MANUFACTRUING PROCESS

- Production or manufacturing can be simply defined as value addition processes by which raw materials of low utility and value due to its inadequate material properties and poor or irregular size, shape and finish are converted into high utility and valued products with definite dimensions, forms and finish imparting some functional ability. A typical example of manufacturing is schematically .

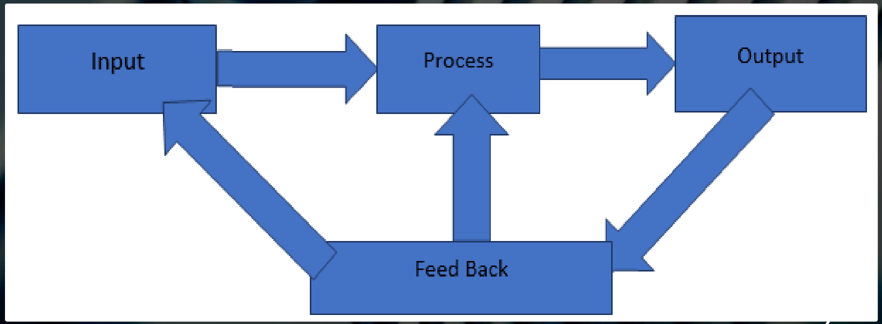
MANUFACTURING PROCESS

- Manufacturing is close loop of input-process-out put through feed back system where ………

- **Input:** Raw material :
- Wood,
- Metal,
- Plastic etc.

- **Process** :Casting,Welding,Forging,Machinining,Sheet metal, Fitting etc.

- **Out put-** desired product



Content

- Introduction
- Mechanical properties
- Classification of casting process
- Advantage of casting process
- Metal Solidification
- Pattern
- Pattern allowance
- Function of pattern
- Pattern material
- Types of pattern
- Sand mould making process
- Molding sand,
- Type of molding sand,
- Properties of molding sand
- Core prints, core shifting and chaplets
- Cupola furnace

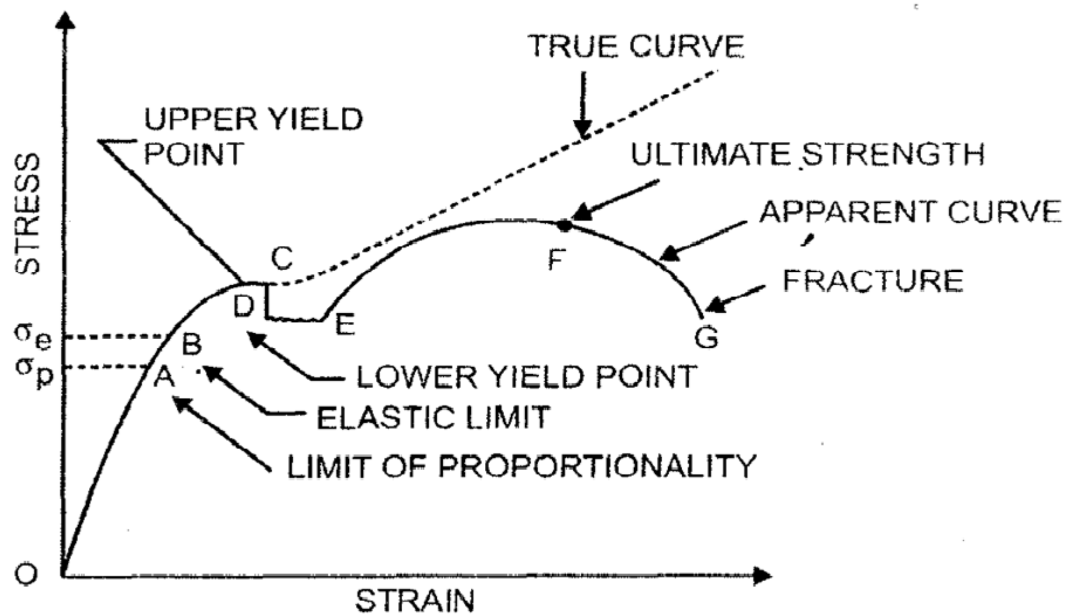
Content

- Gating system
- Riser and its type
- Special Metal Casting Process
- **Metal mold casting**
- Gravity or permanent mold casting
- Pressure die casting
- Slush casting
- **Non-metallic mold casting**
- Centrifugal casting:
- True centrifugal
- Semi-centrifugal
- Centrifuge
- Investment casting
- Shell molding
- Casting Defects

MECHANICAL PROPERTIES

- ❖ The practical application of engineering materials in manufacturing engineering depends upon thorough knowledge of their properties. Behavior of material under loading is always matter of interest among engineers. few of these properties are as :
- ✓ Strength
- ✓ Elasticity
- ✓ Stiffness
- ✓ Malleability
- ✓ Ductility
- ✓ Brittleness
- ✓ Toughness
- ✓ Hardness.

Stress-Strain Curve



MECHANICAL PROPERTIES

- **Strength:**

The strength of a material is its capacity to withstand destruction under the action of external loads. It, therefore, determines the ability to withstand stress without failure. The maximum stress that any material can with stand before destruction is known as ultimate strength.

- **Elasticity**

It is a property of material by virtue of which deformation caused by applied loads disappear upon removal of load. It is the tensile property of material.

- **Stiffness**

The resistance of a material to elastic deformation or deflection is called stiffness or rigidity. A material which suffers slight deformation under heavy load has high degree of stiffness or rigidity.

MECHANICAL PROPERTIES

- **Malleability**

It is an ability of a material to be flattened into their sheets without cracking by hot or cold working. It is a compressive property.

- **Ductility**

It is a property of the material which enables it to draw out into thin wires. It is a tensile property.

- **Brittleness**

It is a property of material of breaking without much permanent distortion. Brittle material have very less tensile strength.

MECHANICAL PROPERTIES

❖ Hardness

It is the ability of a material to resist scratching ,abrasion ,cutting, indentation or penetration.

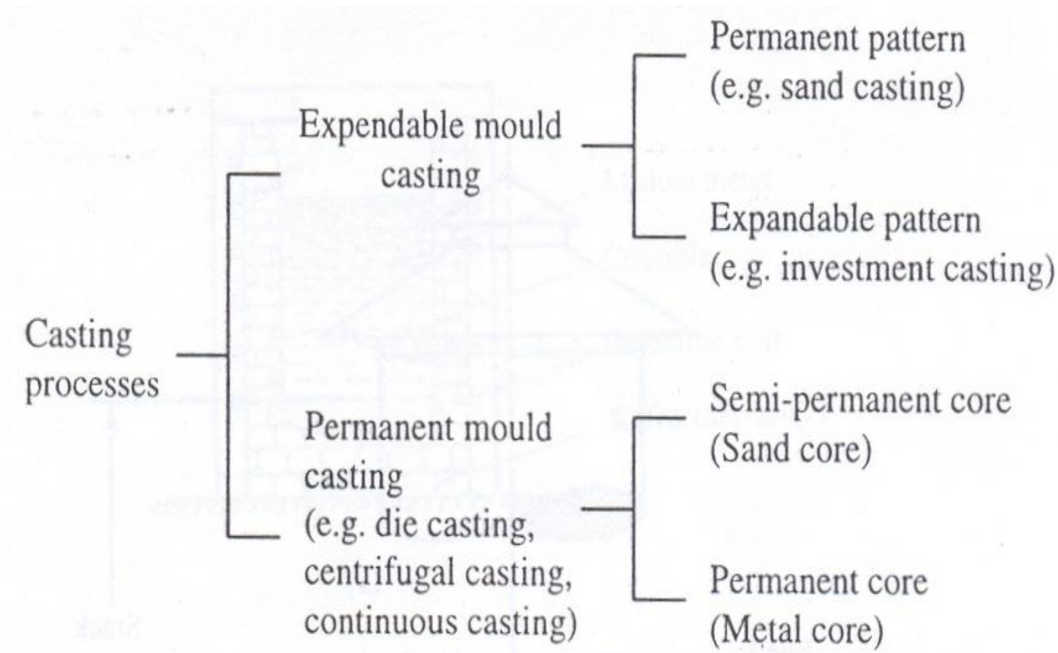
Whereas hardenability indicates degree of hardness that can be imparted to a metal by the process of hardening.it is determined by Jomy test.

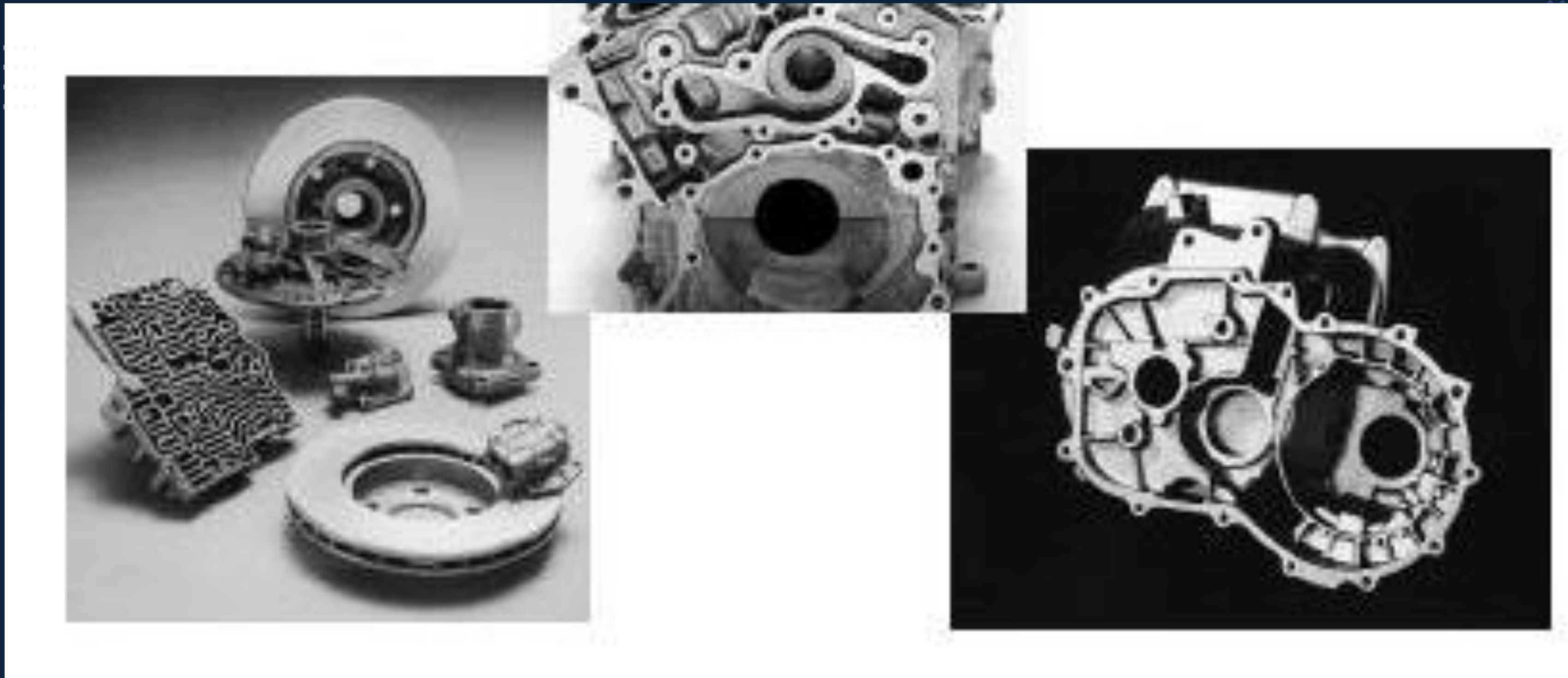
❖ Toughness

It is a measure of amount of energy a material can absorb before actual fracture or failure takes place.

The toughness of a material is its ability to withstand both elastic and plastic deformation.

METAL CASTING





Metal Casting

- Metal casting is one of the oldest materials shaping methods known.
- Pouring of molten metal into a formed mold to cool into a solid part is casting.
- Casting and solidification involve pouring and cooling the liquid metal
- Knowledge of metallurgical behavior of metal, Mechanical properties ,heat transfer, fluid mechanics is also necessary.

CASTING PROCESS

- ❖ Ingot casting
- ❖ Continuous casting
- ❖ Shape casting

a. Pattern making

b. Mould making and core making

c. Melting and Casting

d. Fettling

e. Testing & Inspection

ADVANTAGES OF CASTING

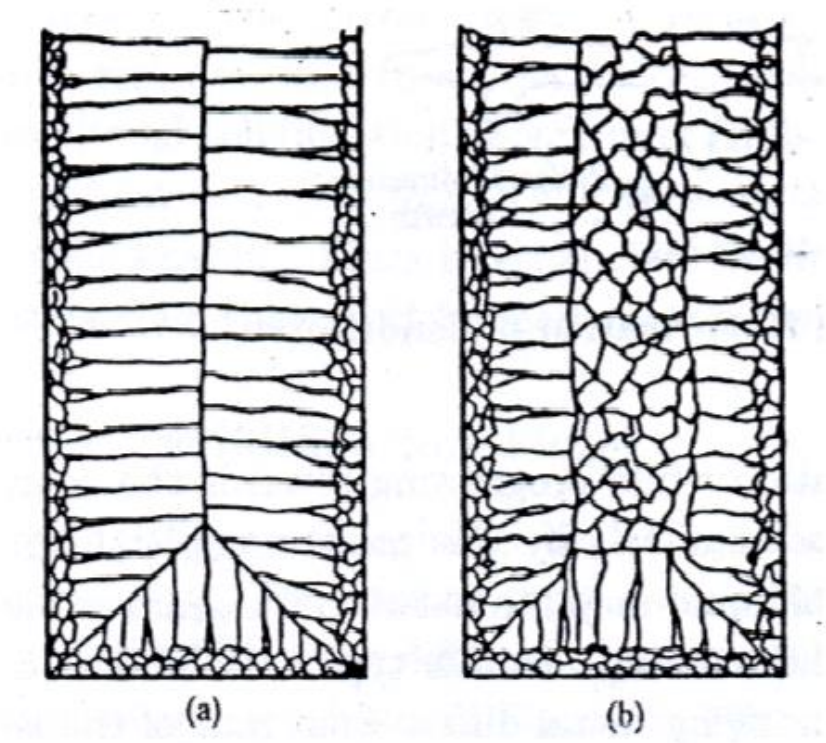
- Molten material can flow into very small sections so that intricate shapes can be made by this process. As a result, many other operations, such as machining, forging, and welding, can be minimized or eliminated.
- It is possible to cast practically any material that is ferrous or non-ferrous.
- As the metal can be placed exactly where it is required, large saving in weight can be achieved.
- The necessary tools required for casting molds are very simple and inexpensive. As a result, for production of a small lot, it is the ideal process.
- There are certain parts made from metals and alloys that can only be processed this way.
- Size and weight of the product is not a limitation for the casting process.

LIMITATIONS

- Dimensional accuracy and surface finish of the castings made by sand casting processes are a limitation to this technique.
- Many new casting processes have been developed which can take into consideration the aspects of dimensional accuracy and surface finish.
- Some of these processes are die casting process, investment casting process, vacuum-sealed molding process, and shell molding process.
- The metal casting process is a labor-intensive process.
- Rejection rate is high.
- Internal defects are not easily noticeable.

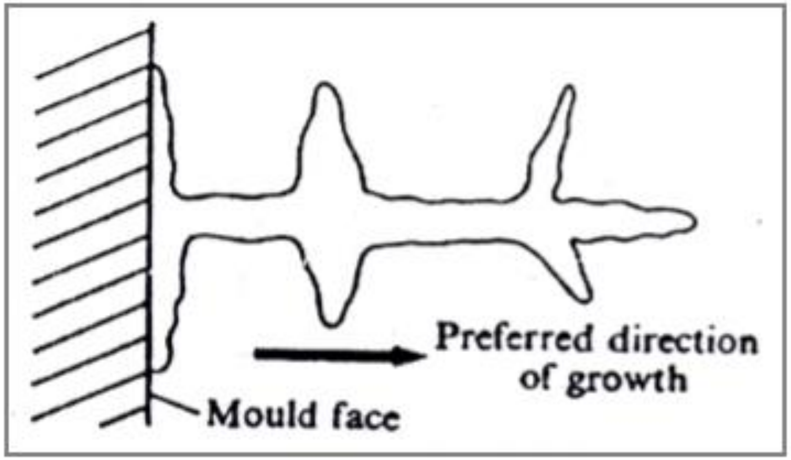
SOLIDIFICATION

- The properties of the casting significantly depends on the solidification time and cooling rate.
- Shrinkage of casting, during cooling of solidified metal should not be restrained by the mould material,
- Otherwise, internal stresses may develop and form cracks in casting.
- Proper care should be taken at the design stage of casting so that shrinkage can occur without casting defects.



