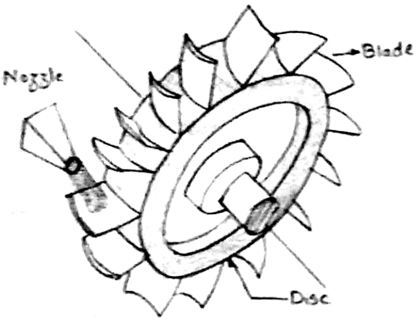
TURBINES

- ⊙ Turbine is a device that converts K.E of stream of fluid [steam, gas, water] into useful mechanical work in the form of rotation of shaft.
- Based on type of fluid turbines are classified as :-
  - * steam turbine
  - * Gas turbine
  - * Water turbine.

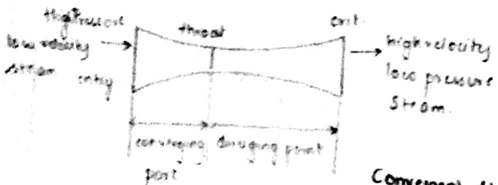
⊙ STEAM TURBINE



→ Steam turbine is thermal prime mover where energy conversion takes place in two stages. i.e conversion of heat energy of steam into K.E in the nozzle and conversion of K.E into mechanical work with specially designed blades.

→ Parts of steam turbine :-

(a) NOZZLE :



Convergent-divergent nozzle.

Nozzle is a passage of varying cross-section through which steam enters. The cross sectional area of nozzle diminishes from entry to the throat and thereafter diverges to the exit.

The steam is expanded in the nozzle to increase its kinetic energy.

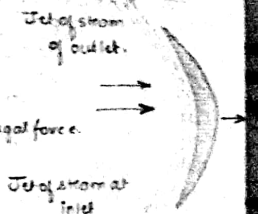
* Working of nozzle :- High pressure and low velocity steam generated in boiler enters the nozzle and as it passes between the entry and the throat, pressure of the steam drops to low value. This drop in P reduces the enthalpy (heat content) of steam and thereby increases its velocity as it moves towards the exit.

(b) Rotor : It is a rotating element and it is thus in the form of circular disc.

(c) Blades : These are mounted on the circumference of the rotor.

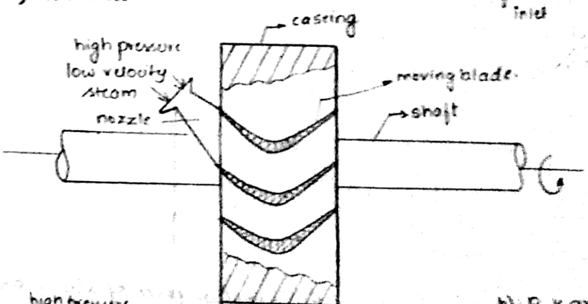
(d) Output shaft : It is connected to the rotor.

* Classification of steam turbine - based on mode of action of steam on blades.
  - Impulse turbine · Eg: De-laval turbine
  - Reaction turbine Eg: Parsons turbine.

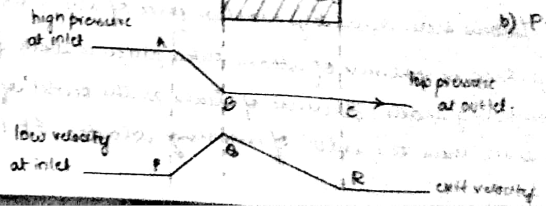


⇒ DE-LAVAL TURBINE

a) Front view.



b) P-V graph.



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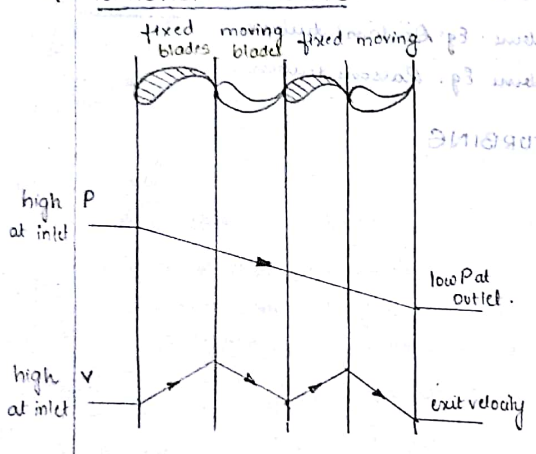
→ Impulse Turbine

Turbine runs by the impulsive action of the steam on symmetrical blades which are fixed on the circumference of rotating wheel called rotor which is connected to a shaft. In this case, drop in pressure of steam takes place only in nozzles and pressure of steam remains constant while flowing through the moving blades (constant cross-sectional area)

WORKING:- The high pressure, low velocity steam generated in a boiler enters nozzle, as the steam passes through the nozzle, expansion of steam takes place. Thus by pressure decrease and velocity increases. The high velocity steam jet coming out of the nozzle hits the blades as a result, rotor rotates which in turn rotates the shaft connected to it. Therefore K.E of steam is converted into rotational energy. This M.E can be utilized for running a generator or any other device.

