HANDWRITTEN NOTES OF

(CASTING)

BY

ENGGBUZZ.COM

Manufacturing Process

It, is a process in which Raw material will be Converted into a finished product.

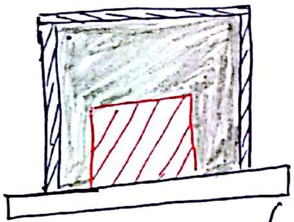
It is a process of value addition to the Raw material.

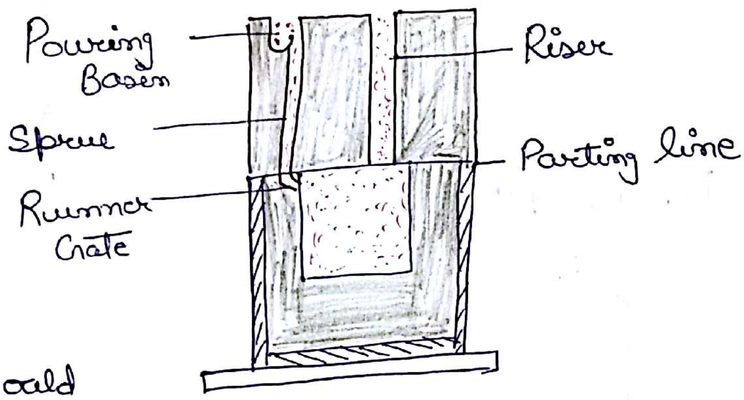
Classification of Manufacturing Process

1) Casting → Primary / Basic Process   ORE → InGots
2) Forming
3) Fabrication Process
4) Material Removal Process

(2), (3), (4) → Secondary Process

Casting :-





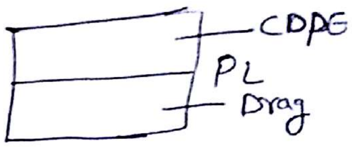
It is a process in which molten liquid metal will be allowed to Solidify in a pre defined Cavity (mould Cavity).

Advantages:

1) Complex shape of the Object Can be easily Produced.
2) It is less expensive process.
3) Ductile & Brittle materials Can be produced.
4) Large Size Object Can be produced by Casting only. (150 - 200 tons)

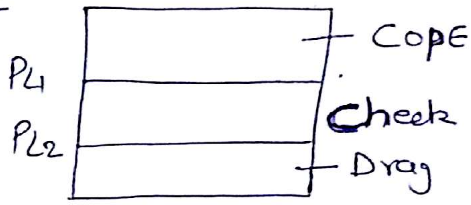
e.g road roller, Machine Tool Beds, engine Block
Gear box housing

Mould Box :- Two Box / Three Box

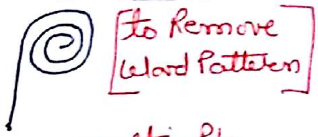


Two Box

three Box



Draw-Spike



Pouring Temp. $T_p = T_m + \Delta t$

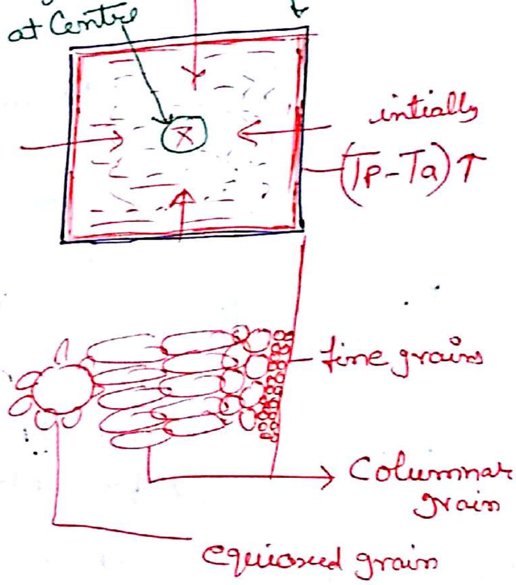
T_m → melting Pt.

Δt (100°–250°) → Degree of Superheat

~~Limitation's of Casting~~ :-

Selection manufacturing Process
↓
Shape & Size
Properties of object (Mechanical)

Cooling is higher at Surface and lower at Centre



Draw Spike

use to remove Pattern from Mould.

Imp

$$T_p = T_m + \Delta t$$

T_p – Pouring Temp.

T_m – Melting Point temp of Material

Δt – Temp. difference

Limitation Of Casting Process :-

1) Casting objects are not having smooth surface finish.
2) It is a labourious Process.
3) There is possibility Of Casting defects. (Gas defects,)
4) Casting objects are not having uniform mechanical Properties, due to, Non uniform Cooling.

Selection Of the Manufacturing Process:

Selection Of manufacturing Process will depend on;

1) Shape & Size of object.
2) Complexity of the object.
3) Accuracy & surface finish required by the Object.
4) Number of Components will be produced.
5) Properties Required by the object.
6) Cost of the Object.

Pattern :-

Pattern is the replica (an exact copy) of final casting to be produced, with some modifications. The modification are in the form of allowances.

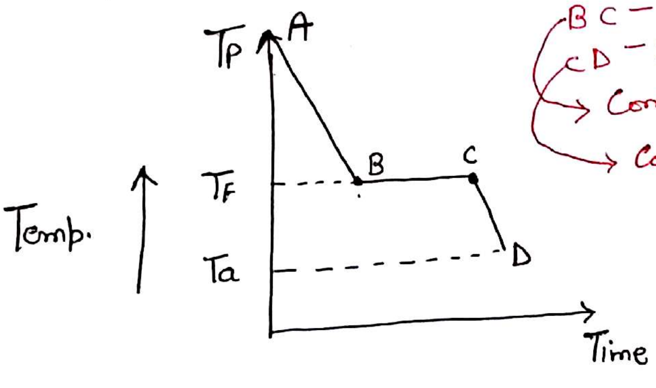
Types of Pattern Allowances:

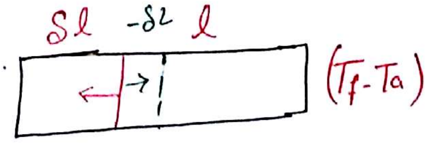
1) Shrinkage (or) Contraction
2) Draft (or) Taper
3) Machining (or) Finish
4) Shake (or) Rapping
5) Distortion (or) Camber

1) Shrinkage or Contraction

Temp. V/s Time graph for pure metal

AB – liquid State – liquid Shrinkage
BC – Solidification – Solidification Shrinkage → Compensated by Providing Riser
CD – Solid State – Solid Shrinkage → Compensated by ↑ size of Pattern





$\delta l = l\,a\,\Delta T$ $(a \to \alpha)$

$-\delta l = l\,a\,\Delta T$ Cofficient of linear expansion

(Imp)

Cooling Process

1) α is +ve → Contraction
2) α is 0 → no change
3) α is -ve → expansion → Besmuth = Invar

When the liquid metal is allowed to solidify, there is a Possibilities of Contraction of material. Due to this size of the casting will be decreased.

→ When the liquid metal is cooled from pouring temp (T_P) to freezing temp (T_f) the shrinkage is liquid shrinkage

→ During Phase transformation, the shrinkage is Solidification Shrinkage / Phase Transformation Shrinkage.

→ When the solid casting is cooled from freezing (T_f) to ambient temp. (T_0) in solid state, shrinkage is Solid Shrinkage

→ Liquid & Solidification Shrinkage can be Compensated by Providing the Riser.

→ Solid Shrinkage is Compensated by ↑ the size of the Pattern, in the form of Shrinkage allowances.

→ Shrinkage Values for different materials :-

1) Bismuth & Invar → Negligible Shrinkage
2) White metal → 5mm/m Shrinkage
3) Cast Iron (CI) → 10mm/m Shrinkage
4) Aluminium → 13mm/m
5) Copper → 17mm/m
6) Steels → 20mm/m
7) Brass → 24 mm/m

imp **NOTE:**

→ Solid Shrinkage is max. for Brass, which requires, large Sized Pattern.

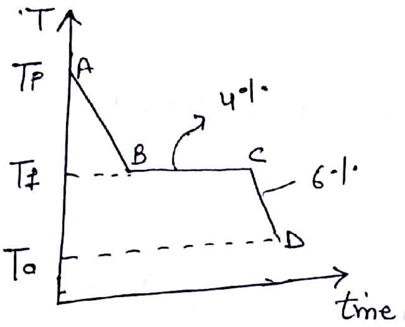
→ Liquid & Solidification Shrinkage is max. for Aluminium. Which requires more volume of Riser.

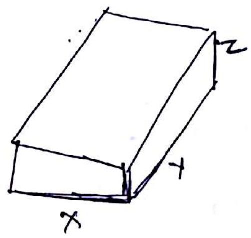
→ Total Shrinkage is max. for Steel material.

Problem

Q) A cubical Casting of 50mm Size, undergoes volumetric Solidification Shrinkage of 4% and volumetric Solid Contraction of 6%. There is no riser is used and Pattern making allowances is not Considered. What is the final Size of the casting.

Soln





vol. of material at B = $(50)^3 \text{ mm}^3$

vol of material at C = $0.96 \times (50)^3$

vol. of material at D = $(0.96 \times (50)^3)\, 0.94$

$$a^3 = 112800 \text{ mm}^3$$

$$\boxed{a = 48.31 \text{ mm}}$$ Ans

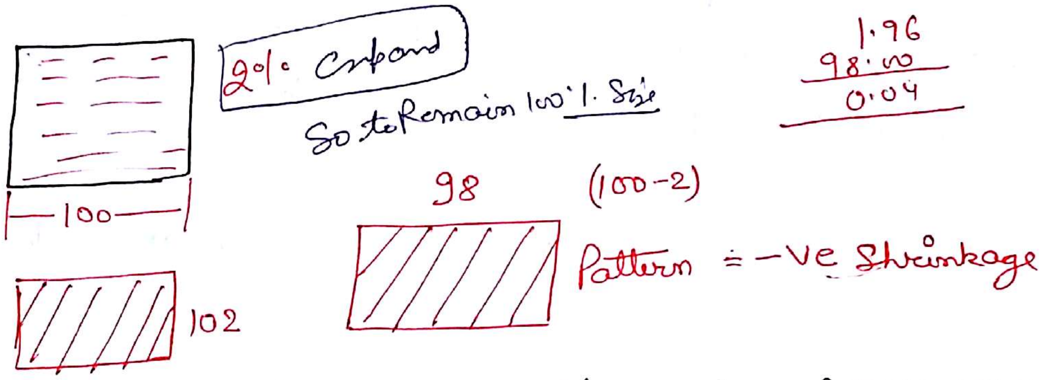
(Qn)

For grey cast iron $\alpha \rightarrow -ve$ — Produce by cupula furnace & Si will be added to Pig iron. iron & Carbon both seprated.

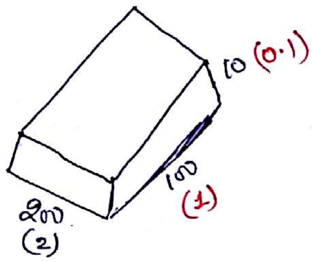
expansion — 1 - 2.5 % Solid State

By cooling the Grey Cast iron, there is a possibility of expansion of the material due to, Conversion of Carbon into graphite flake (BCC to HCP).

To overcome this, size of the Pattern will be reduced by considering (-ve) shrinkage allowances.



Qn) A Grey Cast iron block of dimension, $200 \times 100 \times 10\ mm^3$ is produced by sand moulding process. Pattern making allowance is 1%. What is the ratio of volume of the Pattern to volume of the Casting.



