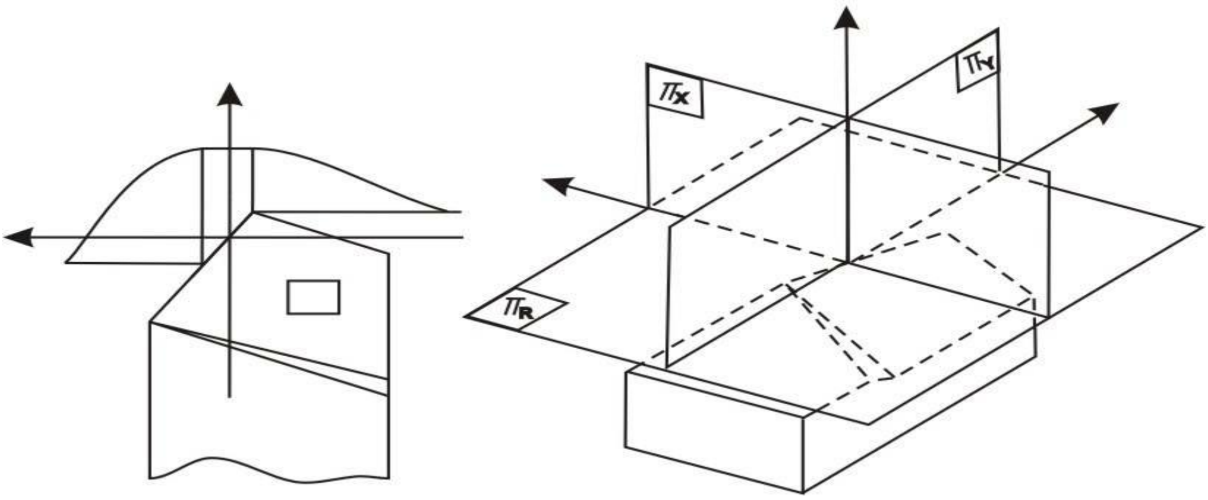
**Demonstration (expression) of tool geometry in :**

**Machine Reference System -** This system is also called ASA system; ASA stands for American Standards Association. Geometry of a cutting tool refers mainly to its several angles or slope of its salient working surfaces and cutting edges.

- Those angles are expressed w.r.t. some planes of reference.
- In Machine Reference System (ASA), the three planes of reference and the coordinates are chosen based on the configuration and axes of the machine tool concerned.
- The planes and axes used for expressing tool geometry in ASA system for turning operation are shown in Fig. below -




*Basic features of single point tool (turning) in Tool-in-hand system*




*Planes and axes of reference in ASA system*

The planes of reference and the coordinates used in ASA system for tool geometry are :

$$\pi_R - \pi_X - \pi_Y \text{ and } X_m - Y_m - Z_m$$

Where $\pi_R$= Reference plane; plane perpendicular to the velocity vector (shown in Fig. above)

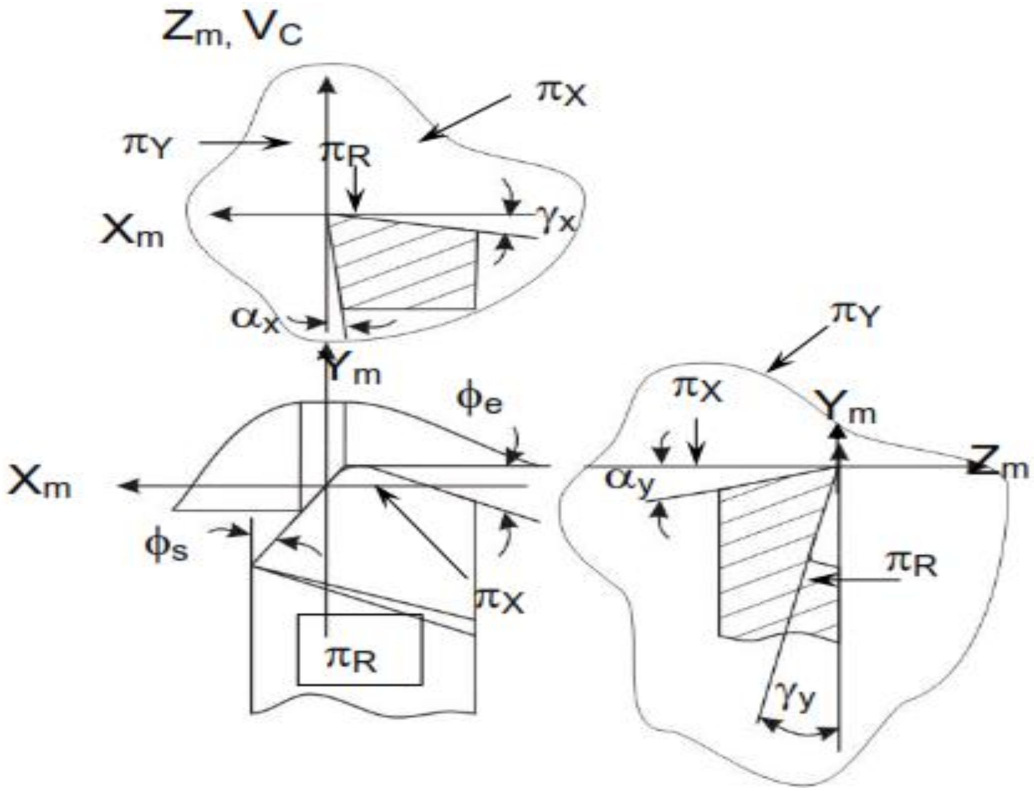
$\pi_X$= Machine longitudinal plane; plane perpendicular to $p_R$ and taken in the direction of

assumed longitudinal feed

$\pi_Y$= Machine Transverse plane; plane perpendicular to both $\pi_R$ and $\pi_X$

[This plane is taken in the direction of assumed cross feed]

The axes Xm, Ym and $Z_m$ are in the direction of longitudinal feed, cross feed and cutting velocity (vector) respectively. The main geometrical features and angles of single point tools in ASA systems and their definitions will be clear from Fig. below




Tool angles in ASA system

Definition of:

 Rake angles: [Fig. above] in ASA system

$\gamma_X$ = side (axial rake: angle of inclination of the rake surface from the reference plane ($\pi_R$)

and measured on Machine Ref. Plane,( $\pi_X$)

$\gamma_Y$ = back rake: angle of inclination of the rake surface from the reference plane and measured on Machine Transverse plane ($\pi_Y$)

 Clearance angles: [Fig. above]

$_X$ = side clearance: angle of inclination of the principal flank from the machined surface (or $V_C$ ) and measured on $\pi_X$ plane

$_Y$ = back clearance: same as $_X$, but measured on $_Y$ plane.

 Cutting angles: [Fig. above]

$_S$ = approach angle: angle between the principal cutting edge (its projection on $_R$) and $\pi_Y$ and measured on $_R$

$_e$ = end cutting edge angle: angle between the end cutting edge (its projection on $_R$) from $\pi_X$ and measured on $_R$

 Nose radius, r (in **inch**), r = nose radius : curvature of the tool tip. It provides strengthening of the tool nose and better surface finish

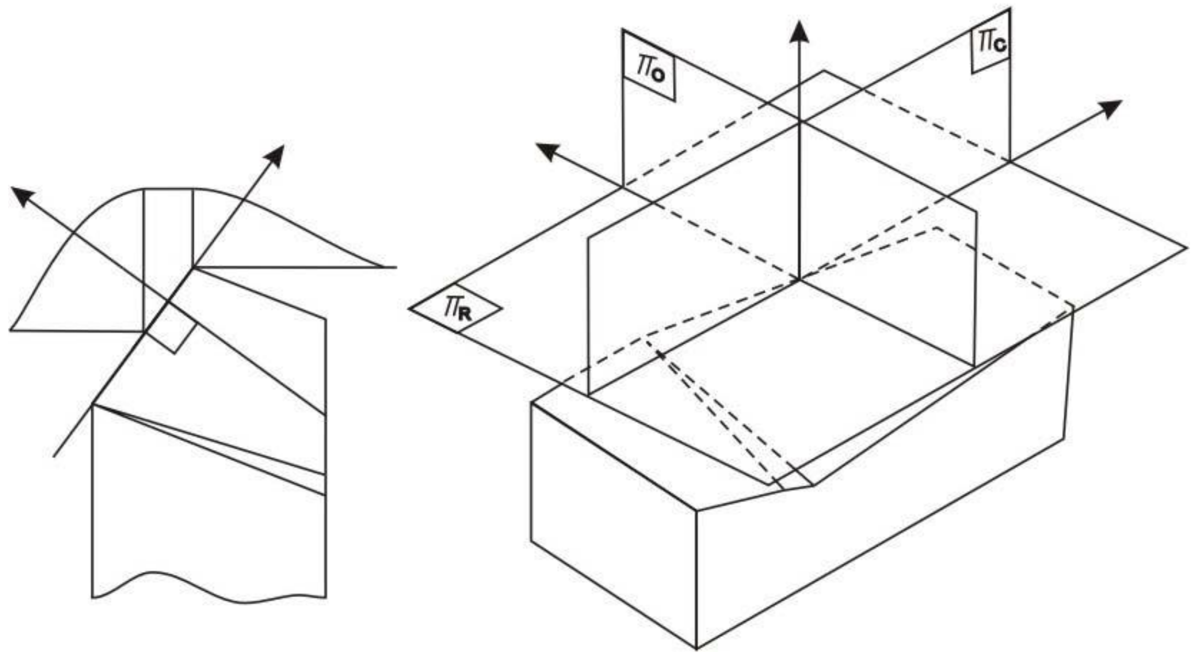
## Tool Reference Systems

### ▯ Orthogonal Rake System – ORS

This system is also known as ISO – old. The planes of reference and the co-ordinate axes used for expressing the tool angles in ORS are:

$$\pi_R - \pi_C - \pi_O \text{ and } X_o - Y_o - Z_o$$

which are taken in respect of the tool configuration as indicated in Fig. below




*Planes and axes of reference in ORS*

where,

$\pi_R$ = Reference plane perpendicular to the cutting velocity vector, $\overline{V_C}$

$\pi_C$ = cutting plane; plane perpendicular to $\pi_R$ and taken along the principal cutting edge

$\pi_O$ = Orthogonal plane; plane perpendicular to both $\pi_R$ and $\pi_C$

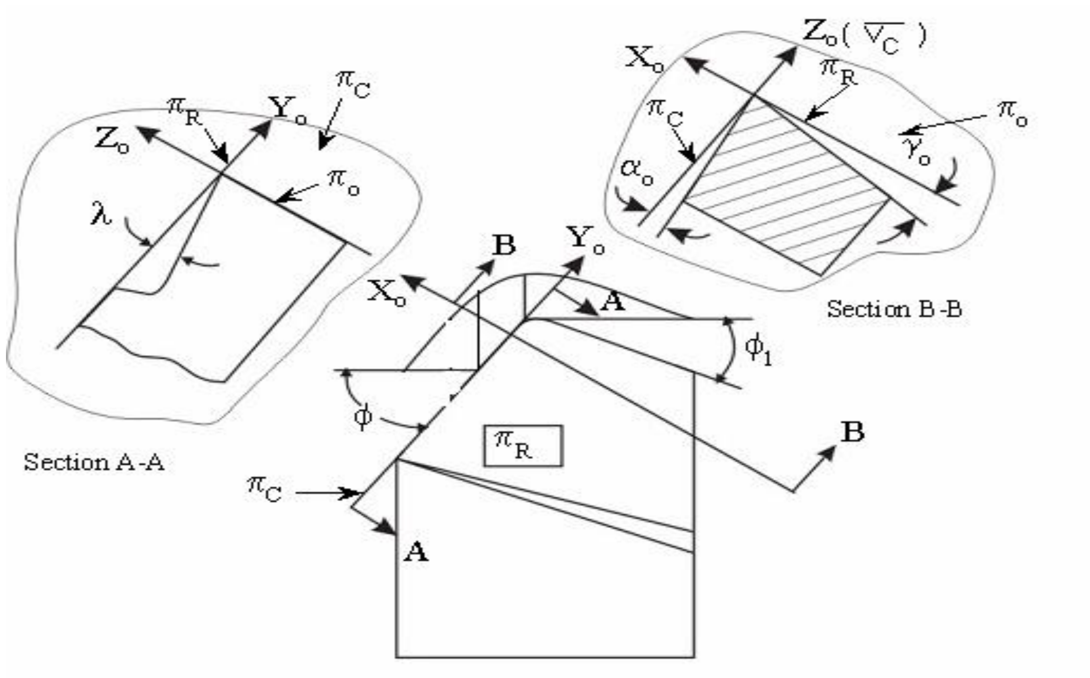
and the axes;

Xo = along the line of intersection of $\pi_R$ and $\pi_O$

Yo = along the line of intersection of $\pi_R$ and $\pi_C$

Zo = along the velocity vector, i.e., normal to both XO and $Y_O$ axes.

The main geometrical angles used to express tool geometry in Orthogonal Rake System (ORS) and their definitions will be clear from Fig. below/next pg.




*Tool angles in ORS system*

Tool signature provides various static geometrical details of that particular cutting tool, especially various angles and nose radius. Commonly, it provides values of rake angles, clearance angles, cutting edge angles, nose radius, etc.

## Systems for specifying cutting tool signature

Single point cutting tools are such cutters that contain only one main cutting edge that can participate in cutting action in a single pass. Examples include turning, boring, shaping, planing, and slotting tools. There exist three conventional systems for designation of such cutting tools, as enlisted below. A particular tool can be specified by all three systems and correspondingly tool signatures will also be different. Different tool signature does not indicate the tool angles are different; instead, it indicates inclination of a surface in different directions.

- American Standards Association (ASA) system
- Orthogonal Rake System (ORS)
- Normal Rake System (NRS)

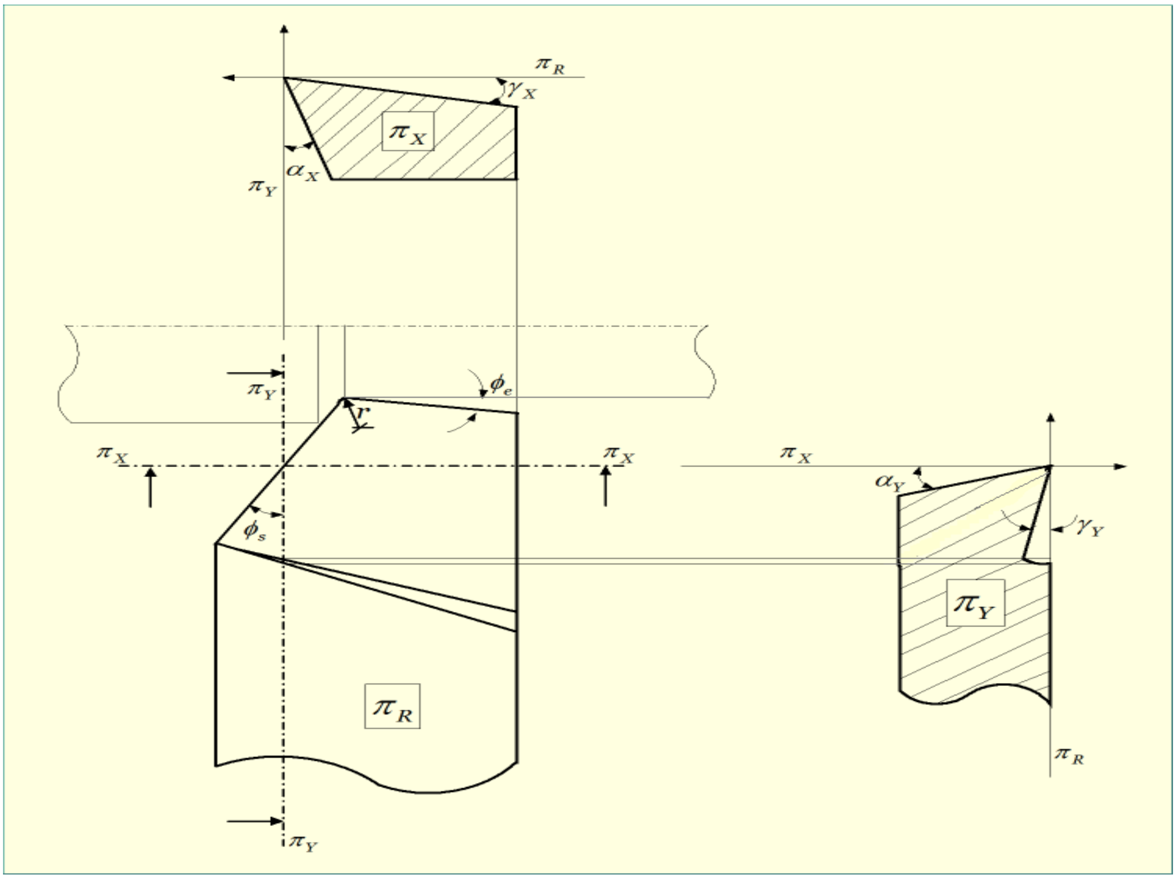
### Tool signature in ASA system

American Standards Association (ASA) system utilizes three mutually perpendicular planes for reference purpose namely Machine longitudinal plane, Machine transverse plane and Reference plane. Tool signature in ASA system consists of two rake angles, two clearance angles, two cutting edge angles and the nose radius of a single point cutting tool. The sequence of writing tool signature in ASA system along with the name of various angles is depicted below. It is to be noted that different persons may use different symbol but the sequence must be maintained. A typical example is also provided below.

### Planes used as reference in ASA system of tool designation

American Standards Association (ASA) system utilizes three mutually perpendicular planes as reference for measuring various angles of a single point turning tool (SPTT). These three planes and their basic characteristics are enlisted below.

- **Reference Plane ($\pi_R$)**—It is a plane perpendicular to the cutting velocity vector ($V_c$).
- **Machine Longitudinal Plane ($\pi_X$)**—It is a plane perpendicular to reference plane ($\pi_R$) and along the direction of longitudinal feed for external straight turning operation.
- **Machine Transverse Plane ($\pi_Y$)**—It is a plane perpendicular to reference plane ($\pi_R$) and along the direction of transverse feed for external straight turning operation. So all three planes are mutually perpendicular.




Representation of tool angles in ASA system of tool designation.

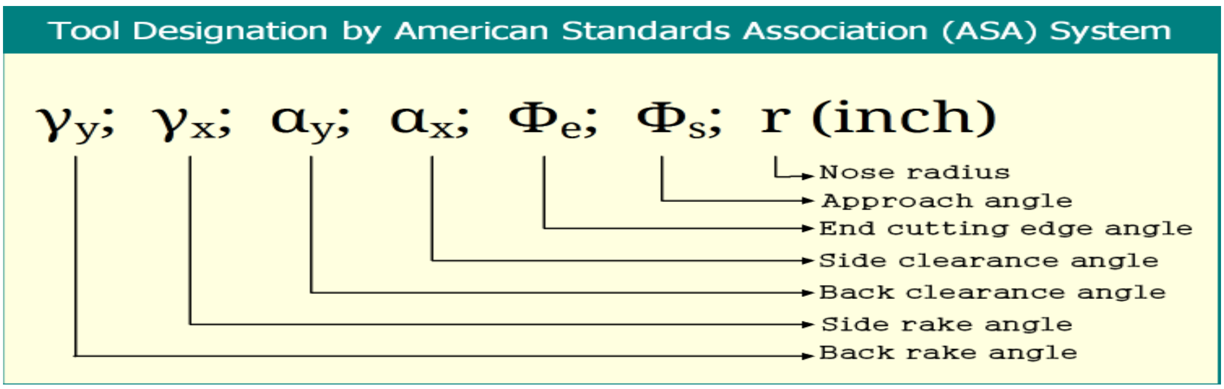
## Various features displayed in ASA system of tool designation

ASA system of tool designation specifies two different rake angles, two different clearance angles, two different cutting edge angles, and the nose radius value in inch. Various features of a single point turning tool (SPTT) that ASA system displays are provided below.

- **Side Rake Angle ($\gamma_X$)**—It is the angle of orientation of tool's rake surface from the reference plane ($\pi_R$) and measured on machine longitudinal plane ($\pi_X$).
- **Back Rake Angle ($\gamma_Y$)**—It is the angle of orientation of tool's rake surface from the reference plane ($\pi_R$) and measured on machine transverse plane ($\pi_Y$).
- **Side Clearance Angle ($\alpha_X$)**—It is the angle of orientation of tool's principal flank surface from the cutting velocity vector ($V_c$) and measured on machine longitudinal plane ($\pi_X$).
- **Back Clearance Angle ($\alpha_Y$)**—It is the angle of orientation of tool's principal flank surface from the cutting velocity vector ($V_c$) and measured on machine transverse plane ($\pi_Y$).
- **Approach Angle ($\Phi_s$)**—It is the angle between principal cutting edge and the machine transverse plane ($\pi_Y$), measured on reference plane ($\pi_R$).
- **End Cutting Edge Angle ($\Phi_e$)**—It is the angle between auxiliary cutting edge and the machine longitudinal plane ($\pi_X$), measured on reference plane ($\pi_R$).
- **Nose Radius (r)—**This is nothing but the curvature at the tool tip. It is to be noted that in ASA system, nose radius value is expressed in inch.

### Tool nomenclature in ASA system

- All of the above mentioned seven features of the turning tool are specified in a particular sequence as shown below. Such specification is also called tool nomenclature or tool signature. The sequence of designation should be followed strictly. However, different people may use different notations for various angles maintaining the original sequence unchanged.



**Example for ASA system of tool designation**

Few points should be considered for giving examples of tool nomenclature. First and foremost one is the value of clearance angles. Clearance angles are always positive—it cannot be zero or negative. Usually it ranges from 3º – 15º. Rake angle can have a positive, negative or even zero value. One example of ASA system of tool designation and interpretation of tool angles from such nomenclature is illustrated in the following figure.

| ASA system of turning tool designation | | | | | | |
|---|---|---|---|---|---|---|
| $\gamma_Y$ | $\gamma_X$ | $\alpha_Y$ | $\alpha_X$ | $\phi_e$ | $\phi_s$ | r |
| 0° | 5° | 6° | 6° | 10° | 30° | 1/12 |
| Back rake angle | | | | | 0° | |
| Side rake angle | | | | | 5° | |
| Back clearance angle | | | | | 6° | |
| Side clearance angle | | | | | 6° | |
| End cutting edge angle | | | | | 10° | |
| Approach angle | | | | | 30° | |
| Nose radius | | | | | 1/12 inch | |

Let us consider another example. Say, a typical turning tool can be specified in ASA system as:

–8º, 6º, 5º, 10º, 15º, 30º, 1/8 (inch)

Therefore, upon interpretation, we may write:

- Back Rake Angle ($\gamma_Y$) = –8º
- Side Rake Angle ($\gamma_X$) = 6º
- Back Clearance Angle ($\alpha_Y$) = 5º
- Side Clearance Angle ($\alpha_X$) = 10º
- End Cutting Edge Angle ($\Phi_e$) = 15º
- Approach Angle ($\Phi_s$) = 30º
- Nose Radius (r) = 1/8 inch

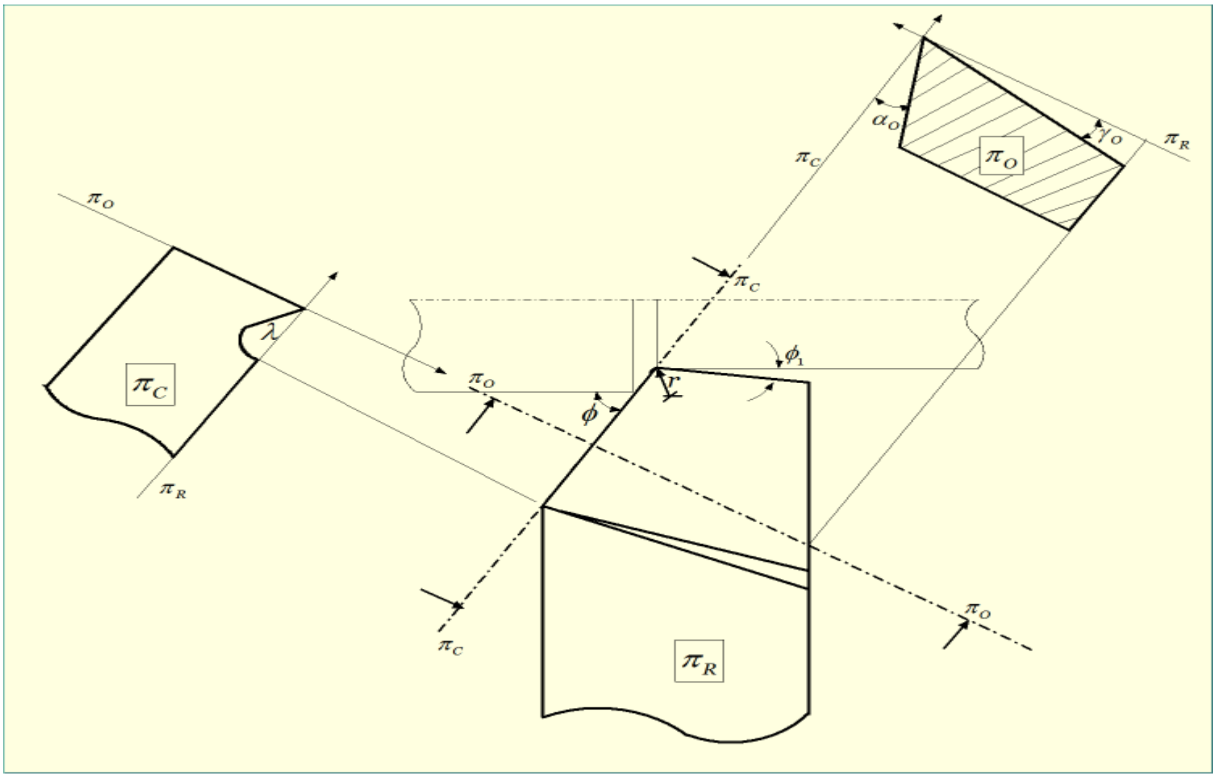
## Tool signature in ORS system

Orthogonal Rake System (ORS) also utilizes three mutually perpendicular planes for reference purpose namely Cutting plane, Orthogonal plane and Reference plane. Similar to the ASA system, tool signature in ORS system consists of two rake angles, two clearance angles, two cutting edge angles and the nose radius of a single point cutting tool. Note that in ASA system, nose radius is measured in inch unit; whereas, in ORS system it is measured in mm. The sequence of writing tool signature in ORS system along with the name of various angles is depicted below. As usual, the sequence cannot be altered but alternative notation can be used. A typical example is also provided below.

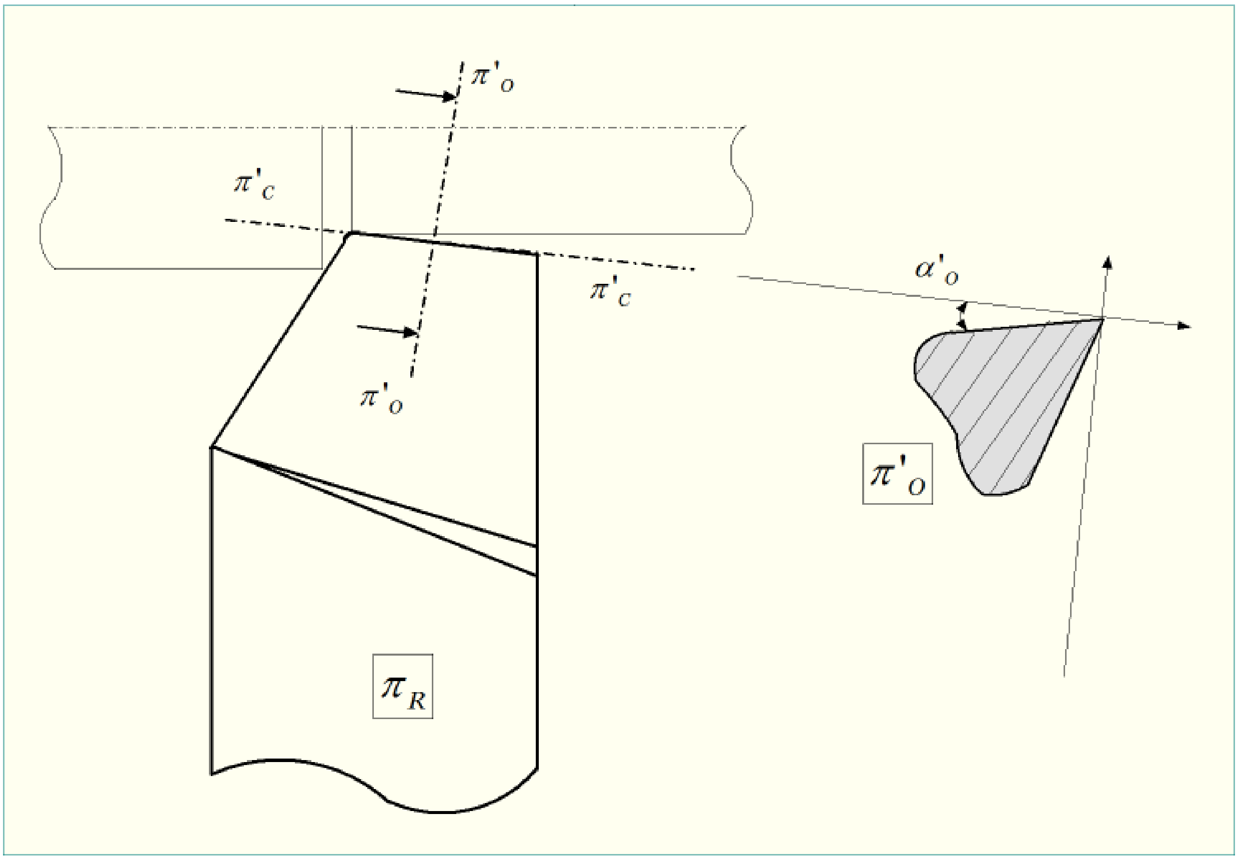
## Planes used as reference in ORS system of tool designation

- Orthogonal Rake System (ORS) utilizes three mutually perpendicular planes as reference for measuring various tool angles. These three planes are enlisted below.

- **Reference Plane ($\pi_R$)**—It is a plane perpendicular to the cutting velocity vector ($V_c$).
- **Cutting Plane ($\pi_C$)**—It is a plane perpendicular to reference plane ($\pi_R$) and contains the principal cutting edge of the tool.
- **Orthogonal Plane ($\pi_O$)**—It is a plane perpendicular to reference plane ($\pi_R$) and also perpendicular to the cutting plane. So all three planes are mutually perpendicular ($\pi_O$ is perpendicular to both $\pi_R$ and $\pi_C$).