→ REACTION TURBINE



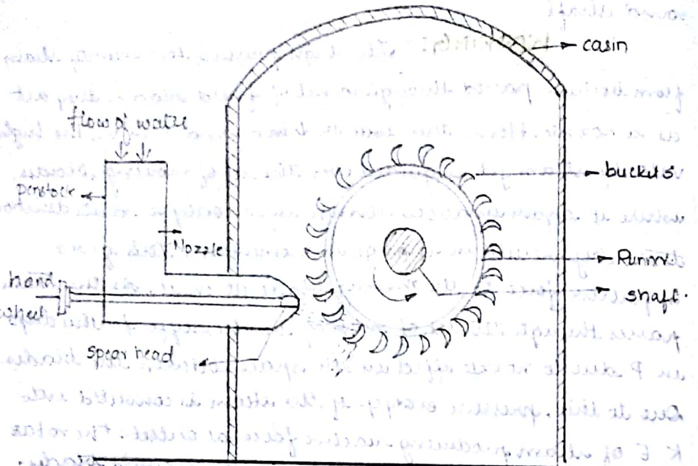
Turbine here runs by reactive force of steam on the blades. Drop in pressure of steam take place in both fixed and moving blade. Pressure of steam at the outlet of moving blade is less than the inlet of moving blades. It consists of a series of fixed and moving asymmetrical blades. Fixed blades are attached to the casing where as moving blades attached on the circumference of rotating wheel called rotor and shaft.

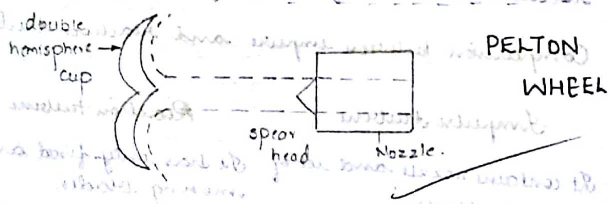
WORKING:- The high pressure low velocity steam from boiler is passed through a set of fixed blades, they act as a nozzle. Hence there will be ↓ in P and ↑ in V. The high velocity steam jet is guided over the set of moving blades, where it again undergoes change in velocity and its direction there by results in change in momentum. This gives impulsive force to the moving blade at inlet. As the steam passes through the set of moving blades suffer further drop in P due to nozzle effect in the space between the blades. Due to this, pressure energy of the steam is converted into K.E of steam producing reactive force at outlet. The rotor rotates due to net force acting on the moving blades.

* Comparison between impulse and reaction turbine.

Impulse turbine	Reaction turbine
• It contains nozzle and set of moving blades.	It has only fixed and moving blades.
• Complete drop in pressure occurs in nozzle.	Drop in pressure partly occurs in fixed blades and partly in moving blades.
• Symmetric profile blades	Assymmetric profile blades.
• Pressure constant both at inlet and exit of turbine	Pressure continuously drop from inlet to exit.
• High rotational energy can be obtained	Relatively low rotational energy
• Compounding is required	Compounding is not required
• Suitable for small capacity power plants.	Suitable for medium and high capacity powerplants

WATER TURBINES.





* Classification of water turbines

I : Based on type of energy available at inlet – Impulse turbine
– Reaction turbine

II : Head at the inlet of turbine – High head turbine.
Medium head turbine.
Low head turbine.

III : Based on direction of flow of runner
- Tangential flow turbine
- Axial flow turbine
- Radial flow turbine.
- Mixed flow turbine

PELTON WHEEL – Tangential flow impulse turbine, used for high heads of small quantity of water flow.

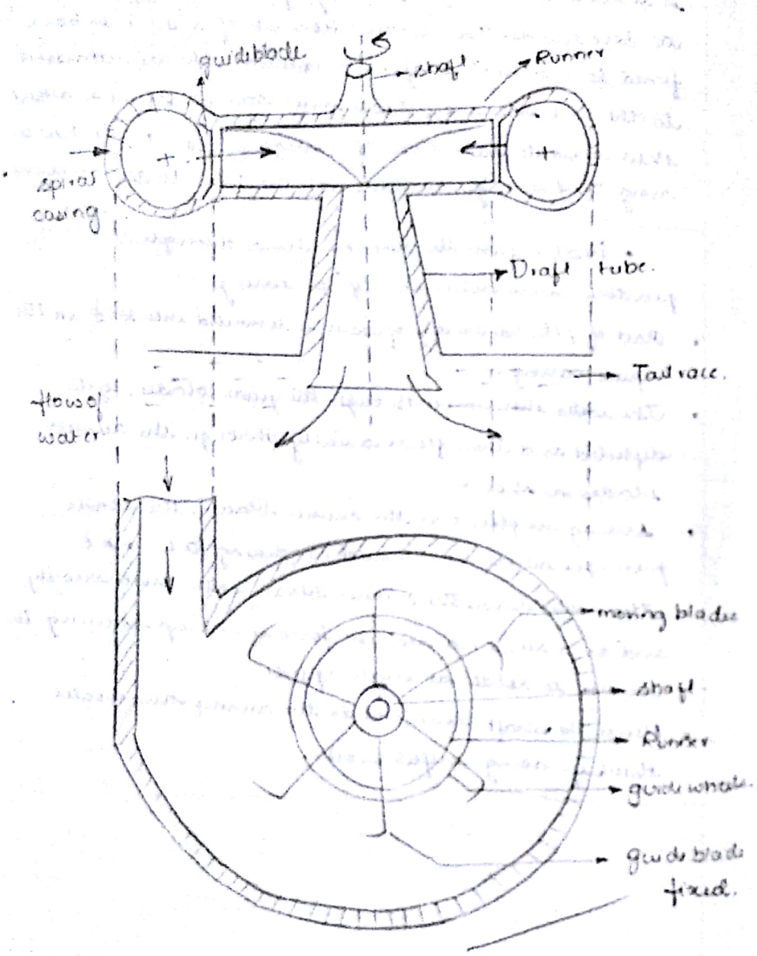
a) Nozzle with a spear head : A nozzle is a passage of varying cross-section attached to the penstock. The water jet emerging from a nozzle is tangential to the circumference of the runner wheel. The flow of water through the nozzle is controlled by a spear head, which is operated by means of hand wheel.