Soln) $\dfrac{\text{Volume of Pattern} : (200-2)(100-1)(10-0.1)}{\text{Volume of Casting} = 200 \times 100 \times 10}$

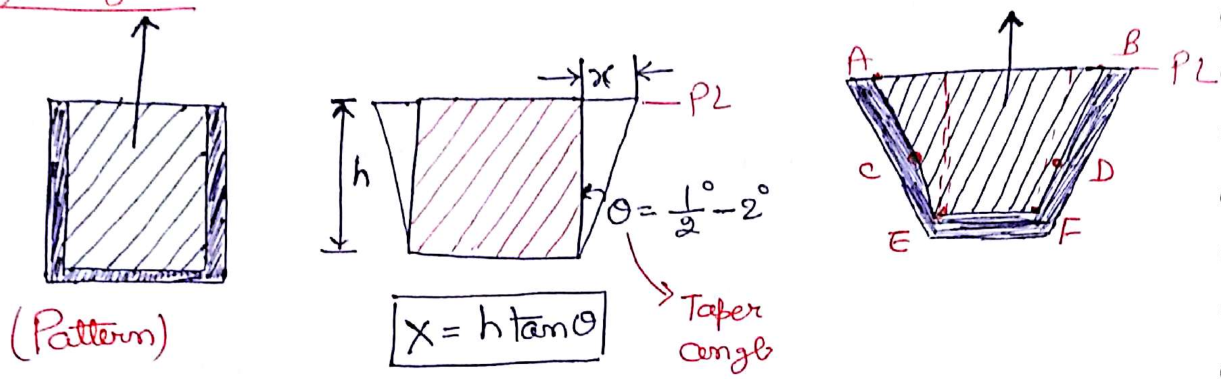
$= 0.097 (<1)$

> 1 for all other material

$= 1$ (Bismuth)

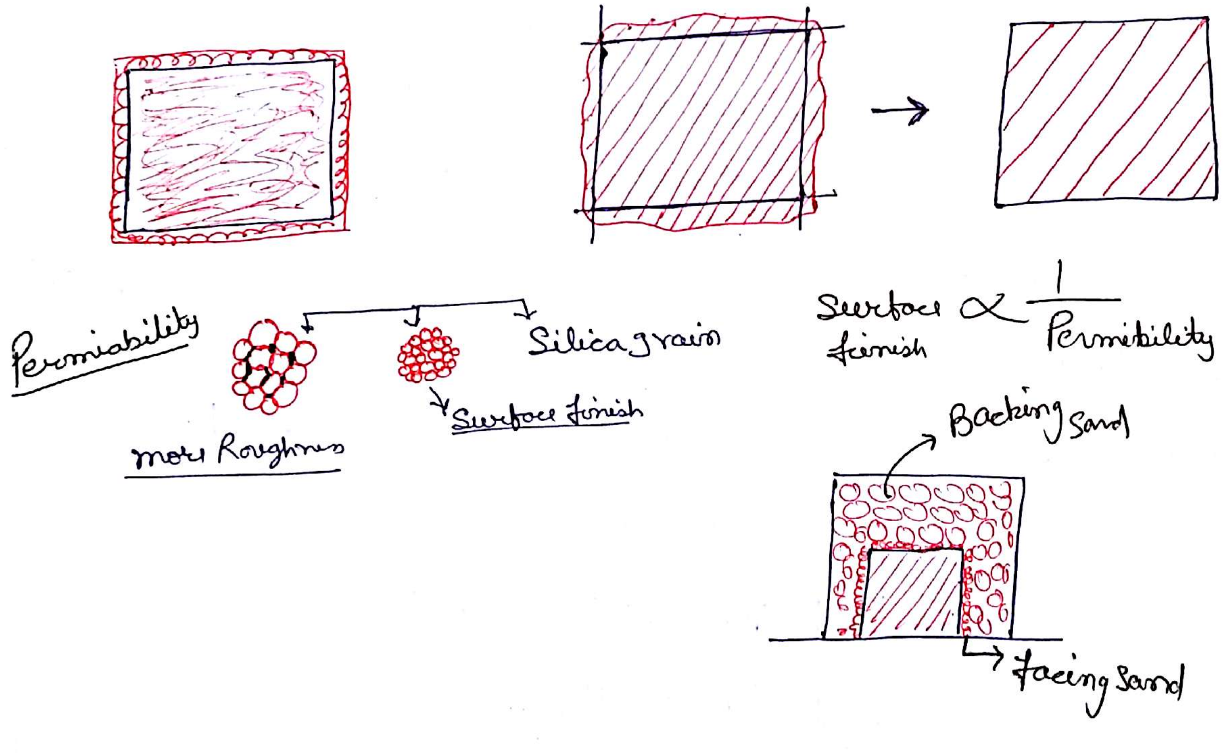
Draft or Taper Allowances :- for high height

for high height



For, easy removal of Pattern, from the mould, form the Vertical Surface of the Pattern, draft or taper allowances are Provided. This will depends on Vertical height of the Pattern.

Machining or finish Allowances: (mm/surface)



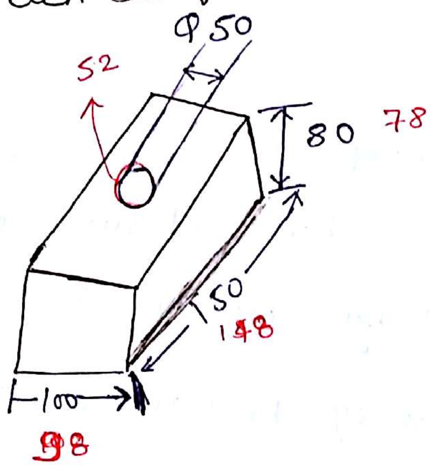
→ Casting Object are not having, Smooth Surface finish.

→ To get better Surface finish on the Castings, machining is required.

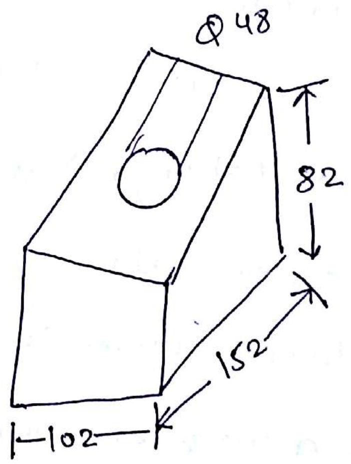
→ Due to machining, Size of the casting will be reduced.

→ To overcome this, machining Allowances are Provided on Pattern. This value will depends on size of the Silica grains and Surface finish required by the Casting.

Qn) Calculate, dimensions of the Pattern, for the casting Shown, below, by ~~transfer~~ Considering machining allowance ~~at~~ 1 mm. on each Surface.



Casting

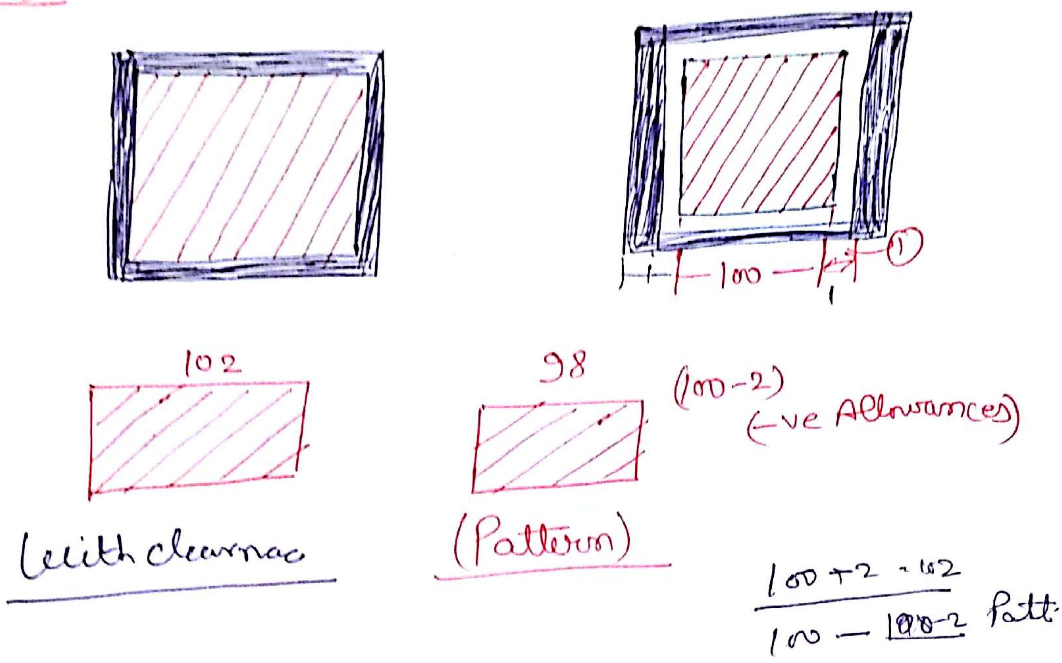


Pattern

Shake (or) Rapping Allowances :- (-ve) Allowances

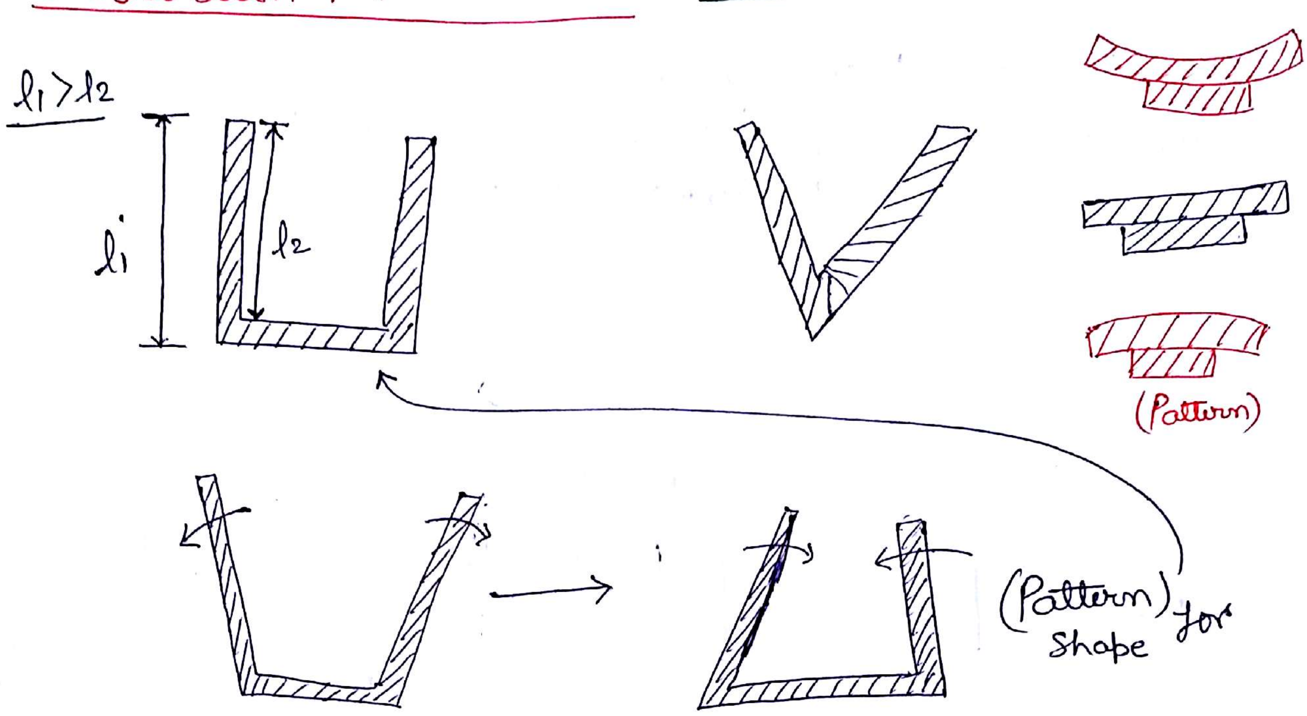
expansion

(for short height)



- → For, easy removal of the Pattern, some clearnac is required b/w Pattern and mould surface.
- → This can be Produced by shaking the Pattern. ~~da~~
- → Due to Shaking, size of the Pattern will be slightly increased.
- → To overcome this, size of Pattern will be reduced by considering ~~Shrunt~~ Shake allowances. i.e (-ve) ~~S~~Allowances (expansion)
- → It is a negative (-ve) Allowances, Provided on the Pattern. Reducing Size of Pattern to get desired casting cavity.
- → This value will depends on strength of mould & Skilled ~~Speed~~ level of the operator.

Distortion Allowance :- Zero Allowance



→ Depending on Shape & Size of the Casting, due to difference in Linear dimensions, there is a Possibilities of Shrinkage Stress can be develop.

→ Due to this, Casting will be getting distorted.

→ To Overcome this, distortion allowance is provided are opposite to the direction of distortion.

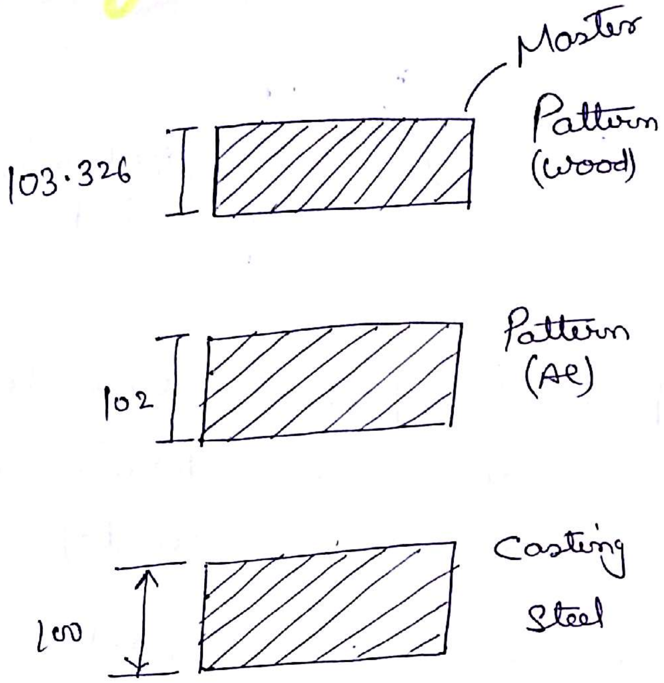
→ These Values will depends on, length to thickness Ratio. $\left(\frac{l}{t}\right)$

distortion depends on $\left(\frac{l}{t}\right)$
↓
length to thickness Ratio.

Pattern Materials :-

1) Wood :- Teak, Mahagony, etc.
2) Metals & Alloys :- Aluminium, cast iron, Brass, Steel, White metal etc.