PURE METAL

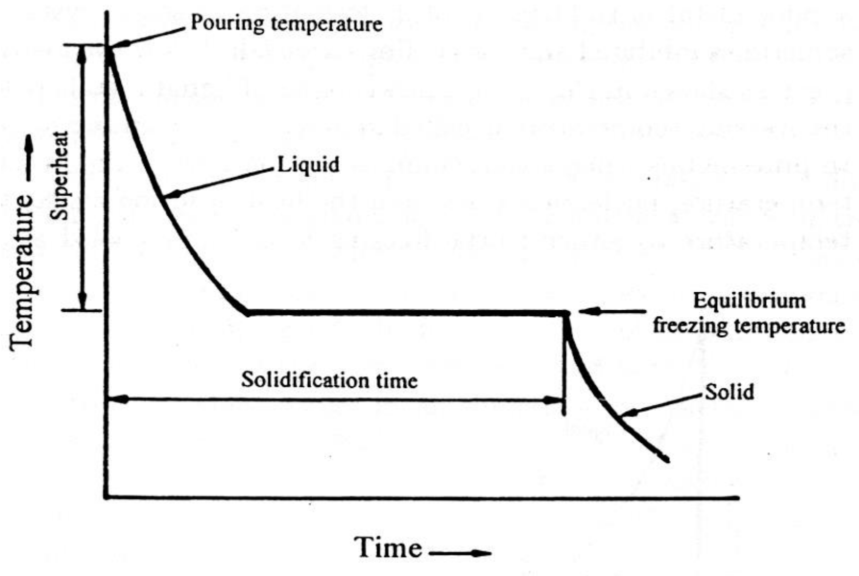
ALLOY



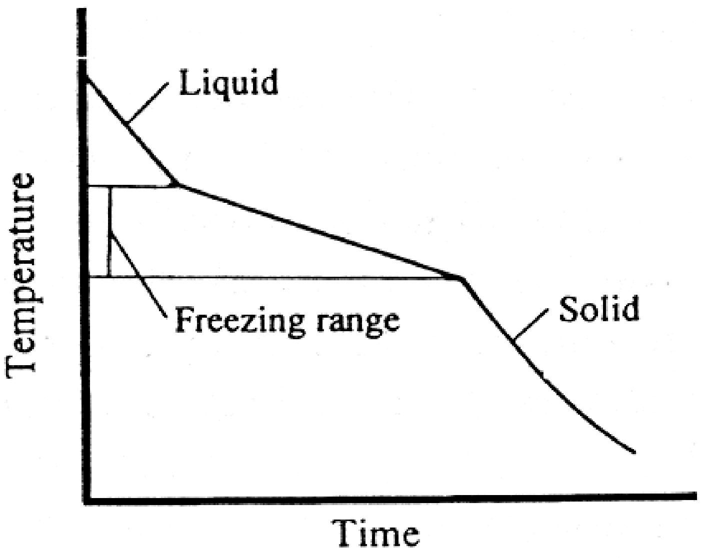
SOLIDIFICATION MECHANISM

DENTRITE FORMATION

Cooling and Solidification

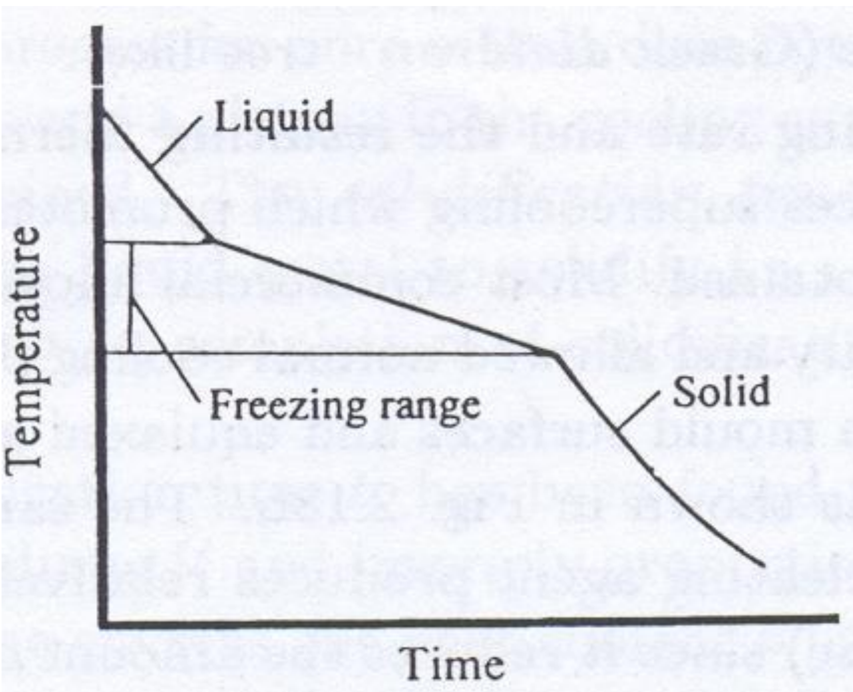


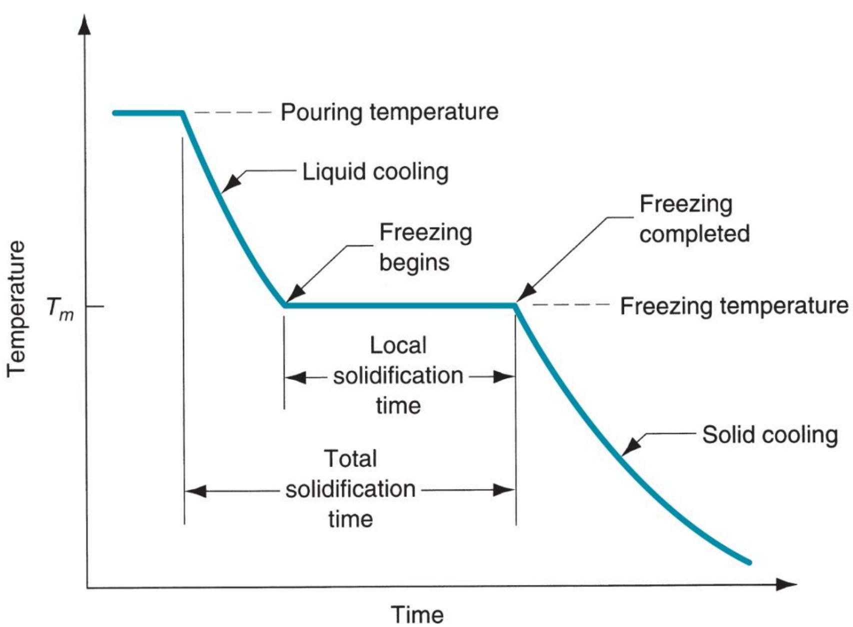
Pure metal



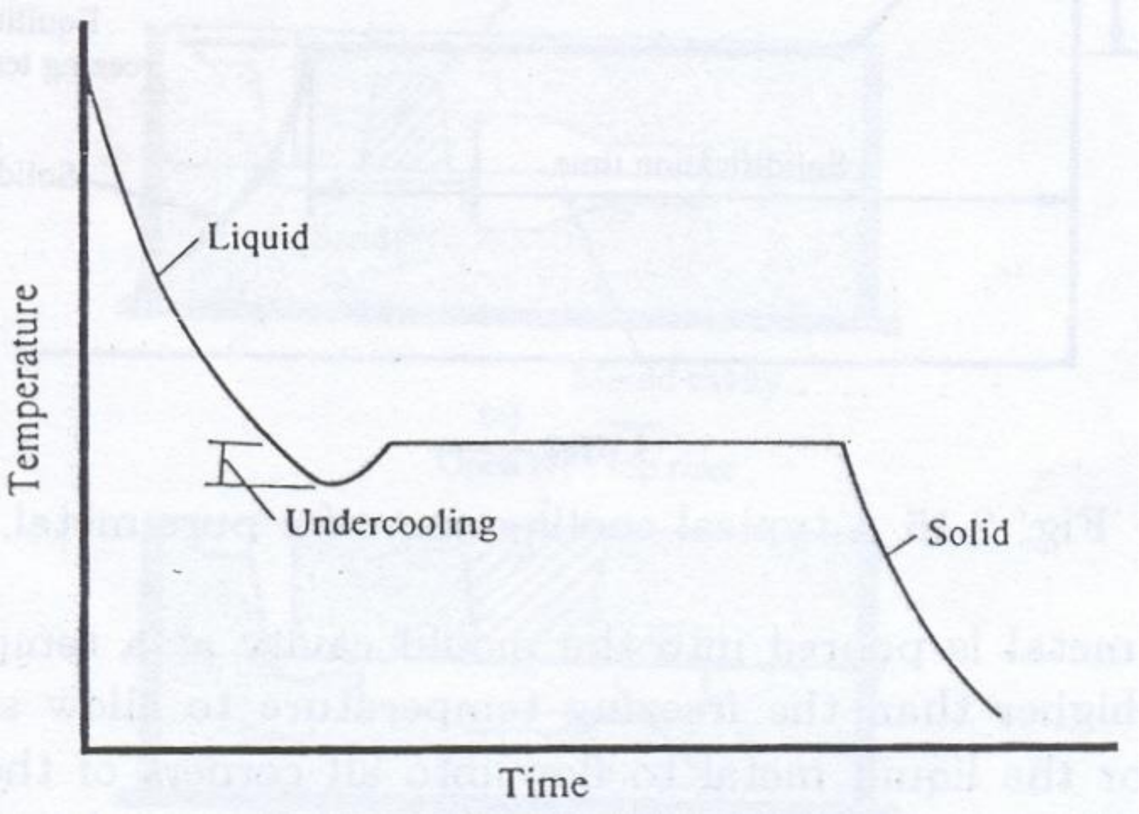
Alloy

COOLING AND SOLIDIFICATION CURVE



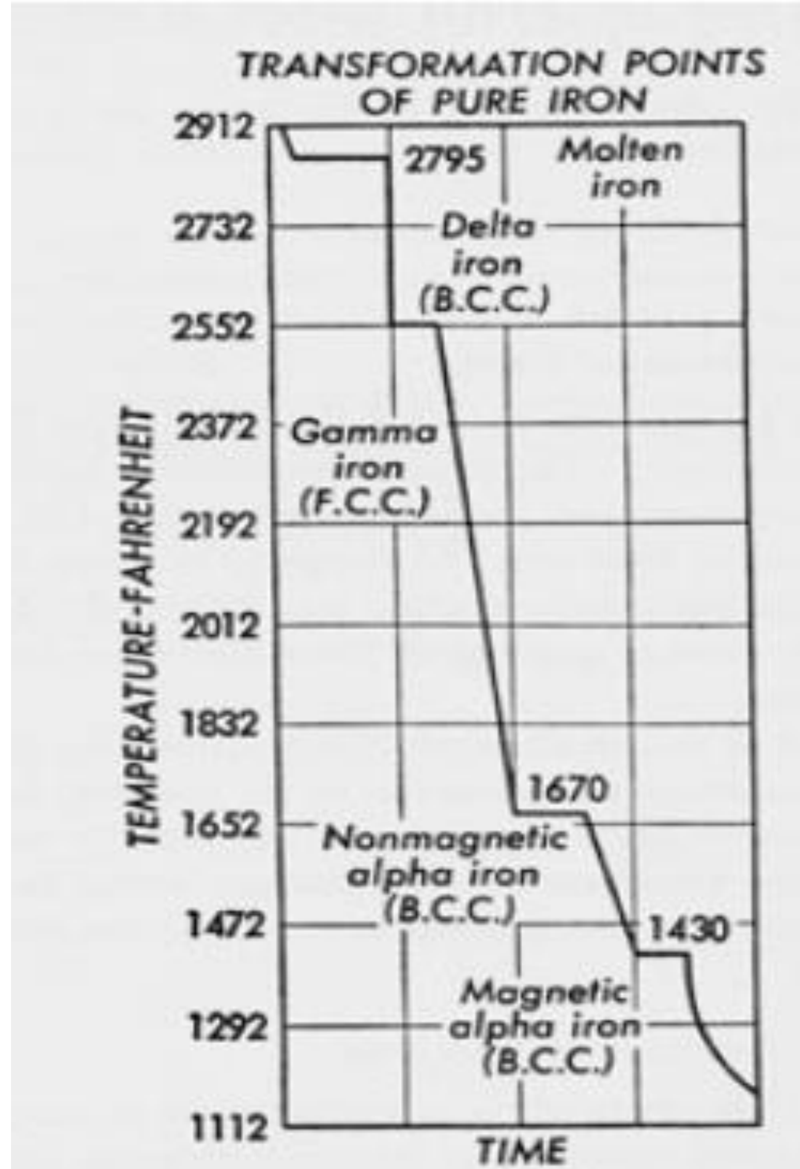


COOLING AND SOLIDIFICATION



COOLING CURVE

- Iron may exist in several allotropic forms like α,β,γ,δ in solid state. the existence of one form to the other depends upon the temperature to which the iron is heated.
- As shown in fig. the first horizontal step appears on this curve at a temperature of 1535 °C.(which is the melting point of pure iron).above this metal is in molten state and upon freezing delta(δ) iron is formed.(BCC structure.)

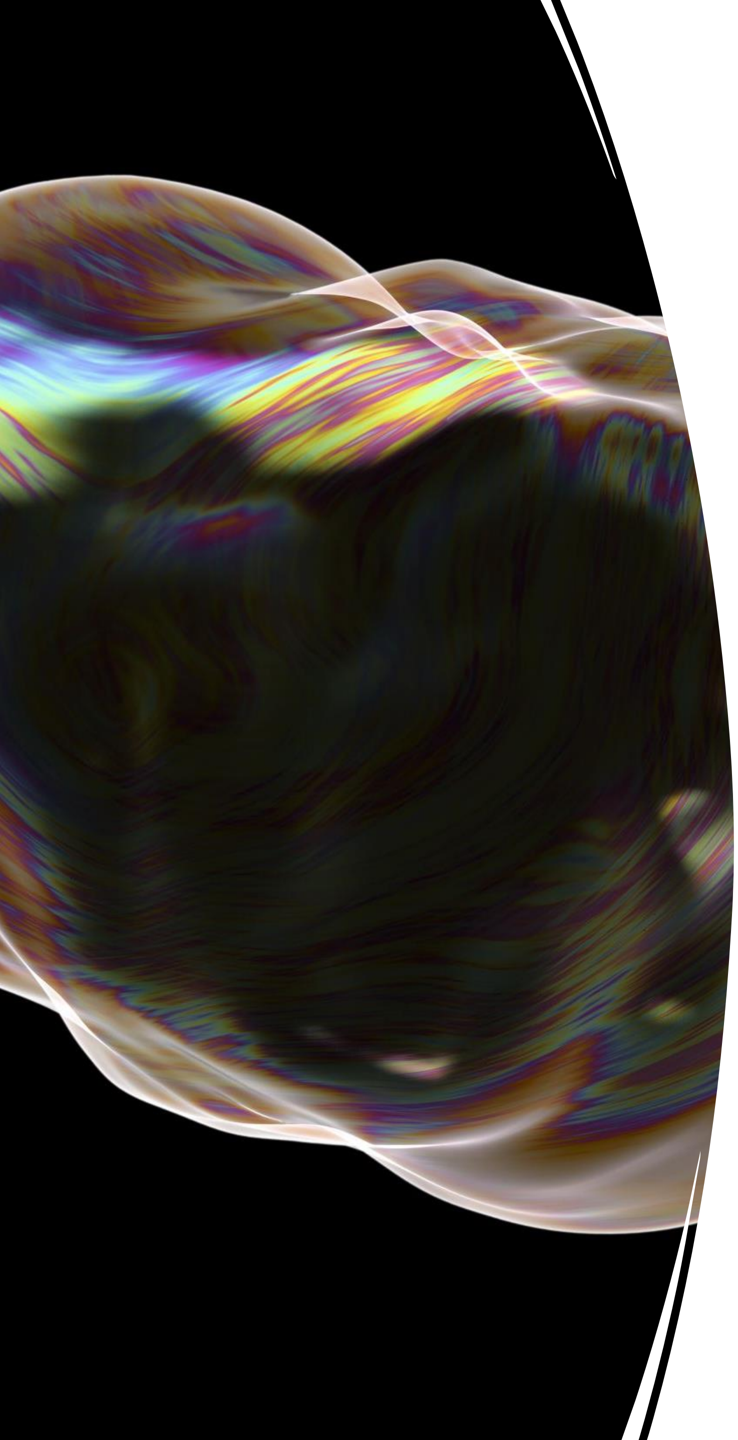


COOLING CURVE

At temperature 1400°C ,delta iron transform into Gamma iron.(FCC)

At temperature 910°C , Gamma iron transform into nonmagnetic alpha iron .(BCC)

At temperature 768°C , nonmagnetic alpha iron transform into magnetic alpha iron which exist at room temperature.



SOLIDIFICATION MECHANISM

- Pure metals solidifies at a constant temp. equal to its freezing point, which same as its melting point.
- The change form liquid to solid does not occur all at once.
- The process of solidification starts with nucleation, the formation of stable solid particles within the liquid metal.
- Nuclei of solid phase, generally a few hundred atom in size, start appearing at a temperature below the freezing temperature.
- A nuclei, more than a certain critical size grows, and causes solidification.

SOLIDIFICATION MECHANISM

By adding, certain foreign materials (nucleating agents) the under-cooling temp. is reduced which causes enhanced nucleation.

In case of pure metals fine equi-axed grains are formed near the wall of the mold and columnar grain growth takes place up to the centre of the ingot.

In typical alloy, the columnar grains do not extend up to the center of casting but are interrupted by an inner zone of equiaxed grains.

By adding typical nucleating agents like sodium, magnesium or bismuth the inner zone of equiaxed grained can be extended in whole casting.

PATTERN

- A pattern may be defined as a model or a form around which sand is packed to give rise to a cavity known as mold cavity in which the when molten metal is poured the result is the cast object.

- To get good casting it is important to produce the correct cavity .The cavity or the mould is created by consolidating the mould material around pattern.

- A pattern is a mold forming tool in the hands of foundry man.

A pattern is model or the replica of the objects to be cast.

But there are certain differences with casting

- Difference in size.(Pattern is slightly larger than casting)
- Difference in material.
- It may be made of many parts.
- It contains the core prints

PATTERN MATERIAL

The material selected should be impervious to moisture and should with stand abrasion. Various material used for pattern making are:

- ❖ Properly seasoned **wood** with straight grain and knot free like white pine(soft), teak, deodar, mahogany, shishm, etc.
- ❖ It is easy to modify and light in weight, But dimension is not stable.
- ❖ **Metal Pattern:** Cast Iron, Aluminum, Brass**.**
- ❖ It is **s**trong ,durable, dimensional accuracy, economical for high production.
- ❖ **Other popular pattern materials are plastic ,resin, pop** etc.

PATTERN ALLOWANCE

- Pattern are never made exactly in size of casting due to effect of atmosphere, rapping, ramming, heat, finish required that may change the size of work piece. For this purpose, certain allowances must be provided to the pattern.
- **Shrinkage allowance:** As a metal cools the volume decreases. During solidification there are three type of contraction.

A. Liquid –liquid contraction

B. Liquid –solid contraction.

C. Solid –solid contraction.

PATTERN ALLOWANCE

- **Liquid shrinkage**: the liquid metal loses volume as it gives up superheat and cools to its solidification temperature.
- **Solidification shrinkage** :As metal freezes changing from a liquid to a higher density solid. for pure metal this contraction will occur at single temperature. But for alloys it will take place over some temperature range.
- **Solid shrinkage**: the solid casting cold from its solidification temperature to room temperature.
- Liquid shrinkage and solidification shrinkage are the concern of riser.
- The solid shrinkage (pattern maker's shrinkage) is accommodated by making the pattern larger than the desired size of the final casting.

METAL	ALLOWANCE (mm/m)
CAST IRON	10.5
STEEL	21.0
ALUMINIUM	16

DRAFT ALLOWANCE

- ❖ This is the taper allowed on vertical faces of a pattern to permit its easy removal from the mold without tearing the mold cavity surface.
- ❖ The amount of draft to be allowed depends upon the size and the shape of the pattern, the depth of the draw.
- ❖ Draft is generally 5mm per meter.

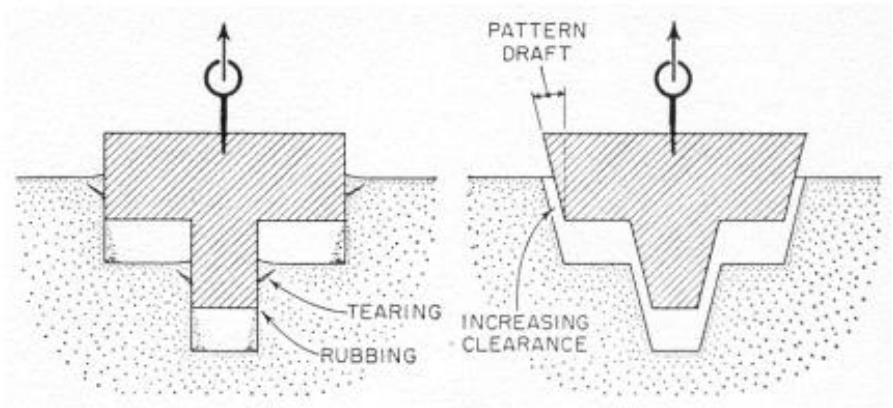


Fig. 1.3. Example of taper allowance.

FINISHING OR MACHINING ALLOWANCE

- ❖ The sand-casting product have poor surface finish.
- ❖ So, whenever the casting is functionally required to be of good surface or dimensionally accurate.
- ❖ It is achieved by subsequent machining.
- ❖ For this, an extra material must be provided on the casting which are to be removed by machining. This may range from 2-20 mm.

Dimension	Allowance(mm)
Cast iron (300-500)	3 - 4
Cast steel (150-500)	5.5
Non ferrous (200-900)	1.5-2.5

DISTORTION ALLOWANCE

- Sometimes castings, because of their size, shape and type of metal, tend to warp or distort during the cooling period depending on the cooling speed.
- This is due to the uneven shrinkage of different parts of the casting.
- Expecting the amount of warpage, a pattern may be made with allowance of warpage. It is also called camber.

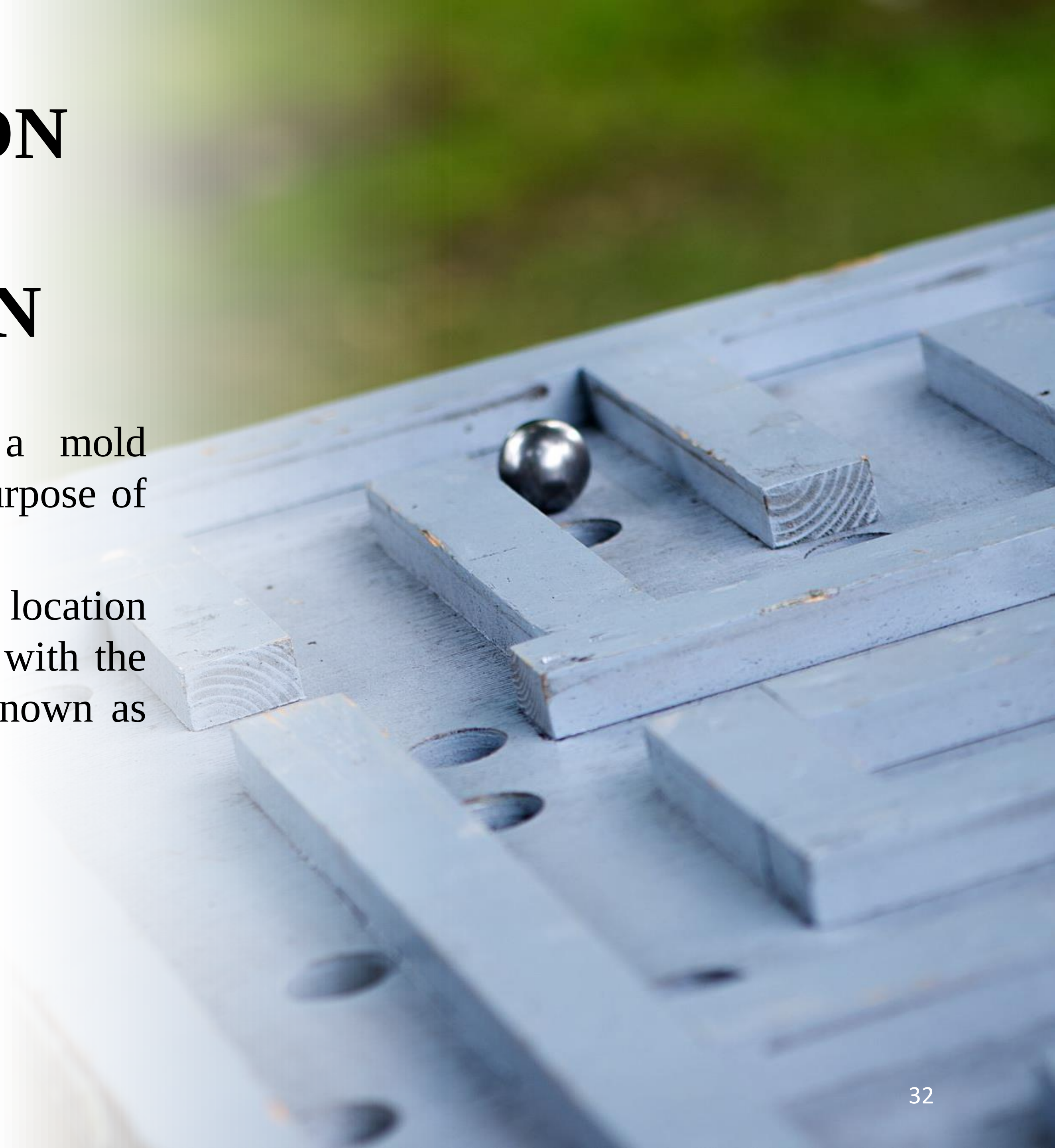
Fig. Example of camber: (a) Casting without camber, (b) Actual casting, (c) Pattern with camber allowance

RAPPING ALLOWANCE

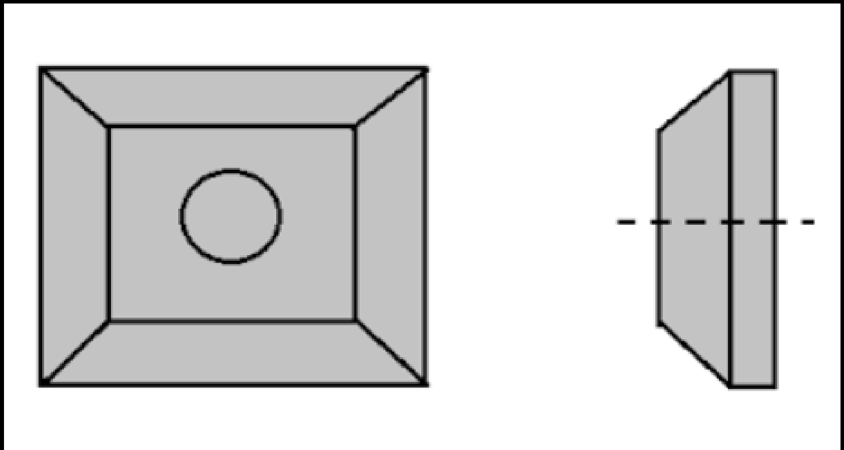
- ❖ Before withdrawal of the pattern from sand mold, the pattern is rapped all around the vertical faces to enlarge the mold cavity slightly which facilitates its removal.
- ❖ Since it enlarges the final casting. So, this dimension should be reduced from size of pattern.
- ❖ This is a negative allowance.