b) Runner and buckets : The runner is a circular wheel with a series of evenly spaced buckets fixed around its periphery. The buckets are shaped like a bowl. The advantage of having double cup shaped buckets is that, the jet of water gets split and leaves symmetrically on both sides of buckets.

c) Turbine casing – The casing prevents the ~~splashing~~ splashing of water and also helps the discharge of water into the tailrace.

Working : Water from the reservoir having potential energy flows through the penstock and enters the nozzle. As water flows through the nozzle the Potential energy of water is completely converted into K.E in the nozzle. The high velocity jet of water issuing ~~completely converted into K.E from the~~ nozzle impinge on the curved blades fixed around the runner wheel. The impulse force due to the high velocity jet of water sets the runner wheel into rotary motion. Hence the shaft coupled to the runner wheel also rotates thereby doing useful work. Thus the potential energy of water is converted into mechanical work. After performing work, the water freely discharge to the tailrace. The work produced at the output shaft is used to drive a generator to produce electricity.

* Francis Turbine.



* **Francis Turbine.**

It is a mixed flow reaction turbine used for medium heads (radial flow)

- Parts.

→ Runner – circular wheel on which a series of curved blades are fixed. The runner is coupled to a rotating vertical shaft.

→ Guide wheel – A stationary wheel around the runner of turbine. A number of blades are fixed around the circumference of guide wheel which allow water to strike at certain angle. The pressure energy of water is converted to K.E during its flow over the blades.

→ Spiral casing – closed passage surrounding the guide blades. The cross-sectional area of the spiral casing gradually decreases along from flow direction in order to distribute water uniform around entire perimeter of runner.

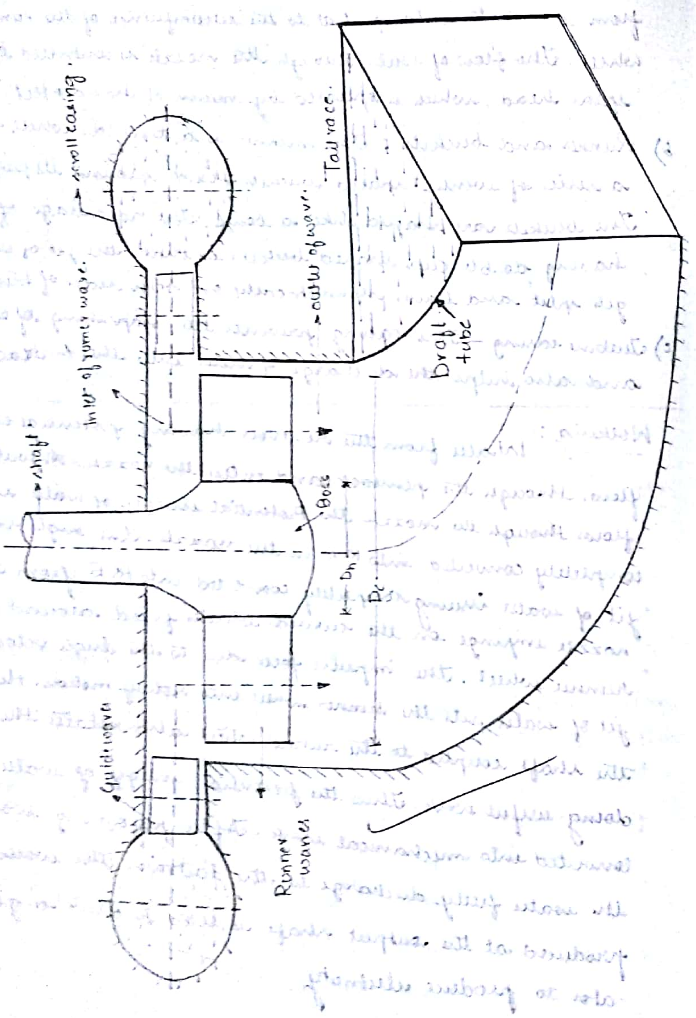
→ Draft tube – Tube of gradually increasing area used for discharging water from exit of turbine.