Imp Double Allowances



Steel : Shrinkage (20mm/m)

1m —— 20mm

100 m — 2mm

Aluminium Al = 13/mm

1000 — 13mm

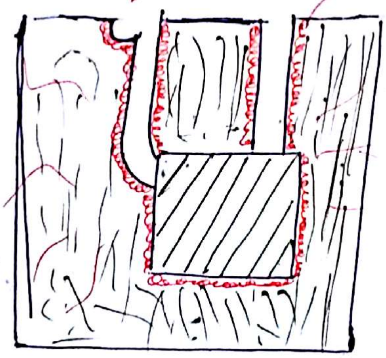
102 — 1.326mm

Double Shrinkage Allowance :-

To Produce no. of Casting in mass Production, metallic Pattern can be used. They can be produced by wooden Patterns and wooden Pattern. On wooden Pattern, Shrinkage of Casting material & Shrinkage of Pattern material, both will be added & this is Known as double shrinkage allowance. Imp

And wooden Pattern is Known as Master

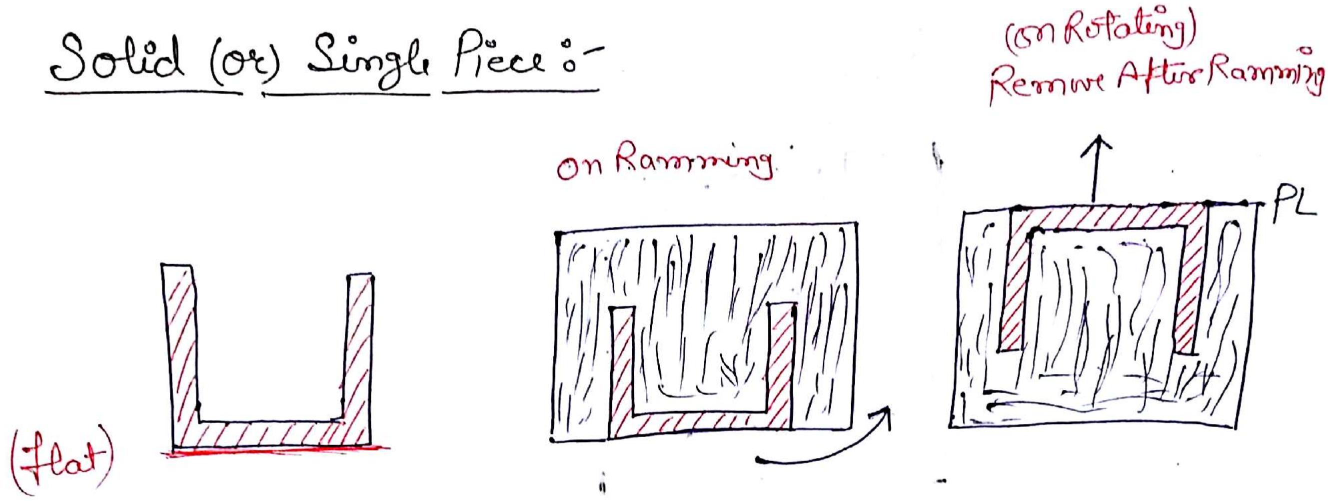
3) Plastic : Polystyrene (230°C), PVC, foam, Thermocol etc.



Wax — Investment C.
Hg — Mercury Cast Process
−39°C (F.P)

Types of Patterns :-

1) Solid (or) Single Piece :-

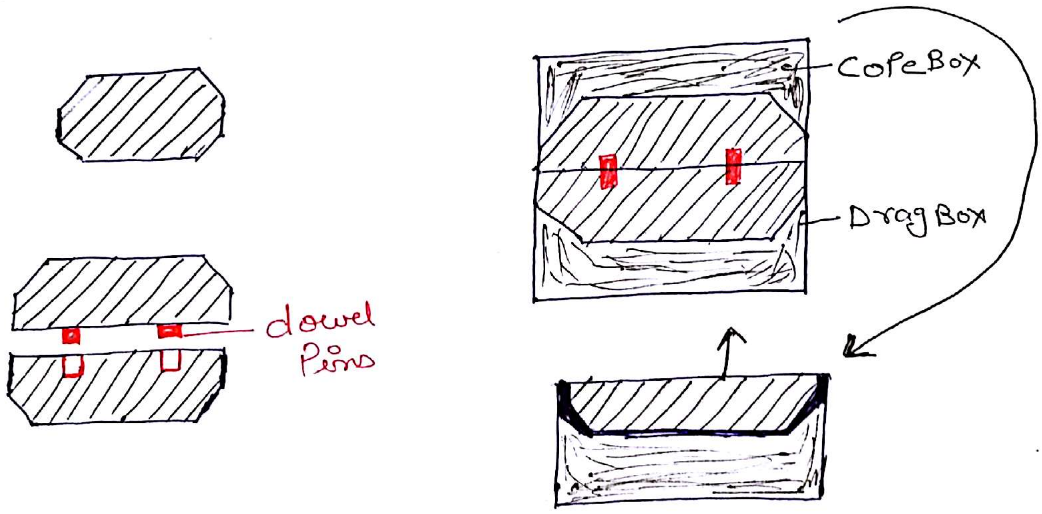


→ If the Object to be produced is Simple in shape & Size, Solid (or) Single piece Pattern is used.

→ One of the Surface of the Object must be flat.

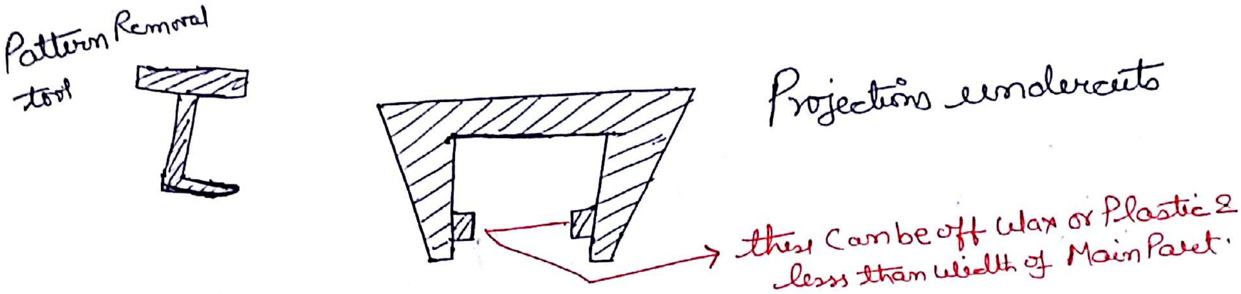
→ It is Completely Provided in the drag Box.

2) Split Piece Pattern :-



→ If the object to be produced is Complex, then they Can be Split into Split pieces along the Parting Line & Split Pieces Can be removed from Cope & Drag Box, Seprately.

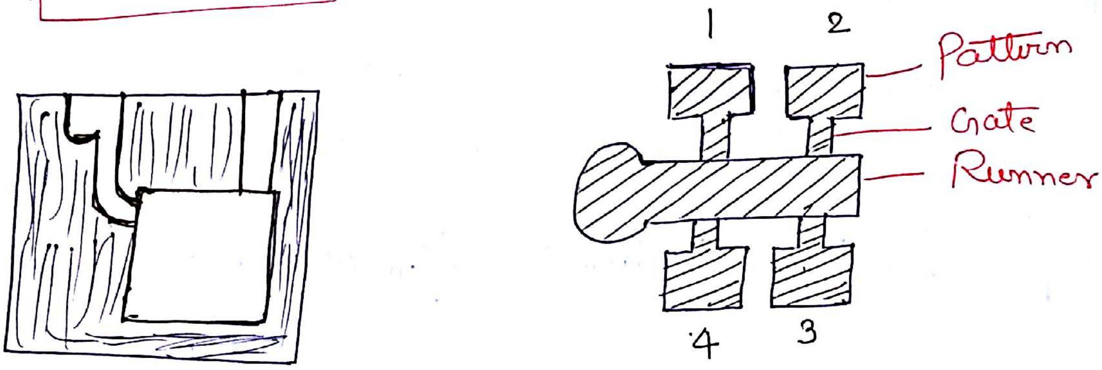
3) Loose Piece Pattern :-



→ If the Patterns are having Projections and undercuts loose Piece Pattern can be used.

→ After Removing the main Part from Pattern, loose pieces can be removed from the cavity.

4) Gated Pattern :- (Runner + Gate)

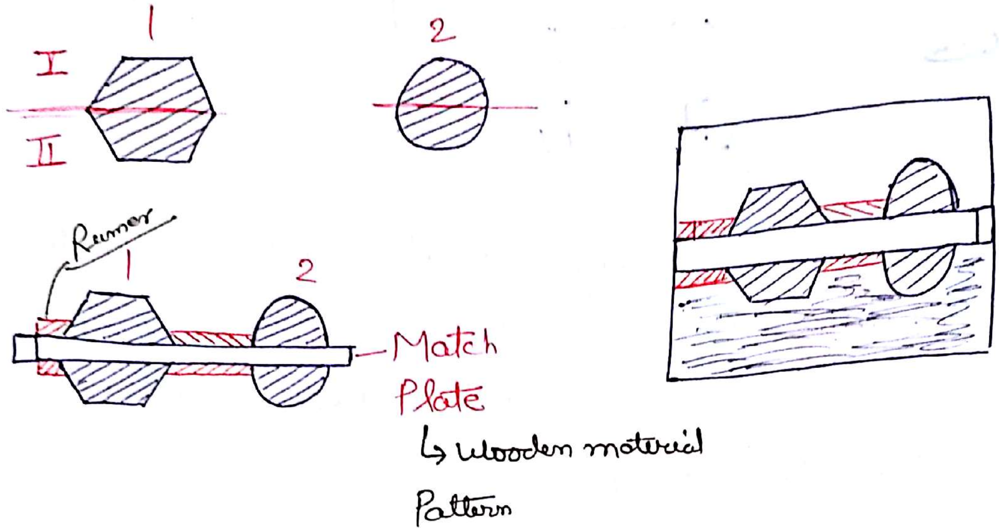


→ To Produce number of Castings in mass Production, Producing of the runner and gate will manually will take more time.

→ To overcome this number of Patterns, along with gating elements will Produce the single pattern known as gated Pattern.

5) Match Plate Pattern :-

Sand will be filled & Ramming Seprately in Cope Box & drag Box

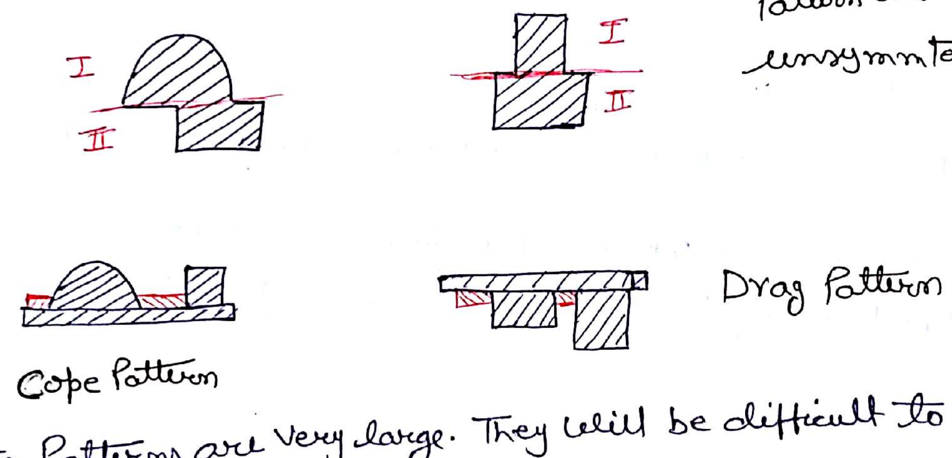


→ To Produce Complex shape of the Object in mass Production, this Pattern Can be used.

→ No. of Patterns can be split, along the Parting line and they can be added on both Sides of match Plate, along with gating elements.

6) Cope and Drag Pattern :- (Two Match Plate)

Pattern are large & unsymmetric



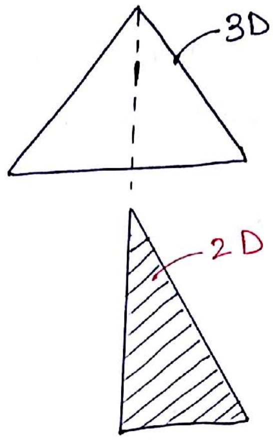
→ If the Patterns are very large. They will be difficult to handle on both Side of Single Match Plate, We can use Cope & drag Pattern.

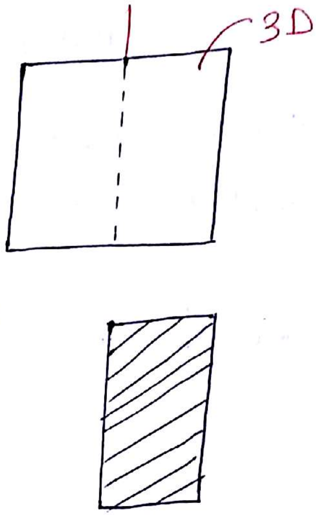
7) Sweep Pattern :-

rotating 2D Pattern to obtain full 3D Pattern.