FUNCTION OF PATTERN

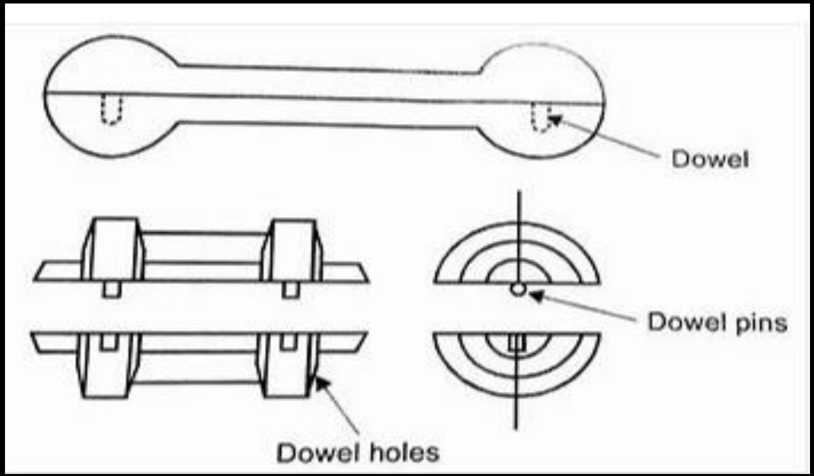
- A pattern prepares a mold cavity for the purpose of making a casting.
- It is used to produce location sites in mold for core with the help of projections known as core prints.



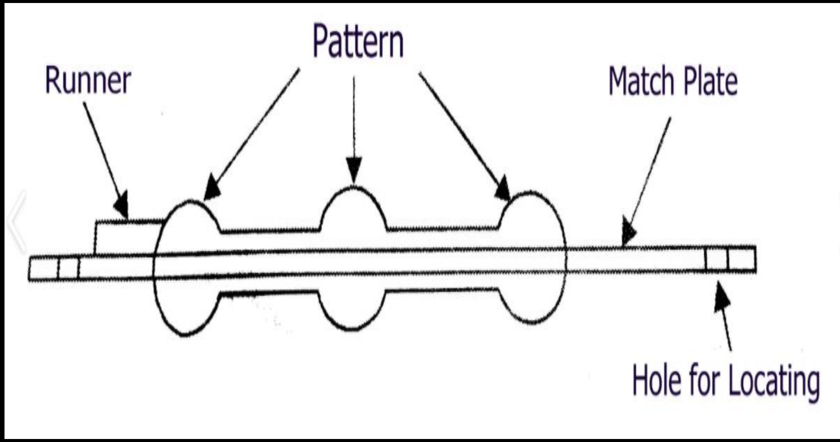
TYPES OF PATTERN



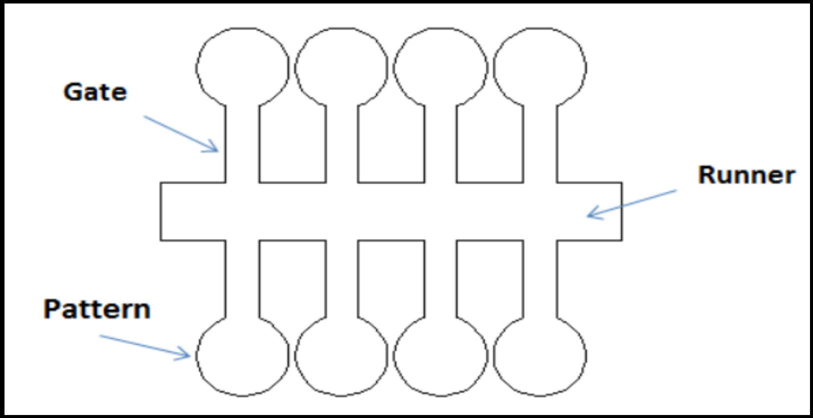
Solid Pattern



Split Pattern



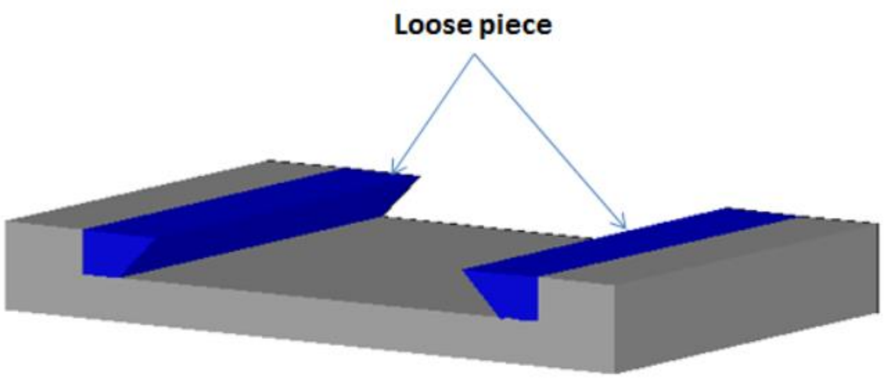
Match Plate Pattern



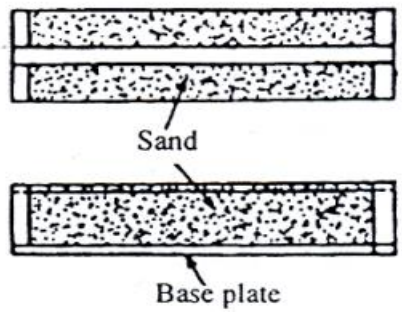
Gated Pattern

TYPES OF PATTERN

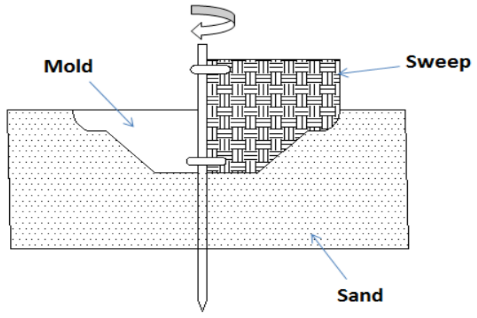
Loose Piece Pattern



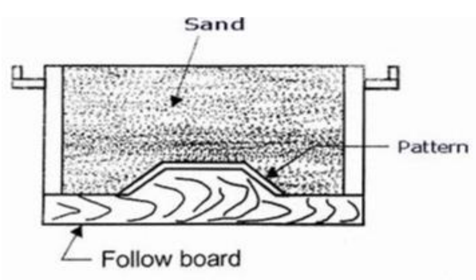
Skeleton Pattern



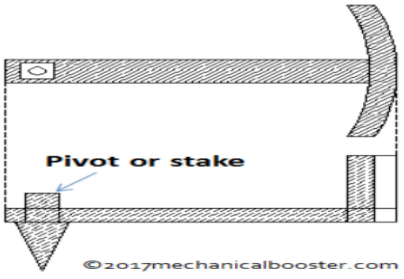
Sweep Pattern



Follow Board Pattern



Segmental Pattern



Color coding for Pattern and core Box

Color	Color Name	Area
	Black	*Surface to be Un-machined
	Red	*Surface to be Machined
	Yellow	*Core prints *Seats for loose core prints
	Yellow Base with Red Strips	*Seats for loose pieces
	Yellow Base with Black Strips	*Stop offs

Steps followed in Sand Molding

01 First bottom board is placed on the floor for making the surface even.

02 The Drag molding flask is kept upside down on the bottom board along with drag part of pattern at centre of flask

03 Dry facing sand is sprinkled over the board and pattern to provide a non sticky layer.

04 Fresh sand is now poured in to drag for thickness of 30-50 mm

05 Rest of mould is filled with backup sand and uniformly rammed to compact the sand.

06 After ramming is over the excess sand in the flask is completely scrapped using a flat bar .

07 Now with vent wire of 1-2mm diameter with pointed end ,vent holes are made in the drag to the full depth of the flask.

08 This completes the preparation of drag.

Steps followed in Sand Molding

9. The finished drag flask is rolled over to the bottom board exposing the pattern.

10. Using a slick, the edges of sand around the pattern are repaired

11. Cope half of the pattern is placed over the drag pattern, align with dowel pins.

12. The cope flask top of the drag is located aligning again with the help of the pins.

13. Dry parting sand is sprinkled all over the drag and on the pattern.

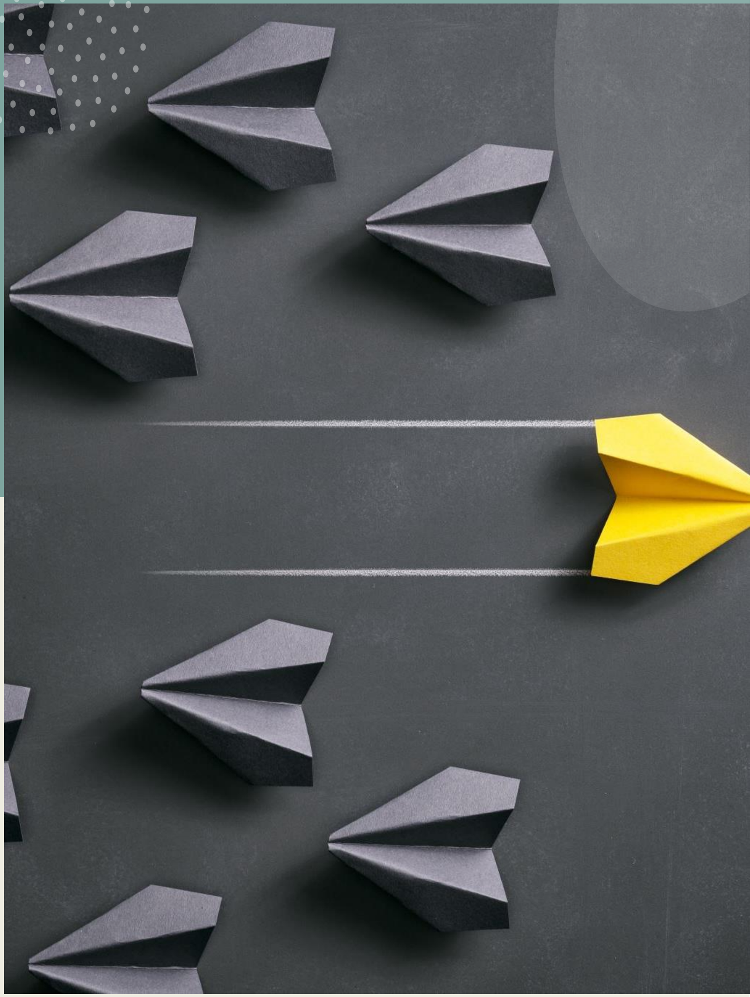
14 A sprue pin for making sprue passage is located at a small distance of about 50 mm from pattern.

15 Riser pin if required is kept at an appropriate place.

16 The fresh sand and backing are sprinkled and thoroughly rammed ,scraped and vent.

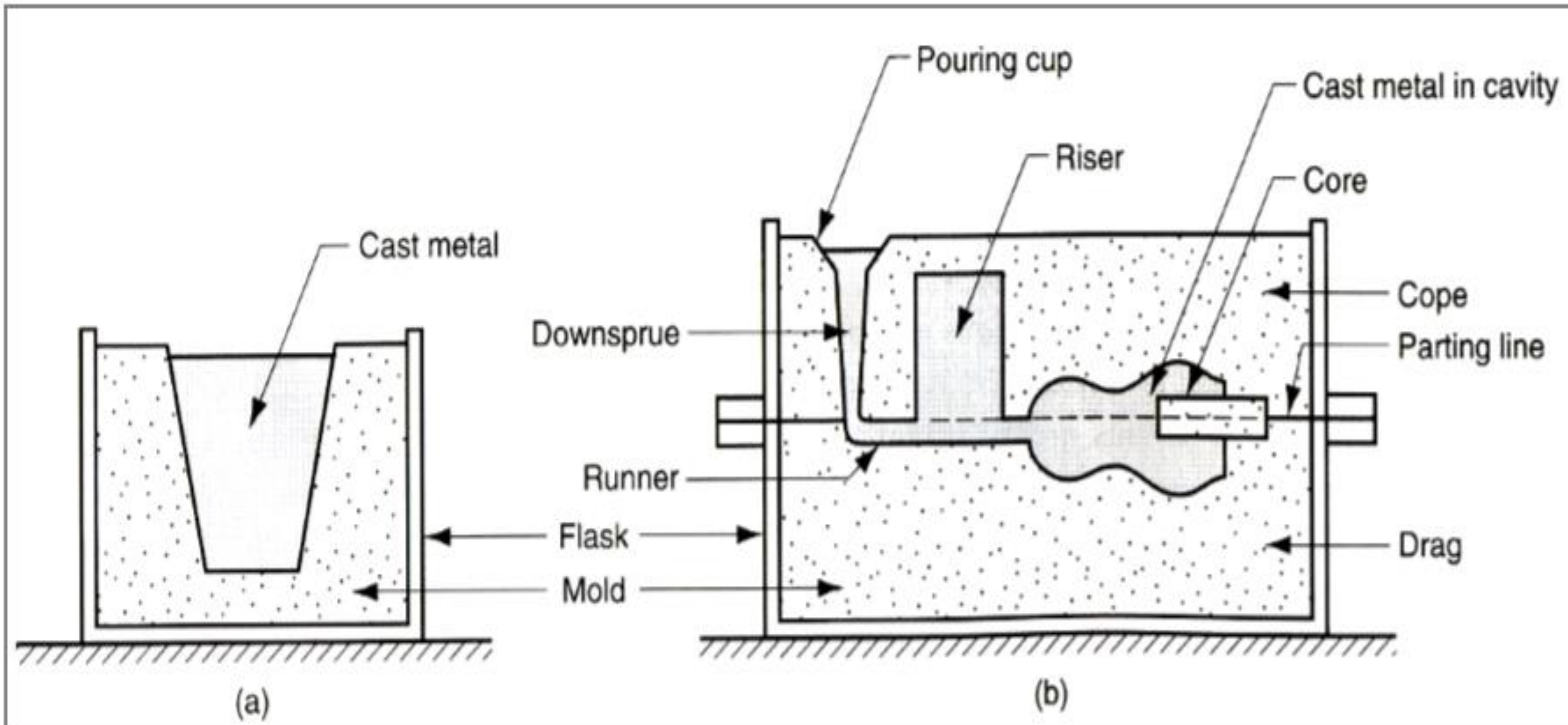
17.Sprue and riser pins are carefully withdrawn from the flask.

Steps followed in Sand Molding

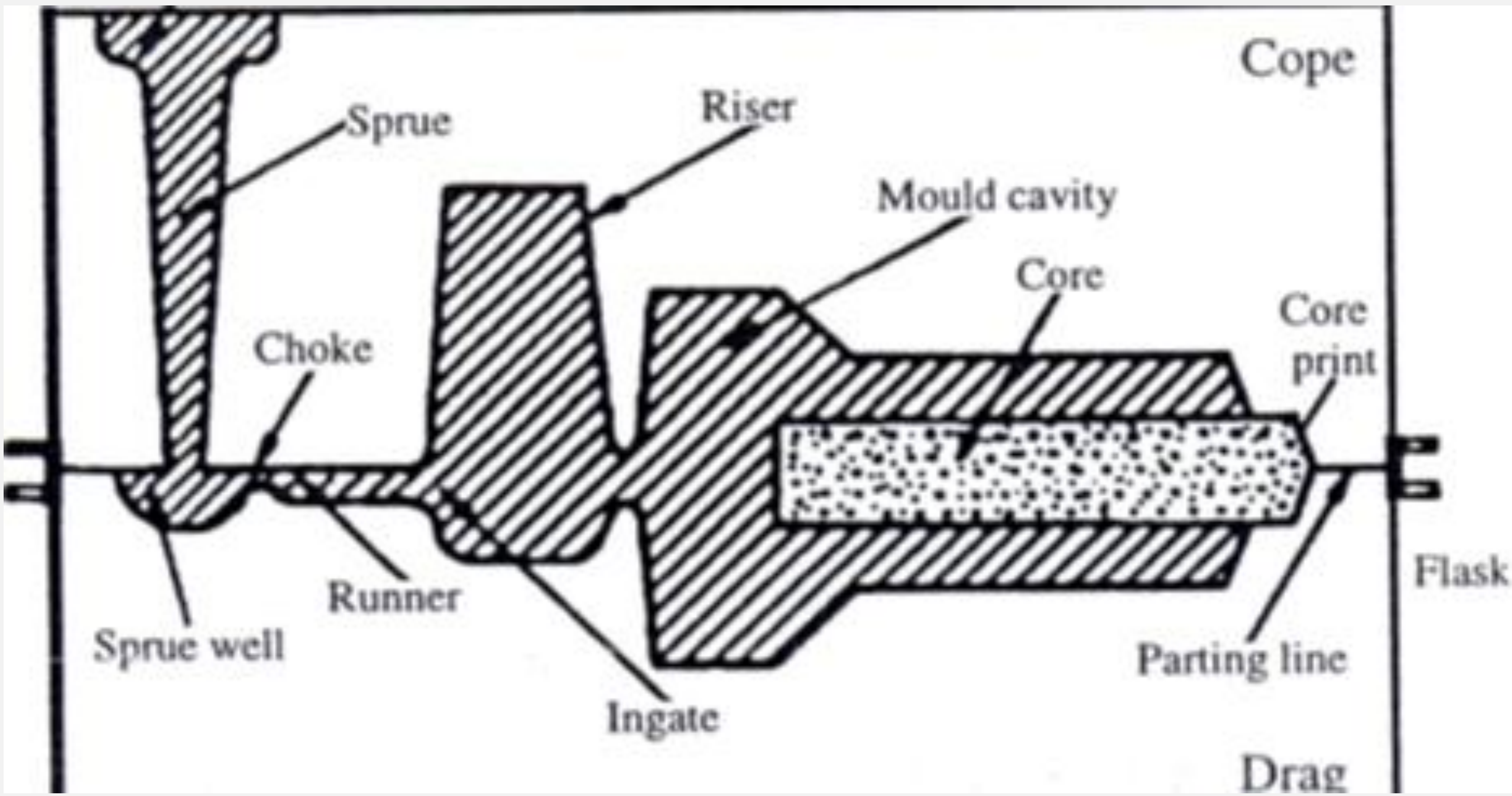


18. Later the pouring basin is cut near the top of the sprue.
19.The cope is separated from the drag and loose sand is removed with the help of bellows.
20. The pattern are withdrawn with the help of draw spike.
21.The runner and gate are cut in the mold carefully without spoiling the mold.
22.The cope is replaced on the drag taking care of the alignment of the two by means of the pins.
23.The mold is now ready for pouring.

Open and Close Mold



SAND CASTING



MOLDING SAND

- Molding is the process in which a desired cavity is formed in a mould.
- Molding sand is one of the most important material in production of sand casting.
- Good sand is generally obtained from the bottom or bank of rivers
- Molding sand is a mixture of silica sand (Sio_2) 70-80 %,Clay(aluminium-Al_2O_3) 10 – 12 %,water 3-6 % and oxide of iron, oxide of lime, lime carbonate, soda, potash.
- The clay used for binding the sand should be refractory and withstand high temperature without melting.
- Bentonite is a special clay for excellent bond for molding sand.

SPECIAL ADDITION TO MOULDING SAND

Sr.No.	PURPOSE	SUBSTANCE
1	To increase bench life	Molasses, cereals
2	To develop hot strength	Silica flour, Iron oxide
3	To improve Collapsibility	Cereals, saw dust,hourse dung,straw,wood flour
4	To improve surface finish& Resistance to penetration	Coal dust, Silica flour
5	To reduce metal mold reaction	Sulphur,boric acid

TYPE OF MOLDING SAND

Based on ingredients

- **Natural sand** : Contain sufficient clay and can be used directly.
- **Synthetic Sand:** This sand is prepared in the foundry by mixing a relatively clay free sand with selected clay binder and suitable additives.
- **Special Sand**: for special purposes and are very costly.
  Eg: Chamotte sand, Chromite. Olivine sand, Zirconium sand
etc.