Representation of tool angles in ORS system of tool designation.




Representation of auxiliary plane angles in ORS system of tool designation.

**Various features displayed in ORS system of tool designation**

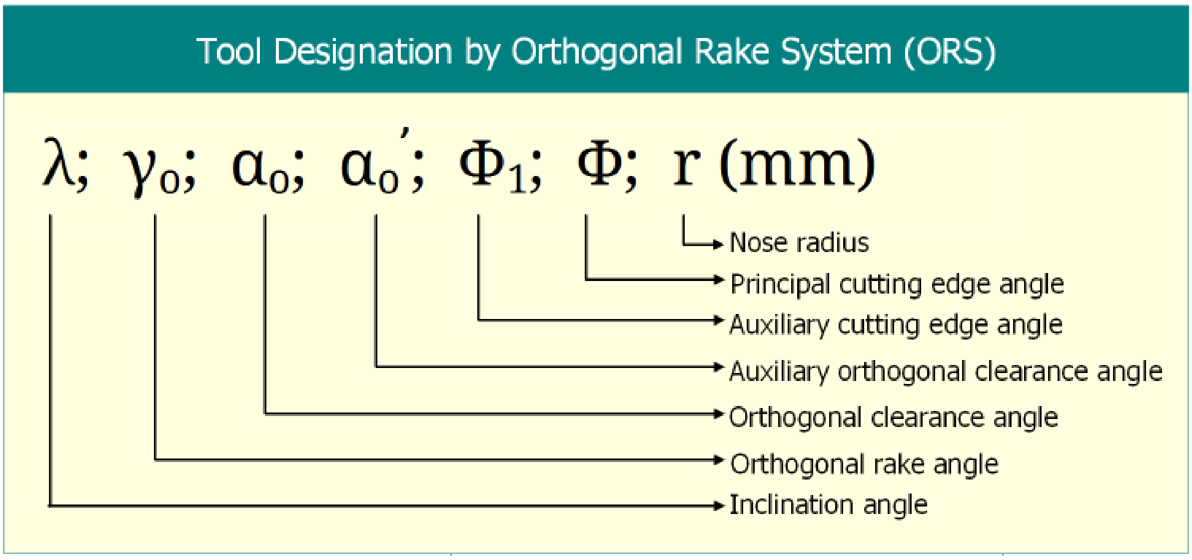
This system of tool designation specifies two different rake angles, two different clearance angles, two different cutting edge angles, and the nose radius value in mm. Various features of the single point turning tool (SPTT) that are specified in ORS system are enlisted below.

- **Inclination Angle (λ)**—It is the angle of inclination of tool's principal cutting edge from the reference plane ($\pi_R$) and measured on cutting plane ($\pi_C$).
- **Orthogonal Rake Angle ($\gamma_O$)**—It is the angle of orientation of tool's rake surface from the reference plane ($\pi_R$) and measured on orthogonal plane ($\pi_O$).
- **Orthogonal Clearance Angle ($\alpha_O$)**—It is the angle of orientation of tool's principal flank surface from the cutting plane ($\pi_C$) and measured on orthogonal plane ($\pi_O$).
- **Auxiliary Orthogonal Clearance Angle ($\alpha_o$')**—It is the angle of orientation of tool's auxiliary flank surface from the auxiliary cutting plane ($\pi_C$') and measured on auxiliary orthogonal plane ($\pi_O$').

- **Principal Cutting Edge Angle (Φ)**—It is the angle between cutting plane ($\pi_C$) (which contains principal cutting edge) and the longitudinal feed direction, measured on reference plane ($\pi_R$).
- **Auxiliary Cutting Edge Angle ($\Phi_1$)**—It is the angle between auxiliary cutting plane ($\pi_C$') (which contains auxiliary cutting edge) and the longitudinal feed line, measured on reference plane ($\pi_R$).
- **Nose Radius (r)—**This is nothing but the curvature at the tool tip. It is to be noted that in ORS system, nose radius value is expressed in mm.

**Tool nomenclature in ORS system**

- All the above mentioned seven features of the turning tool are specified in sequence as shown below. It is also called tool nomenclature. The sequence of designation should be followed strictly. However, different people may use different notations for various angles maintaining the original sequence unchanged.




**Example for ORS system of tool designation**

Few points should be considered for giving examples of tool nomenclature. First and foremost one is the value of clearance angles. Clearance angles are always positive — it cannot be zero or negative. Usually it ranges from 3º – 15º. Also auxiliary cutting edge angle is usually lower than principal cutting edge angle; however, for thread cutting tool, they can be same. A zero inclination angle indicates ORS and NRS system are same. One example of ORS system of tool designation and interpretation of tool angles from such nomenclature is illustrated in the following figure.

Let us consider another example. Say, a typical turning tool can be specified in ORS system as:

–6º, –6º, 10º, 15º, 15º, 45º, 1.2 (mm)

Therefore, upon interpretation, we may write:

- Inclination Angle ($\lambda$) = –6º
- Orthogonal Rake Angle ($\gamma_O$) = –6º
- Orthogonal Clearance Angle ($\alpha_O$) = 10º
- Auxiliary Orthogonal Clearance Angle ($\alpha_o'$) = 15º
- Auxiliary Cutting Edge Angle ($\Phi_1$) = 15º
- Principal Cutting Edge Angle ($\Phi$) = 45º
- Nose Radius (r) = 1.2 mm.

| ORS system of turning tool designation | | | | | | |
|---|---|---|---|---|---|---|
| $\lambda$ | $\gamma_o$ | $\alpha_o$ | $\alpha'_o$ | $\phi_1$ | $\phi$ | r |
| 0° | –7° | 10° | 8° | 15° | 60° | 0.8 |
| Inclination angle ($\lambda$) | | | | | 0° | |
| Orthogonal rake angle ($\gamma_o$) | | | | | –7° | |
| Orthogonal clearance angle ($\alpha_o$) | | | | | 10° | |
| Auxiliary orthogonal clearance angle ($\alpha'_o$) | | | | | 8° | |
| Auxiliary cutting edge angle ($\phi_1$) | | | | | 15° | |
| Principal cutting edge angle ($\phi$) | | | | | 60° | |
| Nose radius (r) | | | | | 0.8mm | |

Tool signature in NRS system

Normal Rake System (NRS) utilizes three planes (not necessarily mutually perpendicular) for reference purpose namely Cutting plane, Normal plane and Reference plane. Similar to the ORS system, tool signature in NRS system also consists of two rake angles, two clearance angles, two cutting edge angles and the nose radius of a single point cutting tool. The following images show the tool signature in NRS system and the way to retrieve values of various angle from the given tool signature.

| NRS system of turning tool designation | | | | | | |
|---|---|---|---|---|---|---|
| $\lambda$ | $\gamma_N$ | $\alpha_N$ | $\alpha'_N$ | $\phi_1$ | $\phi$ | r |
| 0° | –7° | 10° | 8° | 15° | 60° | 0.8 |
| Inclination angle ($\lambda$) | | | | | 0° | |
| Normal rake angle ($\gamma_N$) | | | | | –7° | |
| Normal clearance angle ($\alpha_N$) | | | | | 10° | |
| Auxiliary normal clearance angle ($\alpha'_N$) | | | | | 8° | |
| Auxiliary cutting edge angle ($\phi_1$) | | | | | 15° | |
| Principal cutting edge angle ($\phi$) | | | | | 60° | |
| Nose radius (r) | | | | | 0.8mm | |

## MACHINABILITY

- Machinability is a measure of how easy it is to cut a material with a cutting tool. It's a crucial factor in machining processes because it defines how easily material can be removed with moderate force.
- Machinability video link https://youtu.be/-IvhmjpxM-s?si=qxCIuhG4qJFumQTo

## TOOL WEAR

- Definition of Tool Wear
  Tool wear is the gradual breakdown of machine tools as a result of cutting operation, eventually leading to tool failure. Because tools and workpieces are in constant contact with severe friction and rubbing, tools become stressed over time.
- Video link- https://youtu.be/eCD2g1njeZQ?si=aCWLRQDaHXAzIh8n

### TOOL LIFE

- Tool life T is the period of time, expressed in minutes, for which the cutting edge, affected by the cutting procedure, retains its cutting capacity between sharpening operations.
- Factors that affect tool life include:
  Cutting speed
  Feed and depth of cut
  Tool geometry
  Tool material
- Tool wear is the incremental destruction of cutting-edge tools. It can be caused by:

  Localized pressures and tensions at the tip of the tool
  High temperatures
  Gliding the chip along the rake face
  Moving smoothly along the recently cut workpiece

- Tool wear is not uniform through the life of the tool. The wear is initially rapid, then settles down to a uniform rate, and finally accelerates at a very high rate till catastrophic failure occurs.

- Once a tool is worn to the point that the parts being created are out of spec, it's life is effectively over and the tool should be replaced.

- You can monitor tool life by collecting data from sensors that monitor the tool group when a machine changes to the next tool. This data is sent to a software program or cloud-based machine data platform, where it's analyzed to predict the condition and lifespan of a tool.

## CUTTING TOOL MATERIALS

There are different cutting processes done on varying conditions. Depending on the cutting conditions and the requirements of the respective cutting tool, it is important that they are of the right properties. The type of material selected for a specific application depends on what is being machined. Here is a classification of these materials.

### Carbon Tool Steel

This is one of the inexpensive metal cutting tools common in low-speed machining operations. These carbon steel cutting tools are constructed with a composition of 0.6%-1.5% carbon and small amounts, less than 0.5%, of Si and Mn. To enhance the hardness, other materials such as V and Cr could also be added.

Carbon tool steels are preferred because they are abrasion resistant and can maintain the cutting edge for a long period. However, they lose their hardness when temperatures reach 250 °C. This means that they are not good for high-temperature operations.

Common applications that use carbon steel tool include milling tools, twist drills, and forming tools.

### High-Speed Steel (HSS)

This is another high carbon steel featuring a significant quantity of alloys like chromium and tungsten to increase their hardness and wear resistance. HSS loses its hardness when temperatures hit 650 °C. It is, therefore, advisable to use coolants to increase tool life. The following surface treatment is also used on HSS to improve the properties.

- Super-finishing to lower friction
- Chromium electroplating to lower friction
- Nitriding to increase wear resistance
- Oxidation to reduce friction

High-speed steel tools are common in broaches, single point lathe tools, and milling cutters.

### Cemented Carbide and Cement

The cemented carbide cutting tool is created using metallurgy method. It is made from tungsten, titanium carbide and tantalum with cobalt as a binder. The most notable thing about the cemented carbide tools is that they are very hard and can be used for cutting at high speed and temperatures. For example, you can use them for cutting at temperatures of 1000 °C without losing their properties.

For rough cuts, it is better to use high cobalt tool while low combat tools are ideal for finishing applications.

**Ceramics**

The common ceramic materials used in cutting tools are silicon nitride and aluminum oxide. When the ceramic material powder is compacted and inserted at very high temperatures, the resulting tools are inert and resistant to corrosion. Therefore, they have high compressive strength.

The ceramics are stable when operating even in temperatures of up to 1800°C and are about 10 times faster than HSS. Because the friction between the chip and surface is low and heat conductivity is also low, you do not need an additional coolant.

**Cubic Boron Nitride (CBN)**

CBN is the second hardest material and is commonly used in hand machines. They provide high abrasion resistance and utilize abrasive in grinding wheels. They are ideal at speeds of 600-800m/min.

**Diamond**

This is the hardest material used in tools. It features a high melting point and thermal conductivity. Therefore, it provides excellent abrasion resistance, low thermal expansion, and low friction coefficient. It is considered ideal for machining hard materials like glass, nitrides, and carbides. Note that diamond is not ideal for machining steel.

**Video link-**

**https://youtu.be/79YEVl21to0?si=hrHwW5zPhKZRf2bg**

## CUTTING FLUIDS

- Cutting fluids provide lubrication to the cutting tool and workpiece, which helps to improve the movement of the tool and reduce wear and tear on the machinery.
- Cutting fluids can be used as coolants, lubricants, and flushing fluids, making them a versatile solution for a range of metal cutting operations.
- **Video link-**

  https://youtu.be/GAysUOEU6Yg?si=XYOPSE4fRJchA1rD

## TYPES

- **Cutting fluids, also known as coolants or cutting oil, are multi-purpose formulations. They are typically used in metalworking processes such as machining, grinding, and milling.**

### 1. Straight Oil

Stroth oils are non-emulsifying. These oils are used without diluting them with water. The compositions of this type of oil are base minerals or petroleum oil. Examples of straight oil are paraffin oil, Naphthenic oil, vegetable oil.

In systems where environmentally friendly oil is required, vegetable oil is used because it is biodegradable. Straight oils are best for lubricating, but they cannot serve as a good coolant because they have very cool properties.

### 2. Soluble Oil

Soluble oils are made by mixing mineral oil, water, & coupling agents. It provides good lubrication between water-inaccurate liquids. Soluble oils are used in the machining of both ferrous and non-ferrous metals when high cooling quality is required & chip bearing capacity is not very high.

### 3. Mineral Oil

Mineral oils are typically found in high production machines that have high metal removal rates. They are used in heavy cutting operations as they have very good lubricating properties. A disadvantage of these oils is that they are corrosives and therefore are not used for copper or its alloys.

### 4.Synthetic Liquids

As these are synthetic liquids, they do not contain mineral oil or petroleum. These are water-based liquids, and water provides very good cooling properties. The problem with synthetic fluids is that it is not a good lubricant and also causes corrosion.

Corrosion or corrosion can be prevented by adding corrosion inhibitors to synthetic liquids. Typically, synthetic fluids are used in grinding liquids.

### 5.Semi-Synthetic Fluids

Semi-synthetic fluid is made from a combination of synthetic fluid and soluble oils. For semi-synthetic liquids, approximately 5 to 20% of mineral oil is emitted with water to produce micro abrasion. The size of microalgae particles varies from 0.01 to 0.1 mm, which can easily transmit all light.

### 6. Solid and Paste Lubricants

These lubricants are in the solids phase or as a paste. These lubricants are placed directly on the workpiece or tool. Some examples of this are molybdenum disulfide, graphite, wax stick, etc.

### 7. Cutting Oil

Cutting oil is made by mixing minerals oil & fatty oil. It is used as both a coolant and a lubricant.

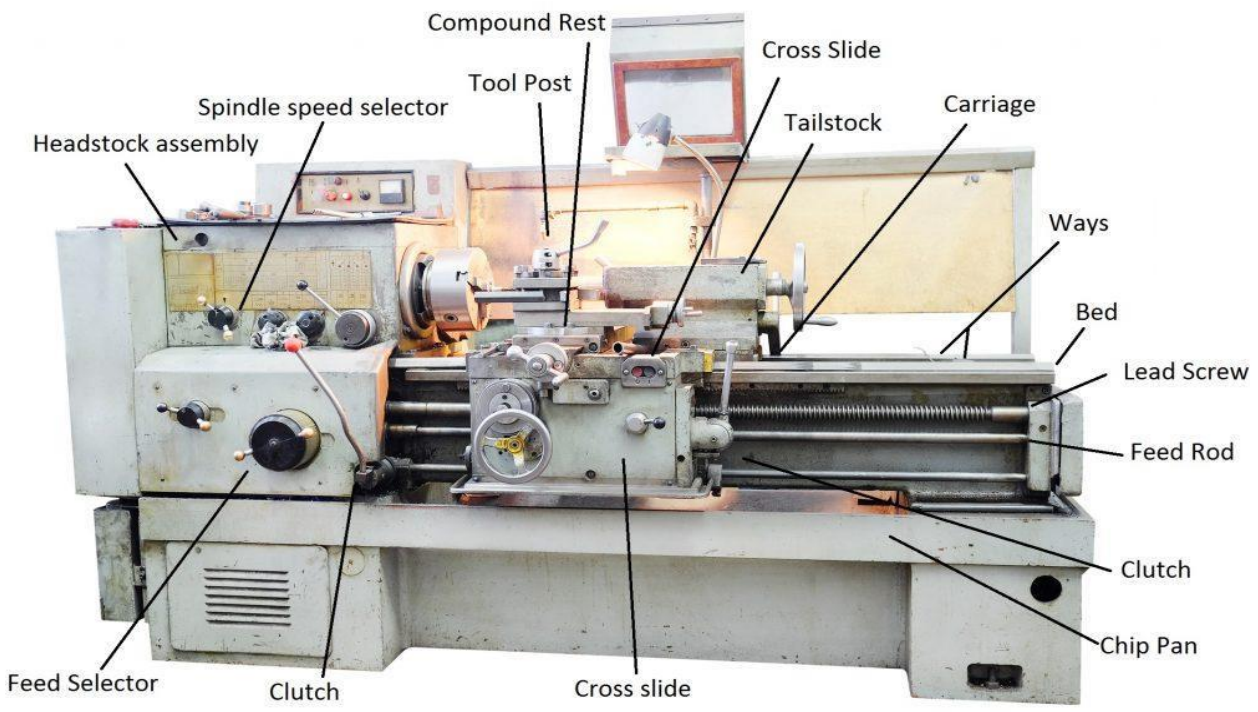
**UNIT II: AUTOMATS, SHAPING AND PLANING MACHINES**

- Capstan and turret lathes construction
- Indexing mechanism operations
- Working principle of single and multi-spindle automats
- Shaping and planning machines -types -construction -Mechanism -and -principle of different types of shaping operations
- Work holding devices.

# CAPSTAN AND TURRET LATHES CONSTRUCTION

## What is Lathe Machine?

- **A lathe is a machine tool that rotates a workpiece around an axis to perform various operations. Lathes are used to shape wooden or metallic products.**



**DESCRIPTION OF LATHE**

Lathe is a machine which has several parts in it. They are

**1. Bed**

It is the base of the machine. On its left side, the head stock is mounted and on its right it has movable casting known as tailstock. Its legs have holes to bolt down on the ground.

**2. Head stock**

It consists of spindles, gears and speed changing levers. It is used to transmit the motion to the job. It has two types one is the headstock driven by belt and the other one is the gear driven.

**3. Carriage**

Carriage is used to carry a tool to bring in contact with the rotating work piece or to with draw from such a contact. It operates on bed ways between the headstock and tail stock.

**4. Saddle**

It is an 'H' shaped part fitted on the lathe bed. There is a hand wheel to move it on the bed way. Cross slide, compound rest, tool post is fitted on this saddle.

a) Cross slide

It is on the upper slide of saddle in the form of dove tail. A hand wheel is provided to drive the cross slide. It permits the cross wise movement of the tool (i.e.) movement of tool towards or away from the operator

b) Compound rest

It is fitted over the cross slide on a turn table. It permits both parallel and angular movements to cutting tool.

c) Tool post

It is fitted on the top most part of the compound rest. Tool is mounted on this tool post. Cutting tool is fixed in it with the help of screws.

**5. Apron**

It is the hanging part in front of the carriage. It accommodates the mechanism of hand and power feed to the cutting tool for carrying out different operations.

**6. Lead screw**

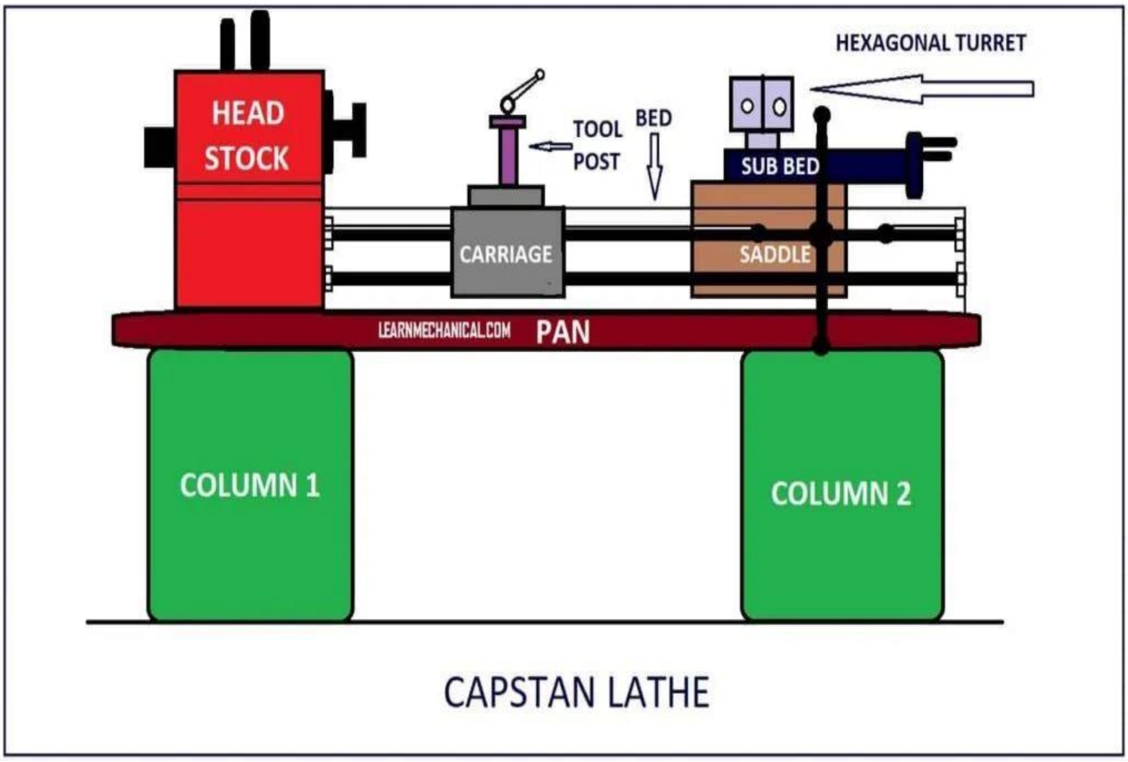
It is a long screw with ACME threads. It is used for transmitting power for automatic feed or feed for thread cutting operation.

**7. Tail stock**

It is located at the right end of the lathe bed and it can be positioned anywhere in the bed. It is used for supporting lengthy jobs and also carries tool to carry out operations such as tapping, drilling, reaming.

## CAPSTAN LATHE CONSTRUCTION

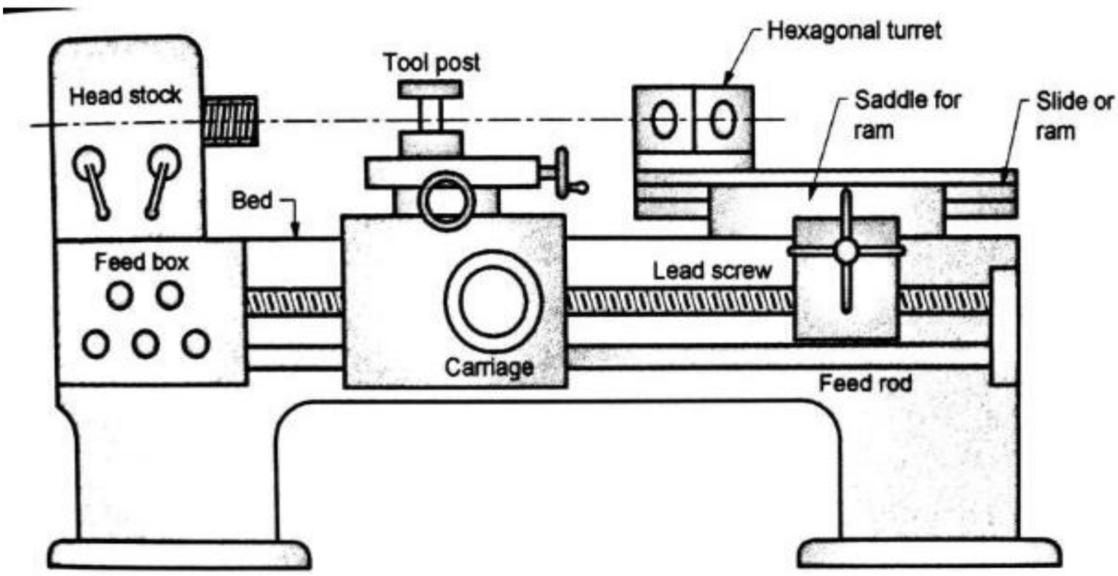
- A capstan lathe is a production lathe that uses a rotatable turret to hold tools for multiple operations. It's also known as a turret lathe.
- A **capstan lathe is a production lathe**. It is used to manufacture any number of identical pieces in the minimum time.
- In the case of a **Capstan Lathe**, **the hexagonal turret is mounted on a short slide or ram** which again fitted with a saddle.
- The saddle can be move accordingly throughout the bed ways and can be fixed to the bed if necessary.
- **It is specially used for bar type jobs.**




### Essential features of capstan or turret lathe

1. Spindle
2. Head stock
3. Carriage
4. Rear tool post
5. Cross slide
6. Slide or ram
7. Hexagonal turret
8. Square tool post on the cross slide

# Schematic diagram of capstan lathe




## Capstan Lathe

- The turret of the capstan lathe machine is mounted on a slide or ram which can be moved longitudinally on the saddle for feeding the tools.
- The saddle itself is mounted on the bed.
- The turret is generally hexagonal but may also be square or round.
- This type of machine is lighter in construction and is suitable for machining bars of up to 60 mm in diameter.
- More than one tool may be mounted on the same face on the turret making it possible to machine more than one surface at the same time.

## Capstan Lathe Parts

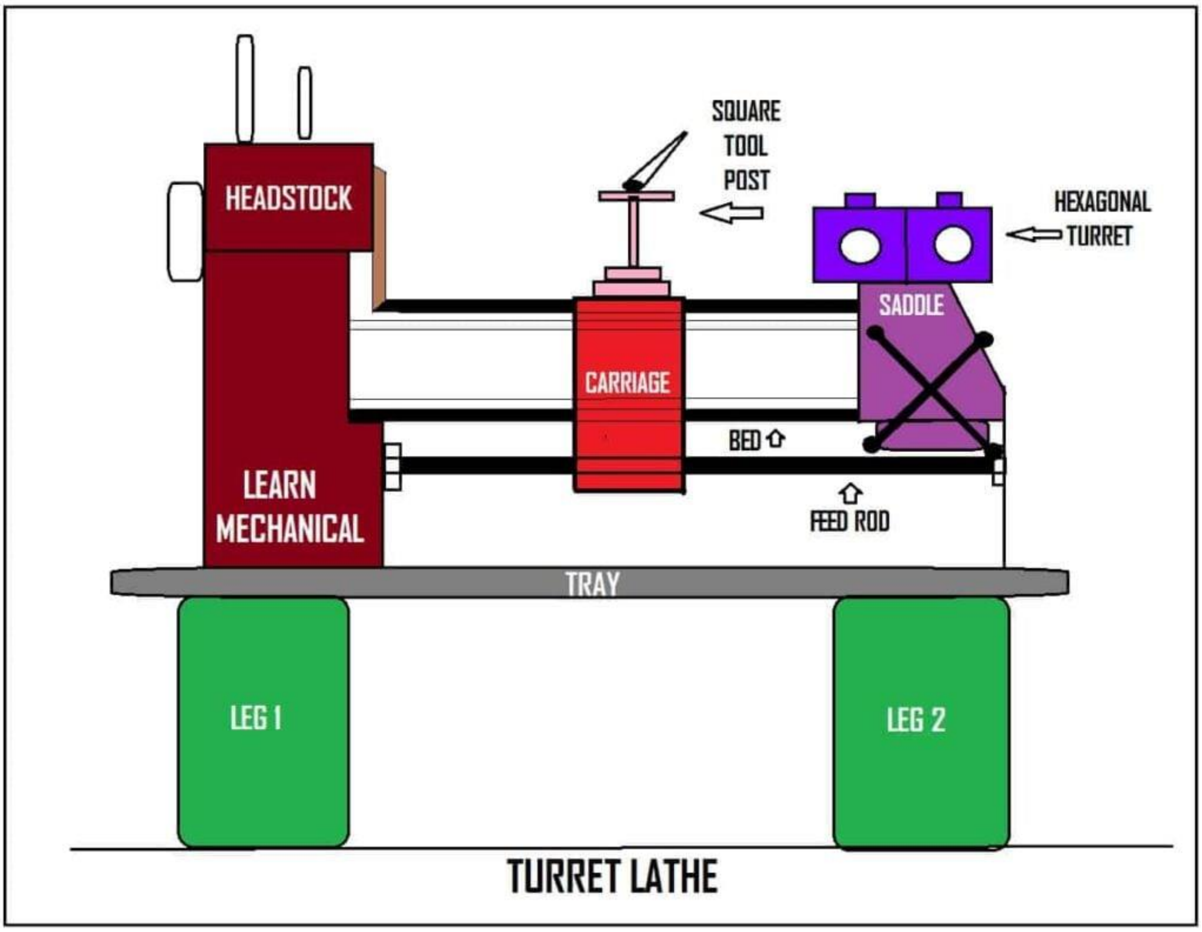
1. Head stock
2. Bed
3. Feed box
4. Carriage
5. Tool post
6. Hexagonal turret
7. Saddle for ram
8. Lead screw

- **Capstan & Turret Lathe Machine video link-**

  https://youtu.be/ar-cG8tHVRQ?si=5cKxFKWPUEH72MRZ

## TURRET LATHE CONSTRUCTION

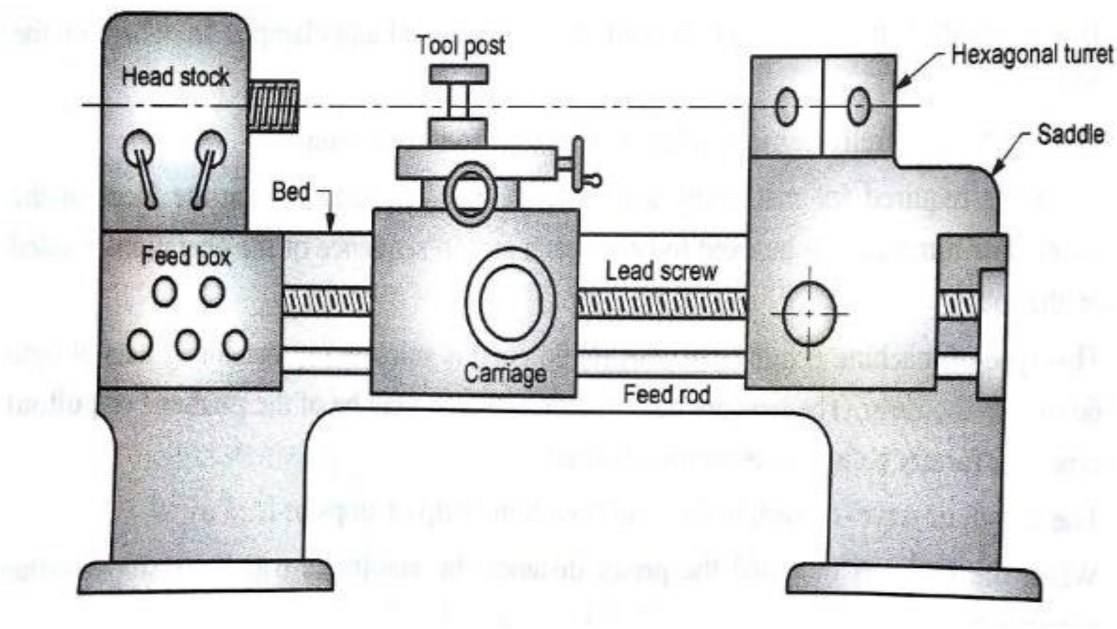
- A turret lathe is a metalworking lathe that uses interchangeable cutting tools to produce duplicate parts.
- A **turret lathe is a production lathe**. It is used to manufacture any number of identical pieces in the minimum time.
- The turret head is mounted on the ram fitted with turret slides longitudinally on the saddle.
- Turret head has a **hexagonal block having six faces** with a bore for mounting six or more than six tools at a time.
- The threaded hole on these faces is used to hold the tools.
- In the case of **Turret Lathe**, the **hexagonal turret directly mounted on the saddle.** The saddle can be move through the bed ways.
- **Turret lathe is generally used for chucking type work.**




### Turret Lathe Parts

1. Head stock
2. Bed
3. Feed box
4. Tool post
5. Carriage
6. Lead screw
7. Feed rod
8. Hexagonal turret
9. Saddle

# Schematic diagram of turret lathe




### Turret Lathe

- The tool turret is mounted directly on the saddle and the feed is given by moving the entire unit.
- The turret lathe can thus operate under more serve condition accommodating heavier work pieces with higher cutting speeds, feeds and depth of cut.
- Turret lathes are capable of turning bars up to 200 mm diameter using collets as well as handling irregular jobs like castings and forgings with chucks.
- Some turret types lathes are equipped with crosswise movement of the hexagonal tool turret by hand or power.
- Turret machines provided with so called side hung type of carriage do not require any support from the rear slide of the bed.