Use: Symmetrical Shape of Pattern

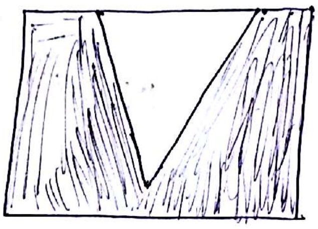
2D – 3D

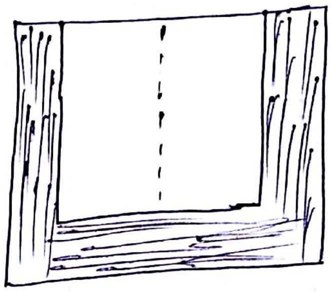


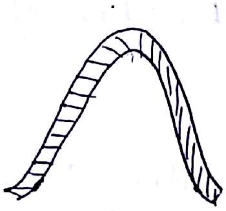


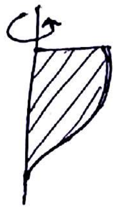
Loam Sand

- 50% Silica
- 50% Clay
  +
  (40% Clay + 10% Water)

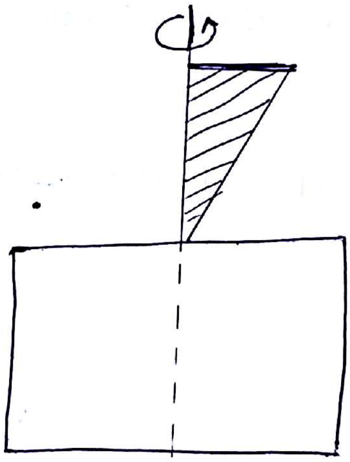


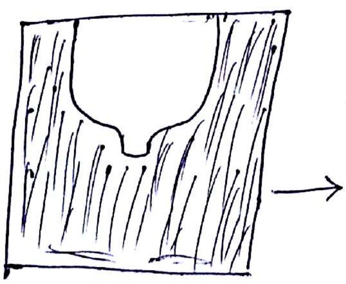


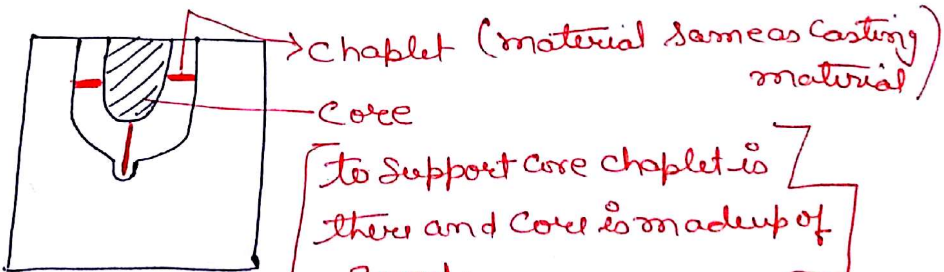




To obtain Cavity in Mould







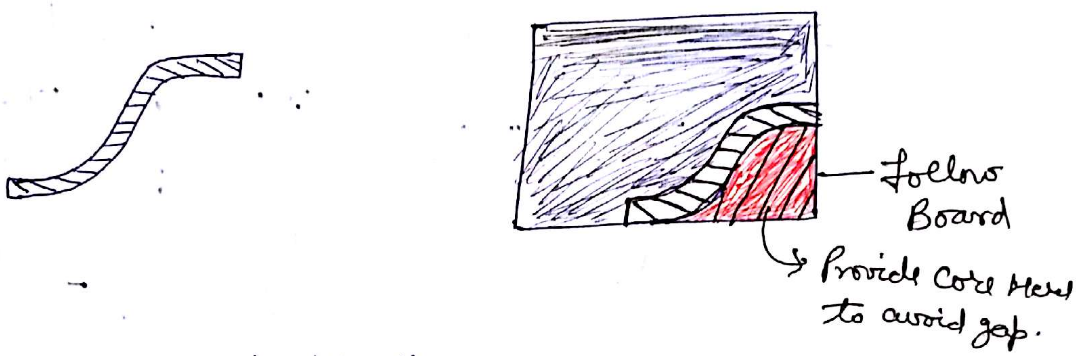
to support core chaplet is there and Core is made up of Sand.

→ To Produce Complex shape of 3D Cavity, 2D, Plane Pattern will be rotated in the mould.

→ It will be use for Symmetrical shape of the Pattern only

→ It is not the true shape of the Pattern.

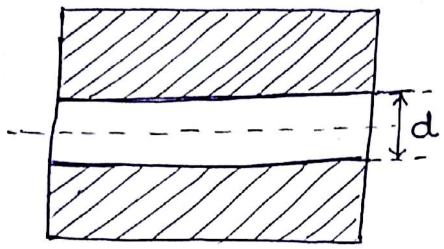
8) Follow board Pattern :-

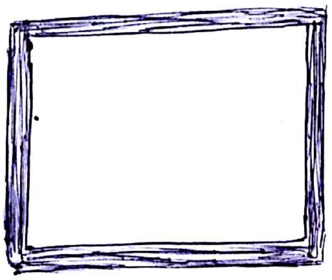


→ If the Patterns are Structrally weak, due to Ramming force, there is a possibility of Breaking of the Patterns.

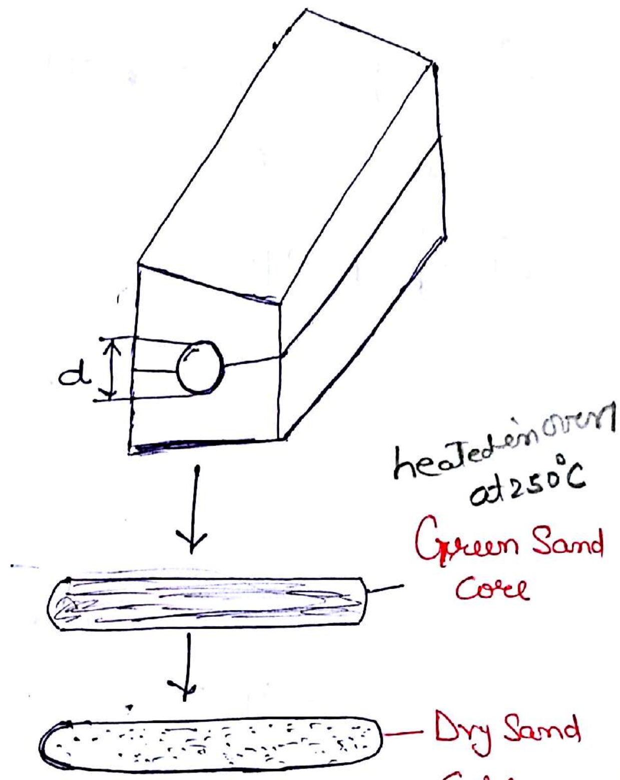
→ To overcome this, Patterns are Suppoted, by Providing a Follow Board.

Core Design :-





Core Boxes :-



Core Sand :

Moulding Sand
+
organic binders
(Linseed Oil,
Molasses, dextrin, etc)

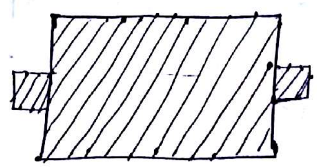
Net Buoyancy Force = Weight of liquid Metal displaced − Weight of Core.

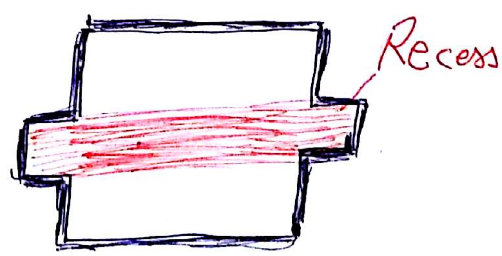
$$P = V_c \rho_m g - V \rho_c g$$
$$P = V_c g(\rho_m - \rho_c)$$

$$P = V_c g(\rho_m - \rho_c)$$

- V_c → Core volume
- ρ_m → Density of Molten liq metal
- ρ_c → density of core Material

Core ~~Paint~~ Prints :

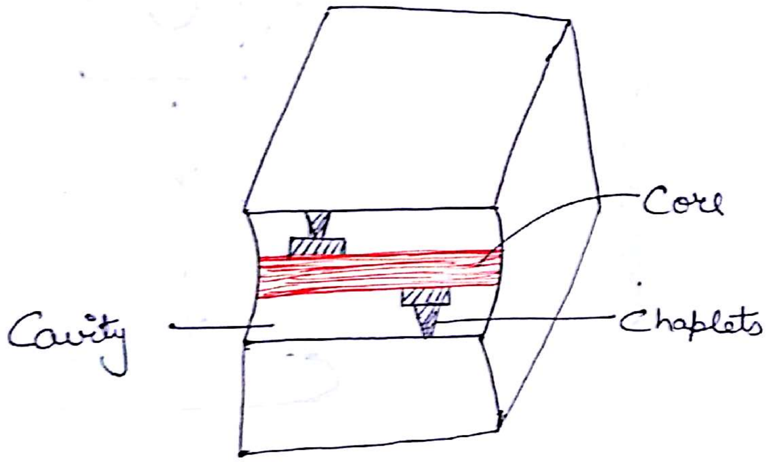




$$P = V_c g(\rho_m - \rho_c)$$
$$P \leq 3.5 A_c$$ → Core Print Area (Surface area)

Core Prints:

Core prints are the Projections on the Pattern and the Recess in the cavity to position the Core properly.



Chaplets:-

→ These are the metallic objects, used to Support the core inside the Cavity.

→ These are made up of Same material as the Casting & become integral Part of Casting

(Pn) A Hollow Casting is produced, using a cylindrical Core of 100 mm dia & 100 mm height. Density of molten liquid metal is 2600 kg/m³, density of core material is 1600 kg/m³.

Calculate the net force (P) on the core prints?

$H = D = 100mm$

$\rho_m = 2600\ kg/m^3$

$\rho_c = 1600\ kg/m^3$

$Vol._{cy} = \frac{\pi}{4} D^2 H$

$$P = \frac{\pi}{4}(100)^2 \times 100 \times 10^{-9} \times 9.81 \times (2600 - 1600)$$

$P = 7.704N$ Ans

$$P = V_c\, g\, (\rho_m - \rho_c)$$

$V_c \rightarrow$ volume of Core

g — gravity

ρ_m — Density of molten metal

ρ_c — Density of core material

Volume of Cylinder $= \frac{\pi}{4} d^2 h$

Moulding Sand:

Sand
- Silica — 70-85%
- Clay — 10-20% — Bonding Material
- Water — 2-8%
- Additives — 1-4%

- Silica — 1710°C — Refractory Temperature
- Olivine — 1800°C
- Zirconium — 2700°C
- Ceramic — 3500°C
- Graphite — 4200°C

Refractoriness Temperature

Refractoriness Temp. > Pouring Temp. of liquid Metal

Clay Materials → Bentonite, Kalonite in form of Powder

Properties of Moulding Sand:

1) Refractoriness:

It is the ability of moulding material to start high temp. of liquid Metal without fusion.

2) Permiability: $P_n = 60 - 120$ (Permiability number)

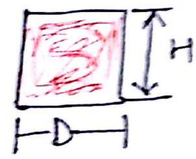
Ability of Moulding Sand to allow the gases to escape is Known as Permiability.

It is expressed by Permiability number.

$P_n - 60 - 120$

$$P_n = \frac{V_a H}{PAT}$$ Imp

$$P_n \propto \frac{1}{T}$$



$H = D = 2''$

$= 2 \times 2.54$

$H = 5.08\ cm$

by American Foundary Society.

V = volume air escape the Job ($2000\ cm^3$)

H = height or dia of Specimen (cylindrical) = $5.08\ cm$

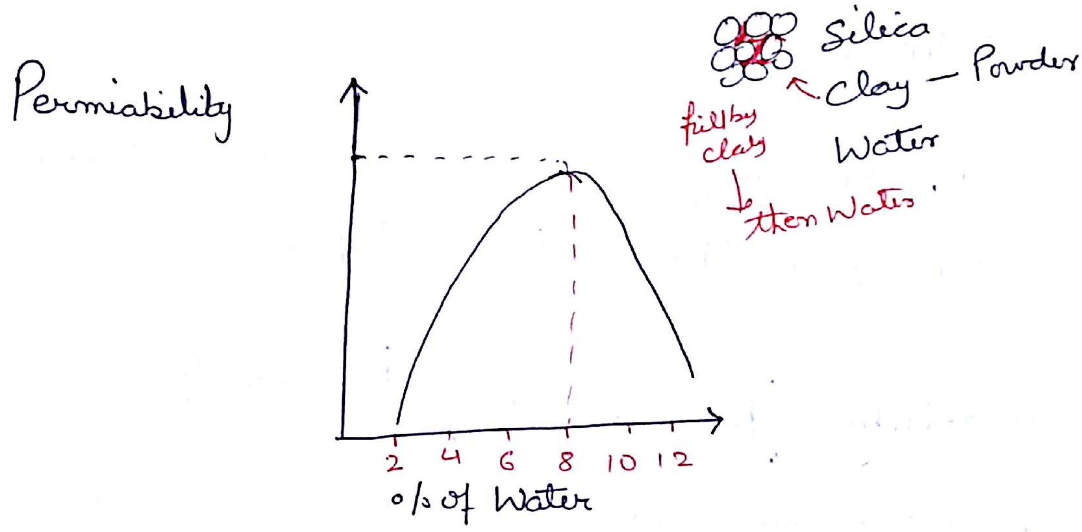
A = Area of Cross section of Specimen $= \frac{\pi}{4} D^2\ (cm^2)$

T = is ~~temp~~ time taken to escape gases out the Specimen.