- Working :-

Water from reservoir flows through penstock and enter spiral casing. As water flows a part of its P.E is converted to K.E water flows through guide blades. gets deflected and flows radially inwards to outer periphery of runner. The water then moves over the moving blades and is finally discharged to tailrace axially from center of runner through draft tube.

During its flow over the runner blades, the blade passage act as nozzle and remaining P.E is converted to K.E since water leaves the blades at high velocity there is reaction force on runner which sets it into rotary motion. Hence shaft connected to runner also rotates thereby doing useful work.

* KAPLAN TURBINE



Construction and working

Kaplan turbine is an axial flow reaction turbine and is used when large quantity of water is available at low heads. The turbine consists of a hub or boss fixed to a vertical shaft. The runner blades attached to the hub are adjustable and can be turned about their axis to take care of change of load. It has a ring of fixed guide blades at the inlet to the turbine.

- Water from the reservoir flows through the penstock and enters the spiral casing.
- Part of potential energy of water is converted into K.E in the spiral casing.
- The water then moves through the guide blades, gets deflected and then flows axially through the runner blades as shown
- During its flow over the runner blades, the blade passages act as nozzle and remaining P.E → K.E.
- The water leaves the runner blades with high velocity and as a result, a reaction force is set up causing the runner to rotate at high speeds.
- Hence the shaft connected to the runner also rotates thereby doing useful work.

MACHINE TOOLS

* The universal engine or lathe is extensively used in job and lot production.

Principle of working of a center lathe.

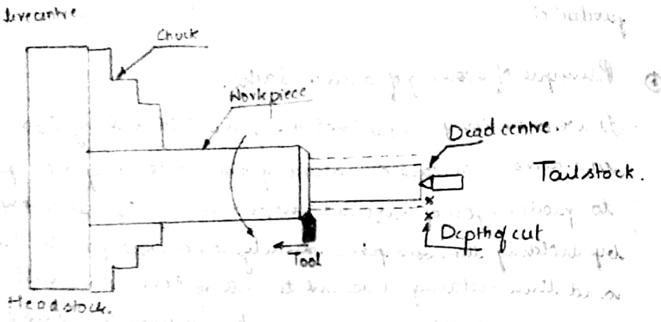
It works on the principle that a rigidly held cutting tool can remove unwanted material from the rotating work-piece to produce job of required shape and size. This is accomplished by holding the work piece securely and rigidly on the lathe and then rotating it against the cutting tool which will remove unwanted materials in the form of chips. The cutting tools

Operations performed on the lathe.

There are many operations which a lathe machine can perform but common ones are:

- Facing
- Knurling
- Thread cutting
- Turning
- Taper turning
- Drilling
- Boring.

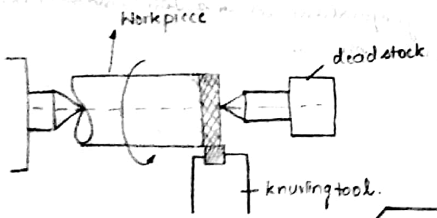
(a) Facing



(a) FACING

- It is the operation of generating flat surface by reducing the length of the workpiece
- Here cutting tool is fed ⊥ to the axis of the rotation of the workpiece.

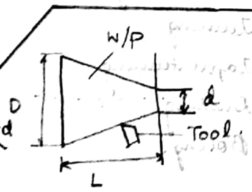
(b) Knurling

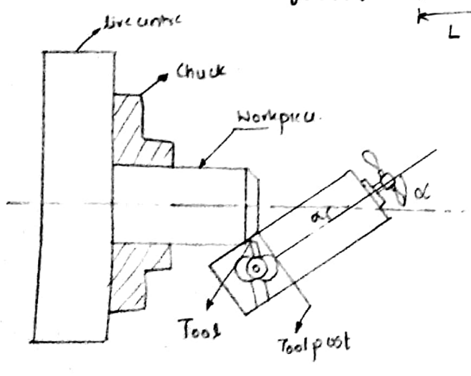


(b) KNURLING.

- It is the process of embossing diamond/angled/straight shaped pattern on the surface of a workpiece using knurling tool.
- The purpose of knurling is to provide an effective grip on a working piece to prevent it from slipping when operated by hand.

(c) Compound slide swivelling method





α - half taper angle

$$\tan\alpha = \frac{D-d}{2L}$$

$D \rightarrow$ large dia of W/P

$d \rightarrow$ small dia of W/P

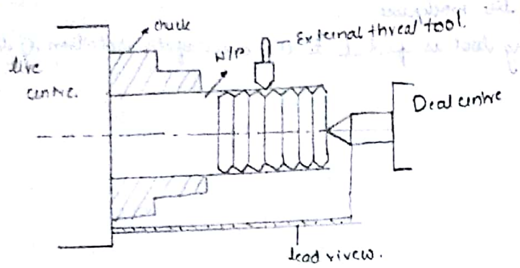
$L \rightarrow$ length of W/P

$$\alpha = \tan^{-1}\left(\frac{D-d}{2L}\right)$$

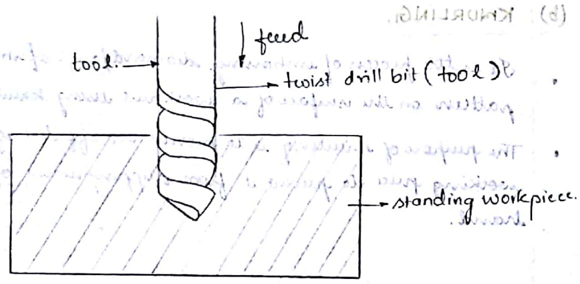
(c) COMPOUND SLIDE SWIVELLING METHOD.