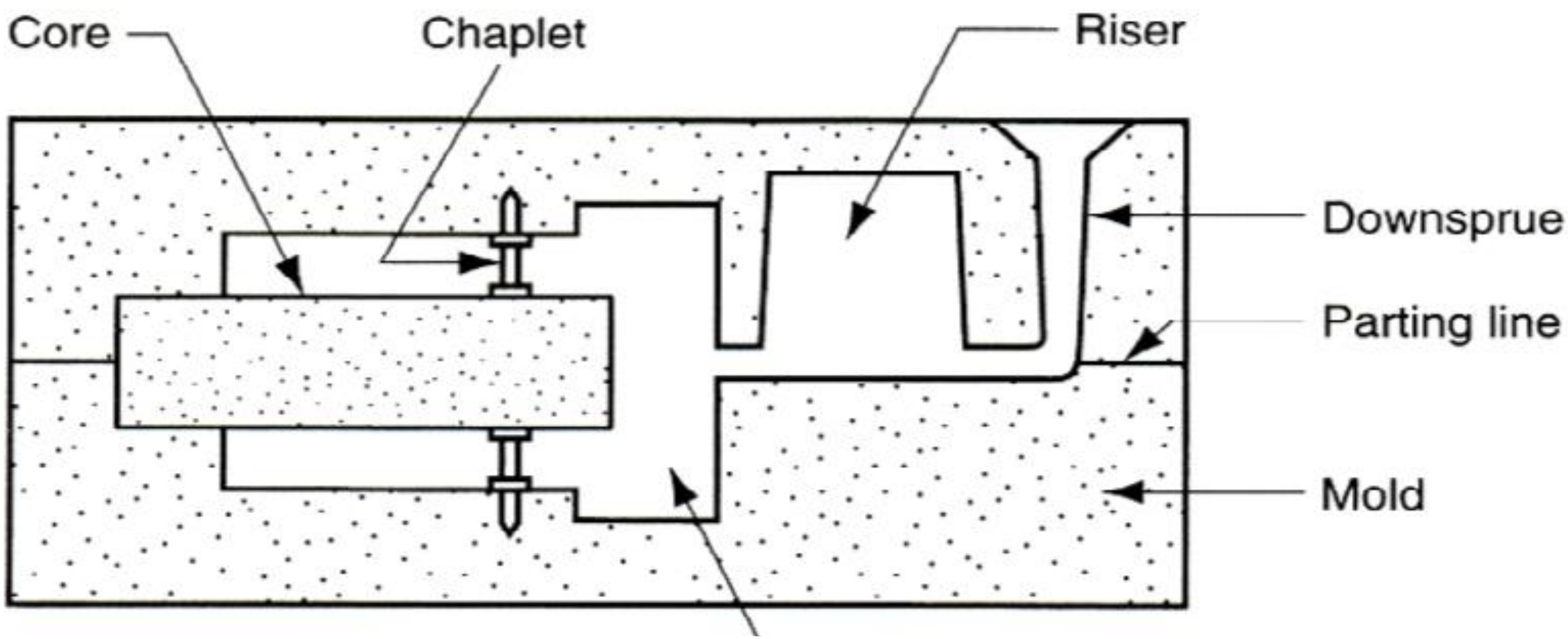
TYPES OF MOLDING SAND

Based on application

- ❖ Green Sand
- ❖ Dry Sand
- ❖ Loam Sand
- ❖ Facing Sand
- ❖ Backing Sand
- ❖ Parting Sand

Properties of Molding Sand

- **Refractoriness** : Ability to with stand high temperature of molten metal. Silica of size 0.3-0.4 mm have highest refractoriness of temperature 1650 degree.
- **Permeability**: Molding sand should be porous to allow easy escape of gases from the mould.
- **Strength** (Dry strength / Green strength): Sand should have sufficient strength to withstand handling.
- **Cohesiveness**: Sand should have certain amount of clay to give it a bond strength.
- **Adhesiveness:** Ability of sand to adhere to the surfaces of other material.
- **Flowability:** Sand should be capable of taking up sharp impressions of the mould.
- **Collapsibility:** Sand should be able to permit the metal to shrink freely after it solidifies by adding cereals or another organic compound.

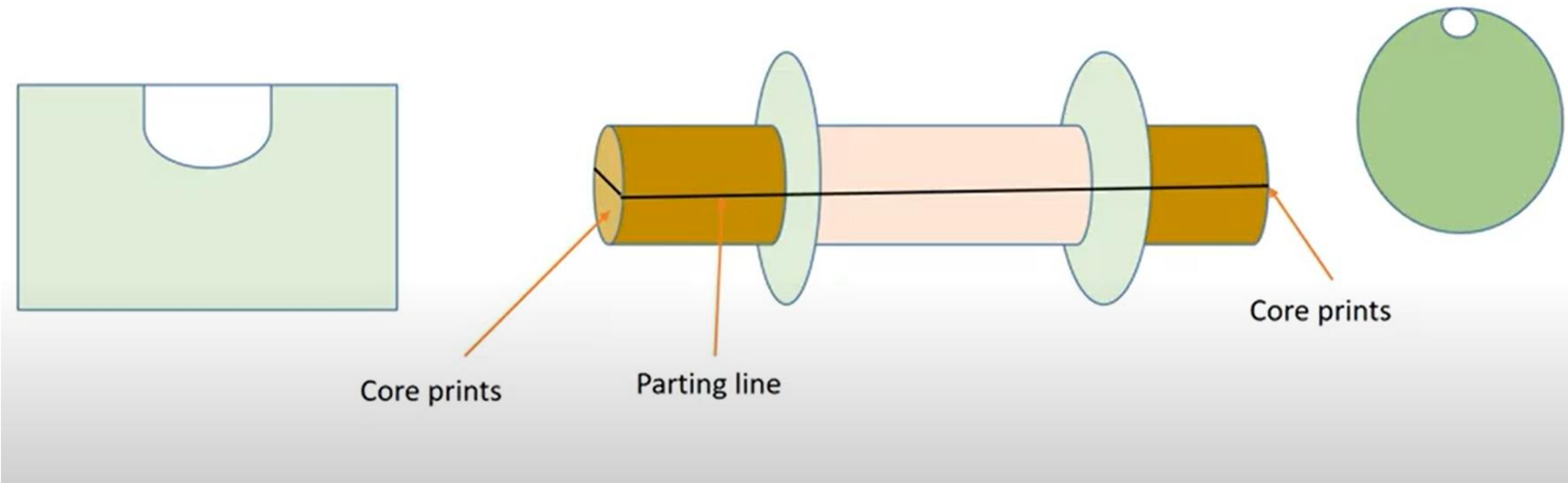


CHAPLETS

- Chaplets are metal supports used to hold a core in place when core prints are inadequate.
- They are too often used to compensate for poor design, improper pattern construction, or bad core practice.
- In all castings (especially in pressure castings), chaplets are a continual source of trouble and should be avoided whenever possible

CORE PRINTS

- Castings are often required to have holes ,recesses of various size and shape.
- These impressions can be obtained by using cores.
- Cores are separately made by pressing sand in boxes known as core boxes.
- To support the core in mold an impression in the form of a recess is made in the mold with help of a projection suitably placed on the pattern. This projection is known as a core print.
- Core print is an added projection on the pattern.it forms a seat in the mold in which the sand core rests during the pouring of the mold.
- Core print must be of adequate size and shape so that it can support the weight of the core during the casting process.



- **CORE PRINTS:** Extended projections on pattern for forming location sites in the mold to hold the core

CORES

Cores are defined as a body of sand which is used to form the hollow interior of the casting or a hole through the casting. These are prepared separately in a core box. Cores are held and located in the molds in the seats formed by the core prints provided on the patterns.

Cores must possess :

❖ High permeability to allow an easy escape to the gases formed.

❖ High refractoriness to withstand high temperature of molten metal.

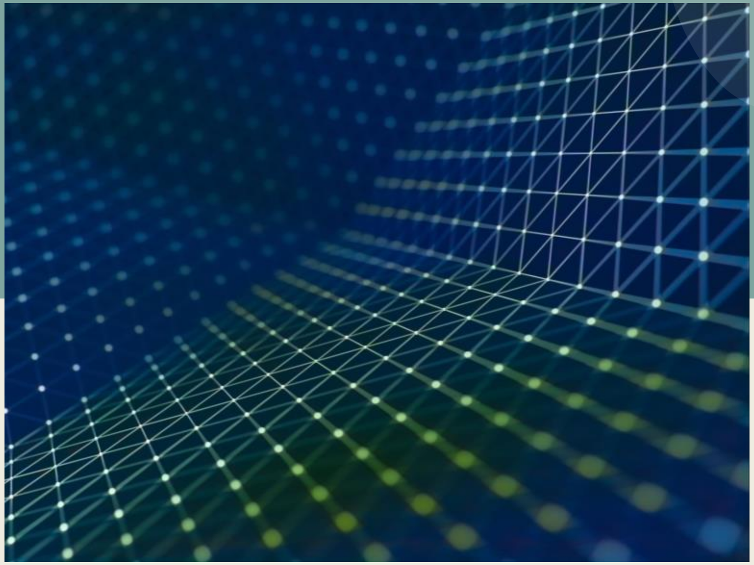
❖ Smooth surface.

❖ High collapsibility ***i.e.*** it should be able to disintegrate quickly after the solidification of the metal is complete.

❖ Sufficient strength to support itself.

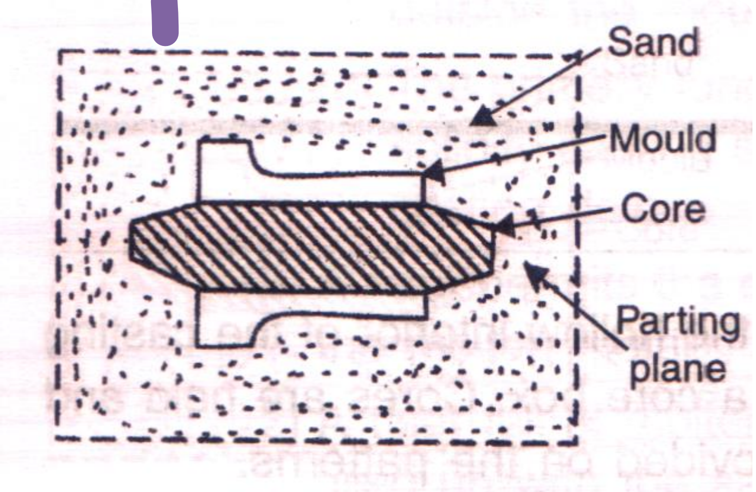
TYPES OF CORES

- ❖ Horizontal core
- ❖ Vertical core
- ❖ Balanced core
- ❖ Hanging or cover core
- ❖ Drop core or stop off core
- ❖ Ram up core



TYPES OF CORES:
Horizontal Core

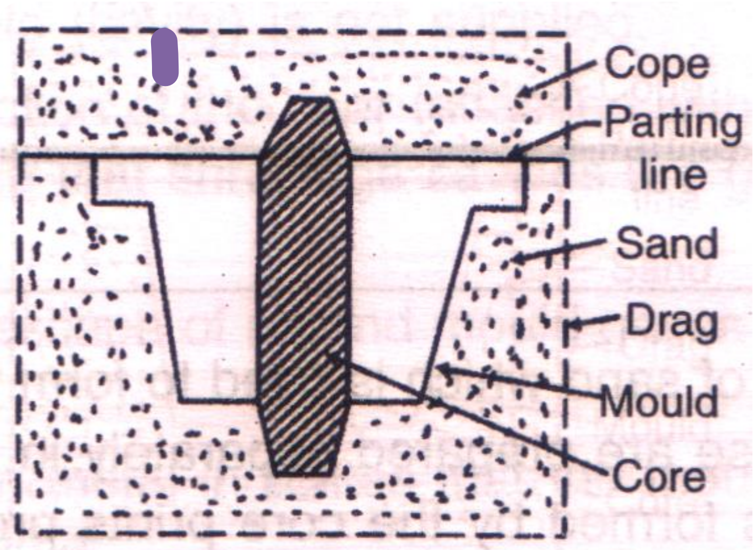
- ❖ A horizontal core is placed horizontally at the parting line of the mold such that one half remains in the cope and the other half in the drag.
- ❖ The ends of the core rest on the seats of the mold provided by the core prints. Core prints are provided on the pattern (generally two piece or split pattern).



Horizontal Core.

TYPES OF CORES :Vertical Core

- This is placed in a vertical position both in cope and drag halves of the mold.
- The amount of taper on the top is greater than that at the bottom.
- It rests on the seat made at the bottom of the mold by the core print and further supported by a similar seat made in the cope.



Vertical Core.

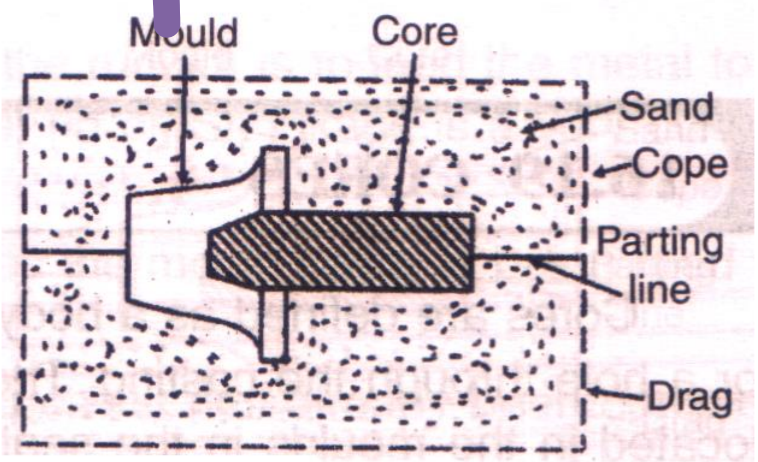
TYPES OF CORES:
Balanced Core

❖ A balanced core is one which is supported and balanced from its one end only.

❖ The core length should be long enough so that sufficient length of the core may be embedded in the sand to balance the weight of the overhung.

❖ If the overhung is too much, the core will be supported by means of chaplets.

❖ It is used when the casting does not need a through hole or cavity.



Balanced Core.

TYPES OF CORES:
Hanging or Cover Core

❖ Hanging core hangs from the cope and does not have any support at the bottom of the drag.

❖ Cover core covers the mold and rests on a seat made in the drag.

❖ Hanging cores are fastened with the help of wires etc.

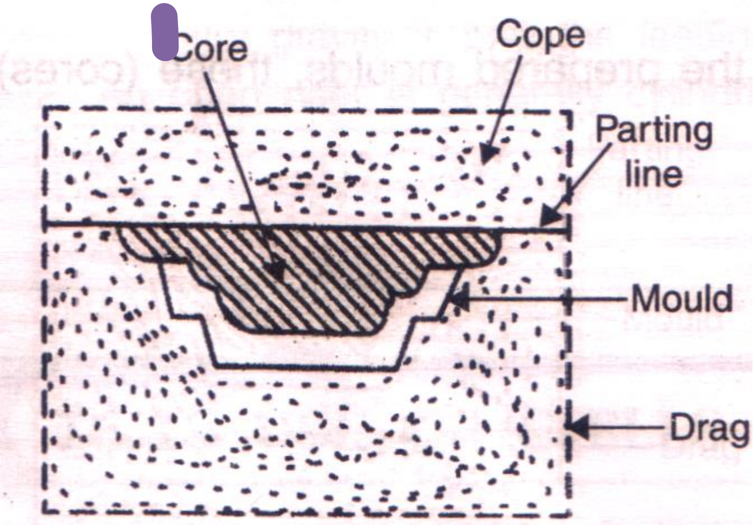


Fig. 16.24. *Hanging or Cover Core.*

TYPES OF CORES : Drop core, Stop Off Core or Wing Core

❖ A stop off or drop core is used when a hole, recess or cavity required in a casting is not in line with the parting surface i.e., it is above or below the parting line of the casting.

❖ These are also known as tail core, saddle core or chair core depending upon its shape and position in the mould.

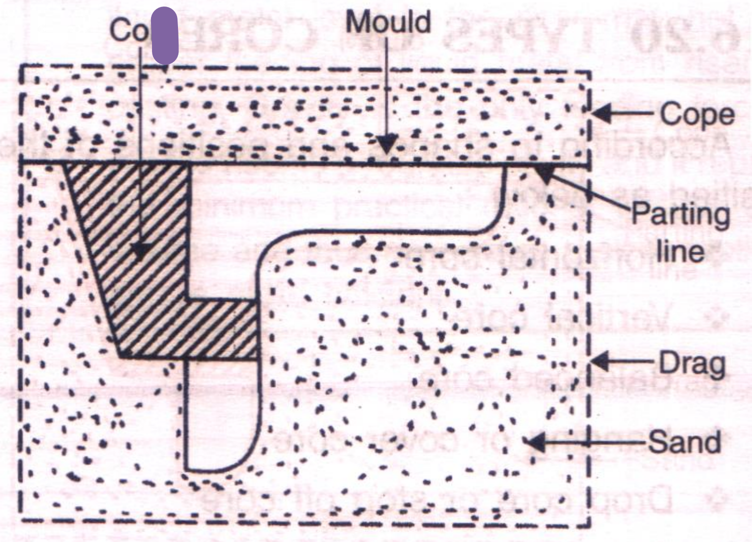


Fig. 16.25. *Drop Core.*

TYPES OF CORES:
Ram-up Core

❖ Ram-up core is placed with the pattern before the mold is rammed up.

❖ These are used when the core detail (cavity) is in an inaccessible position.

❖ These are used to produce interior and exterior portions of a casting.

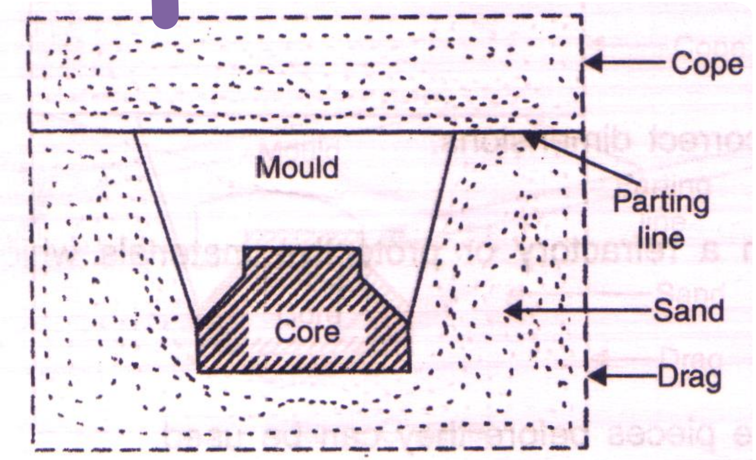
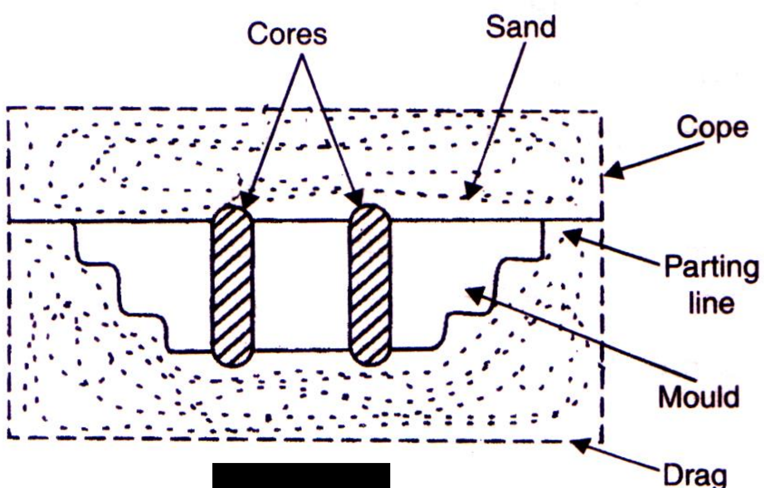


Fig. 16.26. *Ram-up Core.*

TYPES OF CORES

Kiss Core

- ❖ Kiss cores do not require core seats for getting supported. These are held in position between drag and cope due to the pressure exerted by the cope on the drag.
- ❖ Number of holes can be produced simultaneously by using number of kiss cores.