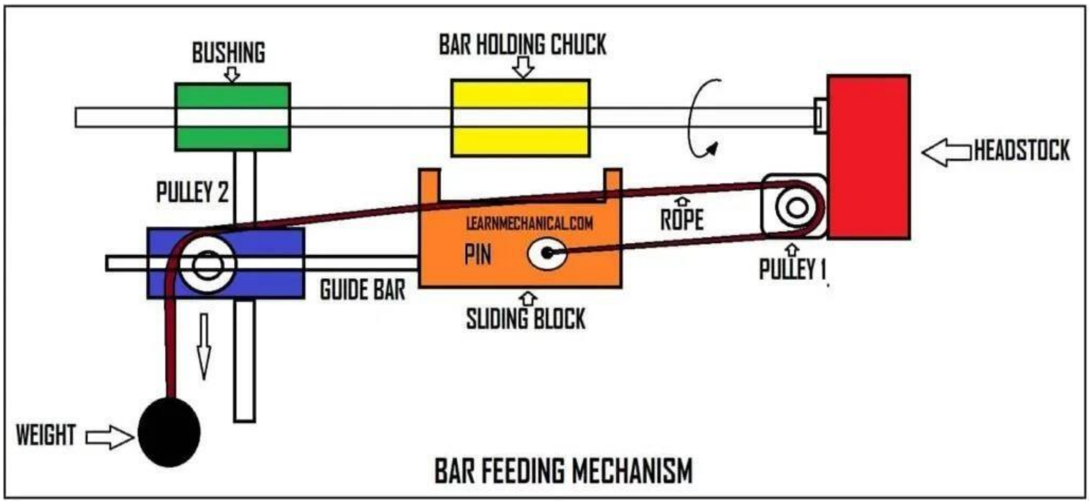
## Capstan and Turret Lathe Working:

- The workpiece is held in collet or chucks which are actuated **hydraulically or pneumatically.**
- All the needed tools are held in the respective holes on the turret head.
- According to the sequence of operation, the tool is moved with the help of a turret head.

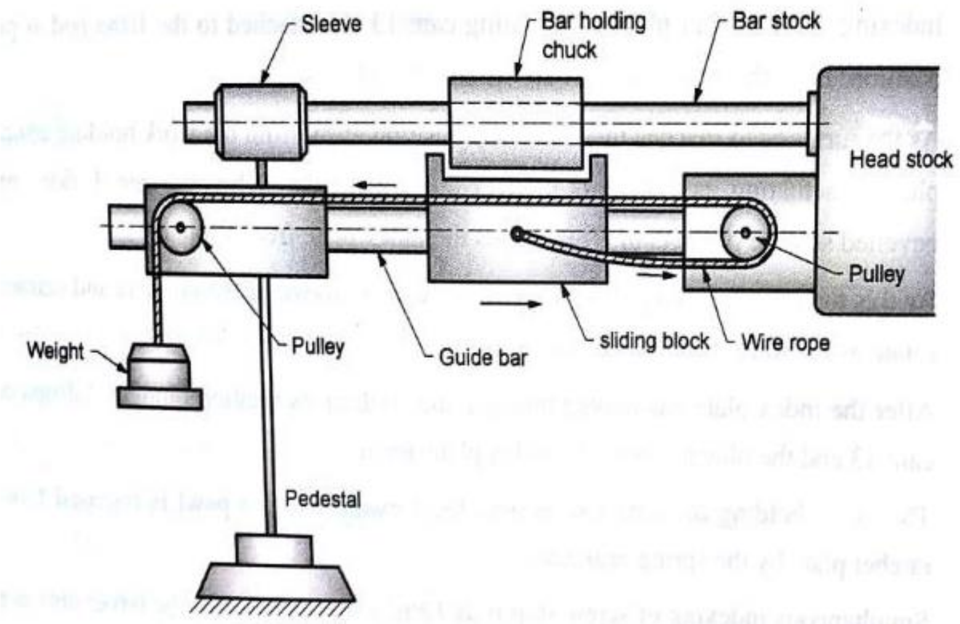
  Drilling, boring, turning, reaming, threading tools are mounted on the turret head.
- Forming, chamfering, knurling tools are mounted on the front end of the turret.
- The Parting tool is mounted in an inverted position on the rear end of the turret.
- After completing each operation, the turret head is moved back to its initial position which indexes the tools automatically.

## Bar Feeding Mechanism in Capstan and Turret Lathe:

- In the **bar feeding mechanism**, the bar is pushed after the chuck is released without stopping the **Lathe Machine**.
- We use this mechanism for minimizing the setting time.
- The bar is passed through the pedestal bushing, bar holding chuck, headstock spindle, and the collet chuck.
- The **collet chuck** is screwed on the headstock spindle and holding the feed bar and also helps the bar to rotates as per spindle speed.
- Bar holding chuck rotates within the sliding block with the rotation of the feeding bar. Also, you can see a rope and a deadweight in this mechanism.
- One side of the rope is attached with the sliding block with the help of pin and another side of rope passes through 2 different pulleys and then connecting with a deadweight at its end.
- So now when the collet chuck released by the lever the dead weight tends to move in the downward direction, due to this it exerts thrust on the bar holding chuck and feed the bar until it touches the workshop.
- As we already have seen that Capstan Lathe is best for bar types jobs that's why we are generally seeing Bar Feeding Mechanism on Capstan Lathe.



## Schematic Diagram of Bar Feeding Mechanism




### Tools used in Capstan and Turret Lathe:

1. Turning tool
2. Facing tool
3. Parting tool
4. Forming tool
5. Chamfering tool
6. Drilling
7. Boring tool
8. Counter bore
9. Reamer
10. External thread cutting tool
11. Internal thread cutting tool

12. Worksop

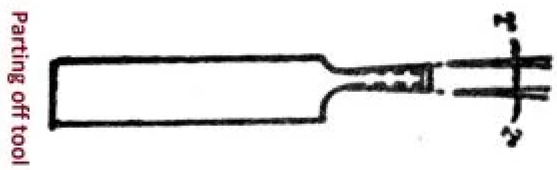
**1. Turning tool**


- **Turning** tool is mounted on the cross-slide or knee holder.
- **Hollow mill** is a special turning tool used in capstan and turret lathe.

**2. Facing tool**


- **Facing tool** may be mounted on the cross-slide or on the knee tool holder.

**3. Parting tool**




- The tool is mounted on the rear tool post.
- All round clearance is given on tool to clear the work while cutting.

**4. Forming tool**


- The **forming** tools may be straight or circular type.

**5. Drill**


- A **drill** is a tool primarily that use for making round holes or driving fasteners.

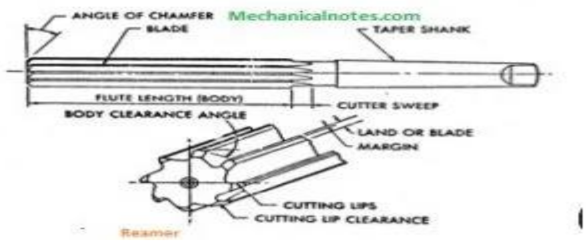
**6. Boring tool**


- The **drilling apparatuses** mounted on drilling bars are utilized for developing a gap in a capstan or turret machine.

**7. Counter bore**


- The **counter** bores are used for enlarging the drilled hole from one end.

9. **Reamer**



- The **reamer** is used for sizing and finishing a hole.
- **Reamers** may have at least two straight or helical woodwinds in the body.

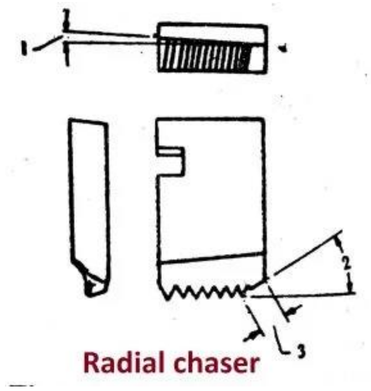
**9. External thread cutting tool**


- **External thread** is cut on a job in a capstan or turret lathe by using any one of the following tools:

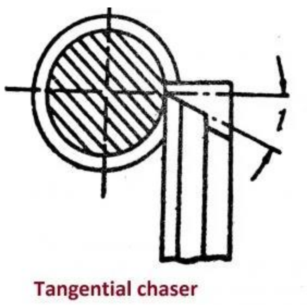
**a. Solid button dies**


**b. Chasers**

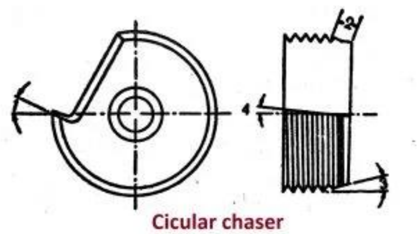

**i.** Radial chaser




ii.Tangential chaser

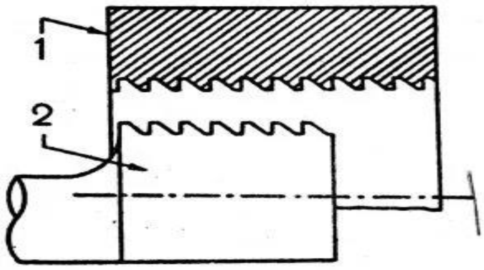



iii.Circular chaser




c. **Single point tools**


**10. Internal thread cutting tool**




Internal thread cutting tool

- The internal thread may be cutting in a capstan or turret lathe by using any one of the following tool.

a. **Solid tap**

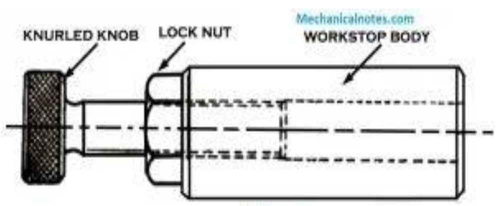
b. **Collapsible tap**

c. **Single cutting tool or chaser**

**11. Chamfering tool**

- The chamfering tool is mounting on the **four-station** turret on cross-slide.
- The extreme longitudinal position of the saddle is adjusting for the stop.

**12. Workstop**




Workstop

- It is a cylindrical bar whose position can be adjusting relative to the spindle nose by the turret stop.
- In some **workstops**, micrometer graduations are provided for an accurate setting.

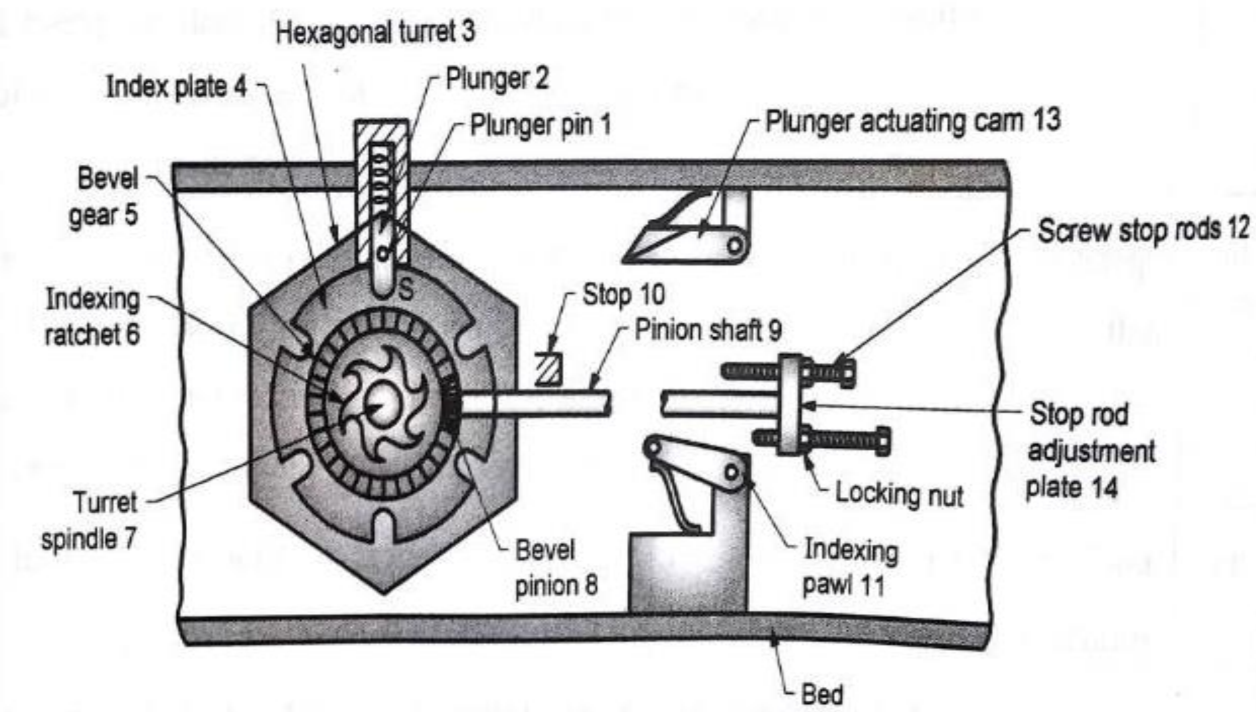
Difference Between **Capstan** and Turret lathe



| S. No. | Capstan lathe | Turret lathe |
|---|---|---|
| 1. | The **turret head** is mounted on the ram and the ram is mounted on the saddle. | The **turret head** is directly mounted on the saddle and the saddle slides over the bed ways. |
| 2. | The **saddle** is fixed during machining. | The **saddle** is moved along with the turret head during machining. |
| 3. | The turret head can't be moved crosswise. | The turret head can be moved crosswise. |
| 4. | The lengthwise movement of turret is less. | The lengthwise movement of turret is more. |
| 5. | Maximum bar size is up to **60 mm.** | Maximum bar size is up to **200 mm.** |
| 6. | **Collect** is used to hold the work piece. | **Jaw** chuck used to hold the work piece. |
| 7. | Rate of tool feeding relatively faster. | Rate of tool feeding relatively slower. |

| | | |
|---|---|---|
| **8.** | It is a light weight machine. | It is a heavier machine. |
| **9.** | It has a simple tool head. | It has hexagonal tool head. |
| **10.** | Automatic indexing. | Manual indexing. |

## INDEXING MECHANISM OPERATIONS




### Capstan and turret lathe mechanism: -

### Turret head indexing mechanism: -

- This is an inverted plan of turret assembly. The turret is mounted on the spindle. The index plate, the, bevel gear and an indexing ratchet are keyed to the spindle. The plunger fitted within the housing and mounted on the saddle locks the index plate by spring pressure and prevents any rotary movement of the turret as the tool feeds into the work.

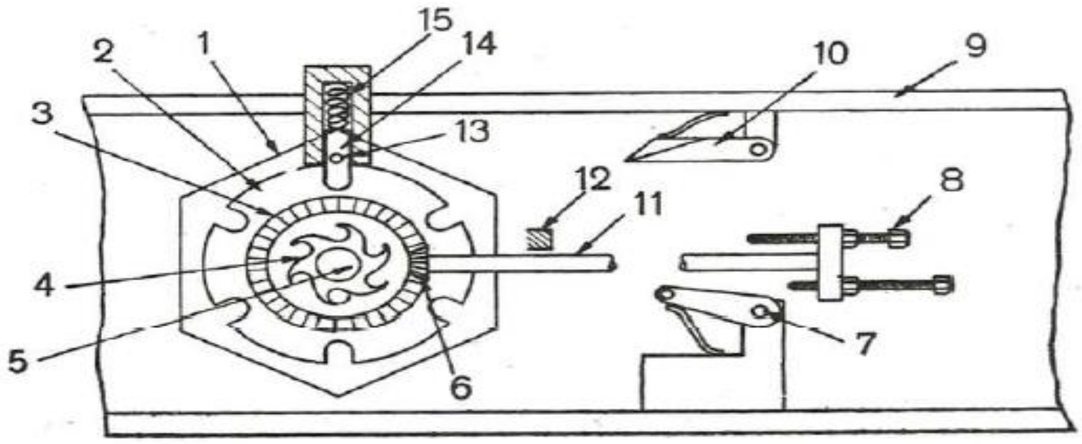



**Figure Turret indexing mechanism**

1. Hexagonal turret, 2. Index plate, 3. Beveled gear, 4. Indexing ratchet, 5. Turret spindle, 6. Beveled pinion, 7. Indexing pawl, 8. Screw stop rods, 9. Lathe bed, 10. Plunger actuating cam, 11. Pinion shaft, 12. Stop, 13. Plunger pin, 14. Plunger, 15. Plunger spring.

- A pin is fitted on the plunger projects out of the housing. An actuating cam and the indexing pawl are attached to the lathe bed at desired positions. Both the cam and the pawl are spring loaded. As the turret reaches the backward position, the attaching cam lifts the plunger out of the groove in the index plate due to the riding of the pin on the bevelled surface of the cam and thus unlocks the index plate.
- The spring-loaded pawl which by this time engages with a groove of ratchet plate, causes the ratchet to rotate as the turret head moves backward. When the index plate or turret rotates through one sixth of revolution, the pin and the plunger drops out of the cam and the plunger locks the index plate at the next groove.
- The turret is thus indexed by one sixth of revolutions and again backed into the next position automatically. The turret holds the next tool is now fed forward and the pawl is released from the ratchet plate by the spring pressure.
- The bevel opinion meshes with the bevel gear mounted on the turret spindle. The extension of the pinion shaft carries a plate holding six adjustable stop rods. As the turret rotates through one sixth of the revolution, the bevel gear causes the plate to rotate.
- The ratio of the teeth between the pinion and the gear are so chosen that when the tool mounted on the face of the turret is indexed to bring it to the cutting position, the particular stop rod for controlling the longitudinal travelling of the tool is aligned with the stop.
- The setting of the stop rods for limiting the feed of each operation may be adjusted by unscrewing the lock nuts and rotating the stop rods on the plate. Thus, six stop rods may be adjusted for controlling the longitudinal travel of tools mounted on six faces of the turret.

## WORKING PRINCIPLE OF SINGLE AND MULTI-SPINDLE AUTOMATS

### SINGLE SPINDLE AUTOMATS

- Single-spindle automatic lathes are a modified version of turret lathes. They have a 6-station turret and up to four cross slides operated by disc cams. The headstock has a sliding headstock traversed by a bell or plate type cam.

### What is the principle of single spindle automats?

- A single spindle automatic lathe is a modified turret lathe that has a 6-station turret, a maximum of 4 cross slides, and a sliding headstock. The cross slides are operated by disc cams, and the sliding headstock is traversed by a bell or plate type cam.


SINGLE SPINDLE AUTOMATIC LATHES

- These machines produce short w/p of a simple form by means of cross sliding tools.
- Machines are simple in design. Headstock with spindle is mounted on bed.
- 2 cross slides are located on bed at front end of spindle.
- Cams on cam shaft actuates movements of cross slide through system of levers.
- Some of the single spindle lathes are:
  1. Automatic cutting off machine
  2. Automatic Screw Cutting machine
  3 Swiss type Automatic Screw machine

**Operation:**

- The required length of work is fed out with a cam mechanism, up to Bar stop which is automatically advanced in line with spindle axis at each end of cycle.
- Stock is held in collet chuck of rotating spindle.
- Machining is done by tools that are held in slides operating only in cross wise direction
- Typical simple parts (3 to 20 mm dia.) machined on such machines.

**1. Automatic Cutting Off Machine:**

- These machines produce short w/p's of simple form by means of cross sliding tools. Machines are simple in design.
- Head stock with spindle is mounted on bed.
- 2 cross slides are located on bed at front end of spindle.
- CAMS on cam shaft actuate movements of cross slide through system of levers.

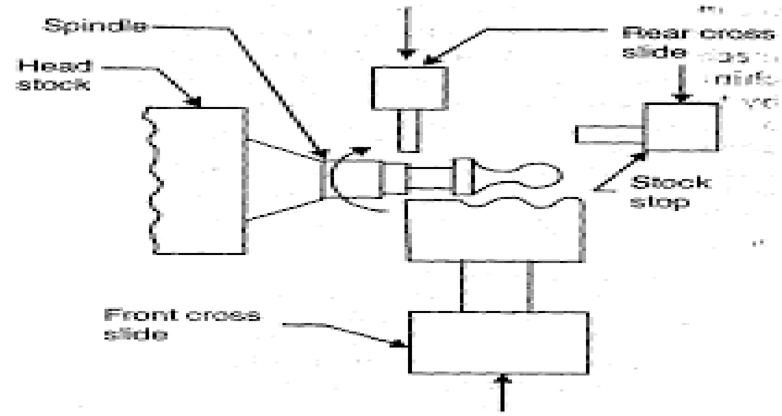


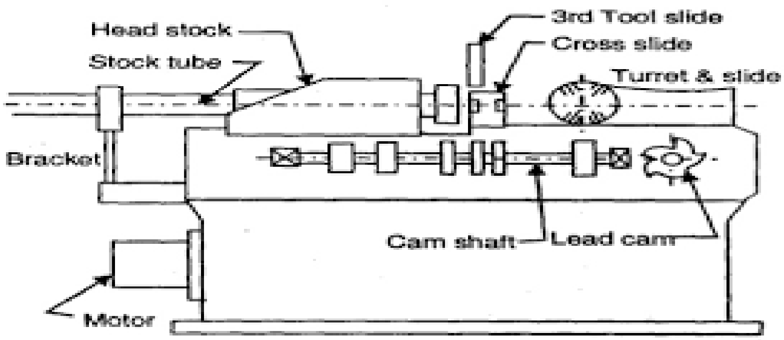

Fig. 8.2. Automatic Cutting-off Machine.

**Operation:**

- The required length of work(stock) is fed out with a cam mechanism, up to stock stop which is automatically advanced in line with spindle axis at each end of cycle.
- Stock is held in collet chuck of rotating spindle.
- Machining is done by tools that are held in slides operating only in cross wise direction.
- Typical simple parts (3 to 20 mm diameter) machined on such a machine is shown in fig.

**2. Automatic Screw Cutting machine**

- This machine is also called Turret type automatic Screw cutting machine, because it has a Turret head.
- This machine is used for producing small screws of all types. Complex shapes on external and internal surface of parts can be produced.
- Parts are produced from bar stock or from separate blanks.
- The size of parts varies from 12.5 mm to 60 mm in. diameter.
- The different operations performed on this machine are Centring, Turning, cylindrical, tapered and formed surfaces, threading, Drilling, Boring, Reaming, Spot facing, Knurling, cutting off.




**Operation:**

- Head stock is stationary & houses the spindle
- Bar stock is held in collet chuck & advanced after each piece is finished & cutoff.
- All movements of machine units are actuated by cams mounted on camshaft.
- Bar stock is pushed through stock tube in a bracket & its leading end is clamped in rotating spindle by means of collet chuck.
- By stock feeding mechanism bar is fed out for next part
- Machining of central hole is done by tools that are mounted on turret slide.

- ❖ Parting off/ Cutting off, form tools are mounted on cross. slide.
- ❖ At end of each cut turret slide is withdrawn automatically & indexed to bring next tool to position.

### 3. Swiss Type Automatic lathes or Sliding He Automatic lathes

- ❖ This machine was designed and developed in Switzerland. It is also called Swiss Auto Lathe.
- ❖ This machine is also known as Sliding Head Screw machine or Movable Head stock machine.
- ❖ This machine is used for machining long accurate parts of small diameters say 2 to 25 mm. These parts are produced from Bar stock.
    - ❖ The machine has the following features:-
        - ➢ A Sliding head stock
        - ➢ A Tool bracket having 2 to 5 tool slides
        - ➢ A special attachment called Feed base.
        - ➢ A Cam shaft

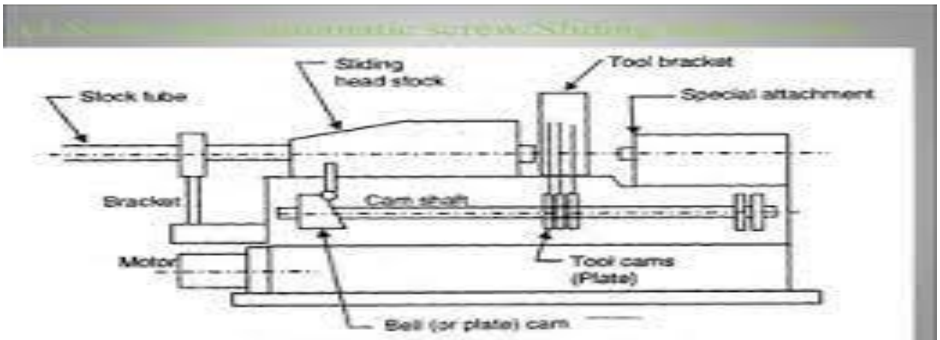



Fig. 8.7. Swiss Type Automatic

### Operation:

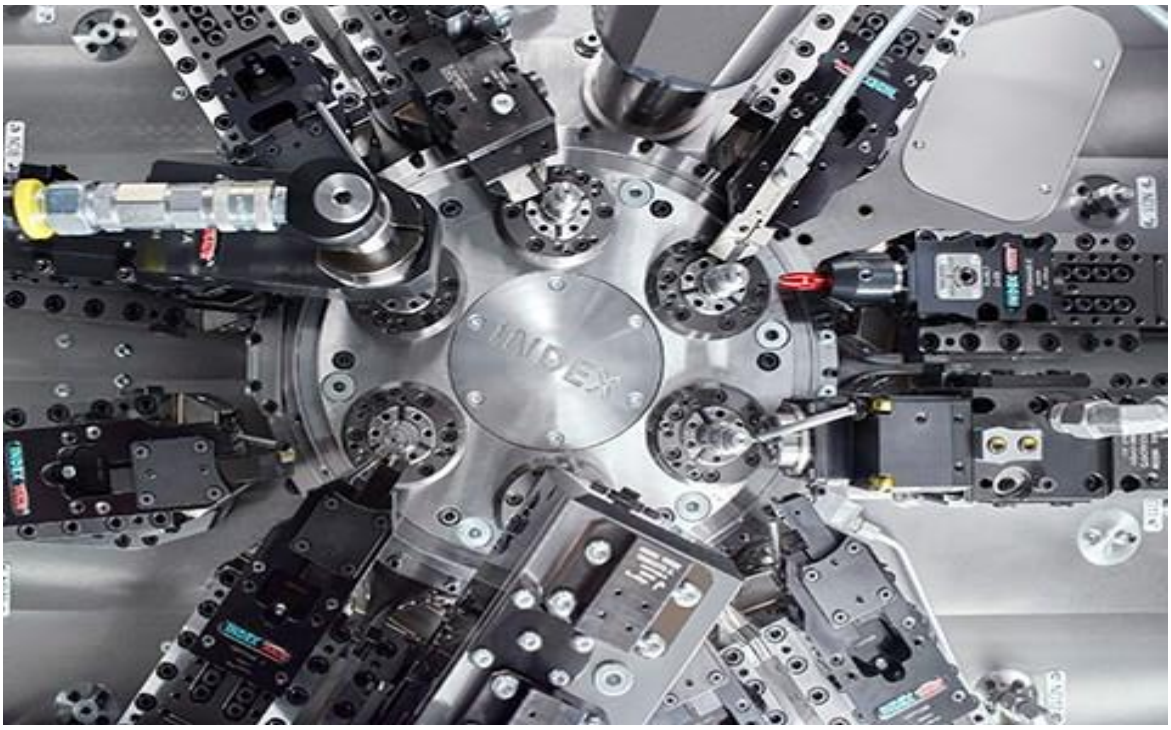
- ❖ The bar stock is held in the rotating spindle by a Coll.
- ❖ Head stock slides along the bed ways with the rotating bar stock. Head stock movements gives longitudinal feed to the work.
- ❖ All the tools in tool slides removes material from workpiece at same time.
- ❖ The tool in the Feed base may also do operations like Drilling
- ❖ After the work piece is machined, head stock slides back to the original position.
- ❖ One revolution of the Cam shaft produces one component.
- ❖ Most of the turning and forming operations are done by the tools held on the Front and Rear tool slides.
- ❖ The vertical tool slides are mainly used for Under cutting, Chamfering, knurling and Cutting off..

## MULTI-SPINDLE AUTOMATS

- ❖ Multi-spindle lathes have multiple spindles, typically two or more. Each spindle contains a bar or blank of material that is being machined simultaneously. A common configuration is six spindles.

### What is the principle of multi spindle automats?

- This type of machine has the ability to provide various types of operations which include boring holes, turning, chamfering, threading, grooving as well as drilling and this is done by moving the piece that is being worked on between six to eight positions in the machine.