P_a = difference of Pressure. (gm/cm^2)

$$P_n = \frac{V_a H}{PAT}$$

Permiability v/s % of Water



→ if the Water is less than 2%, Powder form of the clay will be enter into the voids of Silica Sand & it will Reduce the Permeability

→ if the % of Water ↑ up to 8%, by activating the Bonding Properties of clay. it will be Covering on the Surface of the Silica grains in the form of thin layer. & it will ↑ the Permiability.

→ if Water % is ↑ by 8%, clay will be washed out from the Silica grains & voids are filled with Water & Permiability will be decreases.

Qn) 2000 cm^3 of air is allowed to Standard Cylindrical Specimen for 1.5 minutes. Manometer indicates pressure difference as 5 gm/cm^2. What is the Permiability of Moulding Sand.

Soln

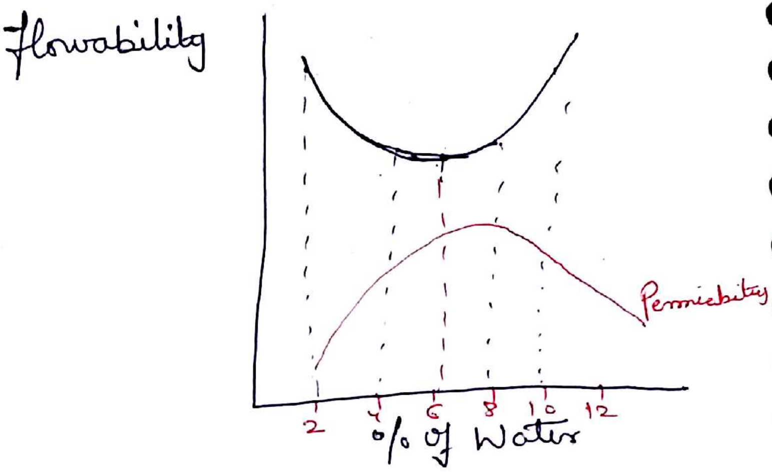
$$P_n = \frac{2000 \times 5.08}{5 \times \frac{\pi}{4}(5.08)^2 \times 1.5}$$

$$P_n = 66.87$$

→ Flowability :-

Ability of the moulding sand, it can move to all the corners of the mould box, due to ramming force.

It is also influences by
- Silica
- Clay
- Water

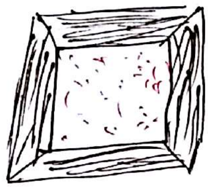


→ Strength of the Mould :-

Green Sand — 2-8% Water

Dry Sand

Hot Sand



→ To Retain Shape & Size of the mould cavity, and to withstand forces apply by liquid metal on the mould surface. mould must have sufficient strength.

Green Sand :

Moulding sand having Moisture is known as green sand, and strength of the mould is green strength.

Dry Sand :

By evaporating the moisture, arround the Cavity, Sand will become dry and strength of the mould is dry strength.

Hot Sand :

After ~~the~~ become the Sand dry, ~~since~~ still the liquid metal will having more heat will ↑ the temp of Sand known as Hot Sand & strength of the mould is Hot strength.

Hardness :- (Mould Hardness no. - 0–100) | Permiability ↓

Avg. Mould Hardness no = 60–80

M.H.N < 60 erosion start

(uniform Ramming is used for Avg. Mould Hardness no 60-80)

→ To minimise the erosion, and to withstand forces applied by the liquid metal, mould must have, Sufficient Hardness. It is a Surface Property.

→ if the mould Hardness is ↑ more than 80, Permiability will be decreases.

→ if the mould hardness is ↓ than 60 dimensional stability of Casting will be disturbed.

→ To Produce average Mould Hardness, uniform Ramming is required.

6) Adhesive Property:

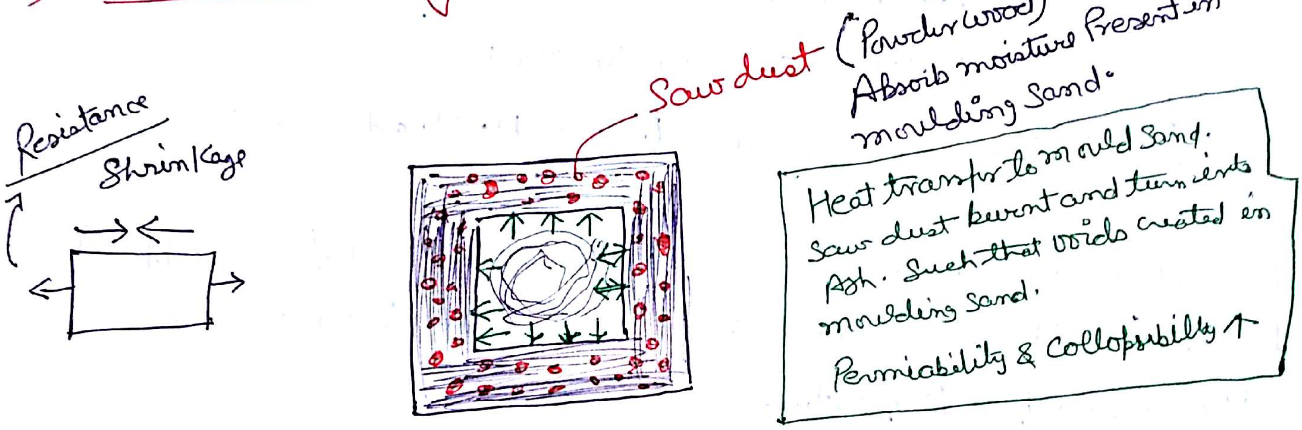
Bond formation b/w two different materials.

7) Cohesive Property:

Bond formation b/w Same material

Moulding Sand also Requires Sufficient Thermal Conductivity (K) & low Coefficient of Linear expansion (α).

8) Collapsibility:



Ability of the moulding Sand, due to which, mould Surface will not offer any Resistance due to Solid Contraction of the Casting is Known as, Collapsibility.

After Solidification cracks are formed on moulding Sand.

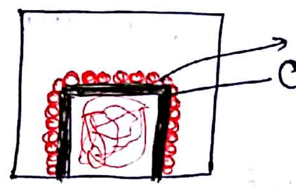
Collapseability:

Additives Used in moulding Sand:-

Saw dust or Wood Powder/Flour] Collapsibility (&) Permiability

Linseed oils, Molasses, dextrin] Mould Hardness

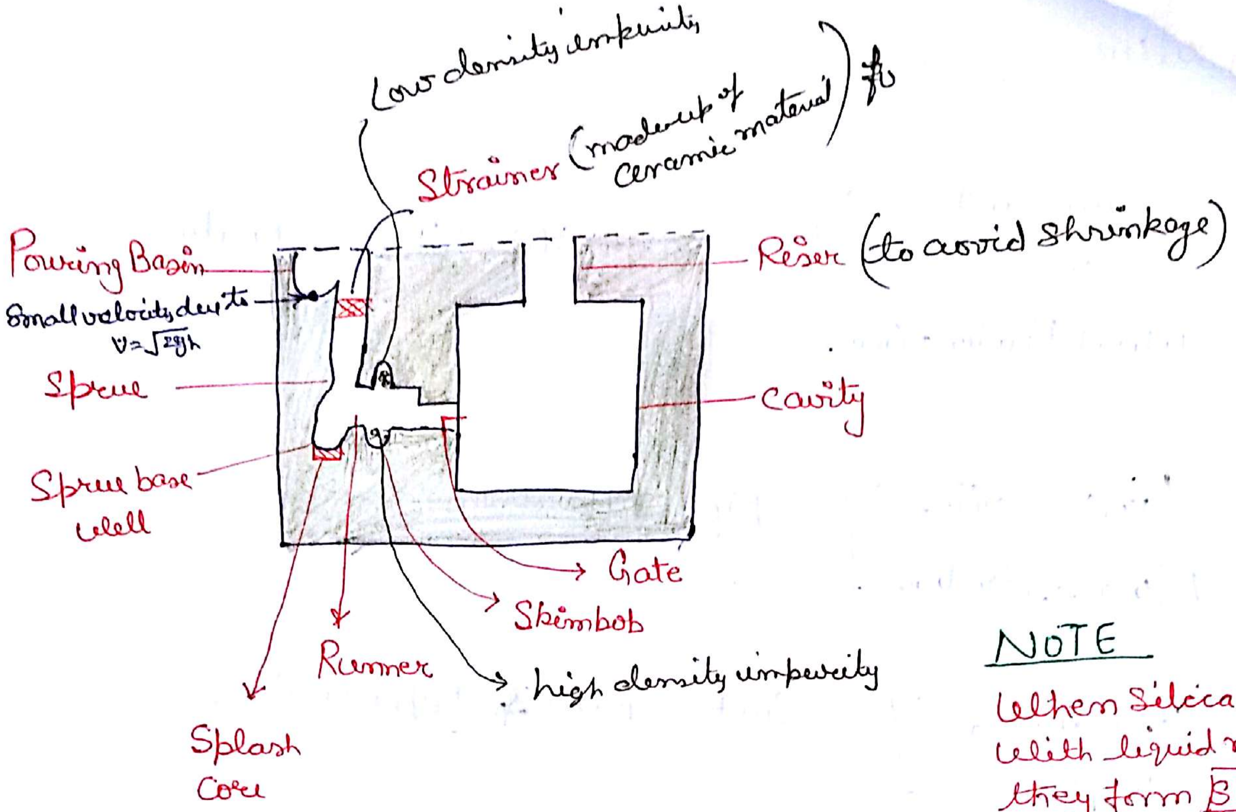
Coal dust & Graphite] Surface finish (&) Refractoriness



fine grain Coal dust] Both ↑ Surface finish

CO_2 gas will Produce after Burning of carbon added into moulding Sand.

Elements Of Gating Design :-

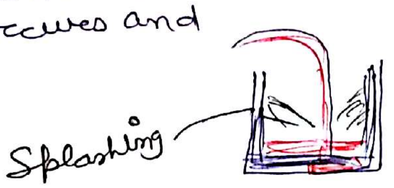


NOTE

When Silica mixed with liquid metal they form SiC
↓
Silicon Carbide which are Hard & Brittle

NOTE

When liquid metal inserted into cavity without gating element erosion will occurs and



After Solidification

inclusions.

Flow must be laminar

NOTE

Casting Yield = Efficiency of Casting Mould System = $\frac{V_c}{V_c + V_g}$

for Steel, brass, Al = 80-85%.

(Aluminium oxide more stable form) → settle down

Al_2O_3 (dross formation)

Density

3.6 gm/cm³ — Density more than Pure liquid

Al — 2.7 gm/cm³

↳ Reactivity with atmosph. gas is ↑ high

topon riser ← ferrous metal Reactivity with atmosph. gas is ↓ less
for ferrous metal enter into cavity with high velocity

Objectives of Gating Design:-

1) Design the gating elements, Such that liquid metal Can be enter into the cavity with optimum velocity, within a given time, without causing Turbulence, Splashing of liquid metal & mould erosion.

2) Design the gating element, Such that pure liquid metal Can be enter into Cavity, without air aspiration effect.

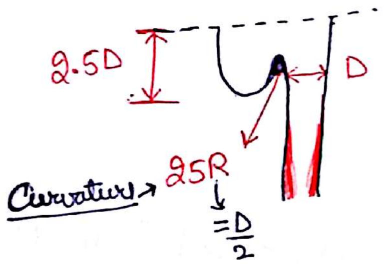
3) Design the gating elements to produce max. Casting Yield.

$$\text{Casting Yield} = \frac{V_c}{V_c+V_g}$$

$V_c \rightarrow$ Volume of Cavity.

$V_g \rightarrow$ Volume of gating element.

Design of Pouring Basin:-



→ Pouring basin is a design, to Reduce the velocity of liquid metal, which is enter into the sprue, to minimise the erosion.

I.ES 10 M

Qn) Calculate dimensions of the sprue to avoid air aspiration effect and to supply the liquid metal, at a rate of 20 Kg/sec. Density of the material is 7800 Kg/m^3. Assume height of the sprue as 20 cm. height of the Pouring basin as 5 cm.

Soln

$\dot{m} = 20$ Kg/s

$\rho = 7800$ Kg/m^3

$h_s = 20$ cm

$h_c = 5$ cm.

$\dot{m} = \rho A V$

$Q = AV = \frac{\dot{m}}{\rho} = \frac{20}{7800}$

$Q = 2.564 \times 10^{-3}\ m^3/s$

$\boxed{Q = 2564\ cm^3}$

$Q = A_2 V_2$

$V_2 = \sqrt{2gh_c}$

$\boxed{V_2 = 99.042\ cm/s}$

$A_2 = \frac{Q}{V_2}$

$A_2 = \frac{2564}{99.04} = 25.88\ cm^2$

$A_2 = \frac{\pi}{4} d_2^2 = 25.88 = \frac{\pi}{4} d_2^2$

$\boxed{d_2 = 5.64\ cm}$

$Q = A_3 V_3$

$V_3 = \sqrt{2gh_t}$

$V_3 = \sqrt{2 \times 981 \times 25}$

$V_3 = 221.47$ cm/s

$$A_3 = \frac{Q}{V_3} = \frac{2564}{221.47} = 11.57 \text{ cm}^2$$

$$A_3 = \frac{\pi}{4} d_3^2 \Rightarrow$$

$$11.57 = \frac{\pi}{4} d_3^2$$

$$\boxed{d_3 = 3.84 \text{ cm}}$$

Gate

Qn In a gating Design height of the Sprue is 200 mm h_s. Cross sectional area of Sprue at the beginning is 650 mm^2. Discharge Rate of liquid metal is $6.5 \times 10^5 \text{ mm}^3/s$. What is the cross sectional area of sprue at the bottom.