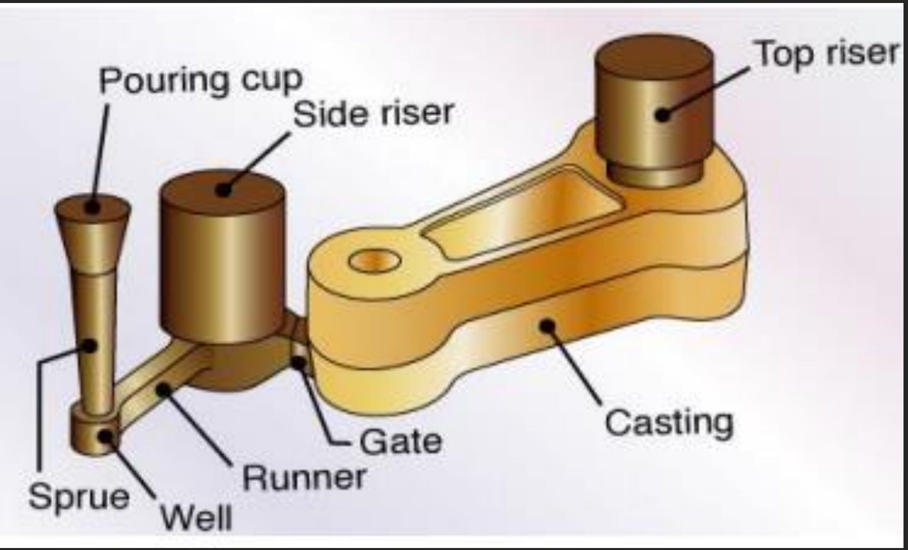
[redacted] *Kiss Core.*

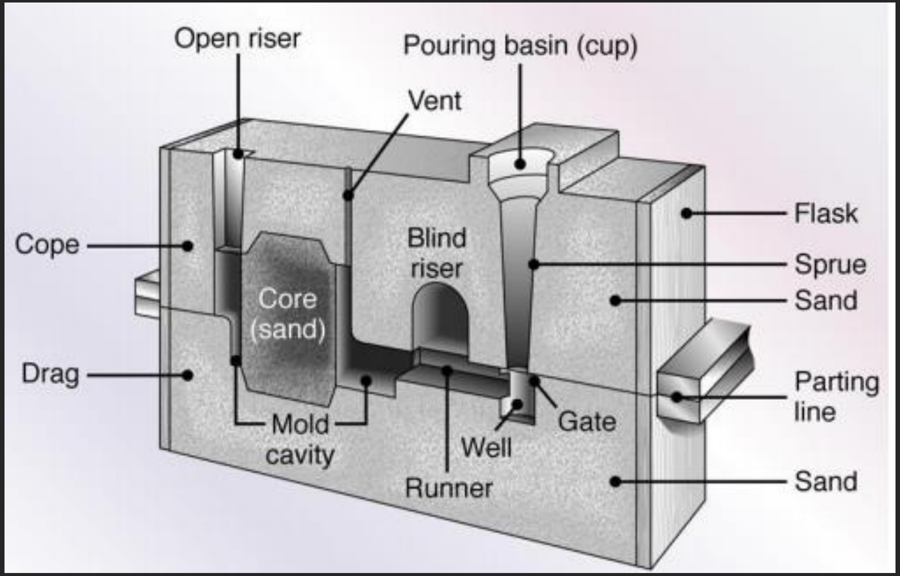
CORE SHIFTING

- If the core gets shifted from its position in the mold, it will result in a displaced cavity and hence a defective casting.
- So, a core must be firmly supported in the core seat specially to overcome vertical movement of the core due to buoyancy forces exerted on core by the being poured molten metal.
- Chaplet are often used to avoid such core shifting.

CHARACTERISTICS OF CORE SAND

- It must have sufficient hardness and strength in both dry and green states
- It must be permeable to allow gases to escape.
- It must be able to with stand high temperature of molten metal.
- It must be collapsible.
- It includes high silica sand and core binder like cereals, resins,molassses and core oil like linseed oil, corn oil.
- Resin binder used are phenol,urea,furan.





—

SAND CASTING MOLD

CUPOLA- FURNACE

- Melting of cast iron(1290 C) is done in cupola because of its low initial cost and low melting cost.
- Most of the foundries operate on a batch basis.
- So, Number of sand moulds are prepared and kept ready for pouring before the molten metal is prepared.
- Cupola has been the most widely used furnace for melting of cast iron.
- Cupola consist of a cylindrical steel shell with its interior lined with heat resisting fire bricks.
- It consists of drop doors at the bottom after closing which a proper sand bed could be prepared.
- This sand bed provides the necessary refractory bottom for the molten metal and the coke .
- Immediately above the sand bed is the metal tapping hole for tapping.
- Above metal tap hole normally in a position opposite to it is the slag hole

CUPOLA-FURNACE

- Above slag hole is the wind box which is connected to the air blowers supplying the requisite air at a given pressure and quantity.
- The air enters the cupola through the tuyeres.
- A little above the charging platform is the charging hole in the shell from where the charge consisting of combination of pig iron, scrap iron,coke,fluxes is put into the cupola.

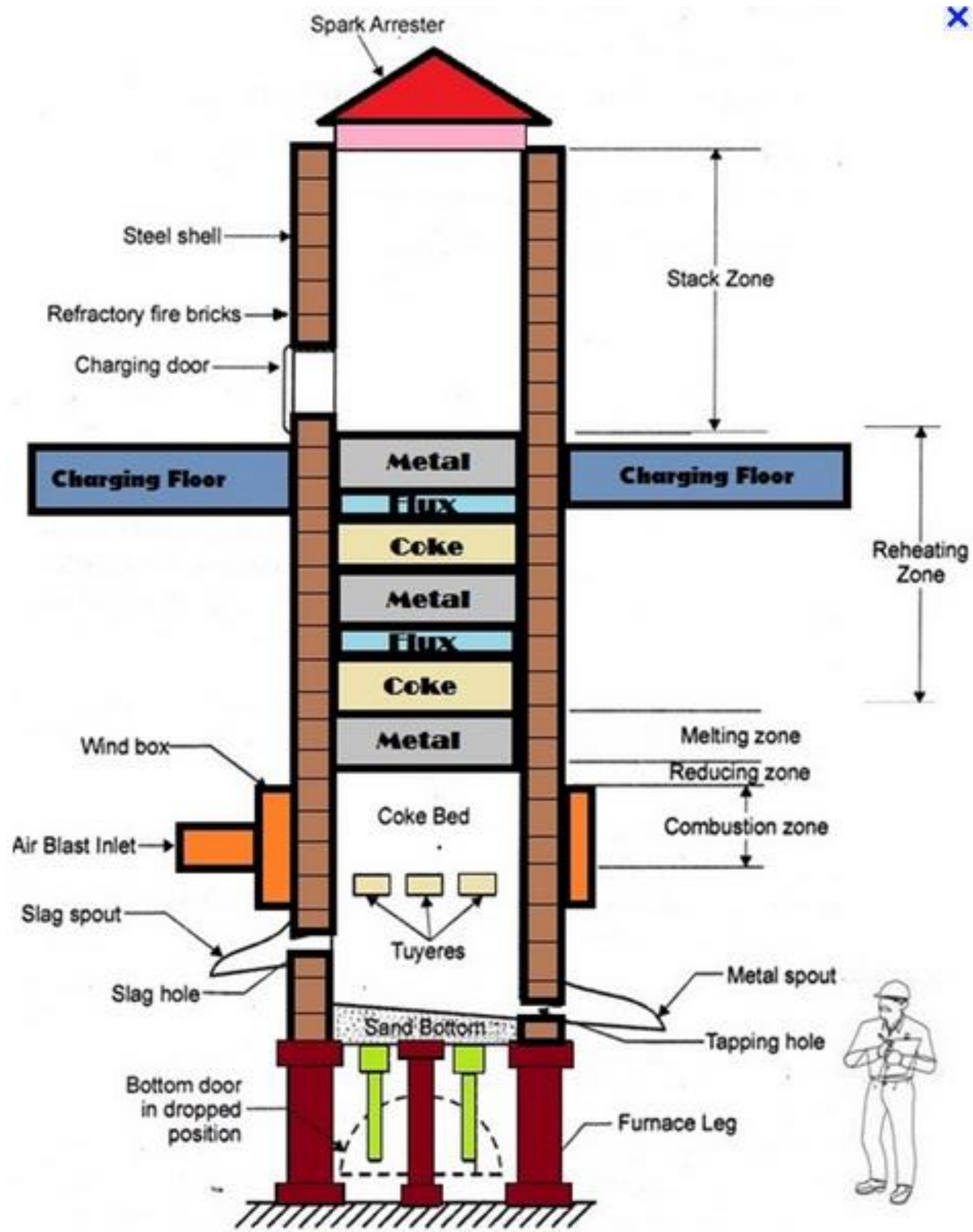
Cupola operation :

- Preparation of cupola
- Lighting fire in the coke bed.
- Charging of cupola.
- Melting
- Slagging and Metal tapping
- Dropping down the cupola bottom.

CUPOLA-FURNACE

- Charge : coke - Flux – Metal
- Flux used is limestone(caco3)from 2 – 4% of metal charge.
- Flux helps to removes impurities in form of slag that float on the metal pool and thus can be easily separated through slag hole.
- Coke size and quality affect the thermal efficiency of furnace. Generally, the coke size 50mm to 75 mm for charge and 120 mm to 150 mm for bed coke.
- Maximum temperature may vary from 1300 to 1550.
- Melting rate varies from 5 tonnes to 12 tonnes per meter sq.per hour.
- Volume of air required for per tonne of metal melted is 840 cu m.
- The ratio of metal to coke charge 10 :1.
- Air required per kg coke is 8.4 cu m.

CUPOLA



Cupola furnace

Zone of cupola

- **Well** : it is a sort of well of molten iron, the molten iron collects in this zone before being tapped.
- The well is situated between the tapered rammed sand bottom and bottom of tuyers.
- **Oxidizing Zone :** it is situated 15 to 30 cm above the top of the tuyers.
- All the oxygen is consumed here.
- Thus, a lot of heat is generated due to exothermic reaction and supplied to another zone.
- The reaction produced 8000 kcal /kg of heat /per kg of carbon in the coke.
- The temperature of combustion zone is 1550 – 1850**°C**.

C(coke) + 0_2 (from air) -> $C0_2$ + Heat

ZONE OF CUPOLA

❖ **Reducing Zone :**

- It is just above the combustion zone.
- It has reducing atmosphere and thus protect from oxidation the metal charge above and dropping through it.
- An endothermic reaction take place in this zone.
- It has temp of the order 1200 **°C**.
- The heat absorbed is of the order of 1600 kcal.
- **$C0_2 + C_2$ -» CO – Heat**

❖ **Melting Zone :**

- This starts from the first layer of metal charge above coke bed to 90 cm height.
- Iron melt in this zone.
- The temp of this zone is 1600 **°C** .
- **3 Fe + 2 CO -» $Fe_3C + C0_2$**

ZONE OF CUPOLA

❖ **Preheating Zone :**

- This starts from above the melting zone and extend up to the bottom of the charging door.
- Preheating zone contains cupola charge as alternate layers of coke ,limestone and metal.

❖ **Stack Zone :**

- Stack zone extend from above the preheating zone to where the cupola shell ends, and spark arrester is attached.
- Hot gases from cupola pass through the stack zone and escape to atmosphere.

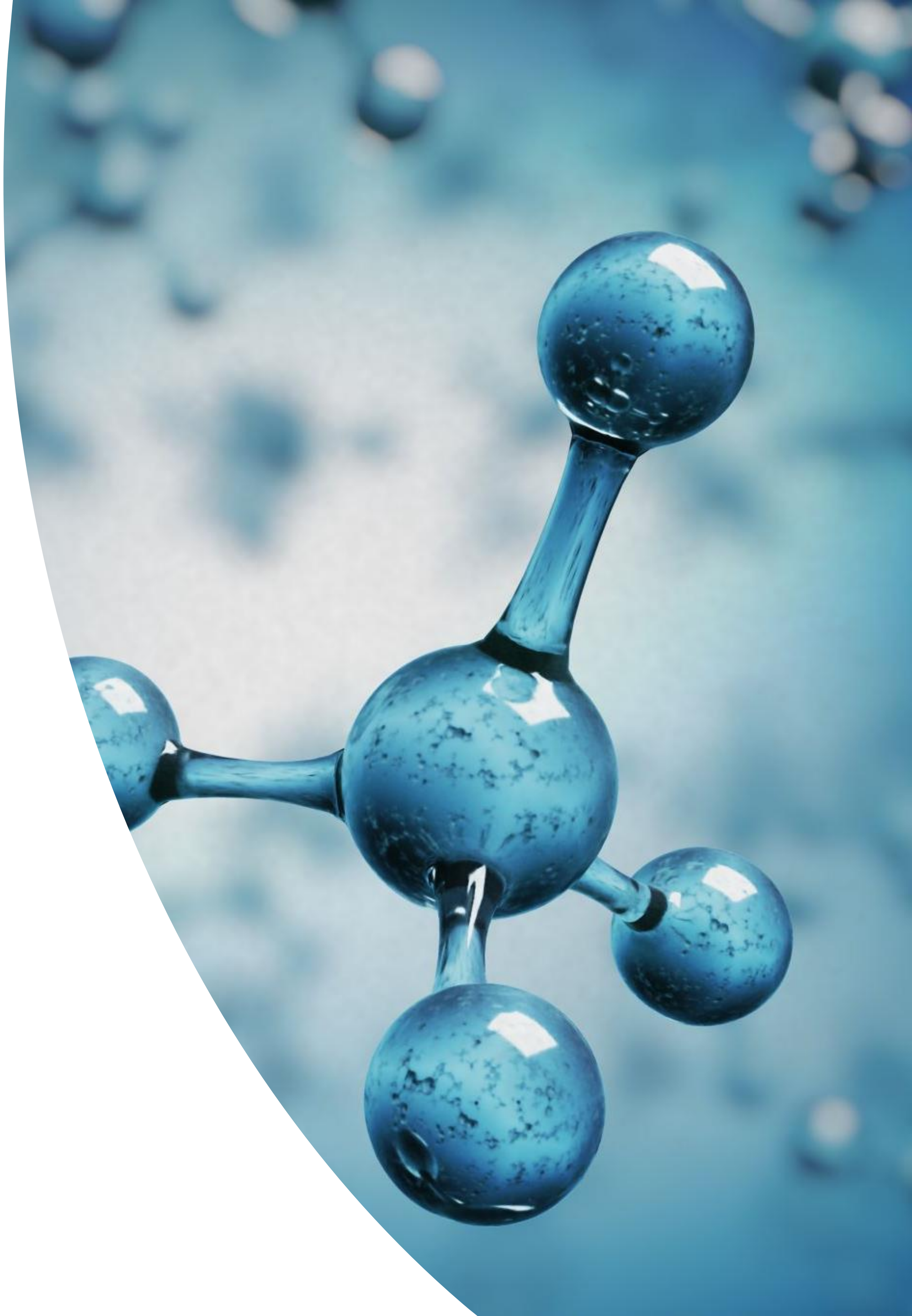
CUPOLA- FURNACE

❖**Advantages** :

- Simple design and easier construction.
- Simple to operate maintain in good condition.
- Economy in operation and maintain in good condition.

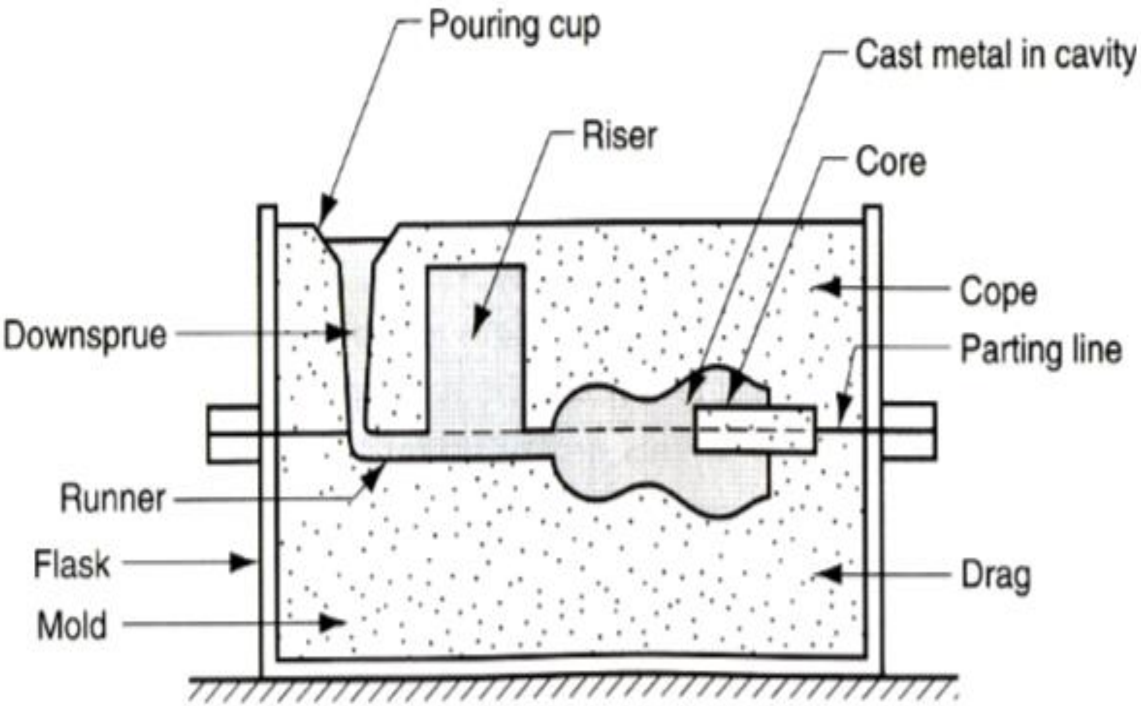
GATING SYSTEM

- ❖ Various elements of gating system
- ❖ Gating ratio
- ❖ Pressurized and unpressurised gating system
- ❖ Casting yield



GATING SYSTEM

- A gating system is the conduit network through which liquid metal enters a mold and flows to fill mold cavity.
- Where the metal can solidify to form the desired casting shape.

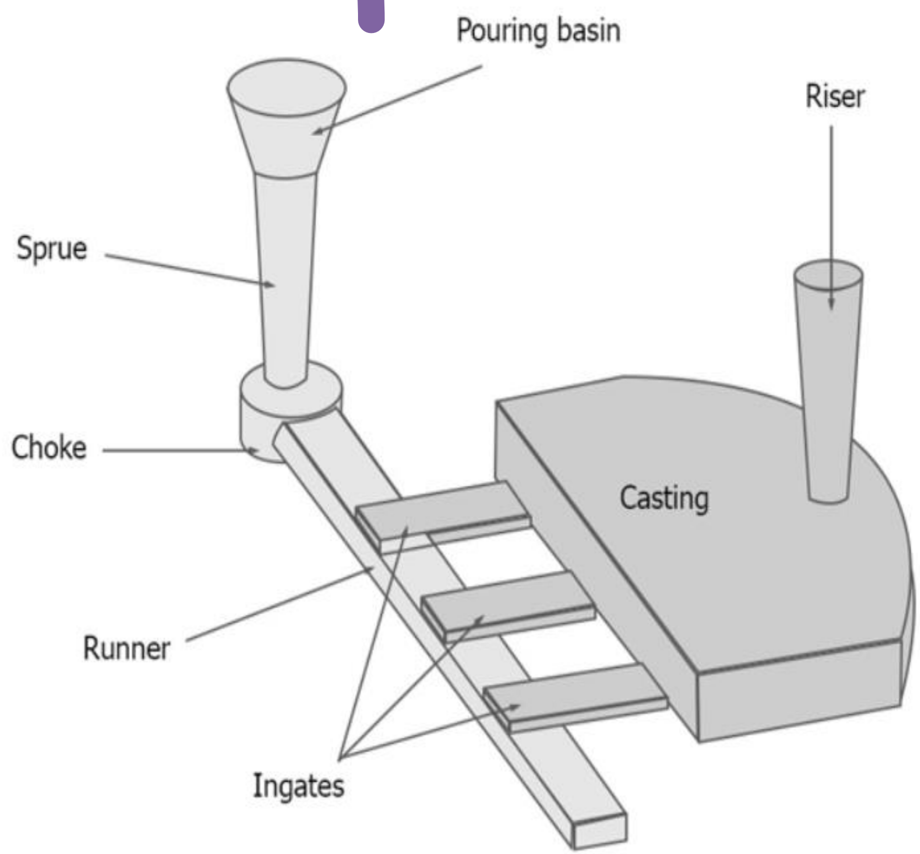


FUNCTION OF GATING SYSTEM

- Minimize turbulent flow to reduce absorption of gases, oxidation of metal and erosion of mold surfaces
- Regulate the entry of molten metal into the mold cavity
- Ensure complete filling of mold cavity
- Promote a temperature gradient within the casting so that all sections irrespective of size and shape could solidify properly

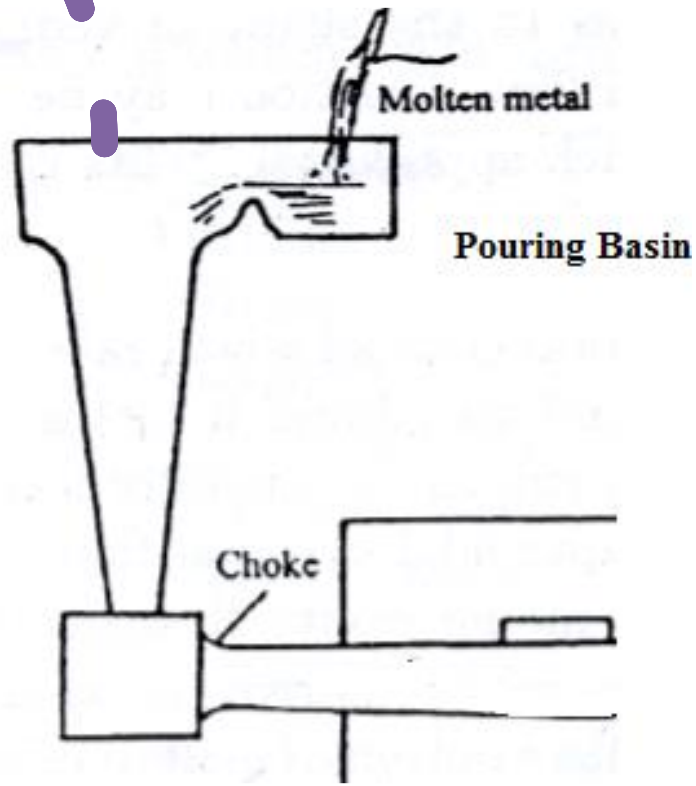
VARIOUS ELEMENT OF GATING SYSTEM

- Pouring basin
- Sprue(Down sprue, down gate)
- Sprue well
- Runner(Cross gate)
- Runner extension
- Ingates
- Riser



Pouring basin

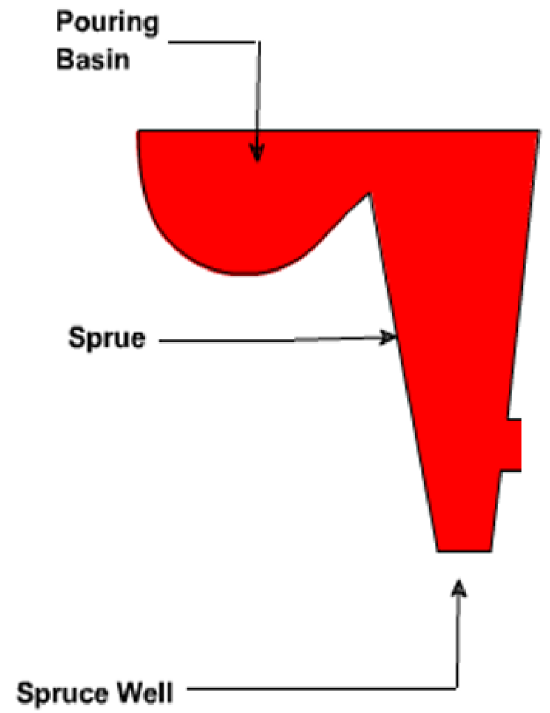
- The molten metal is not directly poured into the mold cavity because it may cause mold erosion.
- Molten metal is poured in to pouring basin which acts as a reservoir from which it moves smoothly into the sprue.
- The pouring basin is also able to stop the slag from entering the mold cavity by means of skimmer



Sprue

- Sprue is channel through which molten metal is brought into the parting plane where it enters the runners and gates to ultimately reach the mold cavity
- **Aspiration**: During pouring of molten metal atmospheric gases introduced to the metal through aspiration
- This occurs when the pressure anywhere in the liquid metal falls below atmospheric pressure which may often happens in the vertical sprue.
- To avoid this, wall of sprue must be tapered.
- The taper required to avoid aspiration can be calculated by using bernoulli's equation.