- The principle of turning taper by this method is to rotate the workpiece on the lathe axis and feeding the tool at an angle to the axis of the rotation of the workpiece.
- The tool mounted on the compound rest is swivelled and clamped at any desired angle.

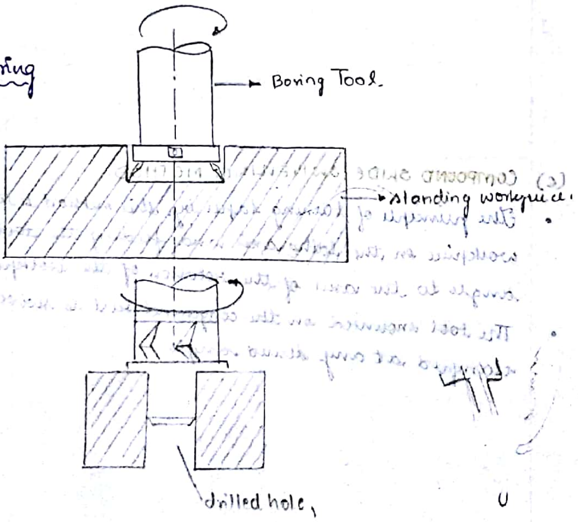
(d) Thread Cutting.



(e) Drilling operation.



Counter boring



THREAD CUTTING

- It is the process of generating screwed threads of desired hand on a cylindrical or conical rod in which tool is fed longitudinally with uniform linear motion while the workpiece is rotating with uniform speed as shown.

DRILLING OPERATION

- a) Drilling
- b) Reaming
- c) Boring
- d) Counter boring
- e) Counter sinking
- f) Spot facing
- h) Tapping.

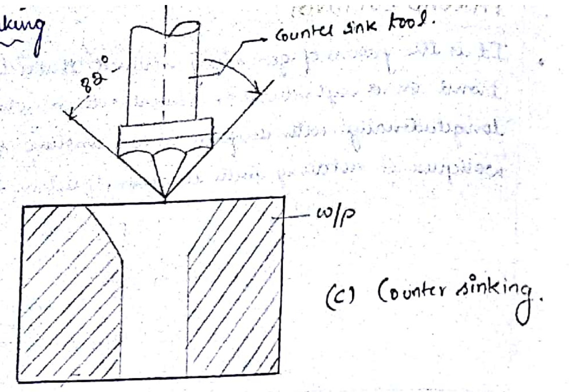
a) Drilling operation.

- Drilling is the operation of producing cylindrical hole by removing metal by rotating edge of a cutting tool called the "drill-bit".
- Before drilling the tip of the drill will be aligned with the centre punch mark on the workpiece and then drill point is pressed at this centre point to produce the required hole.
- Drilling does not produce an accurate hole. The hole so produced is oversized than the drill bit used and hole surface is not smooth.

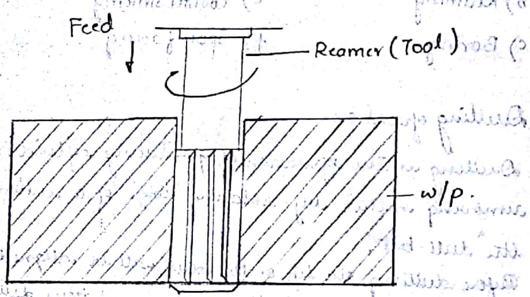
b) Counter boring.

- Counter boring is the operation of enlarging one end of an already drilled hole through small depth using counter boring tool called counterbore.
- The enlarged hole forms shoulder with the original hole.
- Counter boring is performed to accomodate bolt heads, studs etc.

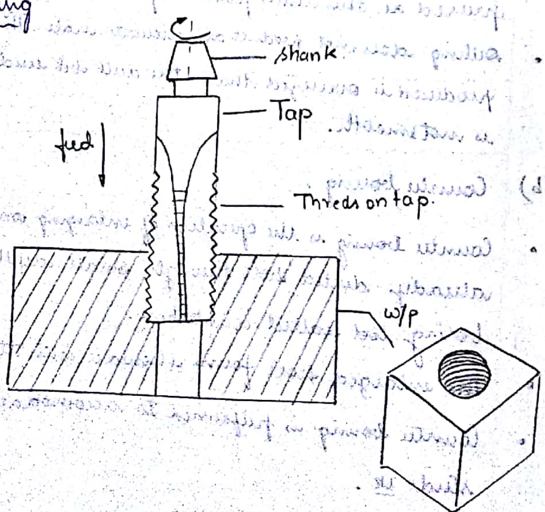
Counter sinking



Reaming



Tapping



c) Counter sinking

- Counter sinking is the operation performed on one end of an already drilled hole to get conical shape using counter sinks.
- Counter sinking is performed to accomodate countersunk screws / screws with conical head.