- These are fastest type of production machines and are made in a variety of models with 2,4,5,6,8 spindles.
- In contrast with single spindle m/c where one turret face at a time is working on one spindle, in multi spindle m/c all turret faces works on all spindles at same time.
- Production capacity is higher, machining accuracy is lower compared to single spindle.
- Because of longer set up time, increased tooling cost these machines are less economical than other on short runs, more economical for longer runs.
- The Multi-spindle automatic lathes are classify as follows: -

1. According to type of work piece used:

    a. Bar type machine

    b. Chuck type machine

2. According to arrangement of spindles;

    a. Horizontal spindle type

    b. Vertical spindle type

3. According to principle of operation:

    a. Parallel action type

    b. Progressive action type

## 1. Parallel Action Multi-Spindle Machine

- This is also called multi spindle flow machine. Same operation is done in all the spindles in the machine.
- The work piece is finished in each spindle in one working cycle. The rate of production is very high.
- This machine is suitable for Production of small parts of simple shape from bar stock.
- The machine has frame with headstock. In the headstock horizontal spindles are situated.
- All the working motion and idle motion of all the spindles are obtained from a cam mounted on shaft.
- If anything goes wrong in one spindle station, the production in that particular station only affected.

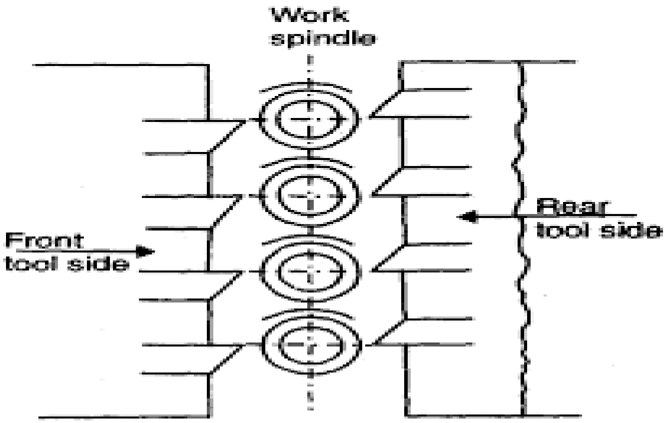



Fig. 8.10. Parallel-action multi-spindle

## 2. Progressive Action Multi-Spindle Machine

- In this type, the work pieces are machined in stages.
- The headstock is mounted on left end of base of machine.
- The headstock has spindle carrier. Working spindles are mounted in spindle carrier.
- Work pieces are held in collets in the spindles.
- Bar stock is fed through each spindle from the rear.
- Cross slides are mounted in a frame above the face of spindle carrier.
- These tool slides carry forming, facing, chamfering and cutting off tools.
- These cross slides travel radially inward for cutting operation.
- The slide movement is controlled by cam in cam shaft.
- The main tool slide is situated in front of spindle carrier. Here also, number of tool slide around its periphery.
- There is one tool slide corresponding to each spindle.
- Tool moves towards the spindle while machining.
- Operations like straight turning, boring and threading are done by tools mounted on these tool slides.

- The spindle carrier indexes on its own axis by 60° at the end of tool return.
- As the spindle carries indexes, work moves from station to station.

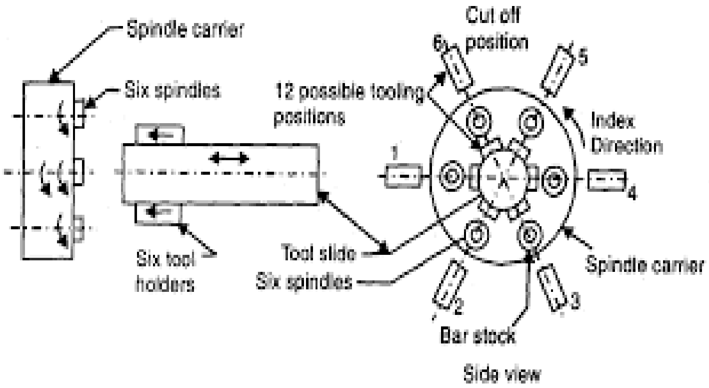



Fig. 8.11. Six Spindle Progressive Action Automatic.

## Different between single &multi spindle automates

| S. No. | Single spindle | Multi spindle |
|---|---|---|
| 1. | There is only one spindle. | There are 2, 4, 5, 6 or 8 spindles. |
| 2. | Only one workpiece is machined at a time. | A number of workpieces are machined at a time. |
| 3. | The rate of production is low. | The rate of production is high. |
| 4. | Machining accuracy is higher. | Machining accuracy is lower. |
| 5. | Tool setting time is less. | Tool setting time is more. |
| 6. | Tooling cost is less. | Tooling cost is more. |
| 7. | It is more economical for shorter as well as longer runs. | It is more economical for longer runs only. |
| 8. | The time required to produce one component is the sum of all turret operation times. | Time required to produce one component is the time of the longest cut in any one spindle. |
| 9. | Tools in turret are indexed. | Workpieces held in spindles are indexed (Progressive action machine). |

## SHAPING AND PLANNING MACHINES -TYPES -CONSTRUCTION -MECHANISM AND -PRINCIPLE OF DIFFERENT TYPES OF SHAPING OPERATIONS

## SHAPING MACHINES

**Introduction:**

The shaper is a machine tool used primarily for:

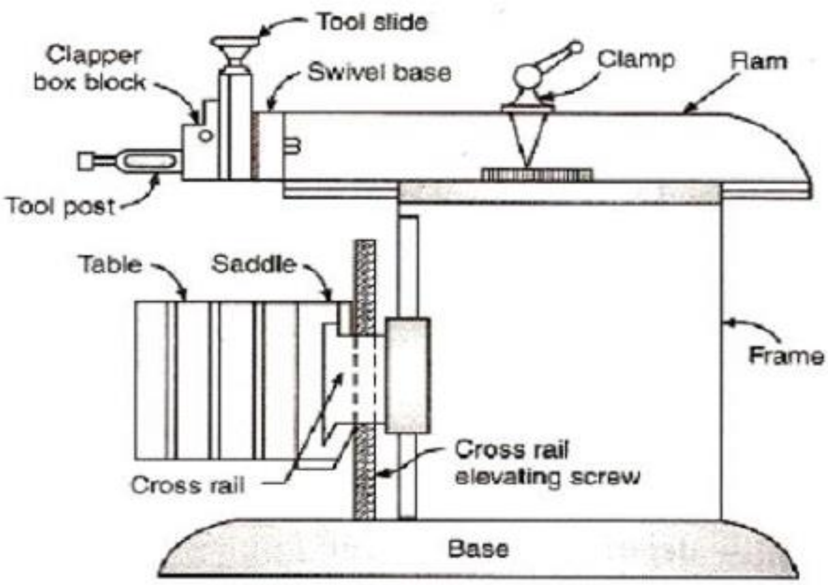
1. Producing a flat or plane surface which may be in a horizontal, a vertical or an angular plane.

2. Making slots, grooves and key ways
3. Producing contour of concave/convex or a combination of these.


**Main Parts of Shaper Machine**

**Working Principle:**

- The job is rigidly fixed on the machine table. The single point cutting tool held properly in the tool post is mounted on a reciprocating ram. The reciprocating motion of the ram is obtained by a quick return- motion mechanism. As the ram reciprocates, the tool cuts the material during its forward stroke. During return, there is no cutting action and this stroke is called the idle stroke. The forward and return strokes constitute one operating cycle of the shaper.




**Construction:**

- ❖ The main parts of the Shaper machine is Base, Body (Pillar, Frame, Column), Cross rail, Ram and tool head (Tool Post, Tool Slide, Clamper Box Block).

**Base:**

- ❖ It is the main body of the machine. It consist all element of machine. It works as pillar for other parts. Base is made by cast iron which can take all compressive loads.

**Ram:**

- ❖ It is the main part of the shaper machine. It holds the tool and provides the reciprocating motion to it. It is made by cast iron and move over ways on column. It is attached by the rocker arm which provide it motion in crank driven machine and if the machine is hydraulic driven it is attached by hydraulic housing.

**Tool head:**

- ❖ It is situated at the front of the ram. Its main function is to hold the cutting tool. The tool can be adjusted on it by some of clamps.

**Table:**

- ❖ It is the metal body attached over the frame. Its main function is to hold the work piece and vice over it. It has two T slots which used to clamp vice and work piece over it.

**Clapper box:**

- ❖ It carries the tool holder. The main function of clapper box is to provide clearance for tool in return stock. It prevents the cutting edge dragging the work piece while return stock and prevent tool wear.

**Column:**

- ❖ Column is attached to the base. It provides the housing for the crank slider mechanism. The slide ways are attached upper section of column which provide path for ram motion.

**Cross ways:**

- ❖ It consist vertical and horizontal table sideways which allow the motion of table. It is attach with some cross movement mechanism.

**Stroke adjuster:**

- ❖ It is attached below the table. It is used to control the stroke length which further controls the ram movement.

**Table supports:**

- ❖ These are attached front side of the table and used to support the weight of table during working.

## Types of Shaper:

Shapers can classified into many types based on several criteria:

1) Based on the type of driving mechanism used

   a) Crank and slotted lever driving mechanism type

b) Whitworth quick return driving mechanism type

c) Hydraulic driving mechanism type

2) Based on the table design

a) Plain Shaper

b) Universal Shaper

3) Based on the position of the reciprocating ram used

a) Horizontal shaping machine (Most common type of shaper used)

b) Vertical shaping machine

c) Travelling head shaping machine

4) Based on the type of cutting stroke of the tool

a) Push out type

b) Draw cut type

## DIFFERENT TYPES OF SHAPING OPERATIONS

Types of operations performed in a shaper

1. Machining horizontal surface.
2. Machining vertical surface.
3. Machining angular surface.
4. Cutting slots, grooves and keyways.
5. Machining irregular surface.
6. Machining splines or cutting gear.

## MECHANISM

**Quick Return Mechanism -Types**

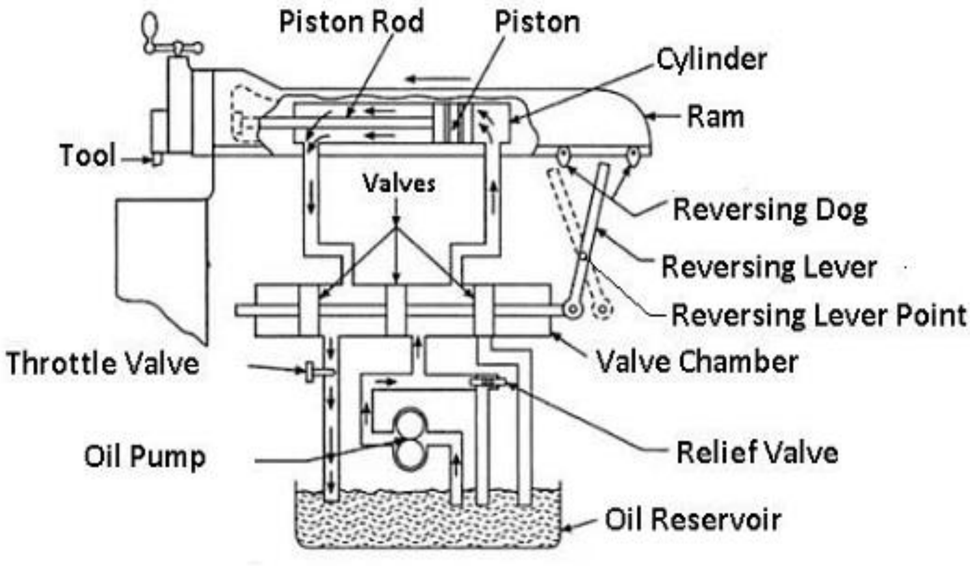
- ❖ A quick return mechanism is an system to produce a reciprocating effect such that time taken by systemin return stroke is less time taken by it in the forward stroke.In quick return mechanism, a circular motion is converted into reciprocating motion just like crank and lever mechanism but it has return stroke time is different from forward stroke time.This mechanism is used in many machines. Some of them are shaper machines, slotter machines, screw press, mechanical actuator etc. With the help of quick return mechanism, the time needed to cutting is minimized.

**Types of Quick Return Mechanism: -**

**1 Hydraulic Drive:**

- Hydraulic drive mechanism is one of the mechanisms used in shaper machine.
- In this mechanism, the ram is moved forward and backward by a piston moving in a cylinder placed under the ram.
- This machine consists of a constant discharge oil pump, a cylinder , a valve chamber and a piston.

- The piston rod is bolted to the the ram body.
- Hydraulic fluid is used in hydraulic quick return mechanism for the movement of ram.




**Working of Hydraulic Drive :-**

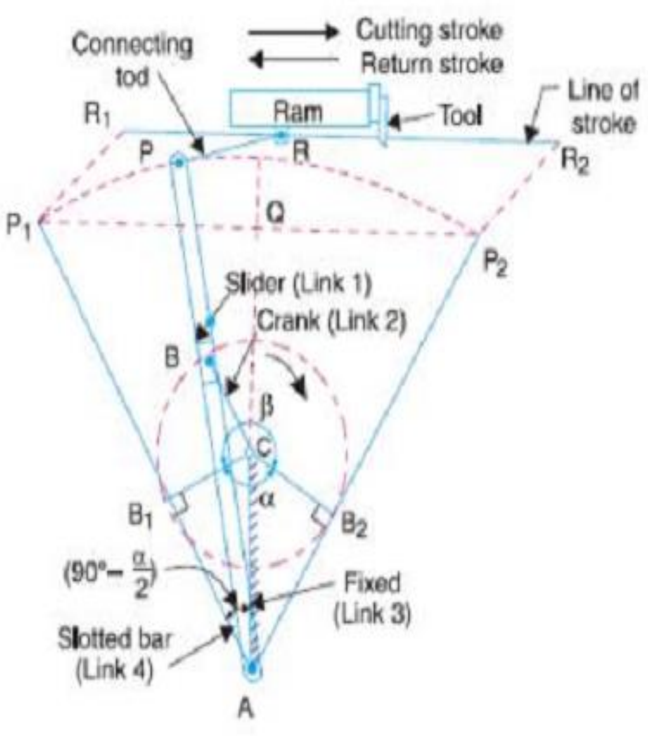
- ❖ In hydraulic drive, there is a tank at the bottom which contains the hydraulic fluid.
- ❖ This tank is also known a soil reservoir.
- ❖ At first the oil from the reservoir.
- ❖ This oil is passed through the valve chamber present in the right of the oil cylinder exerting pressure on the piston.
- ❖ Any oil present in the left side of the piston is discharged to the reservoir through the throttle valve. At first the fluid in the tank is pumped out and this fluid passes through the passage present in the right side of the cylinder.
- ❖ This fluid exerts pressure on the piston and the ram of the machine performs forward stroke.
- ❖ When the ram moves forward, the lever changes its position and hits the reversing dog. As the lever changes its position, the three valves connected to the lever also change their position and now the oil can pass through the passage present in the left side of the cylinder.
- ❖ After the forward stroke is completed, the valves changes its position and now the pumped fluid from the reservoir moves from the passage present in the left side of the piston. Also, the passage through which the oil return to the reservoir opens and get connected to the right passage and the fluid present on the right side of the piston is discharge to the reservoir.
- ❖ As the fluid moves towards the left side of the piston, the piston which is attached to the ram moves towards right and return stroke is performed by the ram.

- At the end of the return stroke, another dog hit against the lever and the direction of the lever as well as the stroke changes. In this way, the forward and the return stroke of the ram is repeated.
- The quick return takes place due to difference in the stroke volume of cylinder at both ends. The volume of passage at the left side is less than the volume of the passage on the right side. As the pump is constant discharge pump, same amount of oil will be passed on the both passage. So the pressure n the passage with less volume will be more and the return stroke will be faster than the forward stroke.
- The cutting speed can be controlled by controlling the flow of oil which can be controlled by using the throttle valve.

## 2. Whitworth Quick Return mechanism :-

- This mechanism changes the rotary motion to oscillatory motion like the crank and lever mechanism. The difference between the crank and lever mechanism and Whitworth mechanism is that in Whitworth mechanism the return stroke is faster than the forward stroke while in the crank and lever mechanism the forward stroke is of same speed as that of return stroke.
- Parts used in Whitworth mechanism :-

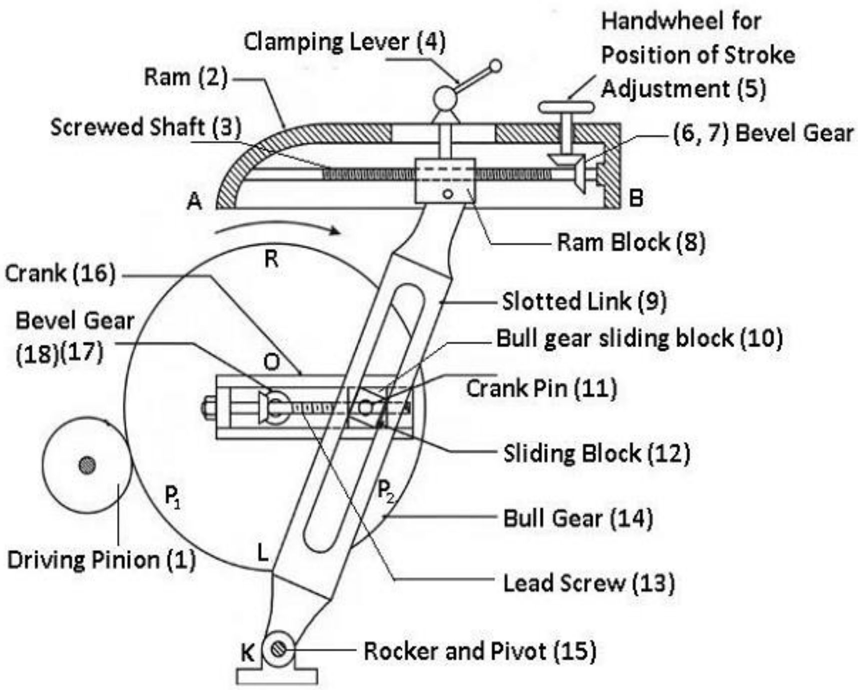
1) Slotted Bar.
2) Slider
3) Crank – It will rotate.



- ❖ Whitworth quick return mechanism is the second inversion of slider crank mechanism in which the crank is fixed.
- ❖ In this mechanism, the Slider in slotted bar is connected to the crank. When the crank rotates, the slider will slide inside the slotter bar and the slotted bar will oscillate. As the slotted bar oscillate, the ram will move in forward and backward direction.
- ❖ The return stroke or ideal is faster than the forward stroke in this mechanism.
- ❖ In the above figure AP is the slotted bar and link 1, CD is link 2, AC which is crank is link 3 and link 4 is the slider.
- ❖ In this mechanism the link CD i.e. link 2 forming the turning pair is fixed as shown in the figure above.
- ❖ The crank AC revolves with uniform velocity with its centre at A.
- ❖ A sliding block attached to the crank pin at B slides along the slotted bar AP and thus causes Ap to oscillate about the pivoted pint A. A short link PR transmits the motion from AP to the ram which carries the tool and thus forward stroke and backward stroke is obtained.
- ❖ The crank needs to rotate through an angle of ( β ) for the forward stroke and it needs to rotate through an angle of ( α ) for forward stroke.
- ❖ As crank moves with uniform angular velocity , time taken to cover angle α will be less than the time taken to cover angle β. Hence time taken in return stroke will be less than time taken in forward stroke. In this way, the quick return mechanism works.

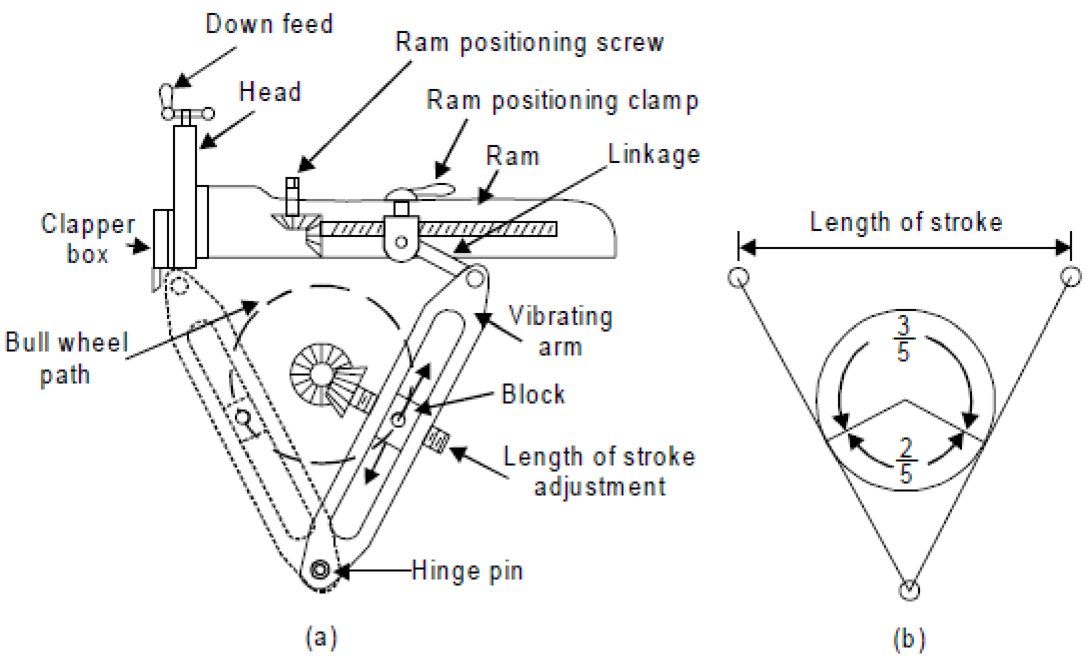
## 3) Crank and Slotted Link Mechanism:-

- ❖ In crank and slotted link mechanism. The power is transmitted to the bull gear by a pinion which receives its power from an individual motor.
- ❖ In a two-gear system, the smaller gear is called pinion and the larger gear is called bull gear.




## Crank and Slotted Link Mechanism (fig below)

- In crank and slotted link mechanism Fig. the pinion receives its motion from an individual motor or overhead line shaft and transmits the motion or power to the bull gear. Bull gear is a large gear mounted within the column. Speed of the bull gear may be changed by different combination of gearing or by simply shifting the belt on the step cone pulley.
- A radial slide is bolted to the centre of the bull gear. This radial slide carries a sliding block into which the crank pin is fitted. Rotation of the bull gear will cause the bush pin to revolve at a uniform speed. Sliding block, which is mounted upon the crank pin is fitted within the slotted link.
- This slotted link is also known as the rocker arm. It is pivoted at its bottom end attached to the frame of the column.
- The upper end of the rocker arm is forked and connected to the ram block by a pin. With the rotation of bull gear, crank pin will rotate on the crank pin circle, and simultaneously move up and down the slot in the slotted link giving it a rocking movement, which is communicated to the ram. Thus, the rotary motion of the bull gear is converted to reciprocating motion of the ram.




## Working of Crank and Slotted Link Mechanism:-

- The radial slide is bolted to the centre of the bull gear. This radial slide carries a sliding block into which the crank pin is fitted.
- As the bull gear will rotate, the crank will revolve at uniform speed.
- The sliding block which is mounted upon the crank pin is fitted upon the crank pin is fitted within the slotted link. This slotted link is pivoted uponat its bottom end attached to the frame of column. The upper end of the sliding link is bifurcated and attached to the ram block by a pin.
- When the bull gear rotates, the crank pin revolves at a uniform speed. The sliding block fastened to the crank pin will rotate on the crank pin circle and at the same time this slider will slide up and down in the sliding link.
- As the slider will move inside the sliding link, it will provide a rocking movement to the sliding link and this movement will be transferred to the ram providing it a reciprocator motion.

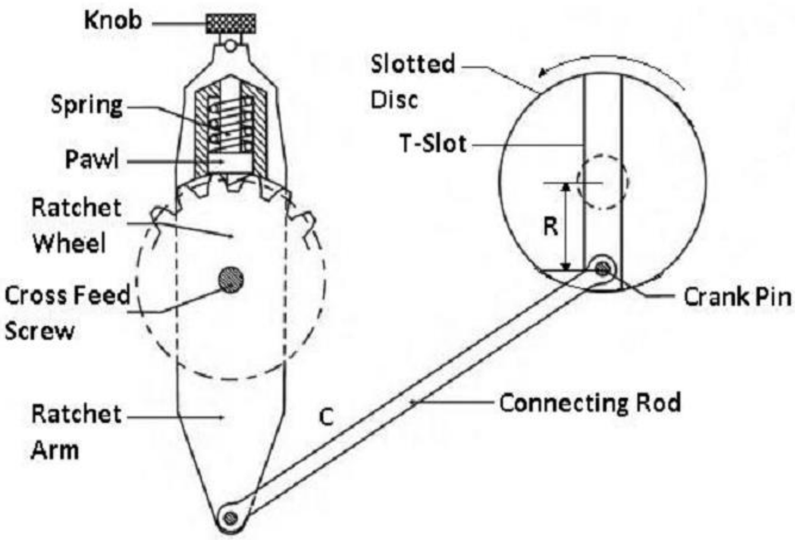
## Automatic Table feeding mechanism of shaper

- The automatic feed mechanism of the table is very simple. This is done by rotating a ratchet wheel, mounted at the cross feed screw. This enables a corresponding equal rotation of the cross feed screw after each stroke.

## Arrangement of parts

- It consists of a slotted disc, which carries a T-slot, as shown in the figure. In this slot is fitted an adjustable pin and to this is attached a connecting rod. The other end of the connecting rod is attached to the lower end of the rocker arm of the pawl mechanism.

❖ The rocker arm swings about the screw C, and at its upper end carries a spring-loaded pawl, as shown




## Working

❖ Note, that the lower end of the pawl is bevelled on one side. This arrangement helps the power feed to operate in either direction, but the same should be set to operate during the return stroke only. If otherwise, the mechanism will be subjected to severe stress. In some latest types of shapers, can driven feed mechanisms are provided which are more efficient and provide a wider range of feed.

❖ Variation in the feed can be provided by varying the distance R between the disc centre and the centre of the adjustable pin. Larger the said distance greater will be the feed and vice versa. The amount of feed to be given depends upon the type of finish required on the job.

❖ For rough machining, heavier cuts are employed, and thus, a coarse feed is needed. Against this, a finer feed is employed in finishing operations. The slotted disc at its back carries a spur gear which is driven by the bull gear. As the disc rotates through this gear the adjustable pin, being eccentric with the disc centre. This causes the connecting rod to reciprocate. This, in turn, makes the rocker arm to swing about the screw C to move the pawl over one or more teeth. Thus transmit an intermittent motion to the cross feed screw which moves the table.

## Shaper Machine – Specifications

a. Length of Ram stroke: (457 mm)

b. Range of Ram speeds: (12, 24, 40 & 72 strokes per minute)

c. Working surface of table: (483 mm * 330 mm)

d. Max Table Travel – Horizontal: (610 mm)

e. Max Table Travel – Vertical: (457 mm)

f. Angular movement of table on either side: (600)

g. Maximum size of Tool Shank in Tool Head: (51m * 21mm)

h. Maximum vertical travel of Tool Slide: (152 mm)

i. Maximum swivel of Tool Head: (600)

j. Main Drive Motor: (3 H.P./ 950 rpm)

## CUTTING PARAMETERS OF A SHAPER

**Cutting Speed**

- It is defined as the average linear speed of the tool during the cutting stroke in m/min, which depends on number of ram strokes ( or ram cycles) per minute and length of the stroke.

**Feed**

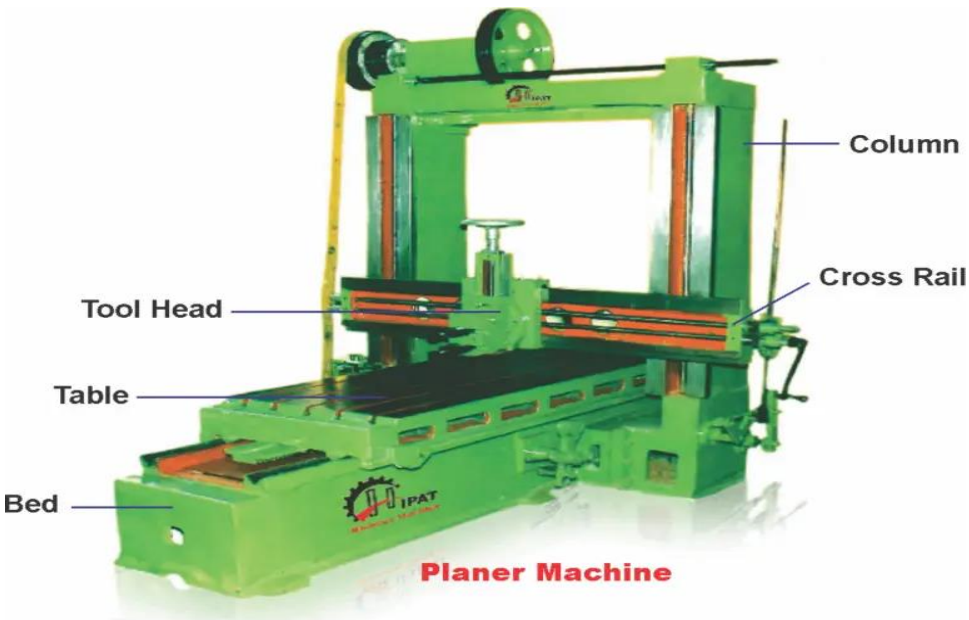
- Feed f is the relative motion of the work piece in a direction perpendicular to the axis of the reciprocation of the arm. In shaper, feed is normally given to the work piece and can be automatic or manual. It is expressed in mm/double stroke or simply mm/stroke because no cutting is done in return stroke.

**Depth of Cut**

- Depth of cut d is the thickness of the material removed in one cut, in mm.

## PLANER MACHINE

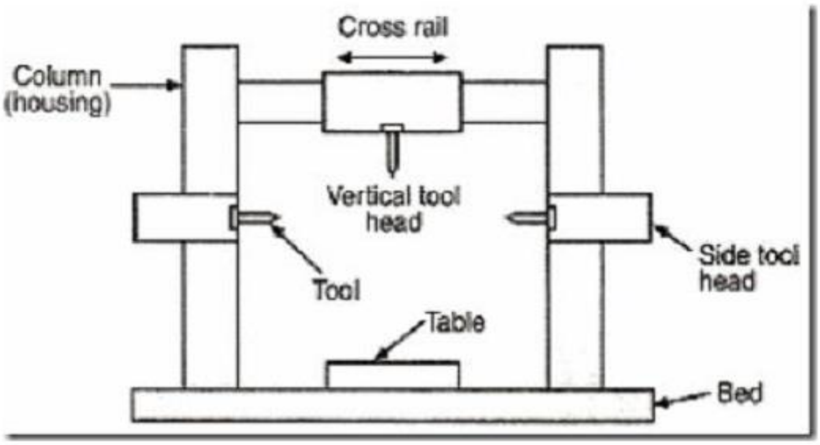
- The planer or planing machine is a machine tool, which like the shaper produces flat surfaces in horizontal, vertical or inclined plane.
- The fundamental difference is that the planer operates with an action opposite to that of the shapers, i.e., the work piece reciprocates past one or more stationary single point cutting tools.
- Planers are meant for machining large sized work pieces, which cannot be machined by the shaping machines.
- The work table is moved back and forth on the bed beneath the cutting head either by mechanical means , such as a rack and pinion gear or by a hydraulic cylinder.