$h_s = 200 \text{mm}$

$A_2' = 650 \text{ mm}^2$

$Q = 6.5 \times 10^5$

$A_3 =$

$Q = A_2 V_2$ $\qquad V_2 = \sqrt{2gh_c}$

$$6.5 \times 10^5 = 650 \times \sqrt{2 \times 9.81 \times h_c}$$

$$\frac{(650000)^2}{~~19.62~~} = \sqrt{2 \times 9.81 \times h_c}$$

$$\frac{650000}{19.62} = \sqrt{h_c}$$

$$3312.9 = \sqrt{h_c}$$

$Q = A_2 V_2$

$$V_2 = \frac{Q}{A_2} = \frac{6.5 \times 10^5}{650} = 1000 \text{ mm/s}$$

$$V_2 = \sqrt{2 \times 9810 \times h_c} = 1000$$

$$h_c = 50.96 \text{ mm}$$

$$h_t = h_s + h_c = 200 + 50.96$$
$$= 250.96 \text{ mm}$$

$$\frac{A_2}{A_3} = \sqrt{\frac{h_t}{h_c}} \Rightarrow \frac{650}{A_3} = \sqrt{\frac{250.96}{50.96}}$$

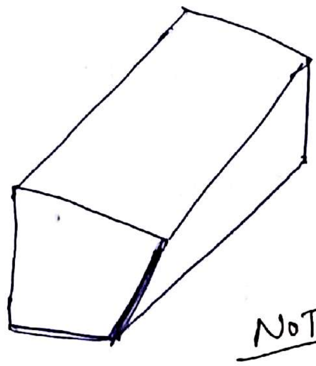
$$A_3 = 292.92 \text{ mm}^2$$

from Continuity

$$\dot{m} = \rho A V$$
$$Q = A V$$

Design of Runner :-

(1)



Trapezoidal cross Section

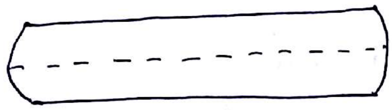
highest Coefficient discharge = 0.9

more surface area

NOTE → ~~SA of~~ more surface area, more heat Rejection, & metal solidify before getting into cavity. So

To minimize ← used. (Cylindrical Shape) ~~Circular cross Section~~.

(2)



Cylindrical Shape

→ To minimize turbulence & discharge losses of the liquid metal, shape of the Runner is Considered as trapezoidal. But it is having more surface area.

→ To minimize Heat Transfer losses of liquid metal, Shape of the Runner is Considered as cylindrical.

Design of GATE (Ingate)

It is the actual entry Point, through which, liquid metal Can be entering into the cavity at a Controlled rate.
Depending on position of the gate w.r.to, cavity, they are of Four Types:-

1) Top gate (or) vertical gate
2) Bottom gate
3) Parting line gate
4) Step gate

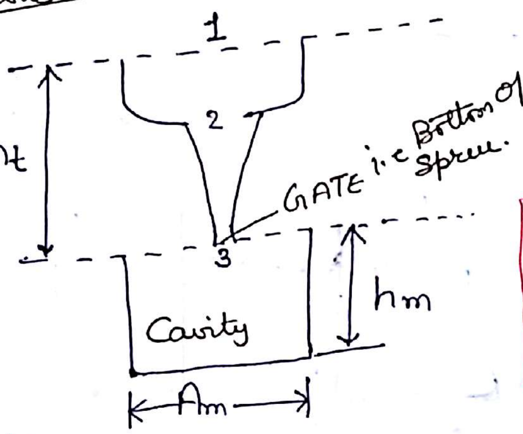
1) Top gate or Vertical gate :

NOTE: Preferred for large size cavity

NOTE) Only use for ferrous Material.

Time taken to fill cavity is less

Δt is very less



$A_3 = A_g$

$V_3 = V_g = \sqrt{2gh_t}$

NOTE: if $P_P <<< P_a$ then air aspiration occurs

NOTE: if direct flow Metal oxide form
Not use for Non ferrous (NON) material & Aluminium

uniform Solidification due to favorable temp gradient $\frac{\Delta t}{h} = \frac{dt}{dx}$

1) Liquid Metal, entering into Cavity, directly from the bottom of the Screw, at atmospheric pressure.
2) Velocity of the liquid metal, in the cavity, will be very high.
3) There is a chance of turbulence and splashing of the liquid metal.
4) It is not using for casting of Non-ferrous material.
5) There is favorable temp. gradient of liquid metal in the Cavity.

$$\frac{dt}{dx} = \frac{\Delta t}{h}$$

Discharge of liquid metal at gate

$$Q = A_g V_g = A_3 V_3$$

Favorable:-

$$dt \cdot A_g V_g = A_m \cdot dh$$

$$t_f \cdot A_g V_g = A_m \cdot h_m$$

Imp. * GATE

$$t_f = \frac{V_m}{A_g V_g} = \frac{V_m}{A_g \times \sqrt{2 g h_t}}$$

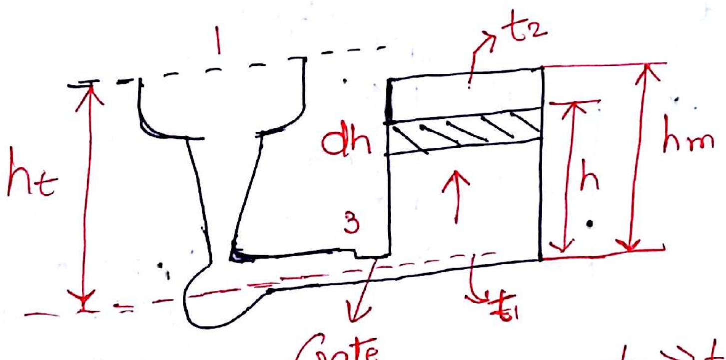
t_f = total time Required to fill the cavity

V_m = volume of the cavity

2) Bottom Gate:-

(use for non ferrous material)
Non uniform Solidification

$$V_3 = V_g = \sqrt{2g(h_t - h)}$$



$t_1 >> t_2 \rightarrow$ Temp.

1) Liquid Metal is entering into the cavity from Bottom to top in upward direction.
2) Velocity of the liquid metal in the cavity is neglected.
3) There is no Possibility of turbulence and Splashing of the liquid metal.
4) It can be used for casting of Non ferrous materials.
5) There is unfavorable temp. gradient of liquid metal (Non uniform Solidification) in the cavity

$dt \cdot A_g V_g = A_m \cdot dh$

$$\int_0^{t_f} dt = \frac{A_m}{A_g} \int_0^{h_m} \frac{dh}{\sqrt{2g(h_t - h)}} \qquad t = 0 \quad h = 0$$

$$t_f = \frac{A_m}{A_g} \cdot \frac{1}{\sqrt{2g}} \left[\frac{(h_t - h)^{-\frac{1}{2}+1}}{-\frac{1}{2}+1} (-1) \right]_0^{h_m} \qquad t = t_f \quad h = h_m$$

$$x^n = \frac{x^{n+1}}{n-1}$$

Imp

$$\boxed{t_f = 2 \cdot \frac{A_m}{A_g} \frac{1}{\sqrt{2g}} \left(\sqrt{h_t} - \sqrt{h_t - h_m} \right)}$$

if:

$h_m = h_t$

$$t_f = 2 \cdot \frac{A_m}{A_g} \frac{1}{\sqrt{2g}} \sqrt{h_t}$$

Now multibly by $\sqrt{h_t}$ on Num. & Denomenator

$$t_f = 2 \cdot \frac{A_m}{A_g} \frac{1}{\sqrt{2g}} \frac{\sqrt{h_t}}{\sqrt{h_t}} \sqrt{h_t}$$

$$\boxed{t_f = 2 \frac{A_m}{A_g} \frac{h_m}{\sqrt{2g h_t}}}$$

$$\boxed{t_{fb} = 2 t_{ft}}$$

Qn) In a gating design, dimension of Cavity is given by 50×25×15 cm^3. Height of the liquid metal, above the gate is 15cm. Crosssectional area of the gate is 5 cm^2. Determine,

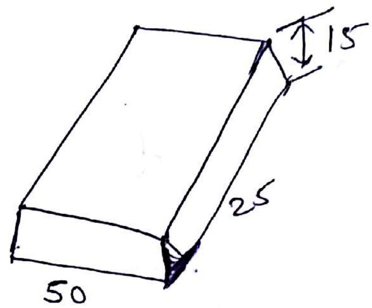
Time Required to fill the gravity using top & Bottom gate?

Soln

50×25×15 cm^3

$h_t = 15$ cm

$A_g = 5\ cm^2$



① Top gate

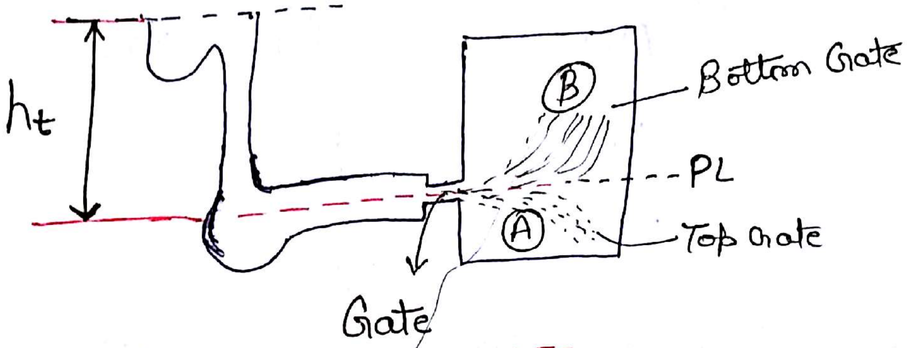
$$t_{ft} = \frac{V_m}{A_g V_g} = \frac{50\times25\times15}{5\times\sqrt{2\times9.81\times15}} = 21.85\ \text{Sec}$$

$$\boxed{t_{ft} = 21.85\ \text{Sec}}$$

② Bottom Gate

$$t_{fb} = 2 \cdot t_{ft} = 2\times21.85 = 43.71\ \text{Sec.}$$

3) Parting Line Gate :-

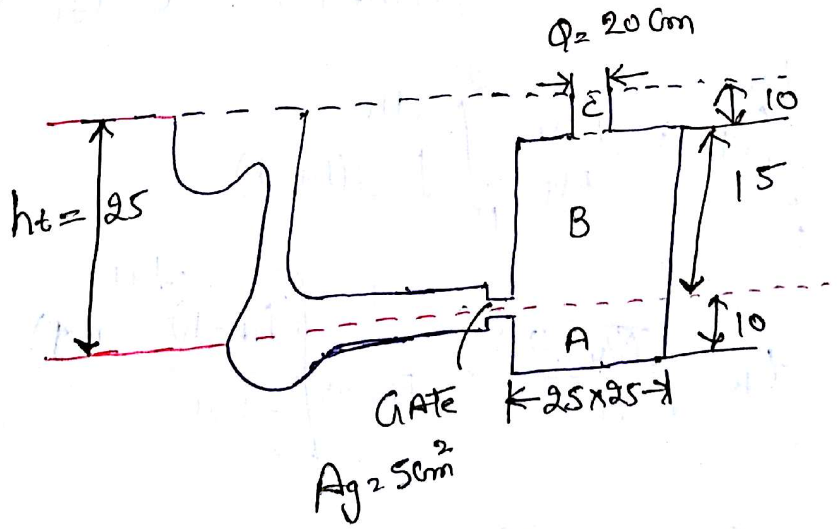


NOTE:
Most Commonly use gating System

NOTE
1. Time taken to fill the Cavity is low bcz of both Top & Bottom Gate
2. due to low size of (A) Top Gate Cavity, less turbulence.

→ Gate Provided along the Parting line. Such that, liquid metal Can be filled into the cavity, below the parting line, by assuming Top gate and above the Parting line by assuming Bottom Gate, to get the advantage of Both top & Bottom Gate, Parting line gate will be most Commonly used gating System

Qn) Determine time Required to fill the Cavity, along With Riser.