d) Reaming

- Reaming is the operation of sizing and finishing a previously drilled hole with a reamer.
- Reamer does not originate a hole, simply it follows the path of originally drilled hole and removes only a small amount of material and produces a smooth finished on the drilled surface.

e) Tapping

- Tapping is the operation of cutting internal threads in a drilled hole with thread cutting tool called tap.
- A tap is a bolt with accurate threads on it.
- During tapping operation the spindle rotates at slow speed

- When the tool moves *perpendicular* to the axis of the workpiece, a *flat surface* is produced. Refer figure 5.1 (c). This operation is known as *facing*.
- When the tool moves at an *angle* to the axis of rotation of the workpiece, a *tapered surface* can be produced. Refer figure 5.1 (d).

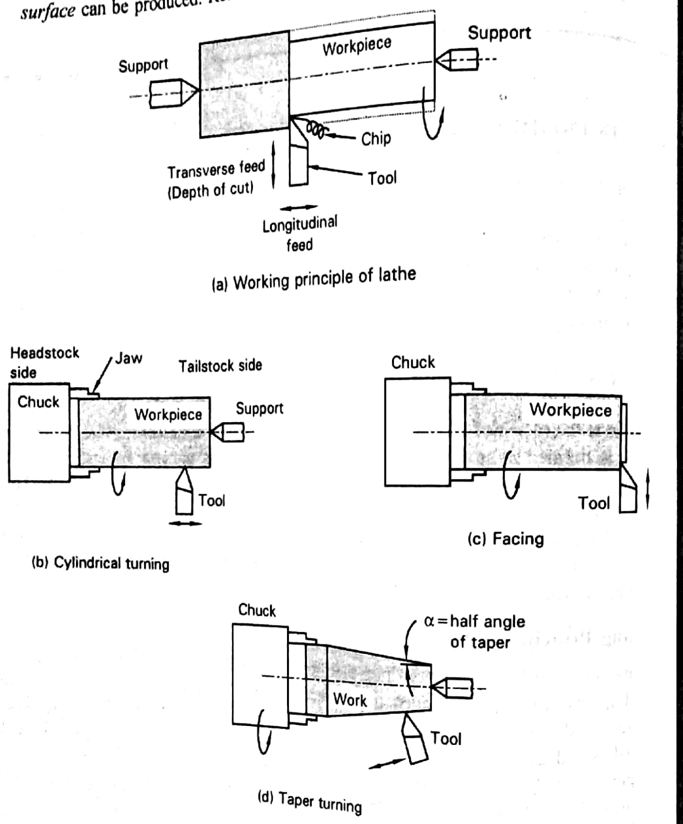


Figure 5.1 Working of a lathe

Apart from turning and facing operations, a variety of other machining operations can be carried out on lathes. These include knurling, thread cutting, chamfering, parting, drilling, reaming, boring, grinding etc.

5.3 PARTS OF A LATHE

Figure 5.2 shows the major parts of a center lathe. It consists of the following parts:

1. Bed
2. Headstock
3. Tailstock
4. Carriage
5. Feed rod
6. Lead screw

1) Bed

It is a rigid structure which forms the base or foundation to support all the other parts such as headstock, tailstock, carriage, etc. It is usually made from *gray cast iron*. At the top of the bed are the guideways, which guides for accurate movement of carriage and tailstock.

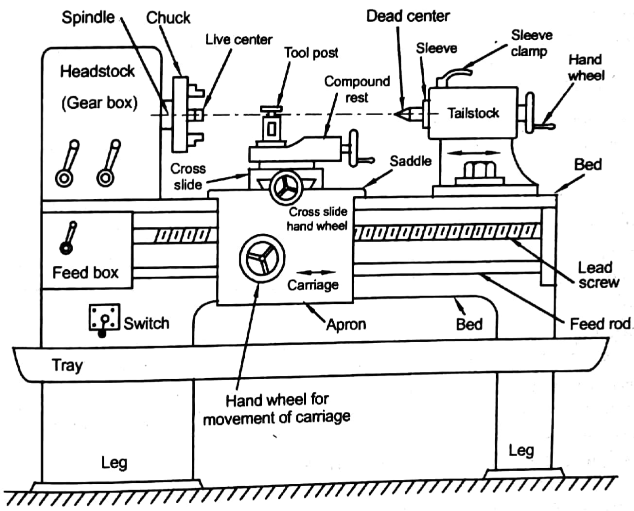


Figure 5.2 Parts of a center lathe

2) Headstock (Live center)

The headstock is mounted at the left end of the lathe bed. It contains gears or pulleys by means of which the workpiece can be rotated at different speeds. The headstock spindle is provided with a *live center* or *chuck* to support one end of the workpiece while it is being rotated.

3) Tailstock (Dead center)

The tailstock is mounted at the right end of the lathe bed. The main functions of the tailstock are:

- To provide support to the other end of the rotating workpiece *(job)*
- To hold a tool for performing operations like drilling, reaming, tapping, etc.

The tailstock can be made to slide along the bed, and can be clamped at any location so as to accommodate the workpiece of different lengths. It can also be shifted laterally on the bed so as to make it offset for cutting tapers.