## CLASSIFICATIONOF PLANNER

Planers are generally divided in to 5 types

1) Double housing planer
2) Open side planer
3) Edge type planer
4) Divide table planer
5) Pit type planer




## Parts of Planner

### 1) BED

- Bed of a planer is large in size and heavy in weight. It supports the column and all other moving parts of machine. It is made slightly longer than twice the length of the table may be moved on it. There is a v shaped ways on the bed which help to reciprocate or back and forth motion to the table.

### 2) TABLE

- Table supports the work and reciprocates along the bed. Table is made from cast iron. The top face of the table is accurately finished in order to locate the work correctly. T- slots are provided on the entire length of the table so that the work and work holding devices may be bolted upon it.

### 3) COLUMN

- These are rigid box like vertical structure placed on each side of the bed and table. They are heavily ribbed to trace up severe force due to cutting. It also facilitates tool head mechanism. The cross rail may be made to slide up and down for accommodating different heights of work.

### 4) CROSS RAIL

- ❖ It is rigid box like casting connecting the two columns. It may be raised or lowered on the face of housing and can be clamped at a desired position by manual or electrical clamping devices. It should remain absolutely parallel to the top surface of the table.

**5) TOOL HEAD**

- ❖ Tool heads are mounted on the crossrail by saddle. The saddle may be made to move transversely on the cross rail to give cross feed. The clapper block is hinged at hinge pins to the clapper block and it holds the tool post in which the tool is clamped by straps.

## Work Holding devices used in Planner

a) Heavy duty vices
b) T-bolts and Clamps
c) Step blocks-bolts and Clamps
d) Poppets or stop pins and dogs
e) Angle plates
f) Planer centres
g) Planer Jacks
h) V- blocks
i) Stops

## Planer Tools

a. Right hand, left hand - Straight roughing tools
b. Right hand, left hand - Bent roughing tools
c. Straight, Round nose, square nose and Goose neck - Finishing tools
d. Grooving or slotting tool
e. T-slot cutting tool
f. Dovetail slide cutting tool

## Specification of a Planer

1. Number of speeds and feeds available.
2. Power Input
3. Floor space required
4. Net weight of the machine
5. Type of drive

## Cutting Parameters of Planner machine

- ❖ Cutting speed - It is the rate at which the metal is removed during forward cutting stroke and is expressed in m/min
- ❖ Feed - It is the distance the tool head travels per double stroke at the beginning of each cutting stroke and is expressed in mm

- ❖ Depth of cut - It is the thickness of metal removed in one cut. It is measured by the perpendicular distance between machined and unmachined surfaces of the work. It is given in mm.

### PLANER OPERATIONS

1. Planing Horizontal Surfaces.
2. Planing Vertical Surfaces.
3. Planing curved surfaces.
4. Planing slots and grooves.
5. Planing at an angle and machining dove-tails.
6. Planing a helix.
7. Gang or multiple planing.

## Different between shaper and planer machine

| Shaper machine | Planer machine |
|---|---|
| In shaper ram moves in reciprocating and back and fourth | Platen/table reciprocates moves and also moves back and fourth |
| In shaper cutting tool moves back and forth | In planer work piece moves in back and forth |
| Used for the machining of small jobs | Used for the machining of large jobs |
| Each stroke of cutting tool ,gives the feed in cross wise. | In Each stroke of Platen or work piece feed are given by feed screw. |
| For the adjustment of Ram stroke crank mechanism are used | For the adjustment of platen gears and rack mechanism are used |
| Only one tool are used | Two or more tools are used |
| In shaper cutting speed ,feed range are in wide range | In planer machine cutting speed , cutting feed are limited |

### WORK HOLDING DEVICES

- ❖ Work holding is a catchall term referring to any device or apparatus used to keep a workpiece stable and immobile. Some common examples are chucks, toggle clamps, power clamps, end stops, soft or hard jaws, locators, vises, fixtures, and jigs. Ideal work holding devices have easily repeatable setups.

### Different types of work holding devices

## Work Holding Devices & Tool Holding Devices

| S.NO. | Work Holding Devices | Diagram | S.NO. | Tool Holding Devices | Diagram |
|---|---|---|---|---|---|
| 1. | jaw Chucks |  | 1. | Straight cutter holder |  |
| b. | Self-centering chuck |  | 2. | Multiple cutter holder |  |
| c. | Independent chuck |  | 3. | Offset cutter holder |  |
| d. | Combination chuck |  | 4. | Combination tool holder |  |
| e. | Air operated chuck |  | 5. | Knee tool holder |  |
| 2. | Collet chucks |  | 6. | Slide tool holder |  |
| a. | Push out type |  | 7. | Knurling tool holder |  |

| | | | | | |
|---|---|---|---|---|---|
| b. | Draw in type |  | 8. | Boring bar holder |  |
| c. | Dead length type |  | 9. | Recessing tool holder |  |

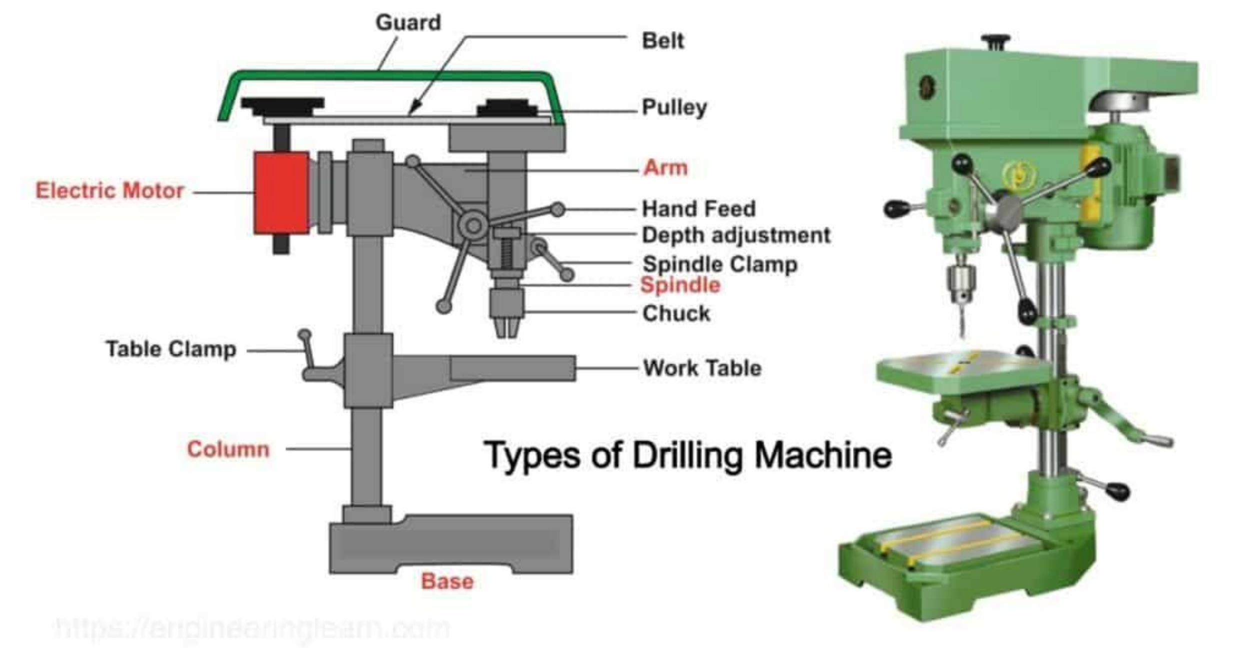
**UNIT III: DRILLING, BROACHING AND GRINDING MACHINES**

- Drilling machines-specifications-types-feed mechanism-operations.
- drill tool nomenclature.
- broaching- specifications- types-tool nomenclature-broaching operations
- grinding- types of grinding machines -grinding wheels-specifications-bonds-mounting and reconditioning of grinding wheels.

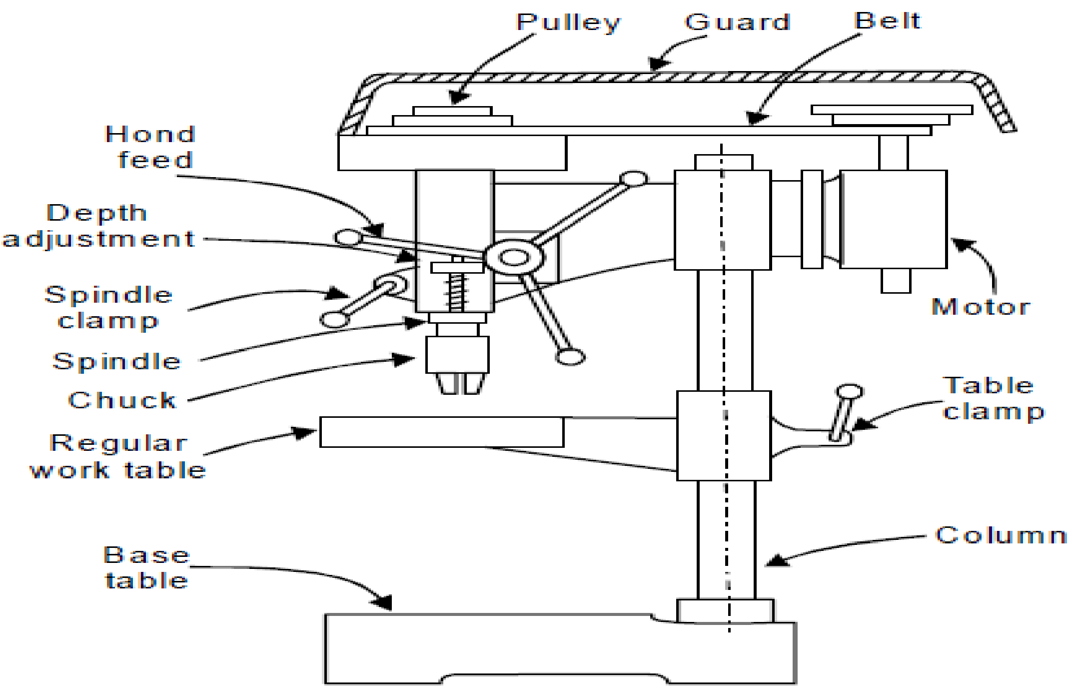
## DRILLING MACHINES-SPECIFICATIONS-TYPES-FEED MECHANISM-OPERATIONS- DRILL TOOL NOMENCLATURE.

## DRILLING MACHINES

- Drilling is an operation of making a circular hole by removing a volume of metal from the job by cutting tool called drill.
- A drill is a rotary end-cutting tool with one or more cutting lips and usually one or more flutes for the passage of chips and the admission of cutting fluid.
- A drilling machine is a machine tool designed for drilling holes in metals. It is one of the most important and versatile machine tools in a workshop. Besides drilling round holes, many other operations can also be performed on the drilling machine such as counter- boring, countersinking, honing, reaming, lapping, sanding etc.




❖ Base table is a heavy casting and it supports the drill press structure. The base supports the column, which in turn, supports the table, head etc. (*vi*) Column is a vertical round or box section which rests on the base and supports the head and the table. The round column may have rack teeth cut on it so that the table can be raised or lowered depending upon the workpiece requirements.




Construction of drilling machine

❖ This machine consists of following parts

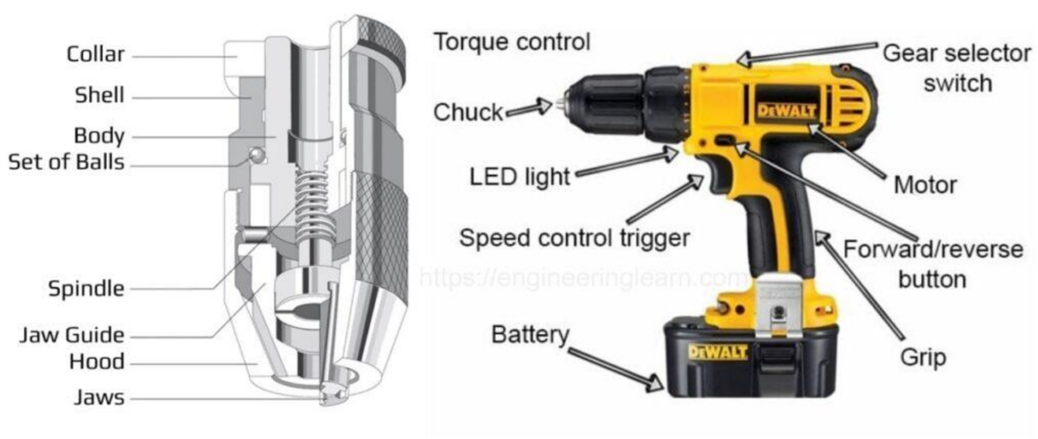
1. Base
2. Pillar

3. Main drive
4. Drill spindle
5. Feed handle
6. Work table

## TYPES OF DRILLING MACHINE

- Drilling machines are classified on the basis of their constructional features, or the type of work they can handle. The various types of drilling machines are:
    - (1) Portable drilling machine
    - (2) Sensitive drilling machine
        - a. Bench mounting
        - b. Floor mounting
    - (3) Upright drilling machine
        - a. Round column section
        - b. Box column section machine
    - (4) Radial drilling machine
        - a. Plain
        - b. Semi universal
        - c. Universal
    - (5) Gang drilling machine
    - (6) Multiple spindle drilling machine
    - (7) Automatic drilling machine
    - (8) Deep hole drilling machine
        - a. Vertical
        - b. Horizontal
- Few commonly used drilling machines are described as under.

### 1. Portable Drilling Machine:




Portable Drilling Machine

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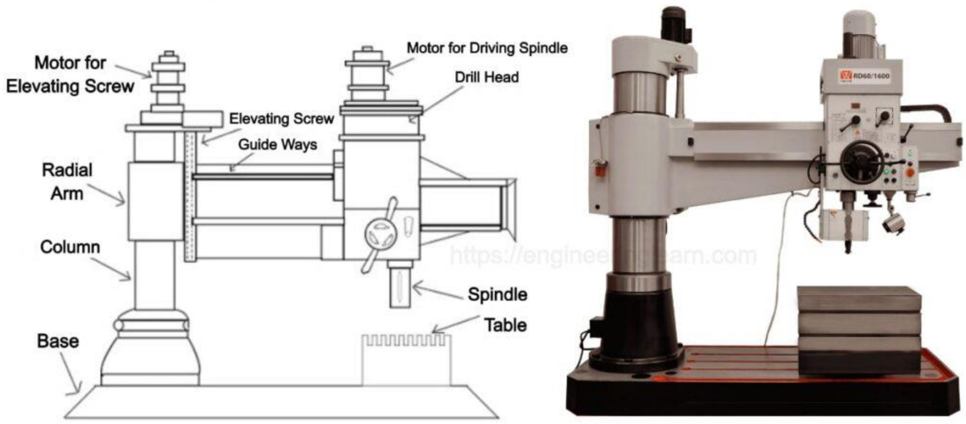
❖ This is known as hand drilling machine. The most common type of machine used by manufacturing company. This is designed for drilling holes into metal, wood or rock etc. This machine is usually smaller in size which makes an advantage for operation at different location sites. It operates with universal type of motor that is having 12-18 mm diameter. These drilling machines are quite efficient with operation abilities at high speed.

### 2. Sensitive Drilling Machine:


Sensitive Drilling Machine

❖ These are called as bench drilling machines, they are used to make small holes at high operating speed. It is mounted on the bench with the help of bolts/ nuts can be connected by hand or machine. Sensitive drilling machine are equipped with base, table & spindle.

### 3. Radial Drilling Machine:




Radial Drilling Machine

❖ These machines are used for making holes larger & heavy workpieces. As the name suggest it is equipped with radial arm in column which allows moving position vertically up or down for drilling the workpieces of various with respect to their different height. It is also used for rock drilling components that can be use by any company. Radial drill machine operates at driving mechanism of separate & different feed. The position of the machine is adjusted by sliding of drill & gateway of the arm.

### 4. Gang Drilling Machine:


❖ This machine having a long table & base structure likes of all other machines. It mainly contain 6 drill head placed side by side. The drill head having separate for their working. These machines are used for drilling, reaming.

**5. Deep Mole Drilling Machine:**


❖ This is a special types of drilling machine, designed to drill deep holes in connecting rods, spindle, as well as barrels of gun. These machines are ideal for creating deep holes achieved at high operating cutting speed & less feed & coolant to be used during the process.

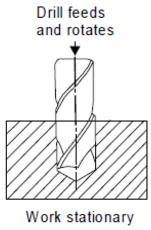
## Operations Performed on Drilling Machine

❖ A drill machine is versatile machine tool. A number of operations can be performed on it. Some of the operations that can be performed on drilling machines are:

| | |
|---|---|
| 1. Drilling | 2. Reaming |
| 3. Boring | 4. Counter boring |
| 5. Countersinking | 6. Spot facing |
| 7. Tapping | 8. Lapping |
| 9. Grinding | 10. Trepanning. |

***Drilling***

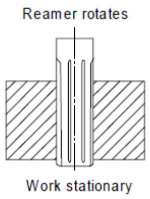
❖ This is the operation of making a circular hole by removing a volume of metal from the job by a rotating cutting tool called drill as shown in Figure. Drilling removes solid metal from the job to produce a circular hole. Before drilling, the hole is located by drawing two lines at right angle and a center punch is used to make an indentation for the drill point at the center to help the drill in getting started. A suitable drill is held in the drill machine and the drill machine is adjusted to operate at the correct cutting speed. The drill machine is started and the drill starts rotating. Cutting fluid is made to flow liberally and the cut is started. The rotating drill is made to feed into the job. The hole, depending upon its length, may be drilled in one or more steps. After the drilling operation is complete, the drill is removed from the hole and the power is turned off.




Drilling operation

***Reaming***

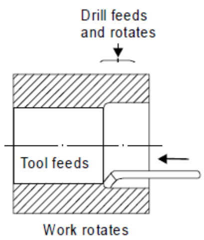
❖ This is the operation of sizing and finishing a hole already made by a drill. Reaming is performed by means of a cutting tool called reamer as shown in Figure. Reaming operation serves to make the hole smooth, straight and accurate in diameter. Reaming operation is performed by means of a multitooth tool called reamer. Reamer possesses several cutting edges on outer periphery and may be classified as solid reamer and adjustable reamer.




Reaming operation

***Boring***

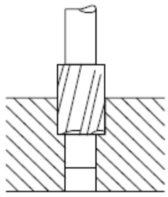
❖ Figure shows the boring operation where enlarging a hole by means of adjustable cutting tools with only one cutting edge is accomplished. A boring tool is employed for this purpose.




Boring operation

***Counter-Boring***

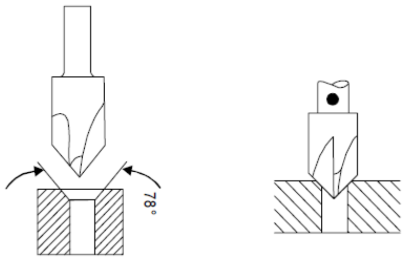
- Counter boring operation is shown in Figure. It is the operation of enlarging the end of a hole cylindrically, as for the recess for a counter-sunk rivet. The tool used is known as counter-bore.



Counter boring operation

***Counter-Sinking***

- Counter-sinking operation is shown in Figure. This is the operation of making a coneshaped enlargement of the end of a hole, as for the recess for a flat head screw. This is done for providing a seat for counter sunk heads of the screws so that the latter may flush with the main surface of the work.




Counter sinking operation

***Lapping***

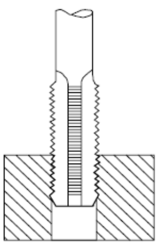
- This is the operation of sizing and finishing a hole by removing very small amounts of material by means of an abrasive. The abrasive material is kept in contact with the sides of a hole that is to be lapped, by the use of a lapping tool.

***Spot-Facing***

- This is the operation of removing enough material to provide a flat surface around a hole to accommodate the head of a bolt or a nut. A spot-facing tool is very nearly similar to the counter-bore

***Tapping***

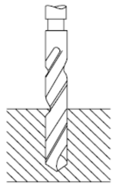
- It is the operation of cutting internal threads by using a tool called a tap. A tap is similar to a bolt with accurate threads cut on it. To perform the tapping operation, a tap is screwed into the hole by hand or by machine. The tap removes metal and cuts internal threads, which will fit into external threads of the same size. For all materials except cast iron, a little lubricate oil is applied to improve the action.



Tapping operation

***Core drilling***

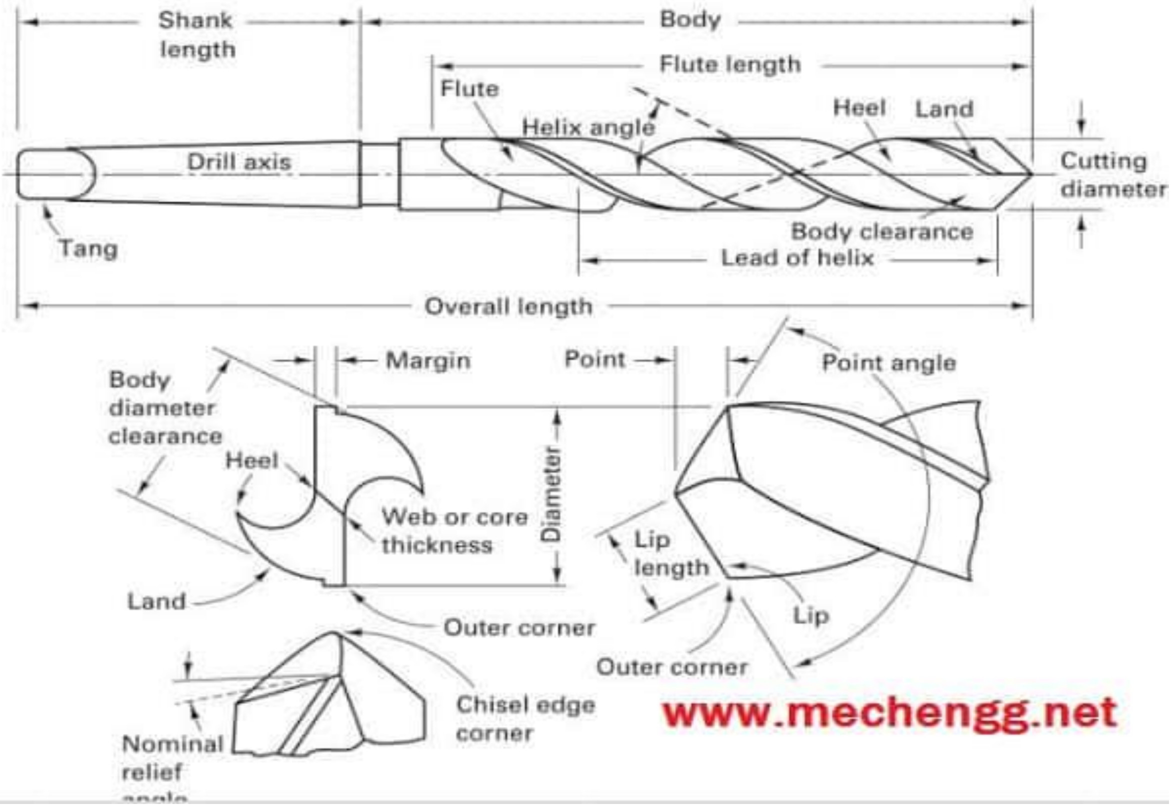
- Core drilling operation is shown in Figure. It is a main operation, which is performed on radial drilling machine for producing a circular hole, which is deep in the solid metal by means of revolving tool called drill.



Core drilling operation

## DRILL TOOL NOMENCLATURE.

- <u>**NOMENCLATURE OF THE DRILLING TOOL (DRILL)**</u>




- **Axis:** It is the longitudinal centre-line of the drill.
- **Diameter:** Largest diameter measured across the top of the lands behind the point.
- **Back Taper:**
    - The diameter reduces slightly toward the shank end of the drill, this is known as "back taper".
    - Back taper provides clearance between the drill and work-piece preventing friction and heat.
- **Body:** It is the part of the drill from its extreme point to the commencement of the neck.
- **Neck:** The portion with reduced diameter in between body and shank.
- **Shank:** It is the part of the drill by which it is held and driven. The shank may be straight or taper.
- **Tang:** The flattened end of the taper shank is known as tang.
- **Point:** It is the conical sharpened end of the drill.
- **Flank:** Surface of drill which extends behind the lip to flute.
- **Flutes:** The grooves in the body of the drill are known as flutes.
- **Flute Length:**
    - The length of flute measured from the drill point to the end of the flute run out.
    - Flute length determines the maximum depth of drilling.
- **Margins:** The cylindrical portion of the land that is not cut away to provide clearance.
- **Helix Angle:** Angle formed between a line drawn parallel to the axis of the drill and the edge of the land. (30° or 45°)
- **Point angle:** This is the angle included between the two lips projected upon a plane parallel to the drill axis and parallel to the two cutting lips. (118°).

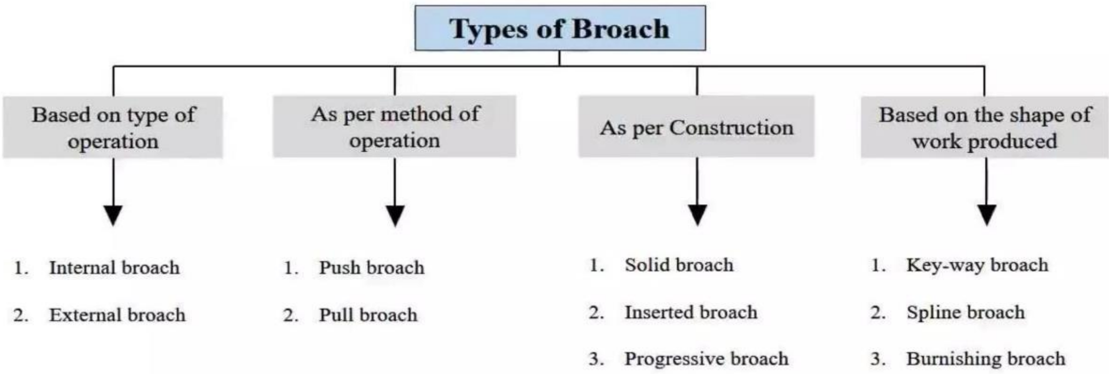
❖ **Chisel Edge:** it is the point where two cutting lips meets at extreme tip.
❖ **Chisel Edge Angle:** Angle between chisel edge and cutting lip measured plane normal to axis.

## BROACHING- SPECIFICATIONS- TYPES-TOOL NOMENCLATURE-BROACHING OPERATIONS .

## BROACHING MACHINE

❖ Broaching is a machining process for removal of a layer of material ofdesired width and depth.
❖ Usually in one stroke by a slender rod or bar type cutter having a series of cutting edges with gradually increased protrusion.

## BROACHING MACHINE TYPES



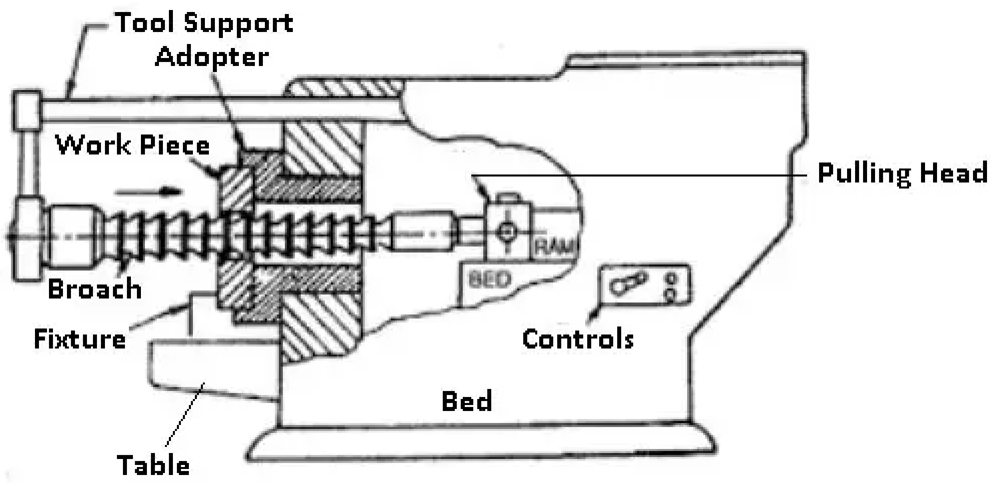

**Following are the main types of broaching machine**

- Horizontal broaching machine
- Vertical broaching machines
- Surface broaching machines
- Continuous broaching machine

### Horizontal Broaching Machine

❖ Nearly all horizontal machines are of the pull-type. They may be used for either internal or external broaching, although internal work is the most common.

❖ A **horizontal broaching machine** is shown in the figure. It consists of a bed or a base a little more than twice the length of the broaching stroke, a broach pilot and the drive mechanism for pulling the broach.

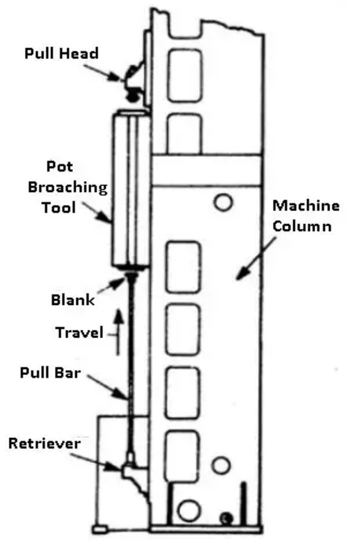



❖ Horizontal broaching machines are used primarily for broaching keyways, splines, slots, round holes, and other internal shapes or contours. They have the disadvantage of taking more floor space than do the vertical machines. However, long broaches and heavy workpieces are easily handled.

## Vertical Broaching Machine

❖ The vertical types may be obtained in either push or pull type. The push-type is the most popular. A **vertical broaching machine** is shown in the figure.