Soln) filling time for A i.e Assuming top gate

Cavity A

$$t_{fA} = \frac{V_m}{A_g V_g} = \frac{25 \times 25 \times 10}{5 \times \sqrt{2 \times 981 \times 25}}$$

$$\boxed{t_{fA} = 5.64 \text{ Sec}}$$

filling time for B i.e Assuming Bottom gate,

Cavity B

$$t_{fB} = 2 \times \frac{A_m}{A_g} \frac{1}{\sqrt{2g}} \left(\sqrt{h_t} - \sqrt{h_t - h_m}\right)$$

$$t_{fB} = 2 \times \frac{25 \times 25}{5} \times \frac{1}{\sqrt{2 \times 981}} \left(\sqrt{25} - \sqrt{25-15}\right)$$

$$\boxed{t_{fB} = 10.37 \text{ Sec}}$$

Cavity C

$$dt \cdot A_g V_g = A_m \cdot dh$$

$$dt = \frac{A_m \cdot dh}{A_g \sqrt{2g(h_t - h)}}$$

if $t = 0$ $h = 15\text{ cm}$
$t = t_{fc}$ $h = 25\text{ cm}$

$$\int_0^{t_{fc}} dt = \frac{A_m}{A_g} \int_{15}^{25} \frac{dh}{\sqrt{2g(h_t - h)}}$$

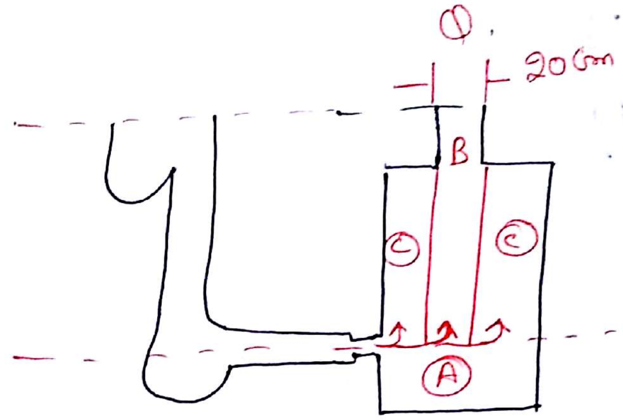
$$t_{fc} = \frac{\pi/4 (20)^2}{5} \times \frac{1}{\sqrt{2 \times 98}} \left[\frac{(h_t - h)^{-\frac{1}{2}+1}}{-\frac{1}{2}+1} (-1)\right]_{15}^{25}$$

$$t_{fc} = 8.96 \text{ Sec}$$

$$\text{total time} = 5.64 + 10.37 + 8.96 = 24.97 \text{ sec}$$

$$\boxed{\text{total time} = 24.97 \text{ sec}}$$

Short Method

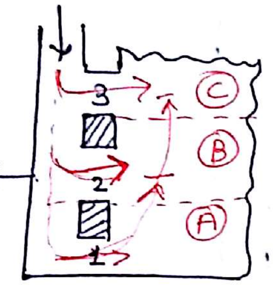


$A_B = \frac{\pi}{4} d^2$ $h_m = 25 \text{ Cm}$

$A_C = \left(25 \times 25 - \frac{\pi}{4} d^2\right)$ $h_m = 15 \text{ Cm}.$

4) Step Gate :- to fill molten metal into very large size cavity

→ gates



NOTE
① ① is Bottom gate
No, turbulence, No splashing
② Time taken to fill cavity is ①

less time to fill cavity
∴ No. Turbolence.

→ To fill the molten liquid metal into very large size mould cavities, no. of gates are provided in the form of step.

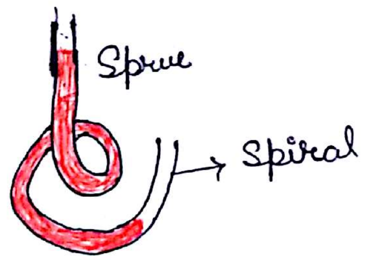
→ liquid Metal can be gradually filling into the cavities, within a given time without causing turbulence & ~~splab~~ splashing of the liquid metal.

Fluidity:

AFS → American Foundary Society

Spiral material → Moulding Sand

Spiral Test:



→ Ability of the liquid metal, to fill into the cavity is known as Fluidity.
→ It is the Property of the liquid metal.
→ It can be determine, by Conducting a spiral test.
→ Distance covered by the liquid metal before solidification in a standard spiral

will gives the value of fluidity.

~~Property~~ ~~Fluidity~~

Property		Fluidity
Pouring Temp.	↑	↑
Viscosity	↑	↓
Density	↑	↓
% of Water in mould	↑	↓
Surface finish Of Cavity	↑	↑

✓✓ Imp Objective
- Which influence the fluidity most? (Property)

CHOKE Area :-

$$CA = \frac{m}{\rho \, t_f \, C_d \sqrt{2 g h_t}}$$

→ It is the min. crossection area in all the gating elements.

→ It will Control the flow of liquid metal, which is enter into mould Cavity.

→ It is first Parameter to be calculated in all the gating elements.

m → mass of Casting

ρ → density of material

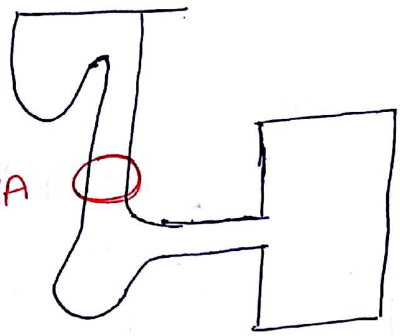
t_f → filling time Required

C_d → Coefficient of discharge

H_t → height of liquid metal above the gate.

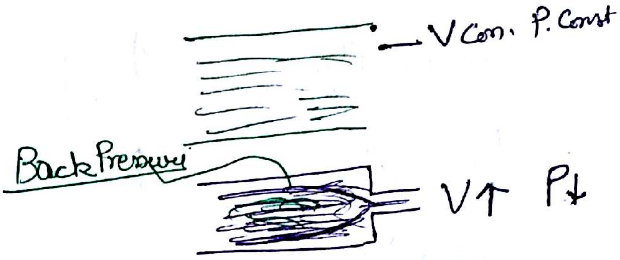
Un-Pressurised Gating :-

$CA = A_s$



1 : 2 : 4
1 : 2 : 3
0.5 : 2 : 1.5

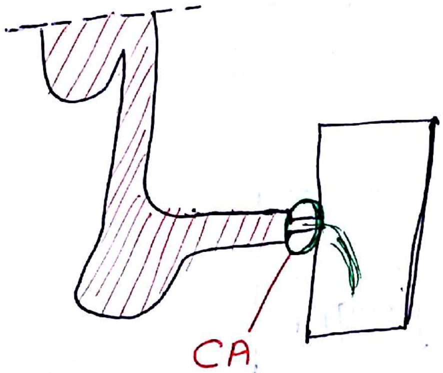
NOTE:
:- Used for non Ferrous material like Al etc.



Pressurised Gating :

Used for Ferrous material

NOTE
No turbulence
Splashing occurs due to ↑V.



$CA = A_g$

Job interview

$$\uparrow \text{Casting Yield} = \frac{V_c}{V_c + V_g \downarrow}$$

$$P = \frac{F}{A}$$

At the Back of gate Pressure is Created on Rest gating Parts.
↓ due to which Pressure of Sprue is greater than Pa

Gating Ratio

3 : 2 : 1
2 : 2 : 1
3 : 3 : 0.5

Pressurised Gating

Un Pressurised Gating

→ Choke Area is at the bottom of the sprue.
→ Velocity of the liquid metal, which is enter into cavity will be less.
** → There is no possibility of Turbulence & Splashing of liquid metals.
** → It can be used for Casting of Non Ferrous materials.
→ There is possibility of Air Aspiration effect.
→ Casting yield will be less

$$\downarrow \text{Casting Yield} = \frac{V_c}{V_c + V_g \uparrow}$$

Pressurised Gating

Choke area is at the ~~bottom of the~~ gate.
→ Velocity of the liquid metal, which is enter into the cavity, is very high.
→ There is possibility of turbulence & Splashing of liquid metal.
→ It can be used for Casting of ferrous materials.
→ There is no possibility of Air Aspiration effect.
→ Casting yield is more.

$$\uparrow \text{Casting Yield} = \frac{V_c}{V_c + V_g \downarrow}$$

Bottom Gating System is like Pressurised Gating System.

Gating Ratio : Gate

It is the Ratio b/w Area of the Sprue, Runner, & Gate.

Area of Sprue : Area of Runner : Area of Gate

↓

Choke Area

1 : 2 : 4		
1 : 2 : 3		unpressurised Gating use for Non ferrous
0.5 : 2 : 1.5		

3 : 2 : 1	
2 : 2 : 1	Pressurised Gating → use for Ferrous
2 : 2 : 0.5	

2 : 1 : 2 → Not exist because of Chance of erosion

1 : 2 : 1 ⟶ Pressurised Gating System

Qn) In a gating design, gating Ratio is 1:2:3. it is used to produce a Casting of mass 30 Kg. Density of the liquid metal is 2600 Kg/m³. Filling time is 11.2 Sec. Height of the liquid metal above the gate is 250 mm. Assume Coefficient of discharge Cd as 0.98. determine the dimensions of the gate?

Soln

Gating Ratio = 1:2:3

$m = 30\,Kg$

$\rho = 2600\,Kg/m^3$

$t_f = 11.2\,Sec$

$h_t = 250\,mm$

$C_d = 0.98$

$$C.A = \frac{30}{2600 \times 11.2 \times \sqrt{2 \times .25} \times 0.98}$$

$$C.A = 4.75 \times 10^{-4}\,m^2 = 4.75\,cm^2$$

As it is unpressurised gating system. (1) : 2 : 3

(1) → Area of Choke

$CA = A_s = 4.75\,cm^2$

$A_g = 3 A_s$

$= 3 \times 4.75 = 14.25\,cm^2$

$$A_g = 14.25\,cm^2$$

$A_g = \frac{\pi}{4} d_g^2 = 14.25$

$d_g = 4.25$ dia of the gate

$A_r = 2A_s = 2 \cdot 4.75$

$= 9.5 \text{ cm}^2$

$A_r = 9.5 \text{ cm}^2$

$A_r = \frac{\pi}{4} d_r^2 = 9.5$

$d_r = 3.47 \text{ cm}$

Gate

Solidification Time :-

NOTE :-

① $(t_s)_r > (t_s)_c$ ← Casting

Chvorinov's Principle :-

$$t_s \propto \left(\frac{V}{A}\right)^2$$

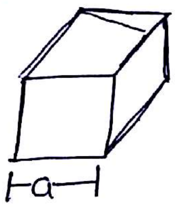
Vol → Amount of Heat avail
Surface Area → Amount of Heat Transfer

$$\uparrow t_s = K\left(\frac{V}{A}\right)^2 \downarrow$$ imp

K → Solidification factor (S/m^2)

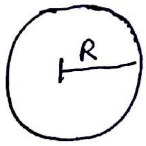
→ (S/m^2)

Volume to Surface area $\frac{V}{SA}$

① 

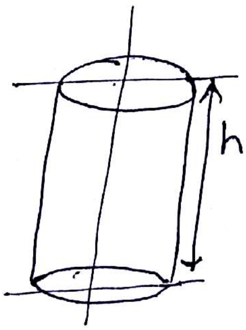
$$\frac{V}{SA} = \frac{a^3}{6a^2} = \frac{a}{6}$$ Cube

② Sphere



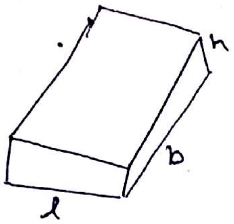
$$\frac{V}{SA} = \frac{4/3\,\pi R^3}{4\pi R^2} = \frac{R}{3} = D/6$$

③ Cylinder



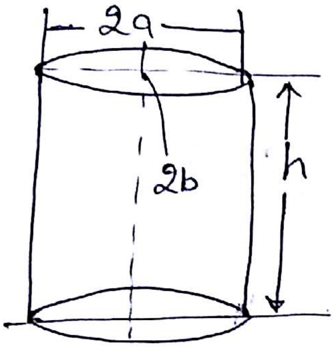
$$\frac{V}{SA} = \frac{\frac{\pi}{4} d^2 \cdot h}{2 \cdot \frac{\pi}{4} d^2 + \pi d h} =$$

④ **Slab**



$$\frac{V}{A} = \frac{lbh}{2(lb+bh+hl)}$$

⑤ **Elliptical Cylinder**



$$\frac{V}{A} = \frac{\pi abh}{2\pi ab + \left(2\pi\sqrt{\frac{a^2+b^2}{2}}\right)h}$$

Qn) A molten drop of liquid metal, which is in spherical form with the radius of 2 mm, will solidify in 10 sec. What is the solidification time of same molten drop which is double in Radius?

$r_1 = 2mm$ $\quad t_{s1} = 10 sec$

$r_2 = 4mm$ $\quad t_{s2} = ?$

$$t_s \quad \frac{V}{A} =$$

$$t_s \propto \left(\frac{r}{3}\right)^2$$

$$\frac{t_{s1}}{t_{s2}} = \left(\frac{r_1}{r_2}\right)^2$$

$$\frac{10}{t_{s2}} = \left(\frac{2}{4}\right)^2$$

$$\boxed{t_{s2} = 40 sec}$$

Qn) A Cubical Casting will solidify in 5 min $(5 \times 60 = 300 sec)$. What is the solidification time of same cubical casting which is 8 times heavier than original casting?