- **Sprue base well**
- This is a reservoir for metal at bottom of the sprue to reduce the momentum of the molten metal.
- The molten metal as it moves down the sprue gains in velocity, some of which is lost in the sprue base well by which the mold erosion is reduced.



Bernoulli's Equation

$$h + \frac{P}{\rho g} + \frac{v^2}{2g} = \text{const.}$$

h = height of liquid

P = Static Pressure

v = metal velocity

g = Acceleration due to gravity

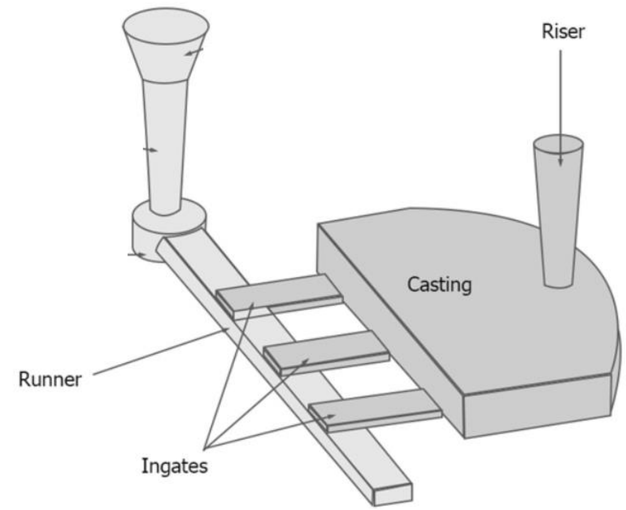
ρ = Fluid density

❖ **Runner** is in the horizontal plane which connects the sprue to its ingates,thus letting the metal enter the mold cavity. The runners are normally made trapezoidal in cross section. Generally, the runner is to cut in the cope and the ingates in the drag. This helps to trap the lag and dross which are lighter and thus trapped in the upper portion of the runners.

❖ **Gates** : Also called ingates, these are the opening through which the molten metal enters the mold cavity. The shape and cross section of the ingates should be such that it can readily be broken of after casting solidification .Also, it allows the metal to enter quietly into the mold cavity.

❖ **Types of Gate:**

- Top gate
- Bottom gate
- Parting gate
- Step gate

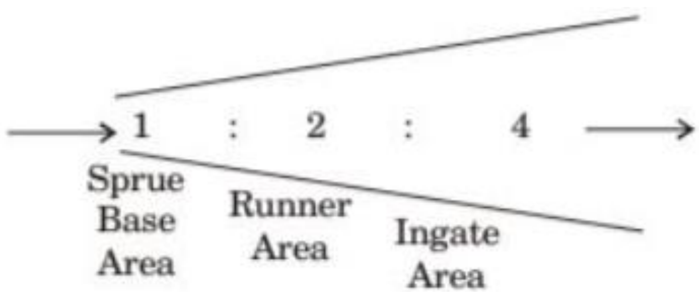


Gating Ratio

- Gating ratio is the term used to describe the relative cross-sectional area of the components of a gating system
- It is usually defined as the cross-section ratio of sprue area ,total runner area, total gate area.
- Depending on the choke area there can be two types of gating system.
- **Pressurized gating system**

  1:2:4
- **Non pressurized system**

  1:3:3



Pressurized Gating system

Gating ratio may be of the order of 1:2:4

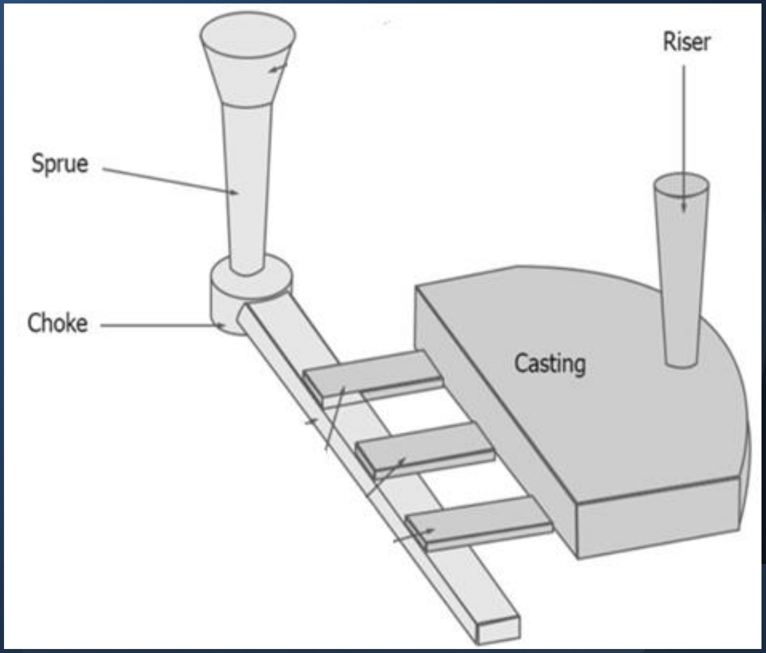
Back pressure is maintained on the gating system by a fluid flow restriction.

This back pressure keeps sprue full of metal ,reduces metal pulling from molds.

Due to high velocity turbulence may occur.

❖ Unpressurized Gating system

- ➢ Gating ratio is 1:3:3
- ➢ Primary restriction is near the sprue.
- ➢ There is possibility of metal pulling from mold wall and air aspiration.
- ➢ Lower metal velocities reduce the turbulence.

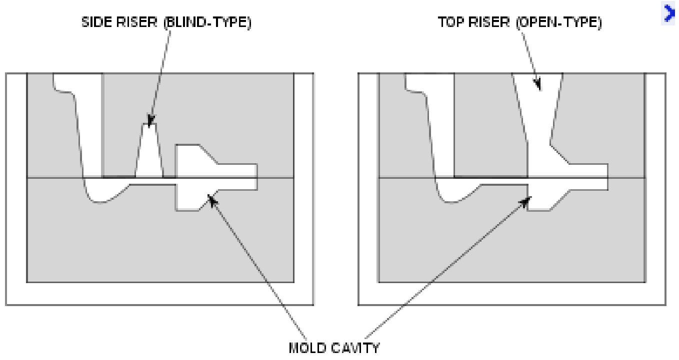


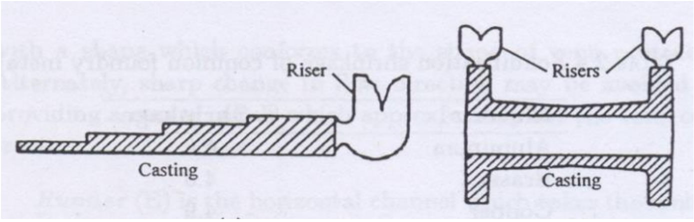
- **Choke Area** : choke is that part of the gating system which possesses the smallest cross-section area.
- In unpressurized gating system sprue serve as the choke.
- In pressurized system gate serve as the choke.
- **Casting Yield** : casting yield is defined as the ratio of actual mass of casting to the mass of the metal poured into the mold.
- Higher the casting yield higher is the economics of the foundry practice.

Casting Yield = (W/w)* 100

- Yield of the casting and riser are interrelated as
- **Yield = (Mass of casting)/(mass of casting + mass of riser)**
- This shows that smaller the riser higher will be the yield

Riser and its type





- ❖ Riser and directional solidification are inter-related because when solidification proceeds directionally from the casting wall towards the riser ,the result is a sound casting .
- ❖ A riser is must for all castings to avoid shrinkage defects.
- ❖ For effective riser design:
- The metal in the riser should solidify in the end.
- The riser volume should be sufficient for compensating the shrinkage in the casting.
- The riser is normally of the following types.
- ❖ **Top riser** ,which are open to the atmosphere.
- ❖ **Blind riser** ,which completely concealed inside the mold cavity itself .

RISER

- Riser size can be reduced by making the solidification more directional by **chill plate, Insulation, radiation shield or all three.**
- Various shape of riser all possible like spherical or cylindrical etc.
- However spherical shape have minimum ratio of surface area to volume and thus slowest cooling. But it is difficult to use.
- So, another shape that is preferred for riser is cylindrical shape.

❖ **Riser Design:** from heat transfer analysis, the solidification time depends primarily on the (V/A) ratio where V is the volume of casting and A is the surface area of heat dissipation. This information is use in designing of the riser.

- The large size riser volume is economical. So, a riser should be designed with the minimum possible volume while maintaining a cooling rate slower than that of the cooling.
- it must be remembered that a liquid metal flows from riser in to mold only during the early part of the solidification process.
- The minimum volume of the riser to be approximately three times that dictated by the shrinkage consideration alone.

RISER

- **Caine's Method :** Caine's relationship assumes that the cooling rate is linearly proportional to the ratio surface area /volume.
- Higher the ratio faster be the cooling.
- Chvorinov has shown that the solidification time of a casting is proportional to the square of the ratio of volume to surface area of the casting.

$$Ts = k\,(V/A)^2$$

Ts = solidification time

V = volume of casting

A = Surface area

Riser

- **Freezing ratio (X)** ,of mold is defined as the ratio of cooling characteristics of casting to the riser.

  X = (A/V)casting/(A/V)riser

- In order to be able to feed the casting **,**the riser should solidify last and hence its freezing ratio should be greater than unity.
- **Riser feeding distance :** While calculating the risering dimension, it was assumed that the riser would be able to feed the entire length of casting. So according to length number of riser may vary.
- **Feeding distance for bars** : single riser can feed (0.5T to 2T) + including edge effect (1.5T to 2T)
- If the length exceed number of riser may increase.
- **Feeding distance for plates:** : single riser can feed (2T) + including edge effect (2.5T)

Riser efficiency

- **Riser efficiency = (Vo- Vf) / Vo**

Vo = initial volume of metal in the riser

Vf = final volume of metal in the riser.

- **Method to increase riser efficiency:** the efficiency of riser can be increased by delaying the solidification in riser or by making solidification in casting fast. following are the ways by which we can do so.

- Locating riser suitably.
- Using insulating material.(powder, sleeve, pad)
- Exothermic material.(Ni,Co,Cu,Mn,Fe) oxide and aluminum.
- Chills(speed up the solidification)
- Padding.(specially for thin section)

Permanent Mold Casting

- For large scale production mold making for every casting to be produced may be difficult and expensive.
- So, a permanent mold is to be made from which large number of castings can be produced at low cost.
- It is also known as Gravity mold casting since metal is fed into the mold by the force of gravity and no external pressure is necessary.
- Castings can be produced from a single die varies from 100 to 250000.
- This process is preferred for small casting of aluminium , zinc ,lead, tin and magnesium alloys.
- Generally simple shapes are produced by permanent mold casting .
- Closer dimensional accuracy, better surface finish, lower percentage of rejection and high production rate are some advantages.

Permanent mold cycle

- Various steps to complete the one cycle are :

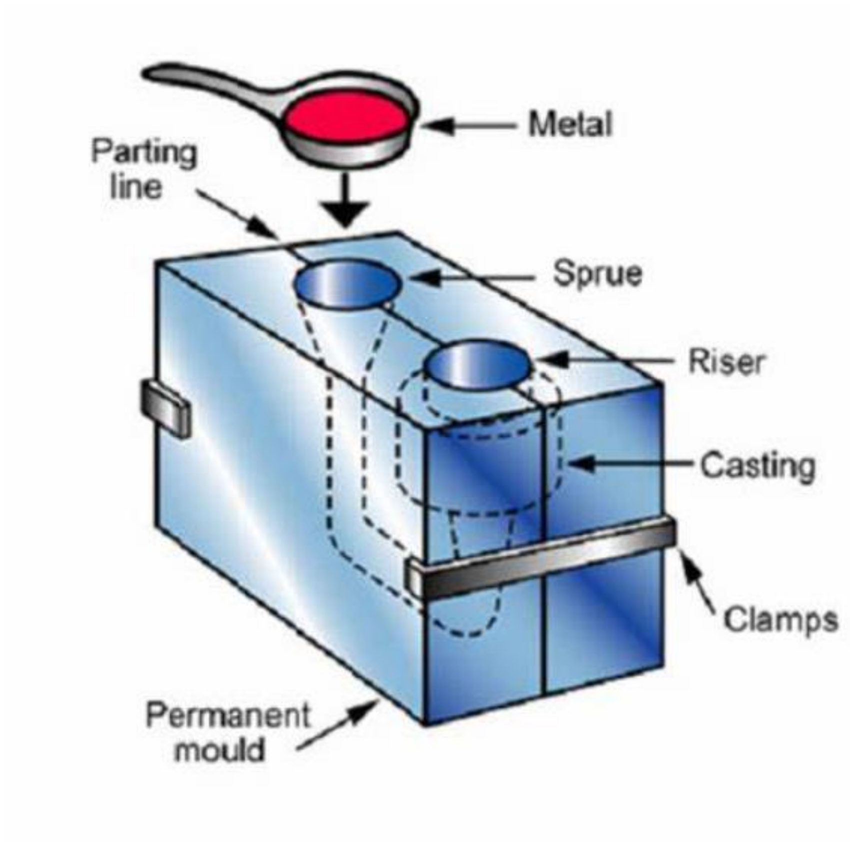
  Step 1. Dies are closed and mechanically clamped.

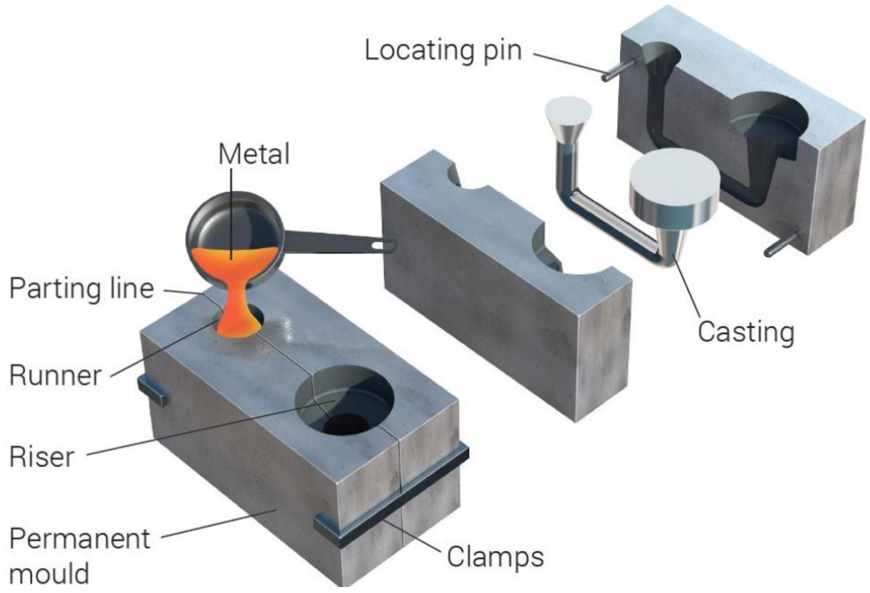
  Step 2. The molten metal is poured.

  Step 3. The metal is allowed to solidify.

  Step 4. After solidification, the dies are open, and casting taken out.

  Step 5. The dies are cleaned for next cycle of operation.
- Material used for making dies are alloy cast iron, grey cast iron, alloy steel for large volume and graphite molds for small volume production.
- Application : Automobile piston, gear blank, connecting rods, cylinder blocks etc.





Permanent mold casting

Pressure Die Casting

- ❖ It involves the production of components by injecting molten metal at high pressures into metallic die.
- ❖ Because of pressure involved in die-casting, any narrow section, complex shapes and fine surface details can be easily produced.
- ❖ In die casting, die consists of two parts, one called the stationary die which is fixed and other is ejector die which is moved out for the extraction of casting.
- ❖ Various steps to complete the one cycle are :

Step 1. Firstly, lubricant is sprayed in the die cavity.

Step 2. Then two halves of dies are closed and clamped.

Step 3. Required amount of metal is injected into the die.

Step 4. The casting is allowed to solidify under pressure.

Step 5. Then casting is opened, and the casting is ejected.

Types of Die Casting

Based on metal injection , die casting can be classified as:

- **Hot Chamber die casting**

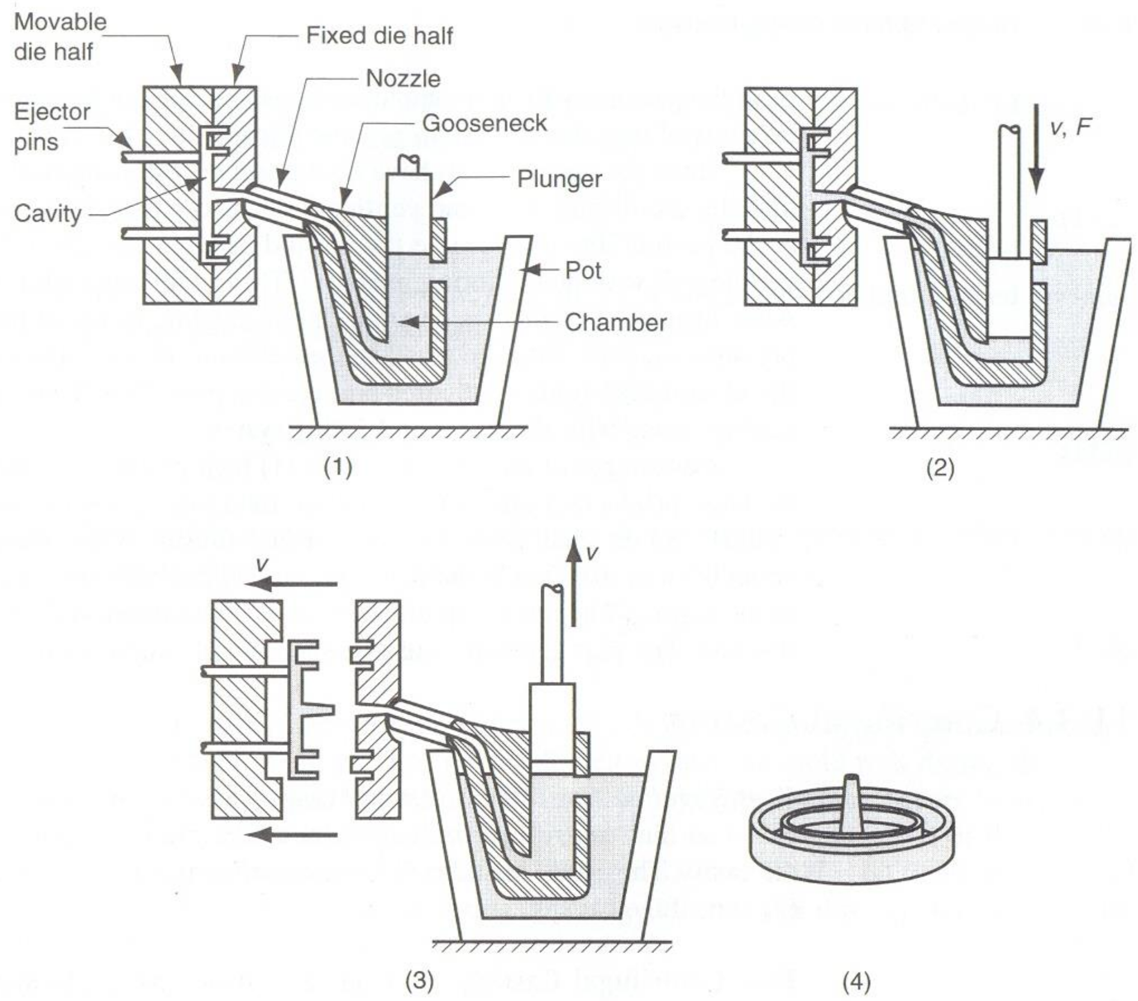
1. Goose neck type.
2. Submerged plunger type.