4) Carriage

The cutting tool is supported, moved and controlled with the help of carriage. It consists of the following parts.

- **Saddle** The saddle can be made to slide along the bed-ways, and supports the cross-slide, compound rest and tool post.
- **Cross-slide** The cross-slide is mounted on the saddle. It allows the cutting tool to move at right angle to the lathe axis thereby providing the necessary depth of cut to the workpiece.
- **Compound rest** It is mounted on the cross-slide and supports the tool post. The compound rest has a circular base graduated in degrees. This helps the cutting tool to be swivelled at any angle to obtain taper surfaces.
- **Tool-post** It is mounted on the compound rest, and is used to hold/support the cutting tool firmly in position during machining.
- **Apron** The apron is fitted beneath the saddle facing the operator. It houses the gears, levers, hand-wheels and clutches to operate the carriage by hand or by automatic power feed.
- **Feed rod** The feed rod is a long shaft that gives automatic feed to the carriage for various operations namely boring, turning etc., *except thread cutting.*
- **Lead screw** It is a long shaft with square threads cut on it. The rotation of the lead screw facilitates the movement of carriage during thread cutting operations.

5.4 CLASSIFICATION OF LATHES

Lathes are designed in a wide variety of types and sizes to suit different applications. It is difficult to classify them into some definite categories. However, based on the construction and functions, lathes are classified as follows:

- Speed lathe
- Engine lathe or center lathe

- Bench lathe
- Tool room lathe
- Capstan and turret lathe
- CNC (Computer Numerical Control) lathe, etc.

Since the scope of the present chapter does not allow a detailed description of all the above mentioned machines, a brief description of the same is provided for the benefit of readers.

a) Speed lathe

It is so called, because of its high spindle speeds. Speed lathes are the simplest of all lathes and carry most of the attachments as other machines, but have no provision for power feed. They have no gearbox, carriage, and lead screw, and hence the tool is fed and controlled manually by hand. Speed lathes are preferred in woodworking, metal spinning, buffing, polishing and other operations, where light cuts are to be made in workpieces.

b) Engine lathe

Engine lathe is one of the most widely used lathes and is so called in view of the fact that earlier lathes were driven by *steam engines*. It is a general purpose turning machine used to perform a variety of operations. Engine lathe is also called *center lathe*, since the workpiece is held and rotated between two centers: one being the *live center*, rotating at the headstock side, and the other, *dead center,* supporting the workpiece at the tailstock side.

c) Bench lathe

Bench lathe is a small sized lathe, usually mounted on a bench. It is similar to a center lathe or a speed lathe carrying similar parts and performing almost all the operations. Its small size makes it suitable for machining light jobs and precision work.

d) Tool room lathe

It is a modern engine lathe equipped with some extra attachments to make it suitable for more accurate and precision type of work carried out in a tool room, for the production of tools, dies, gauges, fixtures, and similar such parts.

e) Capstan and turret lathes

Capstan and turret lathes are production machines, usually semi-automatic type equipped with special tooling facilities. Usually, the tool head (tool carrier) can carry around six to twelve cutting tools that can be fed into the workpiece in a proper sequence. This facility enables the operator to perform different operations without changing tools frequently. Hence it is used in mass production.

f) Automatic lathes

Automatic lathes are mass production machines in which the sequence of operations including change of speeds and feeds, tool movement, indexing of tool head etc., are all carried out

b) Body

The body is the portion of the twist drill that forms the main cutting unit. The body contains two or more spiral or helical grooves called *flutes* that perform three basic functions:

- Forms the cutting edge.
- Help in the removal of chips, and
- Allow the coolant to reach the cutting edges.

c) Point

The point is the cutting end of the drill. It is a cone shaped surface that helps to locate the center point of the hole to be drilled.

d) Neck

It is the small portion of the drill bit that separates the body and the shank.

5.9 CLASSIFICATION OF DRILLING MACHINES

Drilling machines are classified according to their general construction and type of work they are required to do. The different types of drilling machines include:

a) Portable drilling machine
b) Bench or Sensitive drilling machine
c) Radial drilling machine
d) Upright drilling machine
e) Multi-spindle drilling machine
f) Gang drilling machine
g) Automatic drilling machine
h) Deep hole drilling machine
i) Computer Numerical Control (CNC) drilling machine.

Note

- From the syllabus point of view only bench *drilling* and *radial drilling* machines have been discussed in the present chapter.
- Drilling machines are also called *Drill* or sometimes *Drill press*, since a vertical force or pressure is exerted on the tool to generate a hole.

5.10 BENCH or SENSITIVE DRILLING MACHINE

Bench drilling machines are used for drilling small holes at high speeds in small sized workpieces. The diameter of the hole usually ranges from 1.5 mm to 15 mm. The machine

is usually supported on a work-bench and hence the name *bench drilling machine*. Figure 5.13 shows the details of a bench drilling machine.