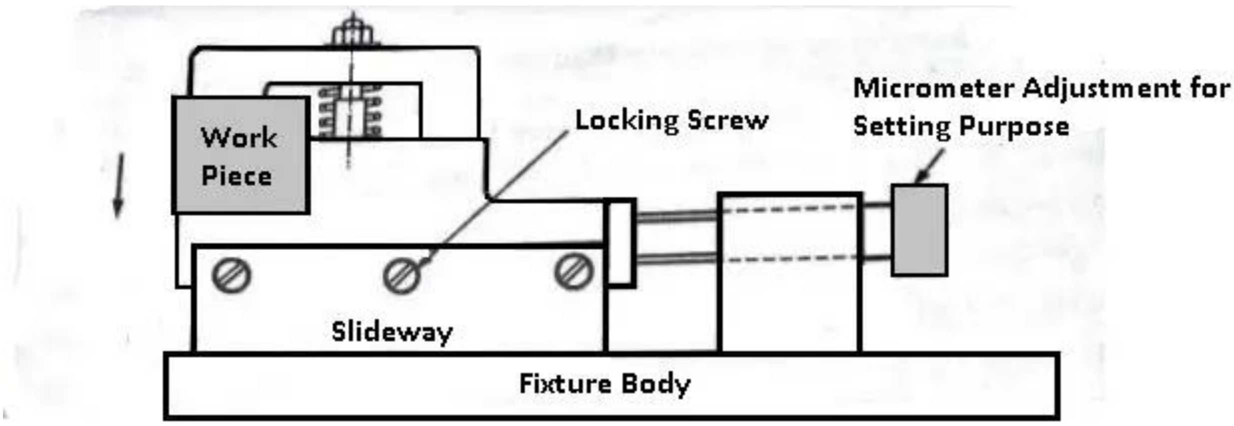
❖ Vertical machines are used in multiple operations since they are convenient to pass work from one machine to another. Of the three models available, pull down, pull up, and push down, the pull-up type is most popular. Vertical machines require an operator platform or a pit and are economical of floor space than the horizontal type.




VERTICAL BROACHING MACHINE

- Modern vertical broaches are offered with both hydraulic and electro-mechanical drives. But hydraulic drives are the most common because they cost less. A vertical hydraulic broaching machine is illustrated in above figure.

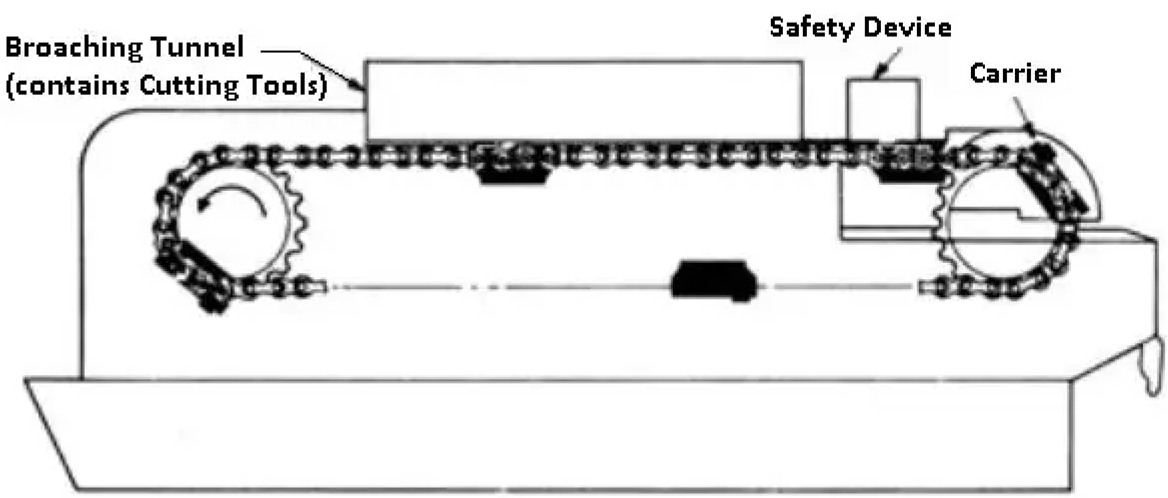
## Surface Broaching Machine




- **Surface broaching machines** have their broaching tools attached to a ram or rams forced in a straight path along guideways past the workpiece. On some surface broaching machines, the ram travels horizontally, on others ram travels vertically. When two rams are used, the machines is called a duplex broach.

## Continuous Broaching Machine

- For mass production of small parts, the highly productive continuous-broaching method is used on rotary or horizontal continuous-broaching machines.




- In the rotary **continuous broaching machines**, the workpiece is loaded on the table which rotates continuously. During the operation the broach is stationary.

- In the horizontal continuous broaching machines the workpieces travel as they are carried by an endless chain. The workpieces are loaded into work holding fixtures mounted on the continuously moving chain. During the operation, the broach is stationary as before. Such machines are used for broaching small parts.

**Following are the classification of broaching methods:**

1. Pull Broaching
2. Push Broaching
3. Surface Broaching
4. Continuous Broaching

Pull Broaching

- ❖ In the pull broaching the work is held fixed and the broach is pulled through the work. Usually, broaches are very long and are held in a special head. Pull broaching method is used for internal broaching but it also used for some surface broaching.

Push Broaching

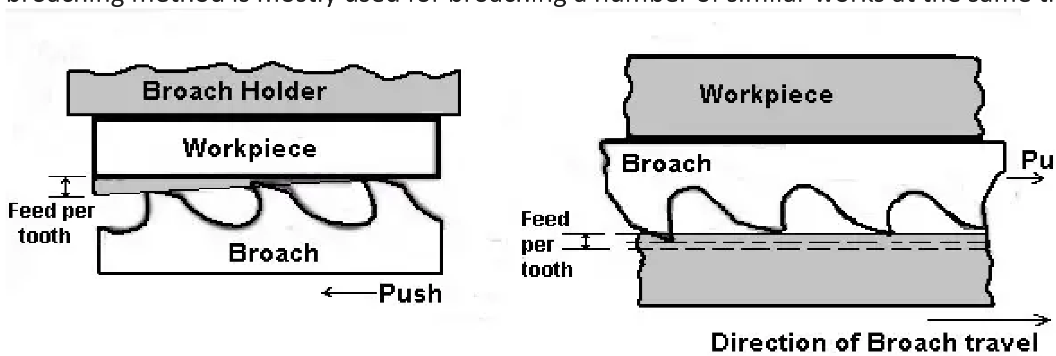
- ❖ In the push broaching the work is fixed and the broach is pushed through the work. Hand and hydraulic arbor presses are commonly used for push broaching. This method is used for sizing holes and cutting keyways.

Surface Broaching

- ❖ In surface broaching either the work or the broaching tool moves across the other. This method has become an important means of surface finishing. Many irregular or intricate shapes can be broached by surface broaching, but the tools must be specially designed for each job.

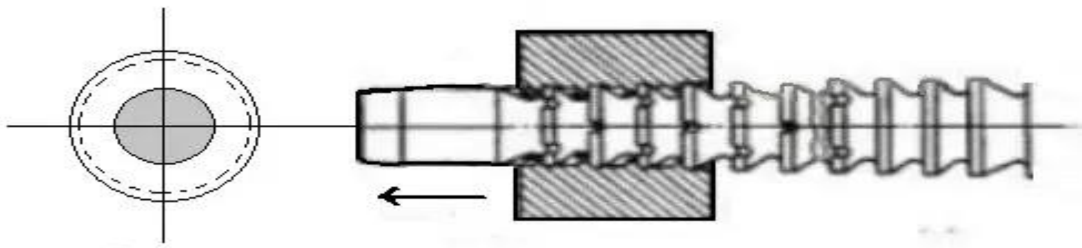
Continuous Broaching

- ❖ In continuous broaching the work is moved continuously and the broach us held stationary. The movement of work may be either straight horizontal or circular. The continuous broaching method is mostly used for broaching a number of similar works at the same time.

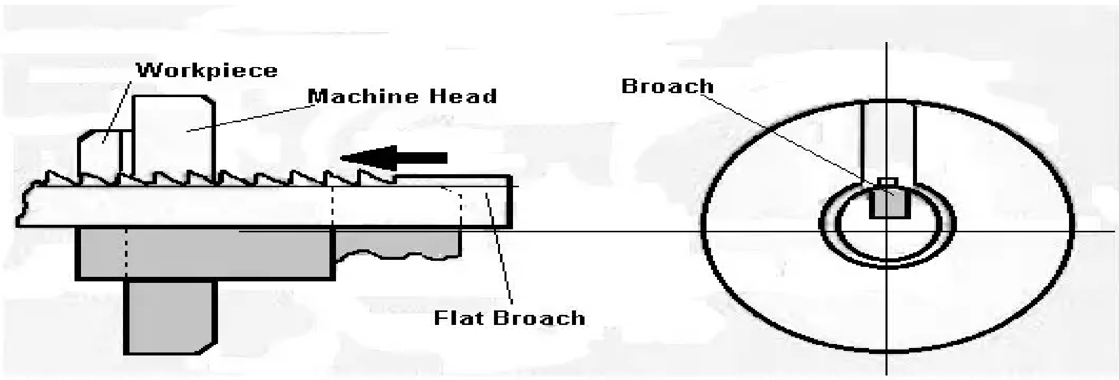



A push type broach in use for machining an external surface

A pull type broach in use for machining internal surface



Broaching hole with a round back




Broaching a keyway in a hole with a keyway broach

- The teeth of a gear or spline may be broached all together or one or a few at a time. A comparatively simple broach can be made to cut one or a few tooth spaces. After one pass, the gear blank is indexed and more of its teeth are cut. Successive passes are made until all the teeth are finished.

## Advantages and Limitations of Broaching

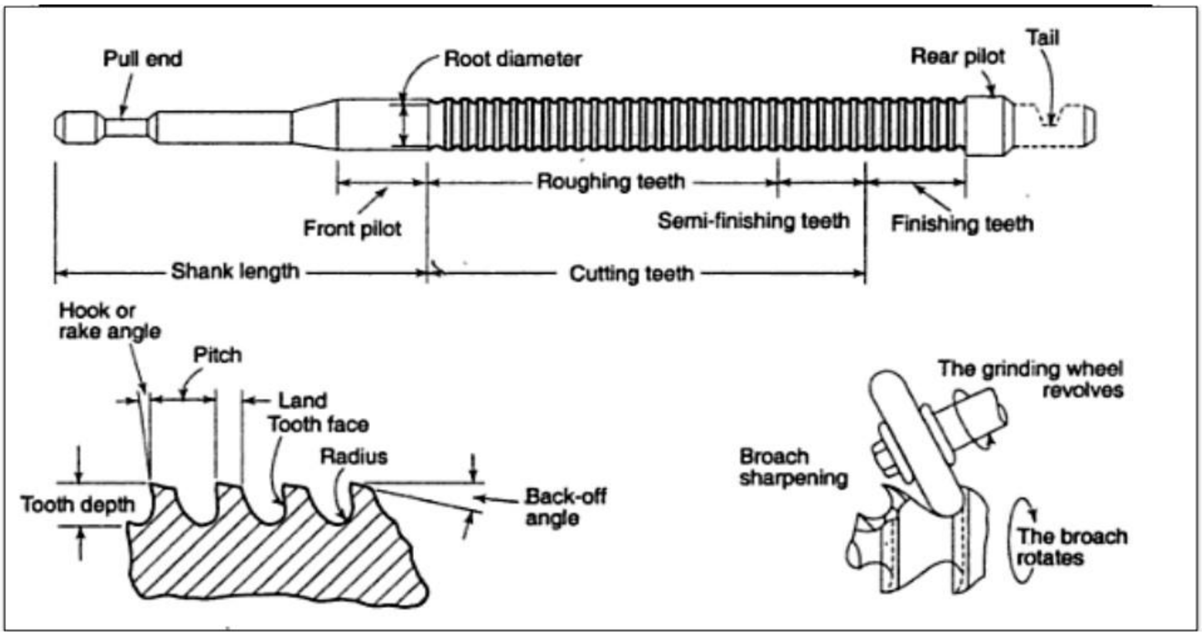
**Following are the features and advantages of the broaching**:

1. The rate of production is very high.
2. Skill is required from the operator to perform a broaching operation. In most cases, the operator merely loads and unloads the work-piece.
3. High accuracy and a high class of surface finish are possible. A tolerance of ±0.0075mm and a surface finish about 0.8 microns (1 micron=0.001mm) can be easily obtained in broaching.
4. Both roughing finishing cuts are completed in one pass of the tool.
5. The broaching process is used for internal and external surface finishing.
6. Any form or shape that can be reproduced on a broaching can be machined.
7. Cutting fluid may be readily applied where it is most effective because a broach tends to draw the fluid into the cut.

**For specific reasons, however, limit the utilisation of the broaching process. They are:**

1. High tool cost. A broach normally makes only one job and is expensive to make and sharpen.
2. Very large work-piece cannot be broached.
3. The surface to be broached cannot have an obstruction.
4. Broaching cannot be used to remove a large amount of stock.
5. Parts to be broached must be capable of being rigidly supported and must be able to withstand the force that set up during cutting.

## BROACHING TOOL NOMENCLATURE



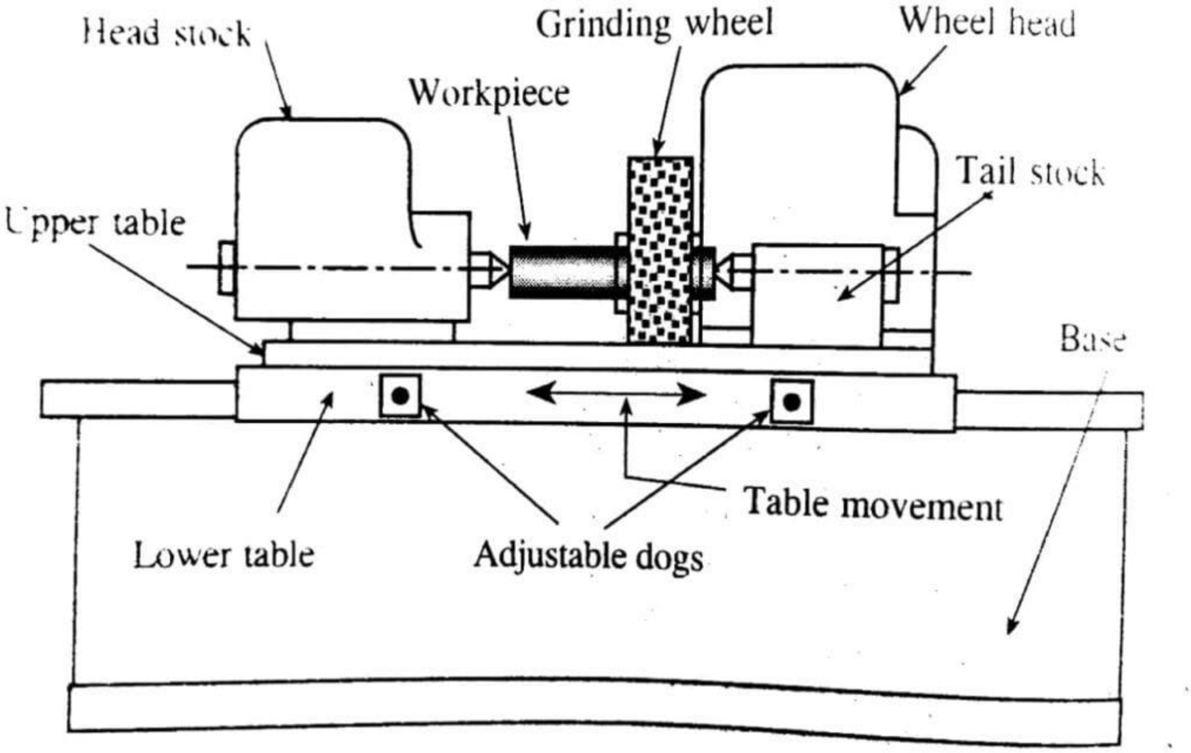

- **Pull end-** connected to pulling head of broaching machine.
- **Front pilot-** this locates the broach centrally with the hole to be broached.
- **Roughing teeth and semi-finished teeth-** used for removing most of metal in broaching.
- **Finishing teeth-** meant for finishing the hole to the size and shape.
- **Rear pilot-** meant for giving support to the broach after the last tooth leaving the work piece.
- **Land-** top portion of teeth.
- **Clearance or back off angle-** back of the tooth sloped to give clearance angle.
- **Rake or face angle-** angle made by sloping the front face of tooth. Depends upon workpiece material.
- **Pitch-** linear distance between one tooth to the next tooth. It is more in roughing teeth than finishing teeth.

## GRINDING- TYPES OF GRINDING MACHINES -GRINDING WHEELS-SPECIFICATIONS-BONDS-MOUNTING AND RECONDITIONING OF GRINDING WHEELS.

## GRINDING MACHINE

- A grinding machine, also called a grinder, is a power tool that uses an abrasive wheel to remove material from a workpiece. Grinding machines are used to:
  - Shape, smooth, or finish workpieces.
  - Improve the accuracy of a product.
  - Maintain the surface finishing of tools.
  - Remove imperfections from a surface by grinding or polishing it.
  - Achieve high surface quality and dimensional accuracy.


Parts of Grinding Machine




**Base or Bed:**

- The base or Bed is made up of cast iron. It is situated horizontally and it is the bottom part of the grinding machine, provides support to all the grinding parts. When machine operation starts some vibration occurs therefore base acts as an absorber of vibrations.

**Column:**

- Colum is like a vertical pillar of the machine in this section the abrasive wheel, wheel head, and wheel guard are kept. The column is also made up of cast iron.

**Headstock:**

- In Lathe Machine this section is known as live center Do you know that? The headstock work is to match the center and helps to grip the workpiece.

**Tailstock:**

- Tailstock is know as dead center. It also provides gripping to the work piece.

**Work Table:**

- Nowadays In the new grinding machine, the headstock and tailstock are replaced with work tables. A worktable is like a magnetic chuck that holds the workpiece.

**Wheel Head:**

- ❖ In this section, the abrasive wheels which are our tool for operation are placed and this is moved vertically up and down. With the use of a Feed hand, we can adjust the wheel head. Moving this wheel head down so that the grinding wheel can touch the workpiece. The wheel head consists of a grinding wheel and driving motor.

**Grinding or Abrasive Wheel:**

- ❖ Grinding or Abrasive wheel is our main tool used here to remove the unwanted material from the workpiece to get desired smoothness and surface finish. The wheels are coated with an abrasive particle. The abrasive wheel comes with various types and properties which Grinding or Abrasive Wheel. There are four commonly used abrasive materials for the surface of the grinding wheels are Aluminium oxide, silicon carbide, cubic boron nitride (CBN), and diamond.

**Cross feed:**

- ❖ Cross feed is also an important part of this machine used for moving up and down or left and right of Wheel head and work table and so on.

**Traversing Wheel:**

There are three types of Traversing wheel.

Hand Traversing Wheel:

- ➢ This wheel is used to move the table in the horizontal direction either left or right according to the tool and the workpiece.

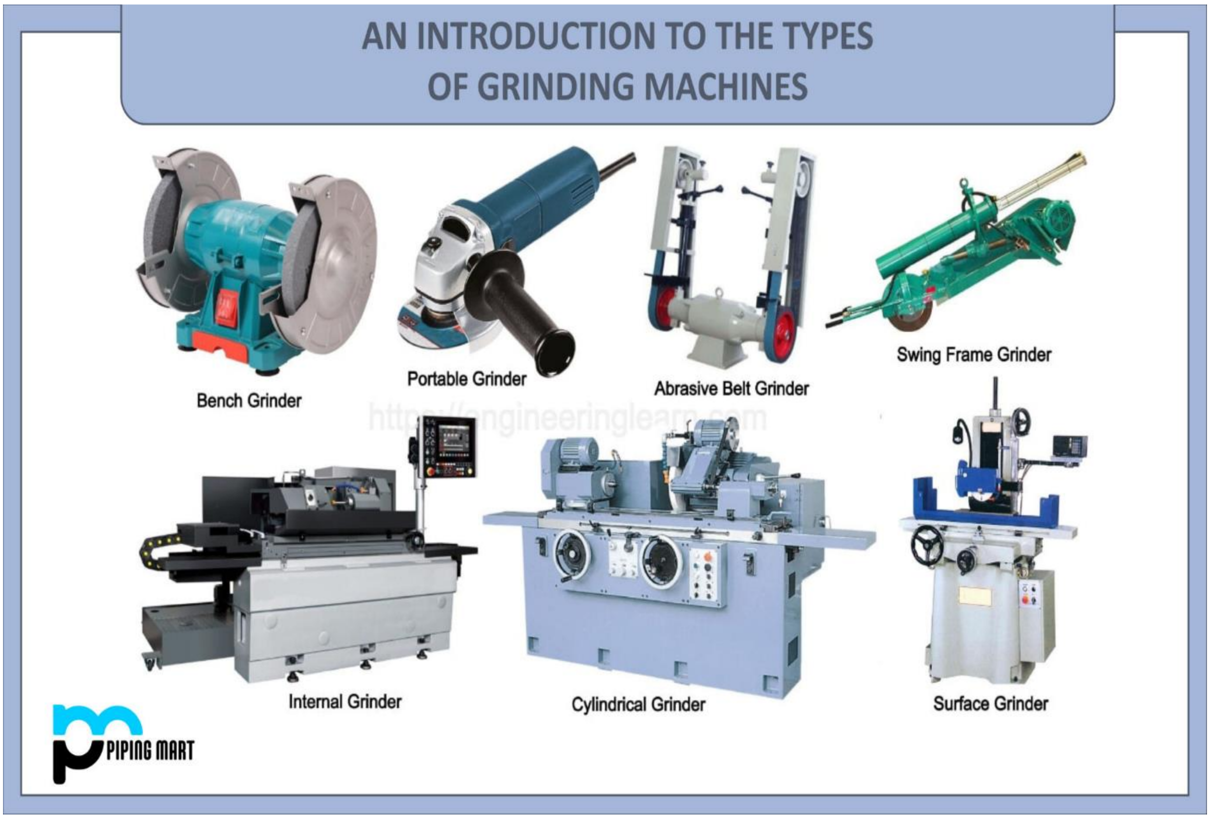
Cross Side:

- ➢ It is used to move the worktable in forwarding and backward directions and

Vertical Feed Hand Wheel:

- ➢ The vertical feed hand traversing wheel is used to move the wheel head in the vertically upward and downward direction.

## TYPES OF GRINDING MACHINES




- **Belt Grinder** – With the help of coated abrasives, a belt grinder is typically used as a machining technique to process metals and other materials. It is comparable to a belt sander (which is often used for wood but sometimes metal). Belt grinding is a flexible procedure used for finishing, deburring, and material removal, among other things.
- **Bench Grinder** – A bench grinder is fixed to a workbench or floor stand and often has two wheels with varying grain sizes for roughing and finishing tasks. It can be used to model tooltips or different tools that need to be created or repaired.
- **Cylindrical Grinder** – Grinding machines that are cylindrical are used to shape a workpiece's exterior. As long as the workpieces revolve around a central axis, these machines will accept them in various shapes. The workpiece and grinding wheel are turned concurrently in a cylindrical grinder. Cylindrical grinders come in multiple designs, including center less, internal, and outside-diameter models.
- **Surface Grinder**: A surface grinder consists of a rotary table, an abrasive wheel, and a workpiece chuck. The material is held in position by the chuck as the wheel, and the object is revolved to create a smooth finish.
- **Center less Grinder**: A center less grinder is a cylindrical grinder that uses two rotary wheels to hold the workpiece in place. A spindle is not used in a center less grinder, as opposed to one that uses one. The rate at which the material is removed depends on how quickly the wheels rotate.
- **Tool & Cutter Grinder**: A tool and cutter grinder employs a CNC machine tool with up to 5 axes and multiple grinding wheels. Drills, end mills, and step tools are milling cutters that can

be produced and sharpened by utilizing this equipment. Manufacturing the tools required by the metal-cutting and woodworking industries also makes extensive use of them.

- **Jig Grinder**: As its name suggests, is used to finish jigs, dies, and fixtures. Its primary use is in the area of drilling holes for grinding pins and drill bushings. It can also be utilized for sophisticated surface grinding to complete work started on a mill.
- **Gear Grinder** – The final machining step to produce high-precision gears is typically a gear grinder. These devices' principal purpose is to eliminate the few thousands of an inch of material that other manufacturing processes leave behind (such as gashing or hobbling).
- **Center Grinder** – When producing all types of high-precision shafts, the center grinder is typically used as a machining method. These devices' primary purpose is to grind a shaft's center accurately. A location with a high repeat accuracy on the live centers is ensured by accurate round center holes on both sides.
- **Die Grinder** – a hand-held rotary tool with high speed and a short grinding bit. They are usually driven by pressurized air but can also be directly or indirectly generated by a small electric motor utilizing a flexible shaft.
- **Angle Grinder** – Another hand-held power tool frequently used in fabrication and construction is the angle grinder.

## GRINDING WHEELS

- A grinding wheel is a rotating disk that contains abrasive particles and grains that are bonded together to form a wheel shape. Grinding wheels are used in grinding machines and are used extensively in industry and manual trades.
- Grinding wheels are used to cut, slice, or refine extremely hard materials, including metals and stones. They are attached to a spindle, and the work centres are attached to a table that can move at different speeds. The abrasive grains splinter off upon contact with the workpiece, thereby continually forming new sharp cutting edges.
- Grinding wheels are made up of a bond and super abrasive. The abrasive grains provide the essential functionality of a grinding wheel because they remove material from the workpiece. Some commonly used grinding wheel abrasives are ceramic alumina, zirconia alumina, aluminium oxide, white aluminium oxide, aluminium oxide and silicon carbide.
- Grinding wheels can be disc-shaped, cone-shaped, or cup-shaped.


## TYPES OF BONDS

- A bond is an adhesive substance that is employed to hold abrasive grains together in the form of grinding wheels. There are several types of bonds. Different grinding wheels are manufactured by mixing hard abrasives with suitable bonds. The table containing the types of wheels manufactured using different types of bonds and their symbols is given below.

| Type of bond | Symbol | Grinding wheel |
|---|---|---|
| 1. Vitrified | V | Vitrified wheel |
| 2. Silicate | S | Silicate wheel |
| 3. Shellac | E | Elastic wheel |
| 4. Resinoid | B | Resinoid wheel |
| 5. Rubber | R | Vulcanised wheel |
| 6. Oxychloride | O | Oxychloride wheel |

## MOUNTING AND RECONDITIONING OF GRINDING WHEELS.

**Here are some tips for mounting grinding wheels:**

**Prepare the wheel**

Visually inspect the wheel
Check the permissible number of revolutions or circumferential speed
Perform a clank test to check for cracks
Handle and store grinding wheels carefully
Select the proper grinding wheel and machine for the job
Lock out and tag all machines before working on them
Don't use power tools to put the wheel on

**Prepare the mounting**

Place plastic or cardboard blotters between the flange and grinding wheel
Make sure that all surfaces between the wheel, blotters, and flanges that should be in contact with each other during mounting are flat and free of foreign particles
Extend the threaded section well inside the loose flange
The wheels must fit freely on the spindle

**Mount the wheel**

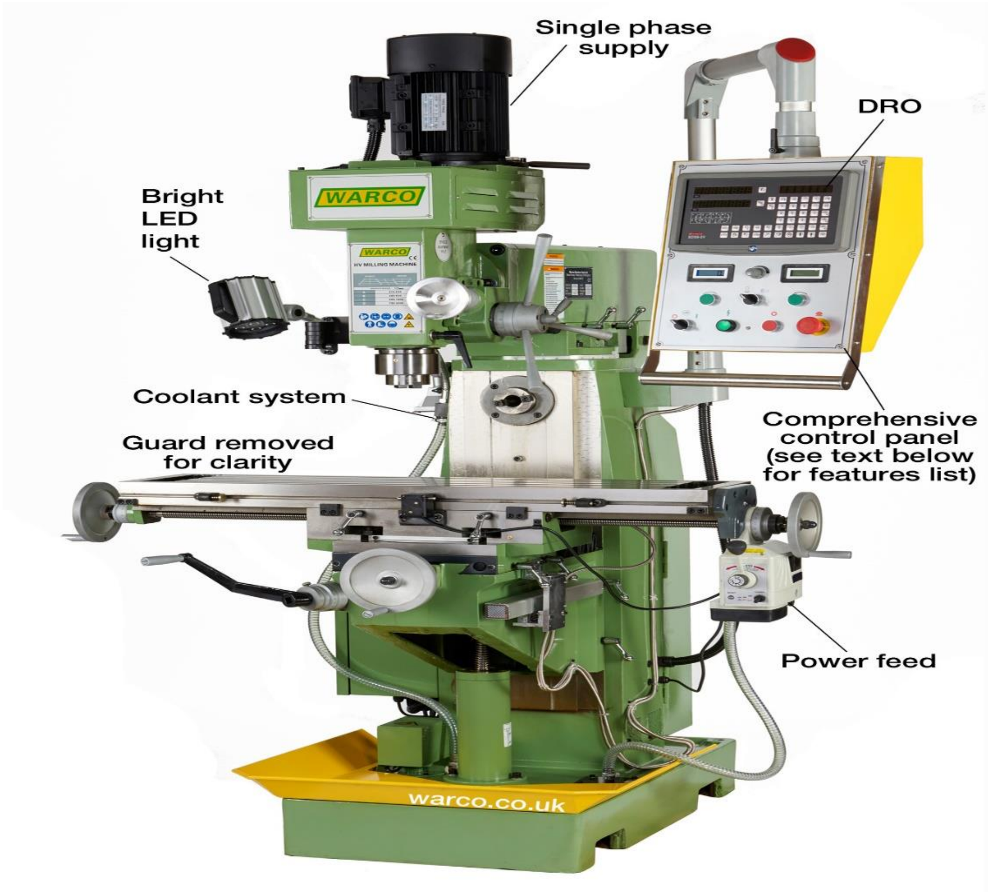
Slide one flange onto the spindle
Slide a blotter against the flange (if required)
Push the grinding wheel against the blotter
Slide another blotter and then a flange against the grinding wheel
Thread the nut onto the spindle
Tighten the nut with an adjustable wrench
Tighten grinding wheels just enough to prevent them from slipping
Tighten the bolts uniformly if there are multiple screw mounting flanges

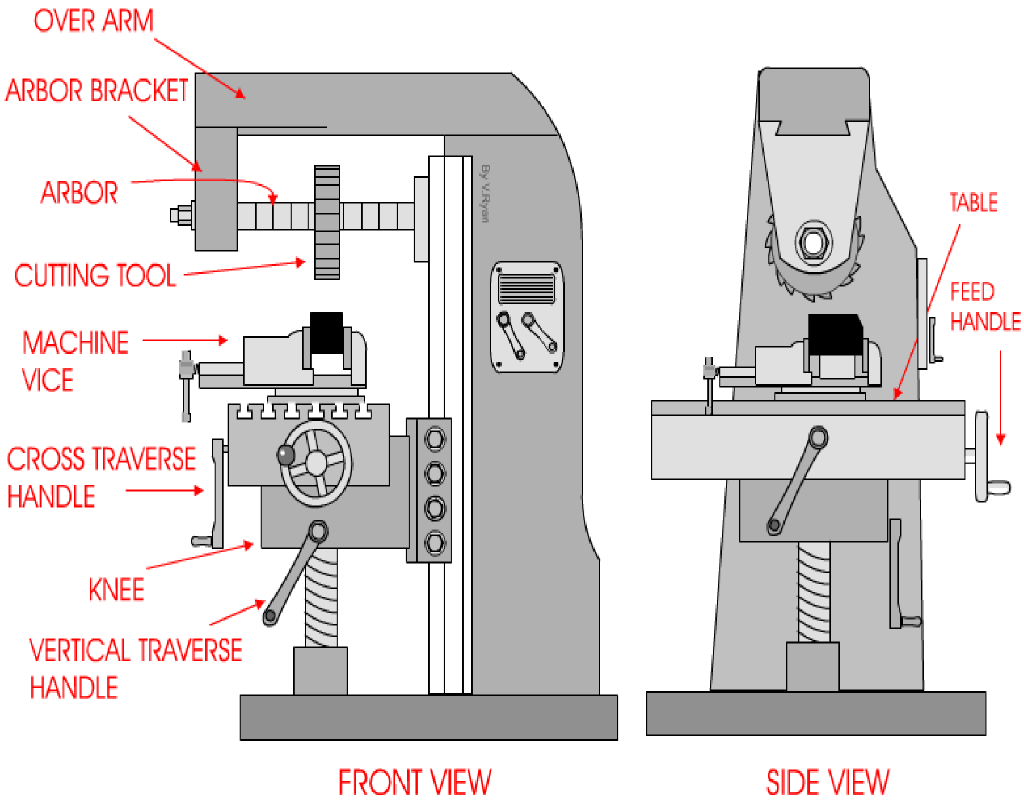
**UNIT IV: MILLING AND GEAR GENERATING MACHINES**

- -Milling.
- -specifications.
- -types.
- -cutter nomenclature.
- -types of cutters-milling processes.
- -indexing-gear forming in milling.
- -gear generation.
- -gear shaping and gear hobbing.
- -specifications.
- -cutters.
- -cutting spur and helical gears.
- -bevel gear generators.
- -gear finishing methods.