- **Cold chamber die casting**

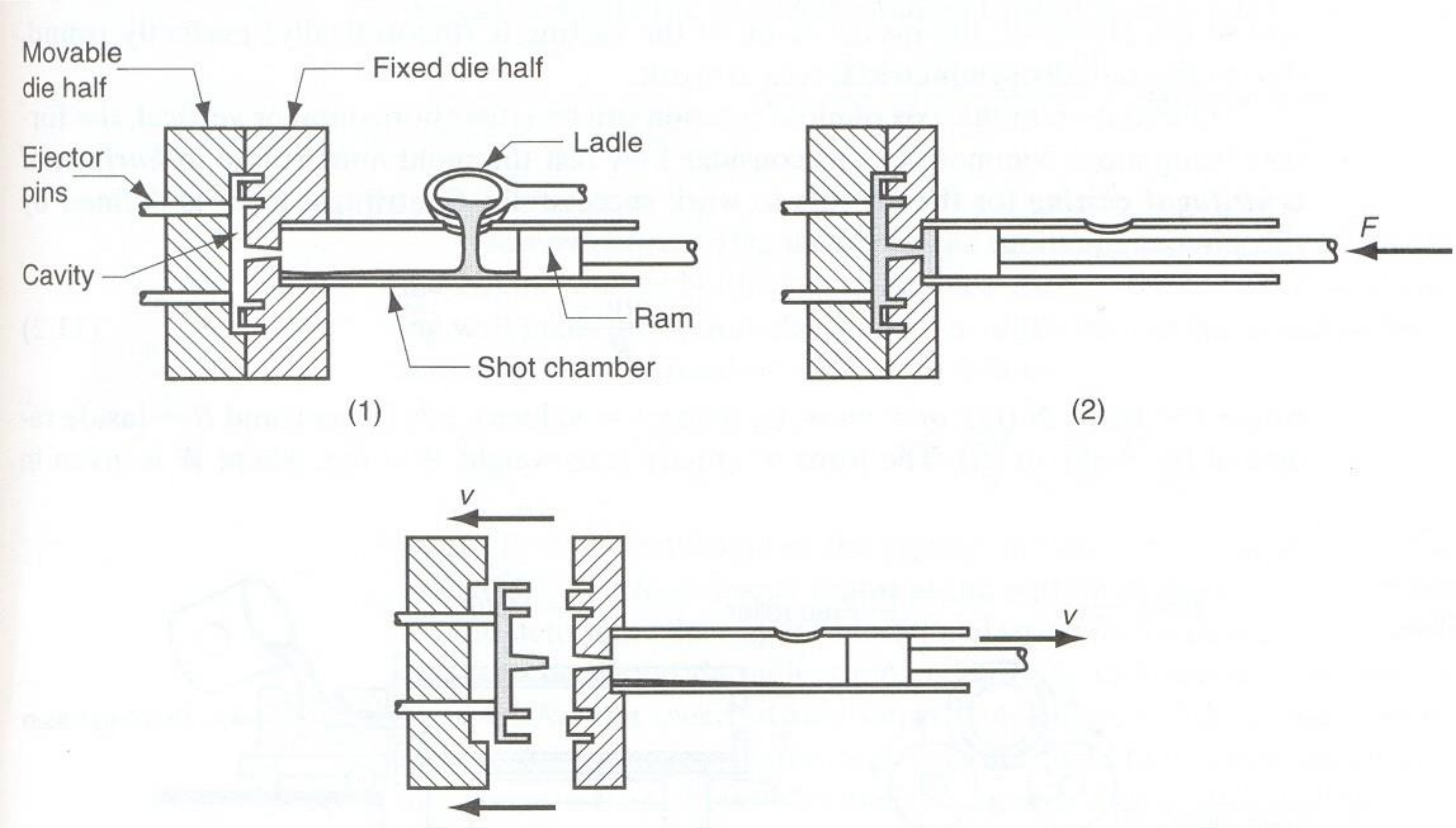
The main difference between these two types is that

- In hot chamber , the holding furnace for the liquid metal is integral with the die-casting machine.
- Whereas in the cold chamber die-casting , the metal is melted in a separate furnace and then poured into the die-casting machine with a laddle for each casting cycle which is also called ‘shot’.

Hot Chamber die casting:



COLD CHAMBER DIE CASTING



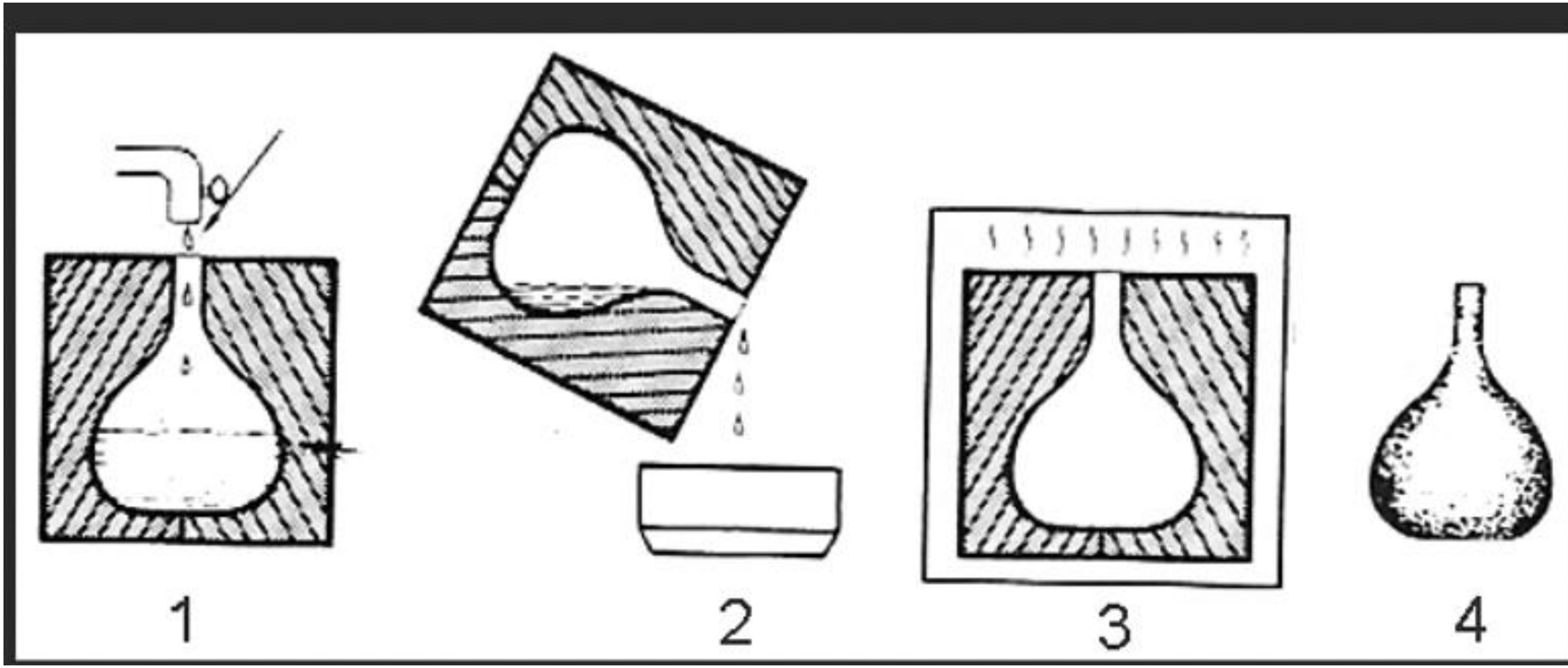
Cold chamber die casting:

Operating Sequence:

1. In cold chamber process . The molten metal is poured with a ladle into the shot chamber for every shot.
2. After feeding the chamber with molten metal, the plunger rapidly advances ,forcing the metal into the die.
3. Then metal is allowed to solidify for sufficient time
4. After solidification dies are automatically open and ejector pins pushes out the casting from the die.
5. Casting of materials like aluminium and brass, which are having high melting point is preferred in this method.

Die Casting:

- **Advantages**
- High production rates.
- Close dimensional control can be maintained.
- Good surface finish.
- Details are reproduced with a high degree of precision.
- The die has very long life.
- It is very economical for large scale production.
- **Disadvantages:**
- Only certain nonferrous alloys can die cast.
- It has size and weight limitation.
- Equipment cost is high.
- **Applications:**
- Various automobile parts like Carburettors, crank cases etc.



Slush Casting

Centrifugal Casting

- **Type of Centrifugal Casting**
  - ✓ True Centrifugal
  - ✓ Semi Centrifugal
  - ✓ Centrifuging

In this process, molten metal is poured into the mold while the mold is revolving. The metal falling into the mold is whirled at the axis of its rotation and spread out by the power of centrifugal force towards the periphery.

Thus, the impurities being lighter in weight, are left behind at the center or inner surface of the casting and can be machined easily for finishing if required.

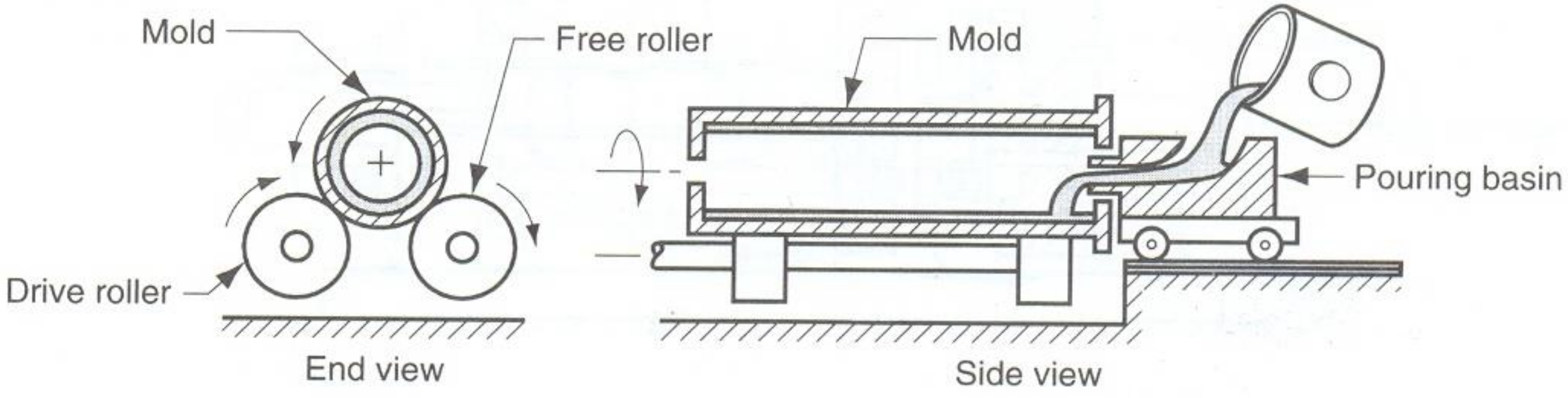
This centrifugal force ensures casting free from porosity defect.

The need of large gates, cores, risers is also eliminated, making the method less expensive.

Centrifugal force helps to distribute liquid metal over the outer surface of the mold away from the axis of rotation before it got freeze.

True Centrifugal Casting

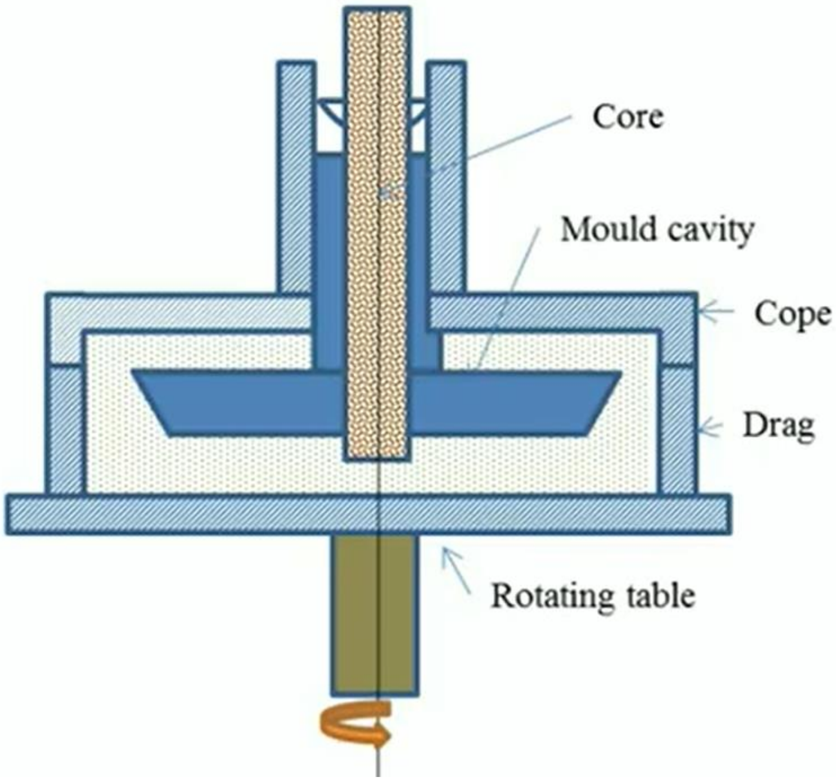
- It is of straight uniform inner diameter and are produced by spinning the mold about its own axis.
- A cylindrical mold is made to rotate on its own axis at a speed such that the metal being poured is thrown to the outer surface of the mold cavity.
- The metal solidifies in form of a hollow cylinder. The thick ness of wall is controlled by the amount of liquid metal poured.
- Casting cools and solidifies from outside towards the axis of rotation, thereby providing conditions which set up directional solidification to produce casting free from shrinkage.
- Since metal is always forces outward because of centrifugal force, no core needs to be used for making the concentric hole.
- The axis of rotation can be either horizontal or vertical. Very long pipes are cast with horizontal axis , whereas short pieces are cast with vertical axis.
- This is used for making hollow pipes, tubes, bushes etc. which are axisymmetric with concentric hole.
- Pipes measuring up to 1200 mm diameter and 4800 mm in length with sectional thickness as low as 6 mm may be produced by this method.



True Centrifugal Casting

Semi Centrifugal Casting

- This method is employed for making large size sand castings which are symmetrical about their own axis, for eg. pulleys , spoked wheels , gears etc.
- While mold rotates about a vertical axis , the metal is poured into a central sprue from where , it first enters the hub and then is forced outwards to the rim by centrifugal force.
- Spinning speeds are lower than in the case of true centrifugal casting(180-200 mpm).
- Unlike true centrifugal casting a core is used to form the central cavity.
- Semi centrifugal castings are normally made in vertical machines.

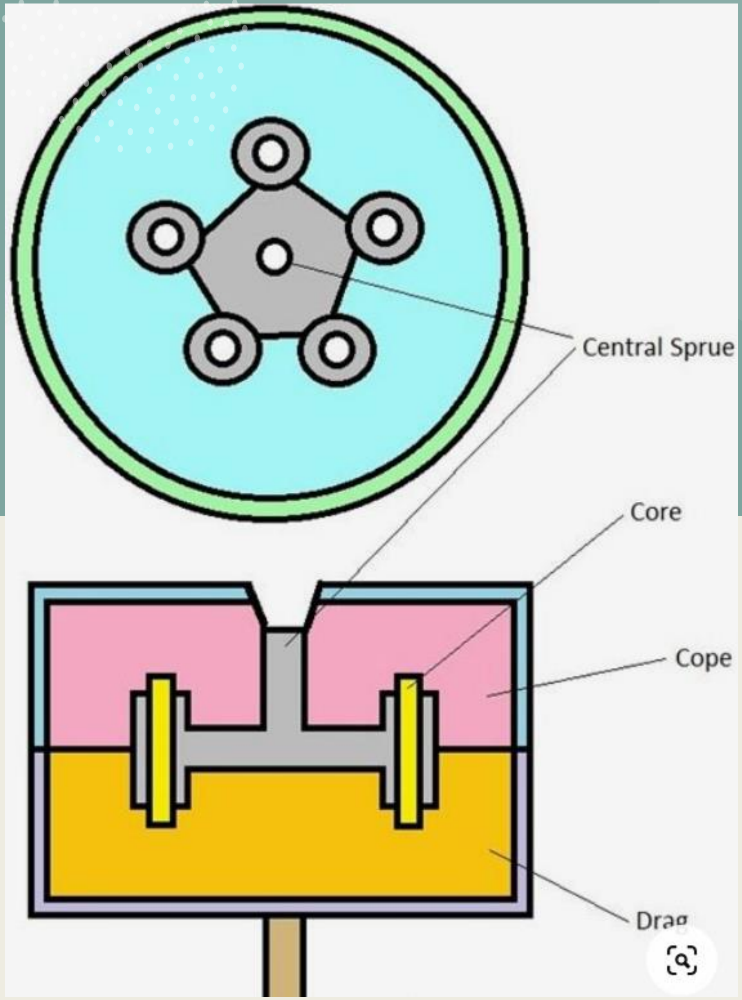


- **Semi Centrifugal Casting**

Centrifuging Casting

- ❖ In this process molten metal is poured in to rotating molds of which several identical mold cavities are symmetrically arranged off the axis of rotation around a central sprue.
- ❖ This central sprue feeds the metal into the cavities through several radial gates.
- ❖ The casting produced are not spun about their own axis. So, parts not symmetrical about any axis of rotation may be cast in a group of molds arranged in a circle.
- ❖ Mold cavities are fed by a central sprue under the action of centrifugal forces.

❖ Centrifuging Casting



Shell Moulding Process

In this process the sand mixed with a thermosetting resin and the sand so mixed is allowed to meet a heated pattern plate (200 ^{o}C).

This causes a skin (Shell) of about 3.5 mm of sand/plastic mixture to adhere to the pattern. Then the shell is removed from the pattern.

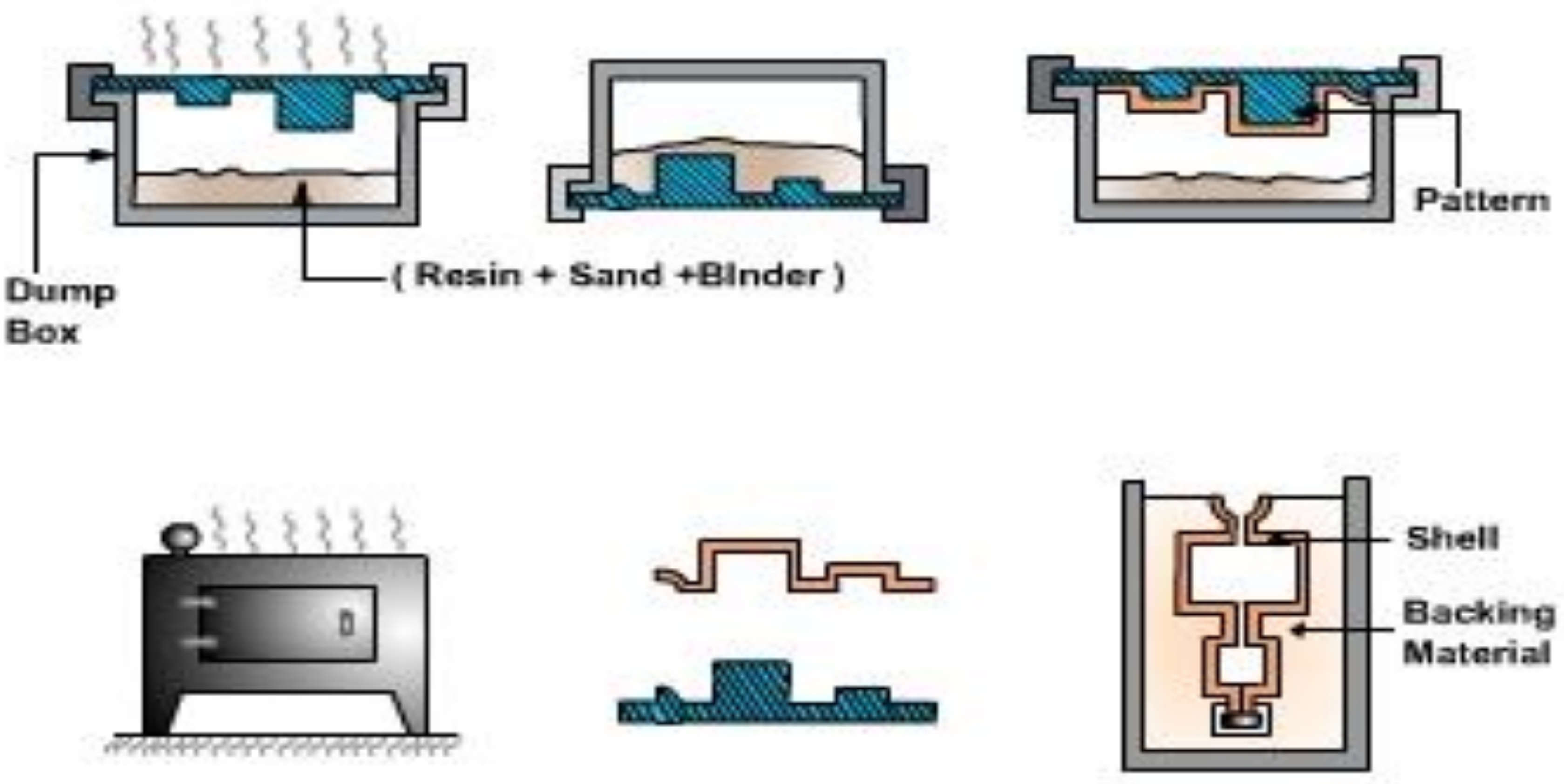
The cope and drag shells are kept in a flask with necessary backup material and the molten metal is poured into the molds.