Construction

The machine consists of the following parts:

a) Base

The base of the machine is made from cast iron material and supports the vertical column. The base is provided with holes to secure it firmly to the table/bench with the help of bolts and nuts.

b) Vertical column

The column is a hollow steel pipe mounted rigidly on the base. It supports the drill head and the worktable.

c) Worktable

The worktable supports the workpiece to be drilled. It is usually provided with T-slots that help the workpiece to be clamped rigidly on the table. The table can be raised or lowered, and can be clamped to the vertical column at any desired position. This helps to accommodate different sizes of workpiece on the table. The table can also be swiveled around the vertical column to any desired position.

d) Drill head

A fixed drill head located at the top end of the vertical column carries an electric motor and a mechanism through which the spindle can be made to rotate, as well as slide up and down. The top end of the spindle is connected to a stepped cone pulley which obtains power (rotary motion) from the motor shaft through a v-belt arrangement. The speed of the spindle can be varied by changing the belt position on the stepped pulley. The lower end of the spindle carries a drill chuck to hold the drill bit rigidly during operation. The vertical movement of the spindle and hence the drill bit, is controlled by the hand feed lever located at the front end of the machine facing the operator.

Operation

In operation, the workpiece is clamped rigidly on the worktable. With the help of a center punch, an indentation mark is made on the workpiece at the location where the hole is to be drilled. The drill bit is made to rotate at a suitable speed by adjusting the v-belt on the stepped cone pulley. With the help of the hand feed lever, the drill bit is moved downwards till the *point (cutting end)* of the drill bit touches the indentation mark. Gradual feed to the drill bit is given by operating the hand feed lever till the desired depth of the hole is achieved. The drill bit is withdrawn slowly from the workpiece by operating the hand feed lever in the reverse direction.

In bench drilling machine, the operator feeds the drill bit by rotating the hand feed lever. This enables him to *sense* or feel the movement of the drill bit into the workpiece, which in turn helps to vary the feed. Hence, the machine is also called *sensitive drilling machine*.

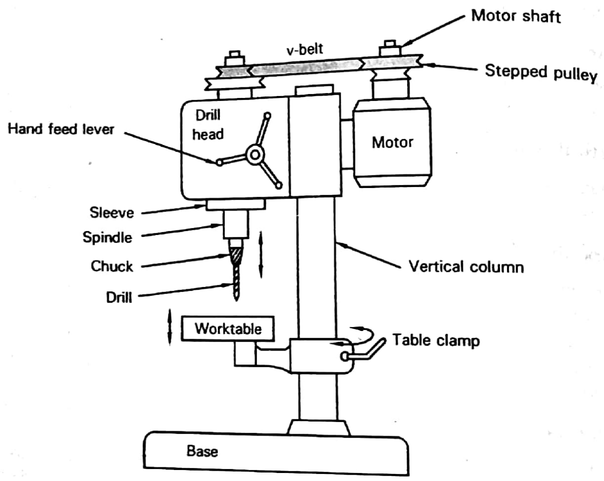


Figure 5.13 Bench or Sensitive drilling machine

5.11 RADIAL DRILLING MACHINE

Radial drilling machines are used for drilling medium or large diameter holes of up to 50 mm in heavy workpieces. Figure 5.14 shows the principal parts of a radial drilling machine.

Construction

The machine consists of the following parts:

a) Base

The base of the machine is a large cast iron material on which is mounted a cylindrical vertical column. The base is provided with T-slots, which help the workpiece to be clamped rigidly to the base of the machine.

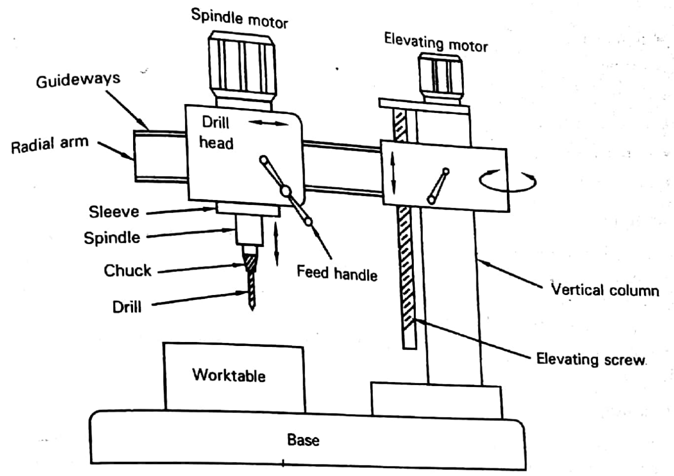


Figure 5.14 Radial drilling machine

b) Vertical column

The column is a long, cylindrical shaped part fastened rigidly to the base. The column carries a radial arm that can be raised or lowered by means of an electric motor and can be clamped to any desired position. The radial arm can also be rotated (swiveled) in a complete circle around the column.

c) Drill head

The drill head is mounted on the radial arm and carries a driving motor and a mechanism for revolving and feeding (power feed) the drill bit into the workpiece. The drill head can be moved horizontally on the guideways provided in the radial arm, and can be clamped to any desired position.

With the combination of the movements of *radial arm* and the *drill head*, it is possible to move the drill bit and hence generate a hole at any desired position without moving the workpiece.

5.12 DRILLING and RELATED OPERATIONS

A variety of operations are performed on a drilling machine. These include:

- Drilling