## MILLING:

- A milling machine removes material from a work piece by rotating a cutting tool (cutter) and moving it into the work piece. Milling machines, either vertical or horizontal, are usually used to machine flat and irregularly shaped surfaces and can be used to drill, bore, and cut gears, threads, and slots.




## SPECIFICATIONS

| | |
|---|---|
| Type | Universal-geared |
| Power | 3 HP |
| Working surface | 1100 X 250 mm |
| Cutting speed (m/min) | 15-88 m/min |
| Feed velocity (mm/min) | 75-355 mm/min |
| Longitudinal travel (X) | 725 mm |
| Cross travel (Y) | 300 mm |
| Vertical travel (Z) | 250 mm |

## TYPES

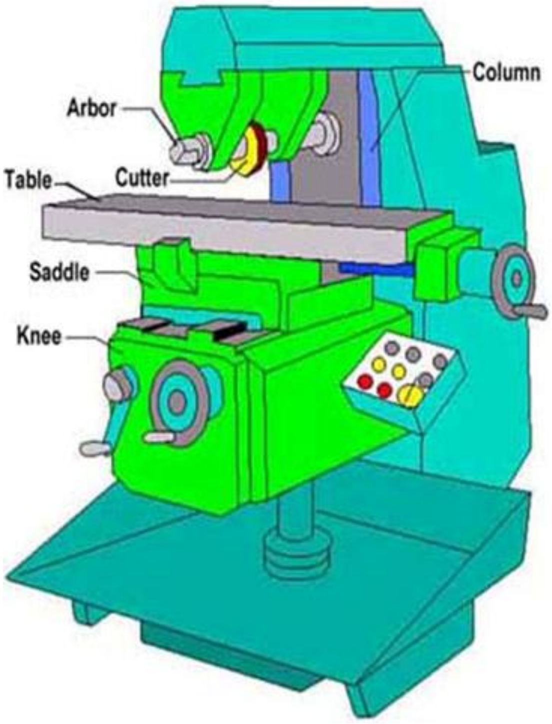
**Knee and Column Type**

1. Horizontal or Plain Milling Machine
2. Vertical Milling Machine
3. Universal Milling Machine
4. Up-word Milling Machine
5. Down-word Milling Machine

### Knee and Column Type

- The most common type of milling machine is called knee and column. In this machine, you will find a vertical column that is attached to the bed that consists of all the gear drives and helps in rotating the knee and saddle. The knee in a knee type milling machine is responsible for providing vertical or up and down movement to the workpiece which is located in the base of the machines. In the upper region of the knee, you will find a saddle attached. The saddle can move in a transverse direction.

### 1. Horizontal or Plain Milling Machine



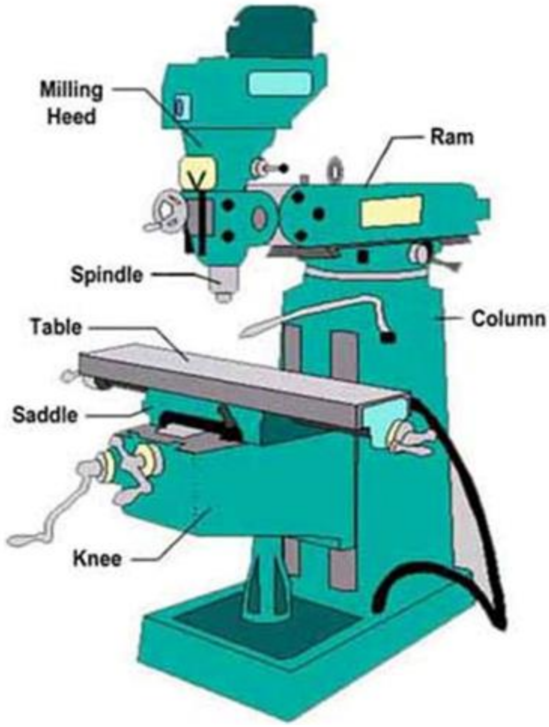

❖ Plain milling machines are more robust than hand millers. The plain milling machines that have a horizontal spindle are also called horizontal milling machines. You can feed the table in vertical, cross, or horizontal directions. The feed includes:

Verticle – adjusts the table vertically.

Cross – moves the table parallel to the spindle.

Longitudinal – rotates the table

## 2. Vertical Milling Machine

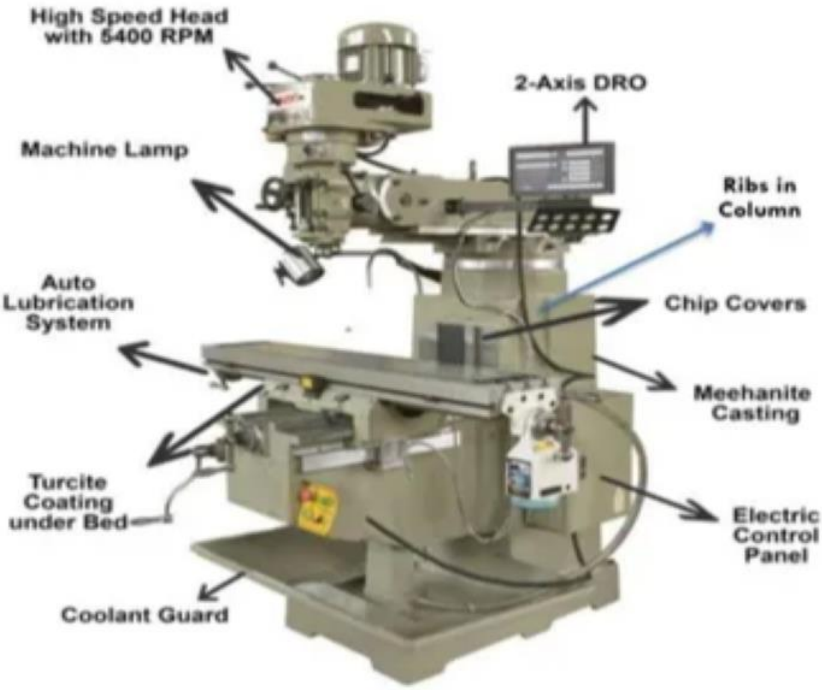



❖ The position of the spindle on a vertical milling machine is perpendicular or vertical to the table. You can use this machine for slots, machining grooves, and flat surfaces. The spindle head is fixed to a vertical column, which rotates at an angle. The milling cutter is fixed on the spindle to work with angular surfaces. In some vertical milling machines, you can adjust the spindle up and down.

DIFFERENCES BETWEEN HORIZONTAL & VERTICAL MILLING MACHINES

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

## 3. Universal Milling Machine




❖ Universal milling machines can adapt to perform a wide range of operations. The table can pivot at any angle for up to 45-degrees on both sides from the normal position. As the table of the horizontal milling machine can move in three directions, it also boasts the fourth movement. This machine can also perform helical milling operations. You can also use additional attachments to increase the capacity of the machine. Some special attachments include:

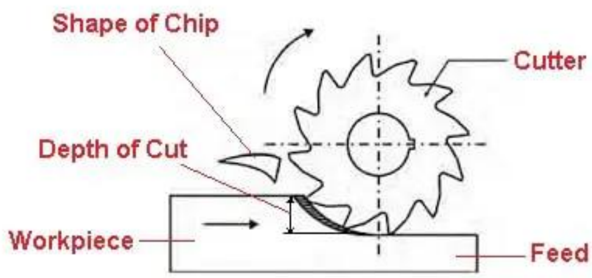
Slotting attachment

Rotary attachment

Vertical milling attachment

Index head or dividing head

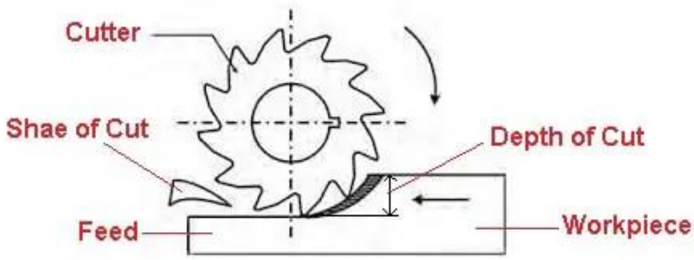
### 4. Up-word Milling Machine




Up Milling

- In up milling (conventional milling), the feed direction of the cutting tool is opposite to its rotation.
- The chip thickness starts at zero and increases toward the end of the cut. The cutting edge has to be forced into the cut, creating a rubbing or burnishing effect due to friction, high temperatures and, often times, contact with a work-hardened surface caused by the preceding edge. All this reduces the tool life.
- The thick chips and higher temperature at the exit from cut will cause high tensile stresses that will reduce tool life and often result in rapid edge failure. It can also cause chips to stick or weld to the cutting edge, which will then carry them around to the start of the next cut, or cause momentary edge frittering.
- Cutting forces tend to push the cutter and workpiece away from each other and radial forces will tend to lift the workpiece from the table.
- Up milling may be advantageous when large variations in working allowance occur. It is also recommended to use up milling when using ceramic inserts in heat resistant alloys, because ceramics are sensitive to impact at workpiece entry.

## 5. Down-word Milling Machine.




Down Milling

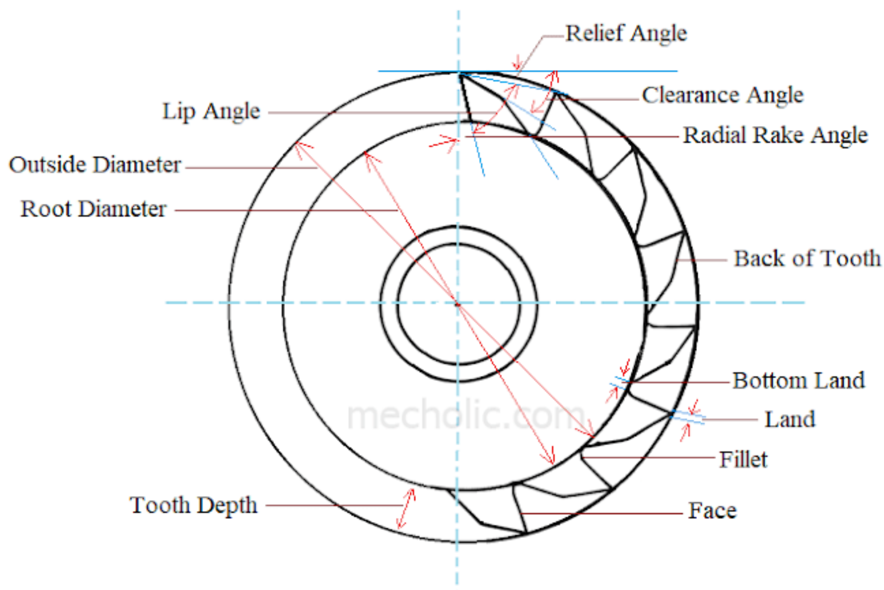
- In down milling (climb milling), the cutting tool is fed with the direction of rotation. Down milling is always the preferred method wherever the machine tool, fixture and workpiece will allow.
- In peripheral down milling, the chip thickness will decrease from the start of cut, gradually reaching zero at the end of cut. This prevents the edge from rubbing and burnishing against the surface before engaging in the cut.
- The large chip thickness is advantageous, and the cutting forces tend to pull the workpiece into the cutter, holding the cutting edge in the cut.
- However, as the cutter tends to be pulled into the workpiece, the machine needs to handle the table-feed play using back-lash elimination. If the tool pulls into the workpiece, feed is unintentionally increased which can lead to excessive chip thickness and edge breaking. Consider using up milling in such cases.

| Difference between up milling and down milling | |
|---|---|
| **Up Milling** | **Down Milling** |
| 1. Cutter rotates against the direction of table feed. | 1. Cutter rotates along the direction of table feed. |
| 2. Chip load on teeth (or uncut chip thickness) increases gradually from zero to maximum during the contact period for each tooth. | 2. Chip load on teeth (or uncut chip thickness) decreases gradually from maximum to zero during the contact period for each tooth. |
| 3. Cutting force in up milling is directed upward, and thus it tends to lift off the workpiece from worktable. | 3. Cutting force is directed downward, and thus it tends to press the workpiece rather than lifting off. |
| 4. Burr is formed only on unfinished surface ahead of the tool feed; however, majority of such burr is removed in the subsequent passes. | 4. Burr is formed at finished surface in opposite side of the tool feed. Thus these burrs are not removed automatically. This leads to degraded cutting quality. |
| 5. Here tooth experience gradual loading as contact starts with zero chip load. | 5. Here tooth experience impact loading due to sudden mating with maximum chip load. |
| 6. No backlash eliminator is required. | 6. Backlash eliminator is required, if machine is older one. |

www.difference.minaprem.com

## CUTTER NOMENCLATURE

- A milling cutter can be considered as the cluster of single point cutting tool. Above figure shows a plain milling cutter. The various parts of milling cutter teeth are cutting edge, face, filling, and body. The teeth of milling cutter either straight (the cutting edge is parallel to the axis of rotation) or helical shaped.




### Elements of plain milling cutter

**Body of cutter**: It is the main frame of milling cutter, on which the teeth rest.

**Periphery**: It is defined as the locus of cutting edges of tooth of cutter.

**Cutting edge**: It is the portion that touches the workpiece during cutting action. It is the intersection of teeth face and tooth flank.

**Fillet**: portion where one teeth joins the face of another tooth. It is a reinforcement to cutting tooth.

**Face of teeth**: it is the surface upon the chip is formed while cutting. It may be curved or flat.

**Back of tooth**: it is the created by fillet and the secondary clearance angle.

**Land**: it is the narrow surface on the back of cutting edge. Land is the result of providing the clearance angle.

**Bottom Land**: the blank space between the consecutive teeth.

**Root diameter**: diameter passing through centre of cutter and joining two ends of the periphery.

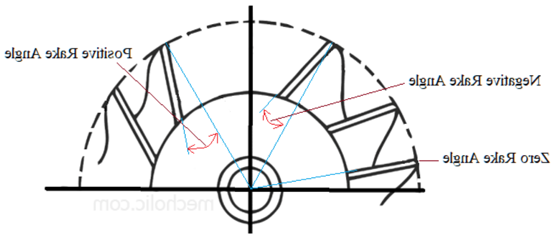
**Root diameter**: passing through centre of cutter and joining two bottom fillet.

## Angles of milling cutter

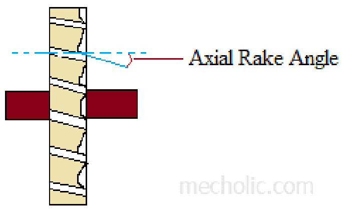
**Lip angle:** It is the angle between the face of the teeth and the land of the teeth. Land is a narrow surface on the back of teeth.

**Relief angle:** it is the angle between the tangent to the outside diameter of the cutter at cutting edge and the land of the tooth. The function relief angle is to avoid the interference between the land of the tooth and the work surface. The relief angle varies with the type of material to be machined.

**Radial rake angle**: it is the angle between the face of teeth and the radial line passing through the cutting edge of the tooth. The radial rake angle may be positive, negative or zero. It is provided free cutting by allowing chips to flow smoothly on the face of the cutter.




**Zero rake angle**: tooth face and radial line coincide.




**Positive rake angle**: tooth body and tooth face are the same side of the radial line.

**Negative rake angle**: tooth surface and radial angle are on opposite side of the radial line.

**Axial rake angle**: angle between the line of peripheral cutting edge and axis of the cutter. It is an angle in a plane perpendicular to the radial plane.

**Clearance angle**: it is the angle between the back of the tooth and the tangent to the outside diameter at the cutting edge of the tooth. It is divided into two according to the clearance surface. (primary clearance angle and secondary clearance angle).

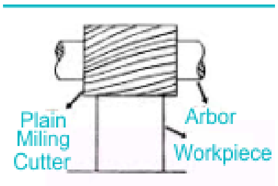
## TYPES OF CUTTERS-MILLING PROCESSES

Plain Milling Cutters
Face Milling Cutter
Side milling cutter
Angle Milling Cutters
'T' Slot Milling Cutter
Form Relieving Cutter

### Plain Milling Cutters:

Plain milling cutters possess a cylindrical shape and feature teeth solely on the periphery surface. These versatile milling cutters are specifically employed for creating flat, plane, and horizontal surfaces in various machining operations. Plain milling cutters can be further classified into the following types:

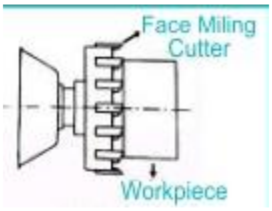
Light Duty Plane Milling Cutters
Heavy Duty Plane Milling Cutters
Helical Milling Cutter



Plain Milling Cutter

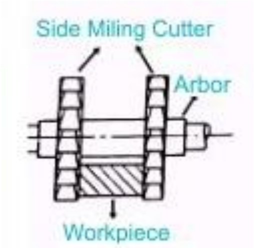
### Face Milling Cutter

The face mill cutter comprises a sizable cutter body featuring multiple securely attached insert tools, allowing for substantial material removal through radially deep and axially narrow cuts. The cutter body's diameter is determined by the workpiece length and the available clearance on both sides of the workpiece. Face mill cutters find application in downward milling. Their inherent rigidity contributes to the surface finish, influenced by the feed rate and the tooth count.




### Side Milling Cutter:

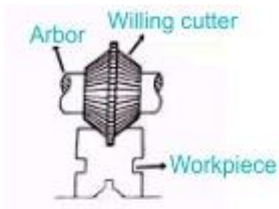
- A side milling cutter is a type of cutting tool with teeth on its side circumference. It is designed for removing material from the side of a workpiece.
- Side milling cutters are used in various machining operations, including slotting, contouring, and angular surface machining, making them versatile tools for different applications.
- These cutters have multiple teeth distributed around their circumference, allowing for efficient and rapid material removal as the cutter rotates.
- Side milling cutters come in different widths, allowing machinists to choose the appropriate cutter width based on the width of the cut they need to make, enabling precise and controlled machining processes.



Side Milling Cutter

## Angle Milling Cutters:

- Angle milling cutters are specialised cutting tools with angled teeth designed to create chamfers, bevels, and angles on workpiece edges, enhancing their visual appeal and functionality.
- These cutters come in various angles, allowing machinists to achieve different chamfer or bevel angles on the workpiece edges, contributing to design versatility.
- They are commonly used in applications where angled edges are required, such as in the creation of bevelled edges on metal components, woodworking, and other industries that demand precise edge finishing.



Angle Milling Cutter

## 'T' Slot Milling Cutter

- T-Slot Milling Cutter is a specialised tool designed for machining T-slots in workpieces.
- It features a unique design with a T-shaped groove that matches the T-slot profile.
- T-Slot cutters come in various sizes to accommodate different T-slot dimensions.

- They are commonly used in the manufacturing of fixtures, jigs, and work holding devices.
- T-Slot milling cutters create precise T-slots with accurate dimensions for inserting T-nuts or other components.

T Slot Cutter

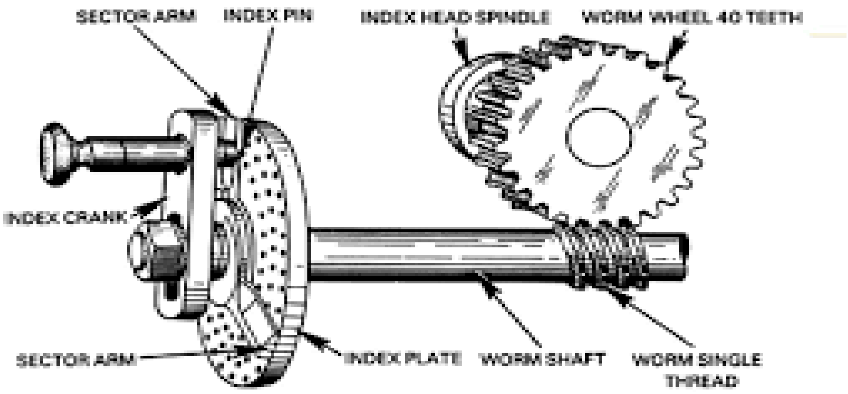
### Form Relieving Cutter:

- A form relieving cutter is a specialised tool used to create intricate profiles on workpieces.
- These cutters can be tailored to match specific profiles or forms required in the machining process, making them ideal for producing unique components with intricate details.
- Form relieving cutters efficiently remove material from workpieces, resulting in faster production times and reduced machining costs, especially for parts with complex shapes.
- Due to their precision and ability to follow intricate profiles, form relieving cutters often produce superior surface finishes, minimising the need for additional finishing processes.

Form Relieving Cutter

## INDEXING-GEAR FORMING IN MILLING:

- **Indexing in milling machines** is a fundamental technique that plays a crucial role in precision machining. This process involves rotating the workpiece or the cutter to a specific angular position, allowing for the precise cutting of slots, grooves, or features at desired intervals. It is an indispensable tool for creating complex geometries and achieving accuracy in milling operations.




**What is Indexing in Milling Machine?**

- The indexing mechanism utilises an index plate, typically a circular disc containing multiple concentric circles of evenly spaced holes. The crank's index pin can be placed into any hole within these circles.
- Many divided heads come equipped with interchangeable plates designed to accommodate specific spacing requirements for gears, bolt heads, milling cutters, splines, and other applications. These plates offer flexibility and convenience in achieving precise indexing for various machining tasks.

**Types of Indexing Methods**

Different methods of indexing are utilised in various machining operations. These methods include:

1. Index Plate

An index plate is a circular metal plate featuring multiple concentric circles of evenly spaced holes. A crank with an index pin can be positioned in any of these holes, facilitating precise indexing for various applications. Commonly used plates include Brown and Sharpe type and Cincinnati type.

For Brown and Sharpe type plates, there are three plates, each featuring six circles with holes arranged as follows:

Plate 1: 15, 16, 17, 18, 19, 20 holes

Plate 2: 21, 23, 27, 29, 31, 33 holes

Plate 3: 37, 39, 41, 43, 47, 49 holes

In the case of Cincinnati type plates, a single plate is used, with holes evenly distributed on both sides:

First side: 24, 25, 28, 30, 34, 37, 38, 39, 41, 42, 43 holes

Second side: 46, 47, 49, 51, 53, 54, 57, 58, 59, 62, 66 holes

**Formula =( linear pitch of the job or workpiece X 40 Indexing movement)/( Lead of the table lead screw)**

## 2. Simple Indexing

Simple indexing is achieved using a plain indexing head or universal dividing head on a milling machine. It employs a worm, crank, index head, and worm wheel to create precise divisions.

The indexing process utilises several components, including a worm, crank, index head, and worm wheel. Typically, the worm wheel is equipped with 40 teeth, while the worm itself is single-threaded. This configuration ensures that as the crank completes one full revolution, the work wheel rotates by 1/40th of a complete revolution.

Moreover, the worm wheel turns by 2/40th (or 1/20) of a revolution. Consequently, for every single revolution of the workpiece, the crank needs to complete 40 revolutions. Additionally, the holes in the index plate play a crucial role in further subdividing the rotation of the workpiece, enhancing the precision of the indexing process.

**Number of Turns = (Number of divisions on index plate) / (Number of divisions required)**

## 3. Compound Indexing

Compound indexing is used when complex divisions are required. It combines two simple indexing movements to achieve the desired result.

**Number of Turns = (N1 * N2) / H**

Where:

"N1" represents the number of divisions on the first index plate.

"N2" represents the number of divisions on the second index plate.

"H" represents the total number of divisions required for the desired compound indexing.

## 4. Differential Indexing

In cases where the divisions needed cannot be obtained through simple indexing, a differential indexing approach is employed. It involves a complex arrangement of gears to achieve the required indexing.

The formula for calculating the number of turns required for differential indexing on a milling machine is:

**Number of Turns = (N1 * N2 - 1) / H**

Where:

"N1" represents the number of divisions on the first index plate.

"N2" represents the number of divisions on the second index plate.

"H" represents the total number of divisions required for the desired differential indexing.

### 5. Direct Indexing

Direct indexing utilises index heads that allow for faster indexing by disconnecting the worm from the worm wheel. A knob controls the index head, facilitating quick and efficient indexing.

The formula for calculating the number of turns required for direct indexing on a milling machine is:

**Number of Turns = (N1 / H)**

Where:

"N1" represents the number of divisions on the index plate.

"H" represents the total number of divisions required for the desired direct indexing.

### 6. Plain Indexing

Plain indexing relies on principles like dividing a full revolution into equal parts. For example, to mill eight equally spaced teeth on a gear, the crank is turned five times after each cut to achieve the desired spacing.

The formula for calculating the number of turns required for plain indexing on a milling machine is:

**Number of Turns = (N / H)**

Where:

"N" represents the number of divisions on the index plate.

"H" represents the total number of divisions required for the desired plain indexing.

### 7. Indexing Operation

Indexing operations follow specific rules to determine the number of turns required to obtain the desired divisions. For example, to cut a gear with 42 teeth, you divide 40 by 42, resulting in 20/21 turns, which corresponds to indexing 20 spaces on a 21-hole circle.

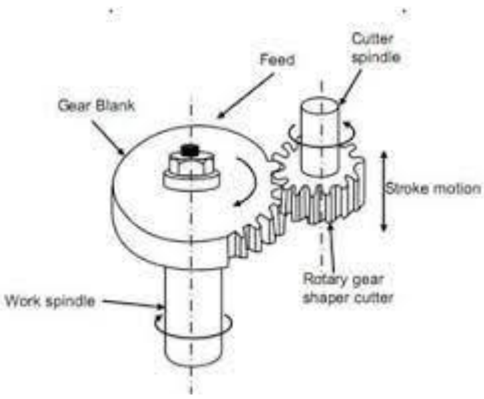
Indexing video link-

Simple indexing https://youtu.be/W_nh-ZIm6fQ?si=BI1iAbfaizCmVR0i

Compound indexing https://youtu.be/WaTqE7hjOTk?si=m6iMU8AKEdbbzGaB

## GEAR GENERATION:

- Gear generation is the process of creating an involute curve using a cutter's straight cutting edges. The two primary gear generating processes are hobbing and shaping.
- Gear milling is a slower gear generation process that involves cutting one tooth at a time. In gear milling, a form-cutting tool on a milling machine cuts gear teeth from a gear blank. The form cutter spins to cut each gear tooth individually, then moves away between each cut to allow the gear blank to rotate for the next cut.
- Historically, gear fabrication methods have been classified into three main categories: generation, forming, and form cutting.




Video link of gear cutting or generation-

https://www.youtube.com/watch?v=39ZiVUA-JNY

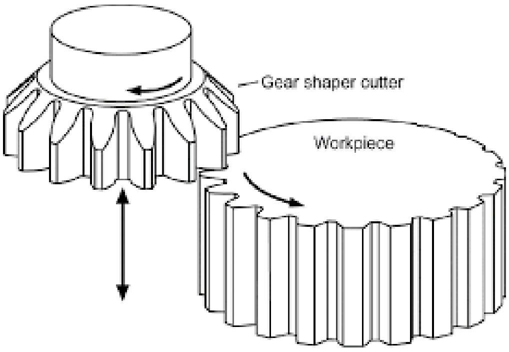
## GEAR SHAPING AND GEAR HOBBING:

### GEAR HOBBING

- Uses a rotating cutting tool called a hob that has helically fluted edges. The hob rotates against the workpiece's surface at high speed to create precisely cut teeth. Hobbing is ideal for mass production of cylindrical components like gears and shafts.

Gear Hobbing video link- https://www.youtube.com/watch?v=kWurSpeVwu4

## GEAR SHAPING




- Used to produce teeth on an external or internal gear by generating straight-sided splines or involute form profiles. Shaping is ideal for manufacturing gears such as spur and helical.

  Gear Shaping video link- https://www.youtube.com/watch?v=--pAaaFJAzI

## SPECIFICATIONS

## CUTTERS

- Gear shaping and gear hobbing are machining processes that create gears. Gear shaping is a subset of milling, and uses a rotating cutter with an axis parallel to the gear to form the teeth. Gear hobbing uses a hob, which is a worm with gashes cut across it, to cut gear teeth into a flat, cylindrical piece of metal.