This process can produce complex parts with good surface finish 1.25 µm to 3.75 µm, and dimensional tolerance of 0.5 %.

A good surface finish and good size tolerance reduce the need for machining.

The process overall is quite cost effective due to reduced machining and clean-up costs. The materials that can be used with this process are cast irons, and aluminum and copper alloys.

Shell Moulding Process



INVESTMENT CASTING

The investment casting process also called lost wax process begins with the production of wax replicas or patterns of the desired shape of the castings.

A pattern is needed for every casting to be produced. The patterns are prepared by injecting wax or polystyrene in a metal dies.

Several patterns are attached to a central wax sprue to form an assembly.

The mould is prepared by dipping pattern into slurry made by suspending fine ceramic material in a liquid such as ethyl silicate or sodium silicate.

INVESTMENT CASTING

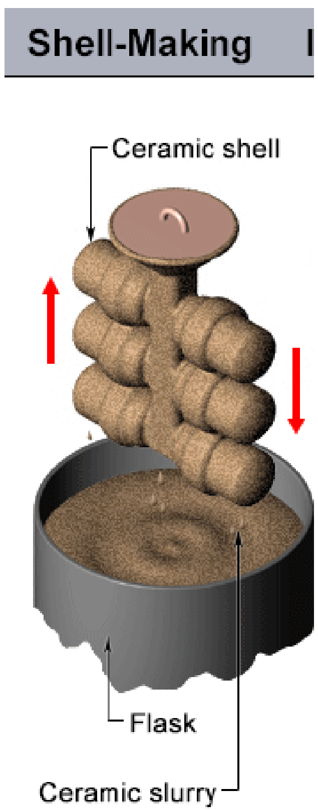
The process of dipping is continued until thickness of the mould is of about 6 to 15 mm

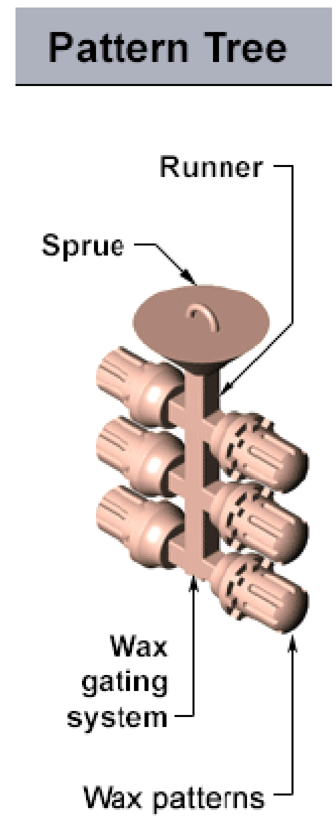
The mould is then heated so that pattern melts and flows out, leaving a clean cavity behind.

The mould is further hardened by heating (100 °C to 1000 °C) and the   molten metal is poured under gravity while it is still hot.

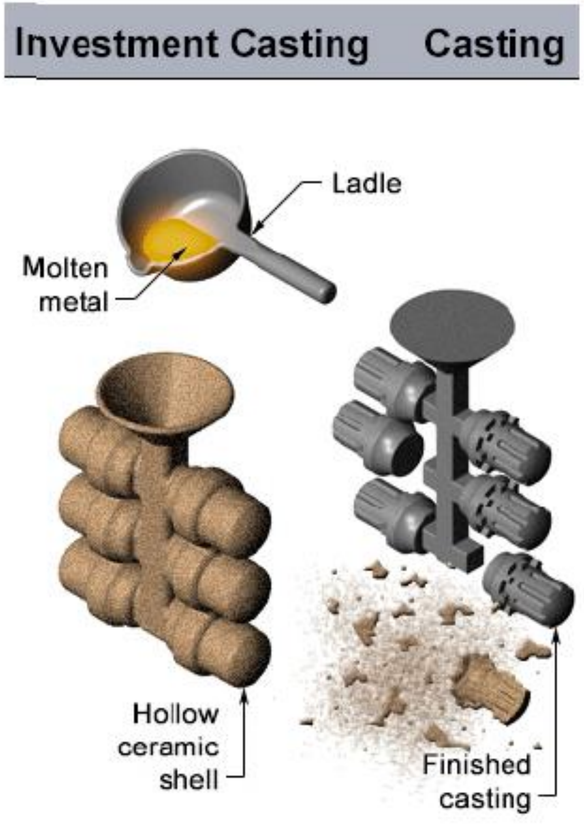
When the casting is solidified, the mould is broken, and the casting taken out.

INVESTMENT CASTING

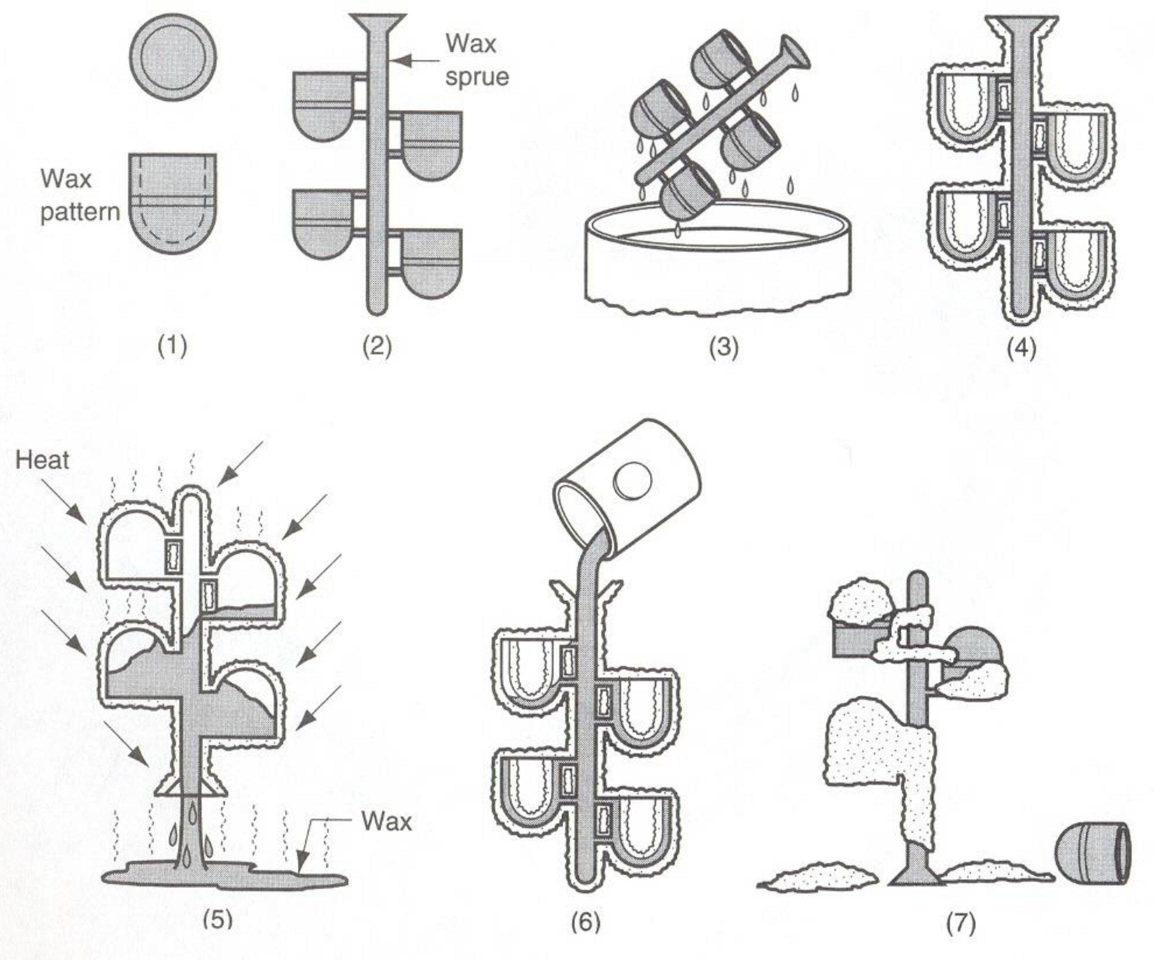




INVESTMENT CASTING



INVESTMENT CASTING



INVESTMENT CASTING

Advantage:

- Complex shapes can be produced easily.
- Very close tolerances and better finish can be produced.
- Lost wax can be reused.
- Additional machining not required.

Disadvantage:

- Process is limited by size and mass of casting.
- This is a more expensive process because of larger manual labor involved in the preparation of the pattern and the mold.

Application :

- Used for making Turbine blades, Jewelry, Surgical instruments etc.

CASTING DEFECTS

- Any unwanted deviation from the desired requirements in a cast product results in a defect. Some defects in the cast products are tolerable while others can be rectified by additional processes like welding etc.
- The following are the major defects which are likely to occur in sand castings:

✓ Gas defects
✓ Shrinkage cavities
✓ Molding material defects
✓ Pouring metal defects
✓ Metallurgical defect

Gas Defects

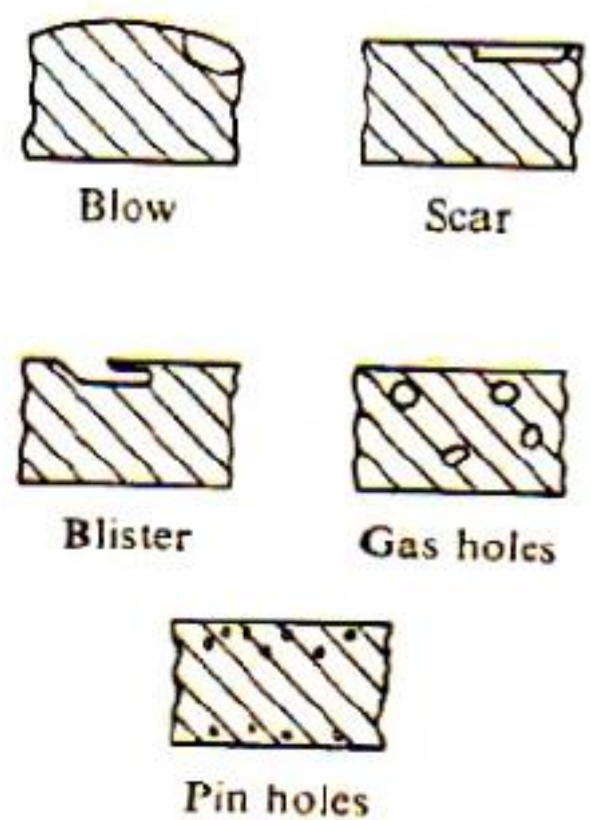
- These defects are due to lower gas passing tendency of the mold which is caused by lower venting , lower permeability of the mold and improper design of the casting. The lower permeability of the mold is due to use of finer size grains of sand, higher percentage of clay & moisture and excessive ramming of the mold.

✓ **Blow Holes**

✓ **Pin Holes**

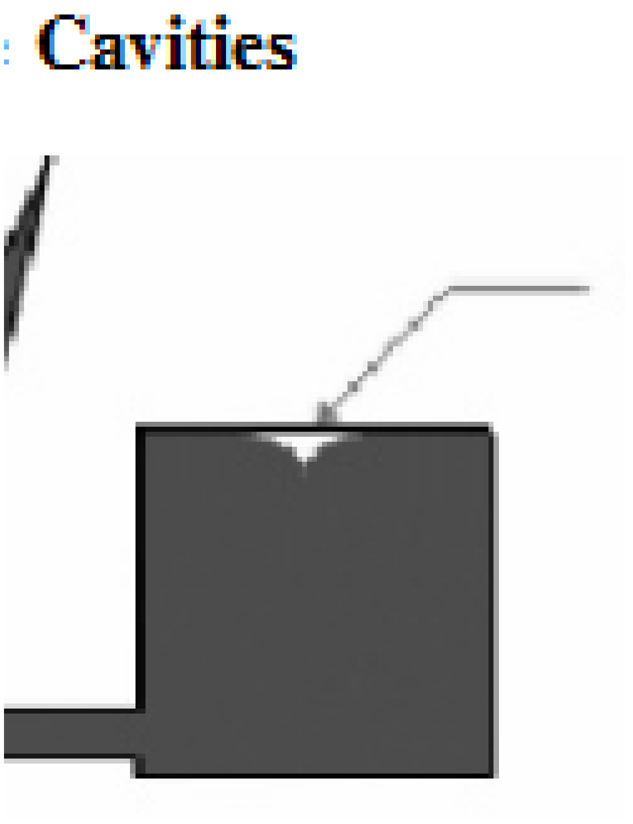
✓ **Scars**

✓ **Gas Holes**

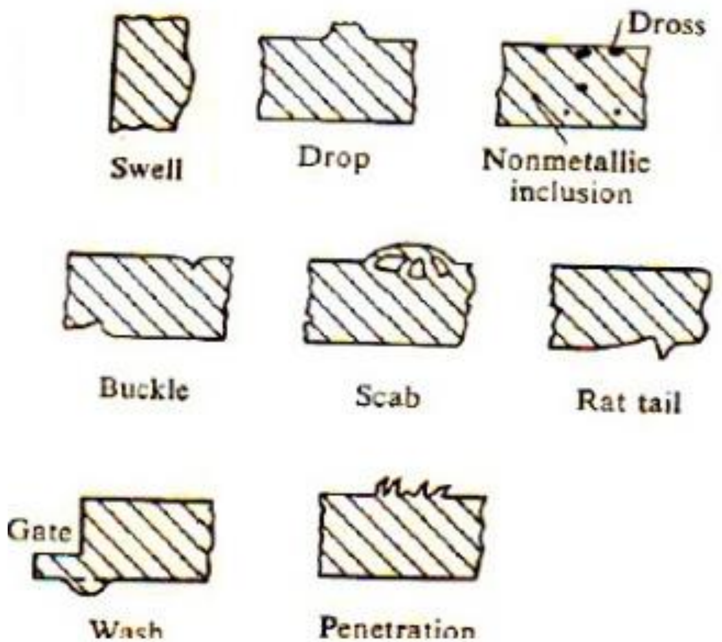


Shrinkage Cavities

- These are caused by the liquid shrinkage occurring during the solidification of the casting. An improper riser and gating system may give this type of defect which has a shape of a funnel.



Molding Material Defects



- ❖ These defects are originated due to some specific characteristics of the molding materials like insufficient strength, improper ramming etc. The various defects under this category are …..

- ✓ Cut and washes
- ✓ Metal penetration
- ✓ Fusion
- ✓ Run out
- ✓ Buckle
- ✓ Rat tail
- ✓ Swab
- ✓ Swell
- ✓ Drop

Molding Material Defects

- **Cuts and Washes**: Theses appear as rough spots and areas of excess metal and are caused by the erosion of the molding sand by the flowing molten metal. This may be due to insufficient strength of mold material or the high velocity of the molten metal. The proper choice of molding sand and appropriate molding method together with better design of gating system which reduces turbulence by increasing the size of the gates or by using multiple ingates can eliminate these defects
- **Metal Penetration**: When molten metal enters the gaps between the sand grains, the result would be a rough casting surface. This is due to the use of coarse sand grains in mold material. This can also be caused by higher pouring temperature. Choosing appropriate grain sizes, together with proper mold wash should be able to eliminate this defect.
- **Fusion**: This is caused by the fusion of sand grains with molten metal, giving a brittle, glassy appearance on the casting surface. The main reasons for this defect are the lower refractoriness of the clay used in molding sand and very high pouring temperature. The choice of an appropriate type and amount of Bentonite would cure this defect

Molding Material Defects

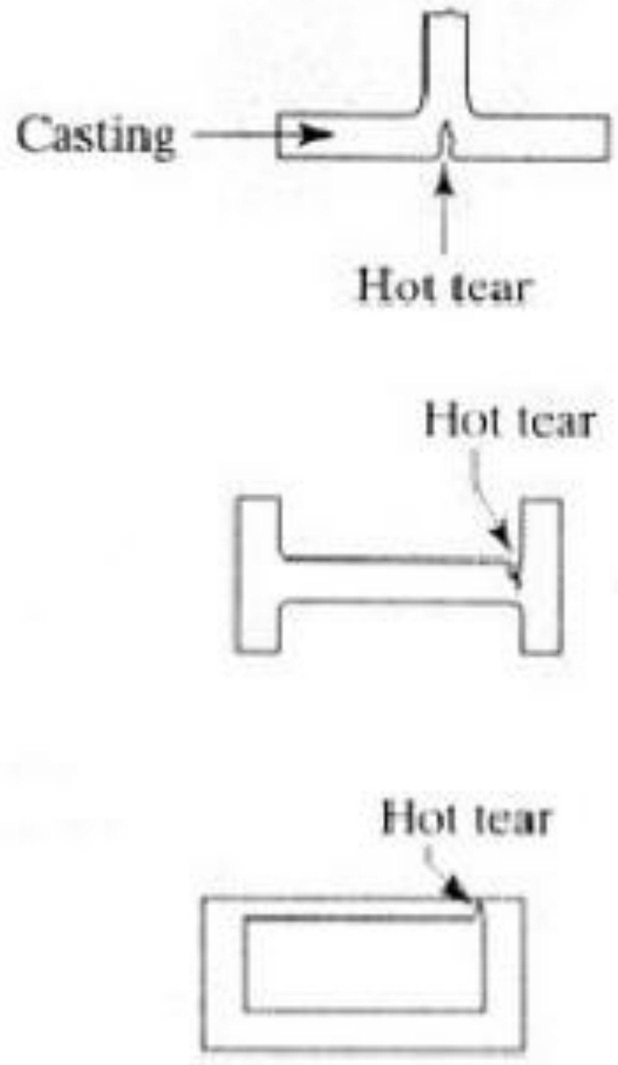
- **Run out**: This is happened when the molten metal leaks out of the mold due to faulty mold making or defective molding flask.
- **Buckles**: This refers to a long, shallow, broad, vee-shaped depression occurring in the surface of a flat casting of a high temperature metal. At this high temperature, an expansion of the thin layer of sand at the mold face takes place before the liquid metal at the mold face solidifies. As this expansion is obstructed by the flask, the mold face tends to bulge out, forming the vee shape. A proper number of volatile additives in the sand-mix is therefore essential to make room for this expansion and to avoid the buckles.
- **Rat tail**: It is a long shallow angular depression normally found in a thin casting. The reason for its formation is the same as that of buckles. Here, instead of the expanding sand up heaving, the compressed layer fails by one layer, gliding over the other.

Molding Material Defects

- **Scab**: This refers to the rough thin layer of a metal, protruding above the casting surface, on top of a thin layer of sand. The layer is held onto the casting by a metal stringer through the sand. A scab results when the up heaved sand is separated from the mold surface and the liquid metal flows into the space between the mold and the displaced sand.
- **Swell**: Under the influence of metallostatic forces, the mold wall may move back causing a swell in the dimensions of the casting. As a result of the swell, the feeding requirements of the casting increase which should be taken care of by the proper choice of risering. The main cause of this defect is improper ramming of the mold.
- **Drop**: An irregularly shaped projection on the cope surface of a casting is called a drop. This is caused by dropping of sand from the cope or other overhanging projections into the mold. An adequate strength of the sand and the use of gaggers can help in avoiding the drops

Metallurgical Defect

- **Hot tears**: Since metal has low strength at higher temperatures, any unwanted cooling stress may cause the rupture of the casting. The better design of casting avoids this defect.

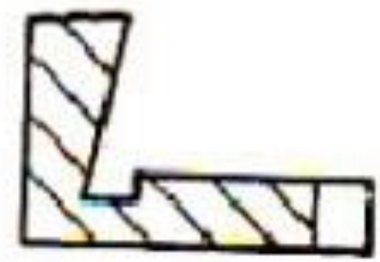


Pouring Metal Defects

❖ **Misrun:** Many a time, the liquid metal may, due to insufficient superheat, start freezing before reaching the farthest point of the mold cavity. This defect is called Misrun.

❖ **Cold shut**: For a casting with gates at its two sides, the misrun may show up at the center of the casting due to non-fusion of two streams of metal resulting in a discontinuity or weak spot in casting.

Cold shut



Misrun