Gear hobbing cutter

Gear shaper cutter

## CUTTING SPUR AND HELICAL GEARS:

SPUR HELICAL

Video Link- https://www.youtube.com/watch?v=qfKbcvYWMuI – HELICAL

https://www.youtube.com/watch?v=NfzP8-j5ysc - SPUR

## BEVEL GEAR GENERATORS:

- Bevel gear generators are power transmission components that transfer mechanical energy between intersecting shafts. They are used to change the direction of shaft rotation, decrease speed, and increase torque between non-parallel rotating shafts. Bevel gears are conical shaped and turn rotary motion input 90 degrees into output rotary motion. The output shaft spins opposite to the input shaft, either changing to clockwise or counterclockwise.

Bevel gear

Video link- https://youtu.be/K3wA6x5wKAE?si=6TlAC7ZWGp0iDVHG

## GEAR FINISHING METHODS

- Finishing operation is generally required to improve dimensional accuracy and surface finish of the gear after machining. Finishing processes applied to gears that have not been heat-treated include shaving and burnishing. Finishing processes applied to hardened gears include grinding, lapping and honing.
- Gear finishing methods are used to improve the performance of gears, extend their service life, and obtain a high degree of surface finish. Some of the conventional gear finishing methods include:

  **Grinding**

  Uses abrasive wheels to remove small variations from gear teeth, resulting in a more accurate tooth finish than gear cutting

  **Lapping**

  The gear is finished by having it come into contact with one or more cast iron lap gears of true shape

  **Honing**

  A method of cutting teeth by means of the pressure and relative sliding between the tooth surfaces during the meshing process of the honing wheel and the honed gear

  **Shaving**

  A surface finishing process that involves removing small metal parts from a gear, making it smoother and correcting gear teeth in terms of spacing, angle, profile, concentricity, etc.

  **Burnishing**

  A finishing application on the gear teeth where a hard die that has the same shape as the gear is pressed against the gear teeth and rotated around it, hardening the surfaces of the teeth and increasing the surface characteristics of gears.

- Classification of machining processes
- Process selection
- Ultrasonic machining
- Abrasive jet machining
- Water jet machining
- Laser beam machining
- Electron beam machining
- Plasma arc machining

## CLASSIFICATION OF MACHINING PROCESSES

- Machining is a manufacturing process that shapes metal by removing unwanted material. Machining processes are classified into two categories based on the shape they machine:
  Circular shapes: Includes turning, boring, drilling, reaming, and threading
  Straight shapes: Includes milling, broaching, sawing, grinding, and shaping
- The three most common machining operations are turning, drilling, and milling. These three methods can be used to machine different kinds of materials, including wood, composites, plastics, and metals.
- **The three main types of machining technologies are:**
  **1.**Traditional machining: Includes turning and milling
  **2.**Non-traditional machining: Includes electrical discharge machining and laser beam machining
  **3.**Hybrid machining: A combination of traditional and non-traditional processes
- **Other machining processes include:**
  Electrochemical machining (ECM): Creates burr-free holes, provides a high-quality mirror surface finish, and is suitable for machining extremely hard metals and alloys
  Broaching: Produces square holes, keyways, and spline holes
  Boring: Enlarges a pre-drilled hole with a single-point cutting tool.

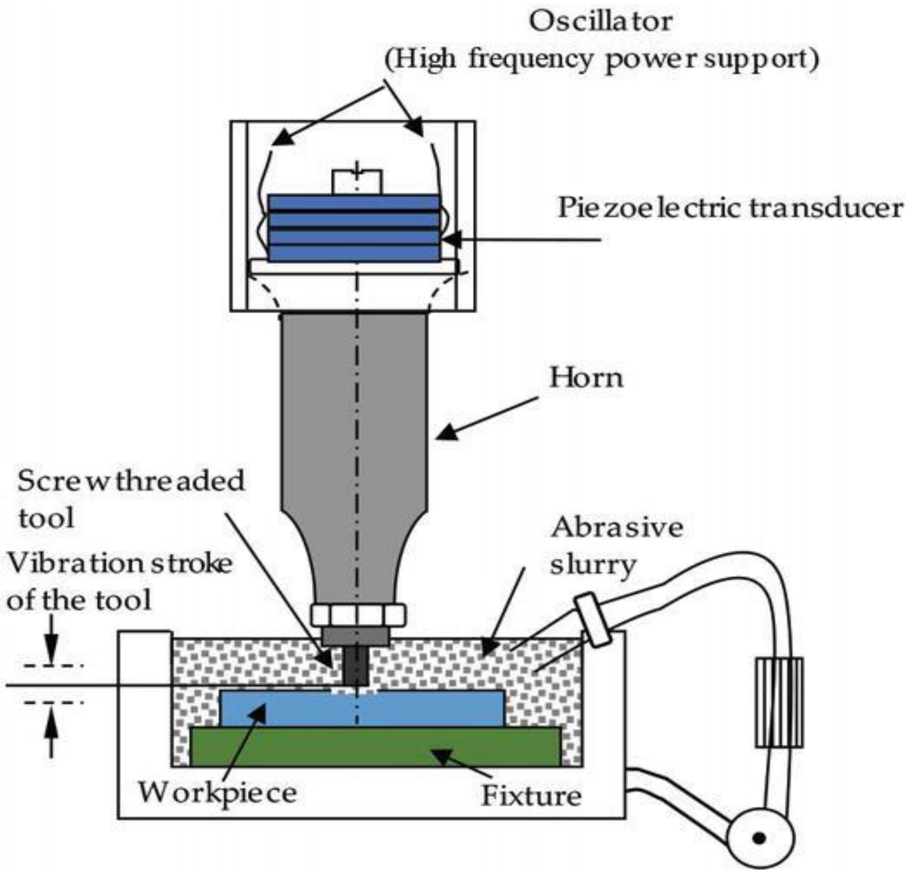
## PROCESS SELECTION

- The selection of a non-traditional machining (NTM) process is based on three parameters: workpiece material, machining operation, and process characteristics.

## ULTRASONIC MACHINING

- Uses a high-frequency vibrating tool to remove workpiece material, with abrasive material mixed with water to create a fine abrasive paste.
- Ultrasonic machining is a non-conventional machining process that utilises abrasive particles to remove material from the workpiece. In this method, the tool does not directly impact the workpiece, but rather the abrasive particles are introduced between them. These rigid and hard abrasive particles enable impact erosion on the

workpiece material, resembling a mode of percussion. The process involves using a ductile tool material to prevent brittle fracture during the hammering action, resulting in precise material removal and delicate machining of intricate components.




**Parts of Ultrasonic Machining**

**Power Supply:**

❖ The power supply, also known as a high-frequency generator or electronic oscillator, converts a standard electrical supply into a high-frequency electrical supply, typically ranging from 20-40 kHz, with small vibration amplitudes in the range of microns.

**Velocity Transformer:**

❖ The velocity transformer, or horn, amplifies and focuses the vibration of the transducer to an intensity suitable for driving the tool during cutting operations. It is made of hard, non-magnetic, and easily machinable materials like K-Monel, metal bronze, or mild steel.

**Tool:**

❖ The tool, made of a ductile material, undergoes hammering or percussion using abrasive particles to remove material from the workpiece. Tool wear and fatigue resistance are crucial, as ultrasonic frequencies increase the hammering rate to enhance material removal.

**Abrasive Slurry:**

- ❖ A slurry of abrasive particles is applied between the tool and workpiece to facilitate material removal. The abrasives, such as boron carbide or silicon carbide, are rigid and hard, ensuring efficient machining. Fresh abrasives are continuously supplied through a water jet to maintain optimal machining efficiency.

**Electro-Mechanical Transducer:**

- ❖ The transducer converts electrical energy into mechanical vibrations, transmitting high-frequency signals with low amplitude to the tool. Two types of transducers are used: piezoelectric transducers and magneto strictive transducers.

**Abrasive Gun:**

- ❖ The abrasive gun delivers the abrasive slurry to the machining site through a water medium, ensuring a constant supply of fresh abrasives under controlled pressure. The water jet also removes debris and broken abrasives during machining.

**Workpiece:**

- ❖ Ultrasonic Machining is ideal for machining brittle non-conductive materials, such as engineering ceramics, without introducing thermal damage or residual stress. This process enables intricate 3D shapes to be machined with precision on the workpiece.

## ABRASIVE JET MACHINING

- ❖ Uses abrasive particles mixed with gas or air to hit the workpiece surface to remove material.
- ❖ This advanced machining technique, known as Abrasive Water Jet Machining (AWJM), utilises abrasive particles as a medium. In contrast to conventional water jet machining, AWJM addresses its limitations by introducing abrasive particles into the water stream. Propelled at a high velocity from the nozzle, this mixture effectively erodes material from the workpiece's surface, achieving precise shaping and sizing with exceptional accuracy.

**Construction of Abrasive Water Jet Machining**

- ❖ The construction of Abrasive Water Jet Machining (AWJM) centers around a high-pressure system and precision components. It begins with a powerful water pump that generates pressures exceeding 40,000 psi, which is directed to a mixing chamber where abrasive particles are added to create a slurry.

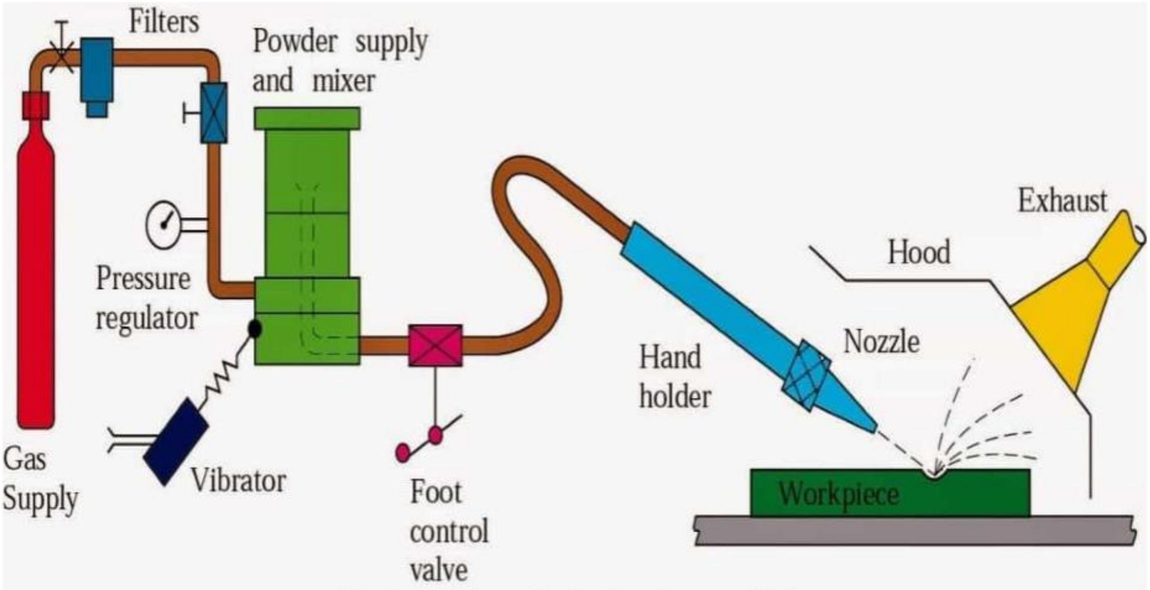


Fig: 1 working of abrasive jet machining

- **The various parts of Abrasive Water Jet Machining are:**

**Reservoir**

- The reservoir serves as the fundamental component for storing water, ensuring a consistent supply to all other parts of the system for proper operation.

**Hydraulic Pump**

- In the AWJM setup, the hydraulic pump assumes a crucial role as it facilitates the transfer of fluid from one location to another. It acts as an intermediary, drawing water from the reservoir and conveying it to the hydraulic intensifier.

**Hydraulic Intensifier**

- Positioned after the hydraulic pump, the hydraulic intensifier is responsible for elevating the water's pressure to the required level for effective operation.

**Accumulator**

- The accumulator functions as a temporary water storage unit, providing water to the system in instances of pressure drops or when high-pressure water is needed.

**Control Valves**

- The pressure control valve within the system plays a dual role, regulating both water pressure and its direction. A flow regulator valve is also incorporated to control the flow of water into the system.

**Flow Regulator**

- As its name suggests, the flow regulator governs the water flow originating from the control valve, directing it toward the nozzle.

**Abrasive Tank**

- Abrasive particles are pivotal in the AWJM process, especially for cutting hard materials. Commonly used abrasives include aluminum oxides, sand, garnet, and glass particles, among others.

**Mixing Chamber**

- In contrast to traditional water jet machining, AWJM employs a mixture comprising 70% water and 30% abrasive particles blended in the mixing chamber.

**Nozzle**

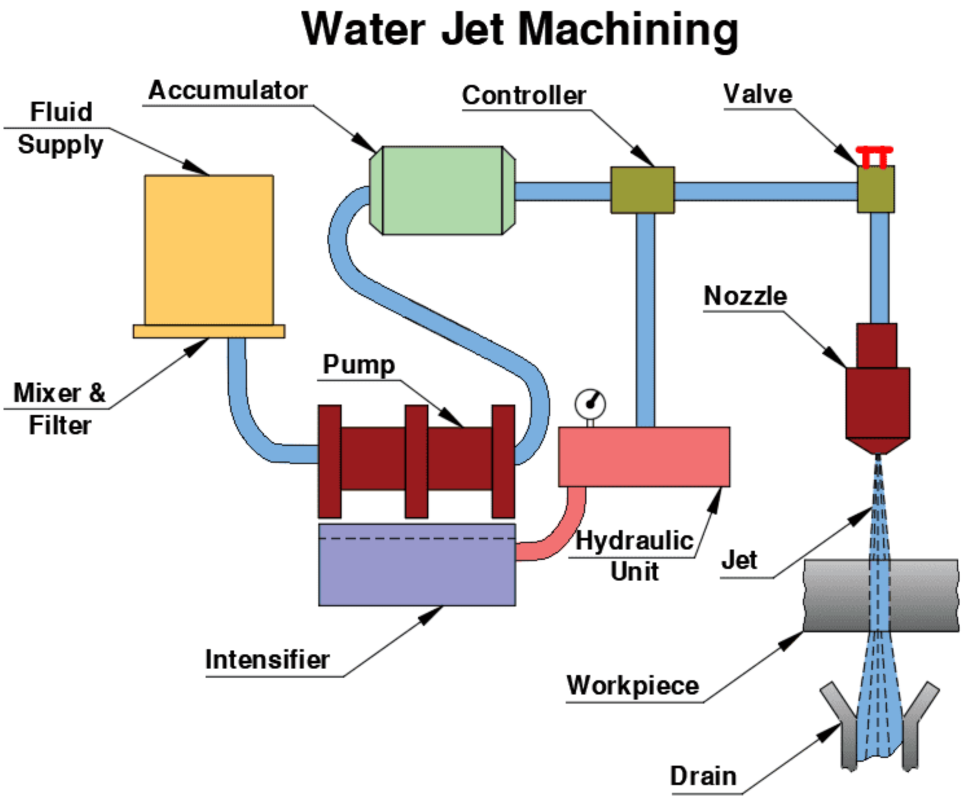
- The nozzle's primary role is to convert high-pressure water into kinetic energy (K.E), which is intensified as the nozzle area decreases. This high kinetic energy of water, combined with abrasive particles, is directed onto the workpiece's surface, rapidly achieving the desired shape and size.

**Drain System**

- The drain system's primary function is to collect water discharged from the work region and return it to the reservoir through the pump and filter, ensuring a continuous water supply for the process.

## WATER JET MACHINING

- Water Jet Machining operates on the principle of water erosion, where a high-velocity jet of water impacts the workpiece surface, resulting in material removal. A pure water jet is employed in the machining process for softer materials. However, the water is mixed with abrasive particles to cut harder materials effectively, transforming it into Abrasive Water Jet Machining (AWJM). In AWJM, the abrasive particles enhance the cutting power, enabling precise and efficient machining of tougher materials.




**Parts of Water Jet Machining**

**Hydraulic Pump:**

- This component circulates water from the storage tank during machining. Operating at low pressure (about 5 bars), it supplies water to the intensifier. A booster raises the initial water pressure to 11 bars before reaching the intensifier.

**Hydraulic Intensifier:**

- Responsible for boosting water pressure to extremely high levels, the hydraulic intensifier receives water from the pump at 4 bars and elevates it to a range of 3000 to 4000 bars.

**Accumulator:**

- The accumulator temporarily stores the highly pressurised water, delivering it when substantial pressure energy is required. It ensures a smooth and stable machining process by eliminating pressure fluctuations.

**Mixing Chamber or Tube:**

- The mixing chamber acts as a vacuum chamber where abrasive particles and water are combined.

**Control Valve:**

- ❖ The control valve manages the pressure and direction of the water jet, enabling precise control over the machining process.

**Flow Regulator or Valve:**

- ❖ The flow regulator regulates the water flow, allowing adjustments as needed during the machining operation.

**Nozzle:**

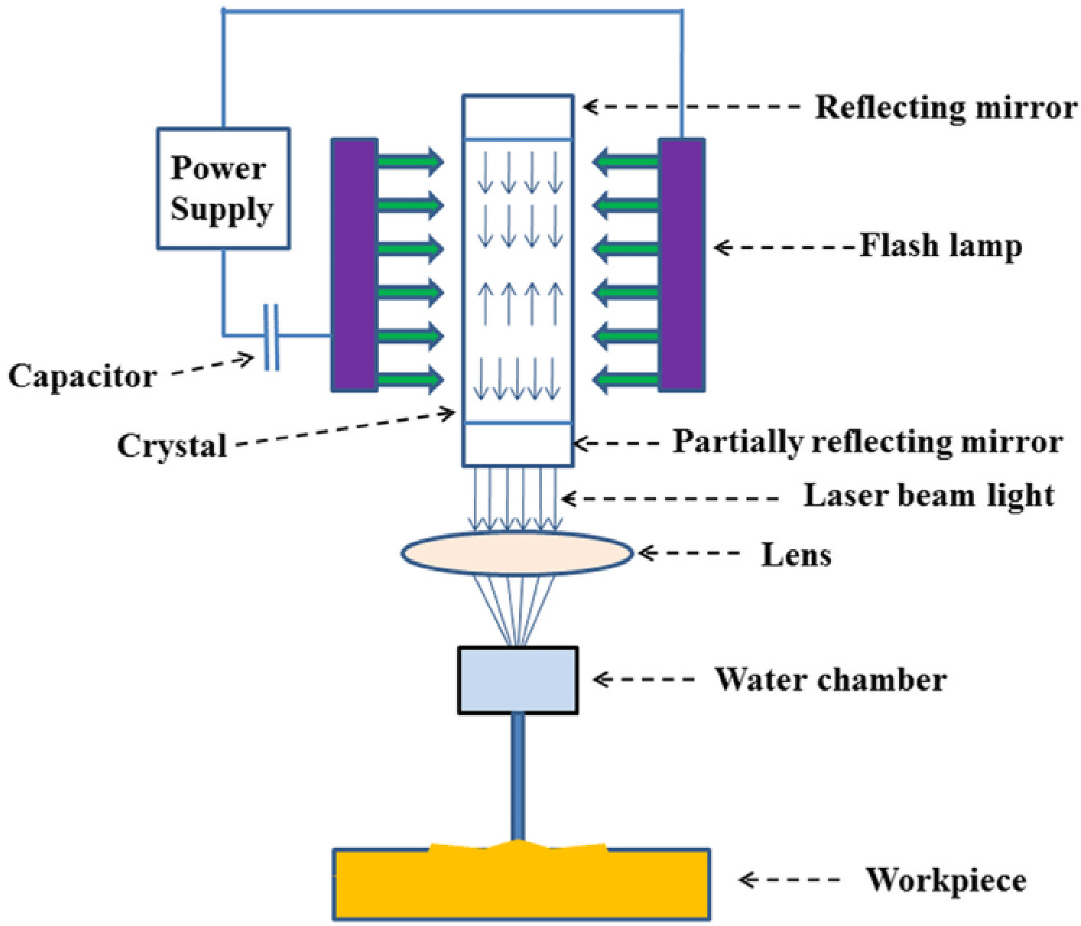
- ❖ This crucial device converts the pressure energy of water into kinetic energy for the water jet. The nozzle creates a high-velocity water jet beam, typically made of ruby or diamond, at the tip to resist erosion.

**Drain and Catcher System:**

- ❖ Post-machining, the drain and catcher system effectively separates debris and machined particles from the water. It removes unwanted metal particles and other contaminants, ensuring clean water returns to the reservoir for reuse in subsequent operations.

## LASER BEAM MACHINING

- ❖ Laser Beam Machining (LBM) is a precise non-contact manufacturing process that utilizes a focused laser beam to remove material from a workpiece. Widely used in industries such as aerospace and electronics, LBM offers high accuracy and minimal heat-affected zones. It's ideal for intricate designs and delicate materials, enhancing manufacturing versatility.




**Parts of Laser Beam Machining**

**Power Supply:**

- The power supply is responsible for providing electric current to the system. In Laser Beam Machining, a high-voltage power system initiates the reaction in the laser, which, in turn, machines the material. The high voltage supply facilitates easy initiation of laser pulses.

**Capacitor:**

- A capacitor bank charges and releases energy during the flashing process, forming a significant part of the machining cycle. It operates in pulsed mode, facilitating efficient charging and discharging.

**Flash Lamps:**

- Electric arc lamps, known as flash lamps, produce intense white light that is converted into a coherent high-intensity beam. These lamps are filled with gases that ionise to generate substantial energy, melting and vaporising the material on the workpiece.

**Reflecting Mirror:**

- Reflecting mirrors come in two main types: internal and external mirrors. Internal mirrors, also called resonators, are crucial for generating, maintaining, and amplifying the laser beam. They direct the laser beam towards the workpiece for material processing.

**Laser Light Beam:**

- The laser light beam is the focused radiation produced through the process of optical amplification based on the coherence of light generated by bombarding active material.

**Ruby Crystal:**

- In certain types of lasers, like the ruby laser, coherent pulses of deep red light are produced through a concept called population inversion. Ruby lasers belong to the category of three-level solid-state lasers.

**Lens:**

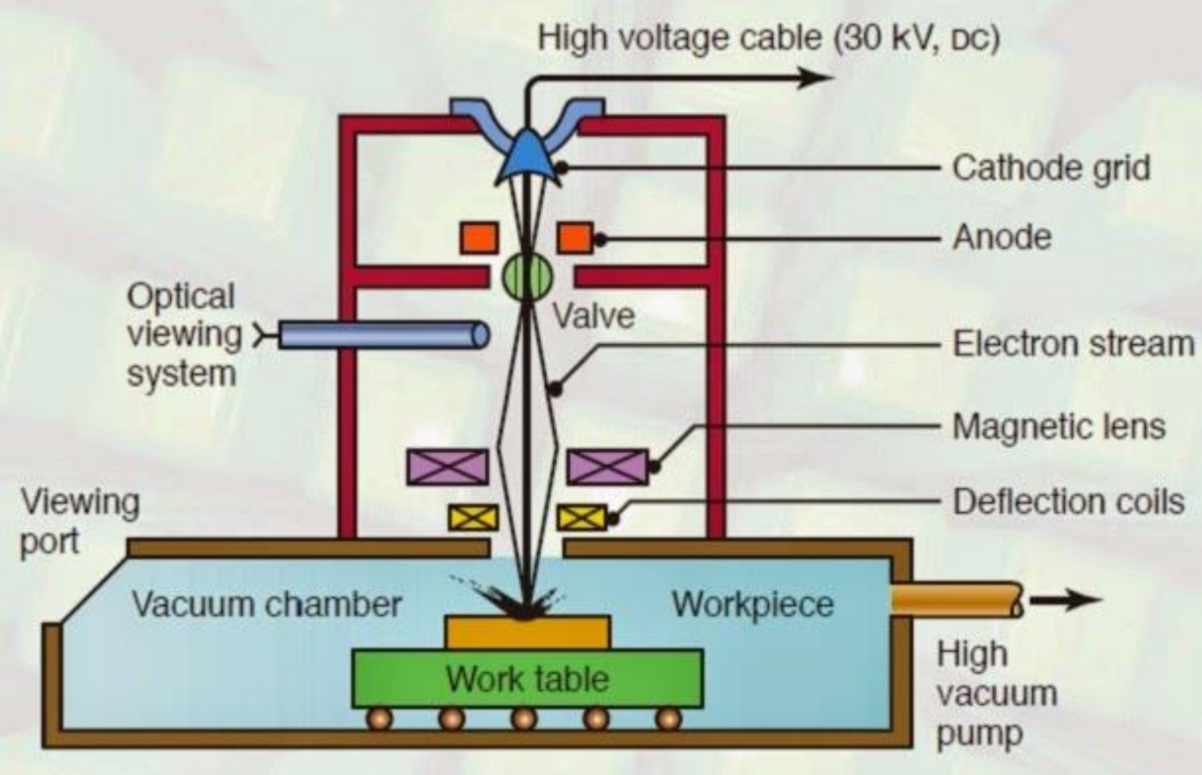
- Lenses are employed to concentrate the laser beam onto the workpiece accurately. The laser light first enters an expanding lens and then a collimating lens, which aligns the light rays in parallel, and the expanding lens adjusts the laser beam to the desired size.

**Workpiece:**

- The workpiece, which can be made of either metallic or non-metallic materials, undergoes the laser machining process. This versatile machining method is suitable for working with a wide range of materials.

## ELECTRON BEAM MACHINING

- Electron Beam Machining (EBM) is a thermal metal removal process where high-energy electrons, generated using electrical energy, are focused into a high-velocity beam travelling at nearly half the speed of light . This precise technique excels in micro-cutting applications.




**Parts of Electron Beam Machining**

**Electron Gun:**

- The electron gun plays a pivotal role in Electron Beam Machining (EBM) and comprises one of three essential components. The tungsten filament, connected to the negative terminal of the DC power supply, serves as the cathode and emits electrons. The grid cup, negatively biased relative to the filament, helps guide the emitted electrons. Finally, the anode, connected to the positive terminal of the DC power supply, plays a crucial role in the acceleration of electrons. Together, these components ensure the generation and control of the electron beam.

**Vacuum Chamber:**

- To prevent collisions of accelerated electrons with air molecules, the EBM setup is enclosed within a vacuum chamber, maintaining a vacuum level typically ranging from 10−510−5 to 10−610−6 mm of mercury. This chamber includes a door through which the workpiece is positioned on the worktable before being sealed. The vacuum environment is vital for preserving the integrity and accuracy of the electron beam machining process.

**Focusing Lens:**

- The focusing lens is a critical component that concentrates the electron beam onto a precise point, reducing its cross-sectional area to a diameter as small as 0.01 to 0.02 mm. This precision in focusing ensures accurate and controlled material removal during the machining process.

**Electromagnetic Deflector Coil:**

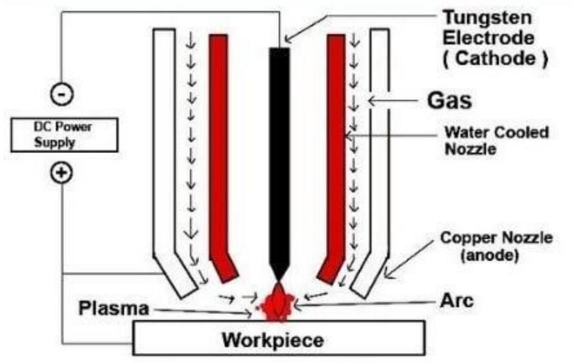
- The electromagnetic deflector coil serves a versatile function in EBM. It enables the electron beam to be directed to different spots on the workpiece and provides control over the cutting path. This flexibility is essential for achieving intricate and precise machining operations.

## PLASMA ARC MACHINING

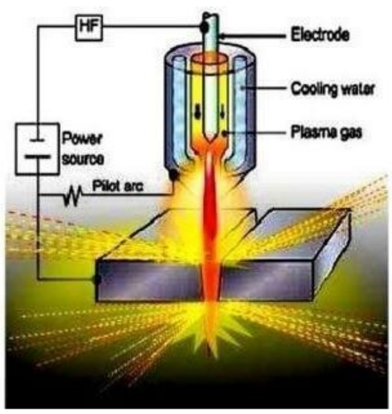
- Plasma arc machining involves the removal of metal through the precise concentration of ionised gas at an extraordinarily high temperature (ranging from 11,000°C to 30,000°C) onto the workpiece. This high-velocity jet of superheated gas effectively melts and eliminates the material, allowing for efficient and accurate metal removal.

**Working of Plasma Arc Machining**

- When DC power is applied to the circuit, a potent arc emerges between the cathode (electrode) and the anode (nozzle). Subsequently, gas is introduced into the chamber, selected from options like hydrogen, nitrogen, argon, or a mixture tailored to the specific metal being worked upon. The gas is then heated to extraordinarily high temperatures, ranging from 11,000°C to 28,000°C, utilising the arc formed between the cathode and anode. As the arc interacts with the gas, electrons collide with gas molecules, causing them to dissociate into individual atoms.
- Due to the arc's intense heat, certain atoms lose their electrons, leading to ionisation, thereby transforming the gas into plasma—an electrically charged state. This ionised gas releases a significant amount of thermal energy. Directed towards the workpiece with high velocity, the plasma jet benefits from the electric arc in several ways. It further elevates the ionised gas's temperature, almost aligns the beam in parallel, and enhances the gas's velocity.
- Upon reaching the workpiece, the plasma jet efficiently melts the material, while the high-velocity gas effectively blows away the molten metal. This process of plasma arc machining effectively removes material from the workpiece, demonstrating its remarkable utility in various industrial applications.



Plasma Arc Machining



**The different parts of Plasma Arc Machining are:**

**Plasma Gun**

- The Plasma Gun employs various gases, such as nitrogen, hydrogen, argon, or gas mixtures, to create plasma. It consists of a chamber housing a tungsten electrode connected to the negative terminal, while the plasma gun's nozzle links to the positive terminal of a DC power supply. Supplying the required gas mixture to the gun initiates a strong arc between the anode and cathode. This collision of electrons and gas molecules results in ionisation, generating substantial heat within the plasma.

**Power Supply**

- Utilising a DC Power Supply, the plasma gun's two terminals are developed, creating a significant potential difference between the cathode and anode. This high potential difference ensures the generation of a robust arc, effectively ionising the gas mixture and transforming it into plasma.

**Cooling Mechanism**

- To manage the heat generated during the process and as hot gases continuously exit the nozzle, a Cooling Mechanism is integrated into the plasma gun. This mechanism typically employs a water jacket, which envelops the nozzle, efficiently dissipating excess heat through a water jet.

**Workpiece**

- Plasma arc machining offers the versatility to work on various materials. Different metals, including aluminium, magnesium, carbon, stainless steel, and various alloy steels, can be effectively processed using this precise and adaptable machining technique.