$t_{s1} = 5 min$

$t_{s2} = ?$

8 times heavier than

$m_2 = 8m$

$V_2 S_2 = 8 V_1 S_1$

$V_2 = 8V_1$

$a_2^3 = 8a_1^3$

$a_2 = 2a_1$

$$t_s \propto \left(\frac{a}{6}\right)^2$$

$$\frac{t_{s1}}{t_{s2}} = \left(\frac{a_1}{a_2}\right)^2$$

$$\frac{5}{t_{s2}} = \left(\frac{a_1}{2a_1}\right)^2$$

$$\boxed{t_{s2} = 20 min}$$

Qn) Two Casting, one is Cube & one is Slab. Both are made up of Same material & Same volume. But the Slab dimension are in the Ratio of 1:2:4.

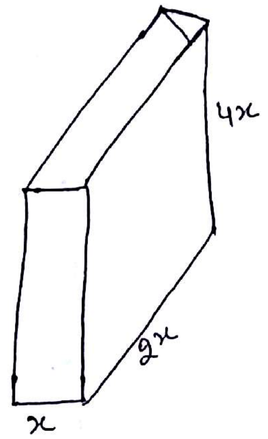
What is the Ratio of Solidification time of Cube to the Slab?

Soln

$V = 1x \cdot 2x \cdot 4x = 8x^3$

$A = 2(1x \cdot 2x + 2x \cdot 4x + 4x \cdot 1x)$

$= 28x^2$



$V_c = V_{Sl}$

$a^3 = 8x^3$

$a = 2x$

$$\frac{(ts)_{cube}}{(ts)_{slab}} = \frac{\left(\frac{V}{A}\right)^2_c}{\left(\frac{V}{A}\right)^2_{slab}} = \frac{A_{Sl}^2}{(A_c)^2}$$

$$= \frac{(28x^2)^2}{(6a^2)^2} = \left(\frac{28}{6}\right)^2\left(\frac{x}{a}\right)^4$$

$$= \left(\frac{28}{6}\right)^2 \cdot \left(\frac{x}{2x}\right)^4$$

$$= 1.36$$

Riser :-

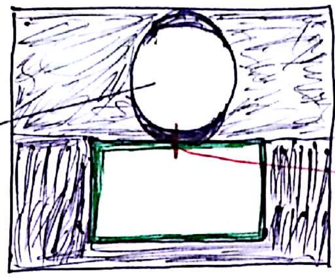
$\left(\frac{A}{V}\right) \Rightarrow$ Cooling characterstic (must min to riser)

└→ min

→ Solidification time t_s → more

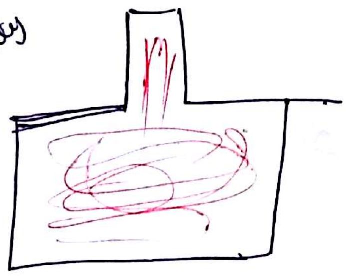
→ Rate solidification in Riser is less in cavity is high

Not used



due to thermal conductivity molten metal get solidy at centre circum ference and molten liquid at centre. so if shrinkage occur it will not supply molten metal to cavity

Point Contact b/w Riser & Cavity

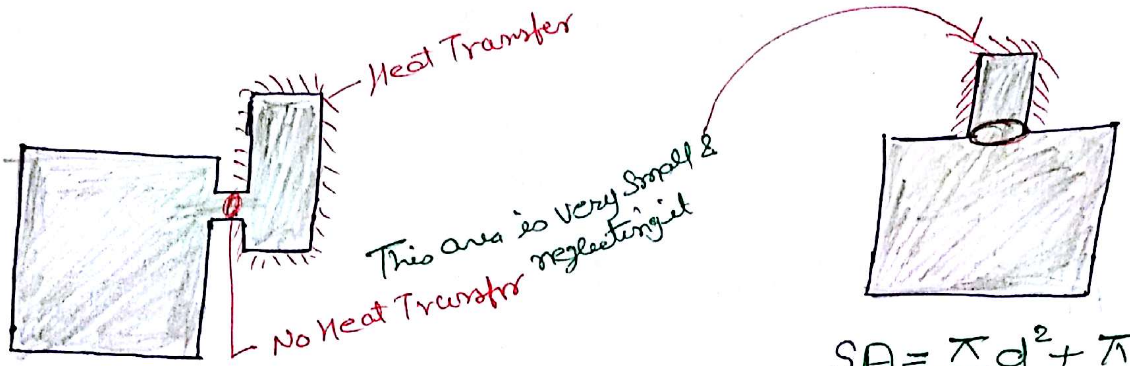


Cylinder → Riser Preferred

→ For the given volume of Riser, Sphere is having min. Surface area to the volume Ratio. Due to availability of liquid metal in Spherical riser is at the center, Supplying of liquid metal, from riser to the cavity will be difficult.

Types Of Riser :-

1) Side Riser (for high depth) (2) Top Riser



$$SA = 2\cdot\frac{\pi}{4}d^2 + \pi dh$$

$$SA = \frac{\pi}{4}d^2 + \pi dh$$

Top Riser is effective when compared to Side riser, due to less surface area exposed to heat Transfer.

Side Risers Can be used, For more depth of mould cavities.

Optimum Condition for minimum Surface area and Maximum solidification time in Case of Cylindrical Riser :-

1) Side Riser :-

$$A = 2\frac{\pi}{4}d^2 + \pi dh$$

$$V = \frac{\pi}{4}d^2 \cdot h$$

$$h = \frac{4V}{\pi d^2}$$ Assuming volume as Constant

$$A = 2\frac{\pi}{4}d^2 + \pi d \frac{4V}{\pi d^2}$$

$$A = 2\frac{\pi}{4}d^2 + \pi d \frac{4V}{\pi d^2}$$

$$A = \frac{\pi}{2}d^2 + \frac{4V}{d}$$

$$\frac{\partial(A)}{\partial(d)} \Rightarrow 0 \Rightarrow \pi d - \frac{4V}{d^2} = 0$$

$$V = \frac{\pi d^3}{4} = \frac{\pi}{4}d^2 \cdot h$$

$$\boxed{h = d}$$

Area to volume Ratio

$$\left(\frac{A}{V}\right) = \frac{2 \cdot \pi/4\, d^2 + \pi dh}{\frac{\pi}{4}d^2 \cdot h}$$

Putting $h = d$

$$\left(\frac{A}{V}\right)_{min} = \frac{6}{d}$$

Top Riser:

$$A = \frac{\pi}{4}d^2 + \pi d h$$

$$V = \frac{\pi}{4}d^2 \cdot h$$

$$h = \frac{4V}{\pi d^2}$$

$$A = \frac{\pi}{4}d^2 + \pi d\left(\frac{4V}{\pi d^2}\right) \Rightarrow A = \frac{\pi}{4}d^2 + \frac{4V}{d}$$

$$\frac{\partial(A)}{\partial(d)} = 0$$

$$\frac{\pi d}{2} - \frac{4V}{d^2} = 0$$

$$V = \frac{\pi d^3}{8} = \frac{\pi}{4}d^2 \cdot h \Rightarrow h = d/2$$

$$\left(\frac{A}{V}\right) = \frac{\frac{\pi}{4}d^2 + \pi d h}{\frac{\pi}{4}d^2 \cdot h}$$

Putting $h = d/2$

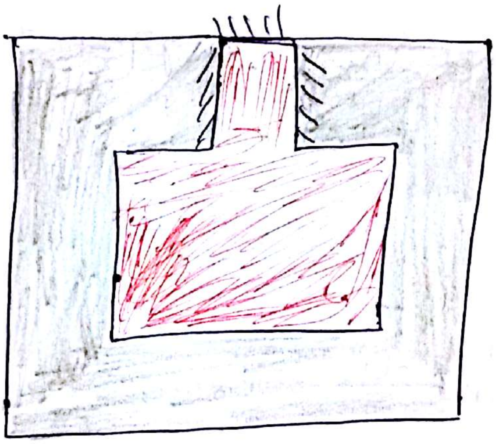
$$\frac{A}{V} = \frac{6}{d}$$

Side Riser	$h = d$	$(A/V) = 6/d$
Top riser	$h = d/2$	$(A/V) = 6/d$

Riser Design :-

1) (a) Volume of Riser = 3 × % of Shrinkage × vol. of Casting
↓
$V = \frac{\pi}{4} d^2 h$
(h & d)

(b) $\left(\frac{A}{V}\right)_c \geq \left(\frac{A}{V}\right)_r$ Cooling characteristics



→ Insulator material

→ Exothermic material
↳ (Thermit mixture, Graphite)

Methods to Increase Efficiency or Performance of the riser:

1) Provide insulating material around the circumference & top Surface of the riser. To minimize the Heat Transfer losses.

2) Provide exothermic material on the top Surface of Riser. Due to exothermic Reaction, Heat will be produced & this will be supplied to liquid metal to increase solidification time of the liquid metal.

3) Use Optimum Conditions in riser design.

4) Use blind risers.

2) Caine's Method :-

$$\text{Freezing Ratio} = \frac{(A/V)_c}{(A/V)_r}$$

NOTE: F.R > 1

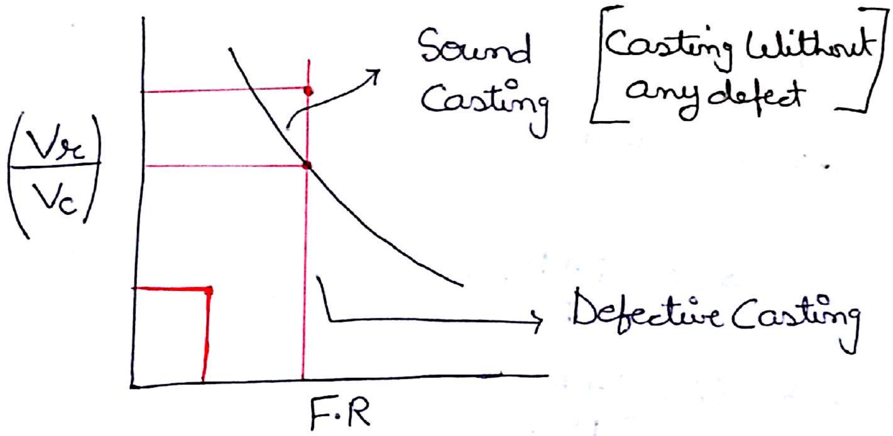
Caine's Formula → $$X = \frac{a}{Y-b} + C$$

NOTE 2: dimension calculated for only Simple Casting b/c calculating $(A/V)_c$ is difficult. e.g. Turbine Blade or Complex Shape

$X = FR$

$Y = \frac{V_r}{V_c}$ a, b, C are Constants

$\frac{V_r}{V_c} < 1$



→ By using this Method, dimensions of the riser can be calculated for simple shape of the casting.

→ For a Complex shape of casting, calculation of (A/V) Ratio is difficult.

→ using the graph, we can also cross check, dimensions of the designed riser is correct or not.

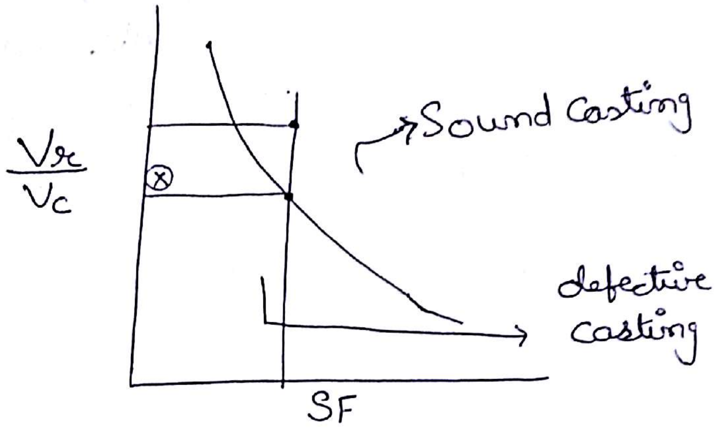
3) Modified Caine's Method :

(Naval Research laboratory Method)

for Solid → Max, L,W,T
for Hollow → mean effective value

$$\text{Shape factor} = \frac{L+W}{T}$$

L → Length
W → Width
T → Thickness



$\frac{V_r}{V_c} = x$

$V_r = V_c \times (x)$

$V_r = \frac{\pi}{4} d^2 \cdot h$

h & d Can be find

Shape factor:

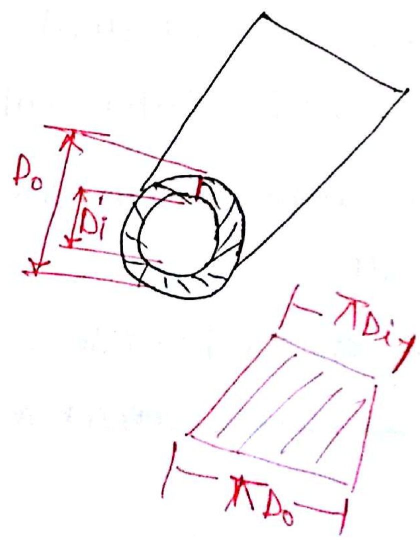
① Cube: → $SF = \frac{a+a}{a} = 2$

② Sphere (Solid) → $SF = \frac{D+D}{D} = 2$

3) Slab → $SF = \frac{L+B}{H}$

④ Cylinder → $SF = \frac{H+D}{D}$

5) Hollow cylinder → $SF = \frac{H + \pi\left(\frac{D_o + D_i}{2}\right)}{\left(\frac{D_o - D_i}{2}\right)}$



4) Modulus Method :-

$$\text{Modulus} = \frac{V}{A}$$

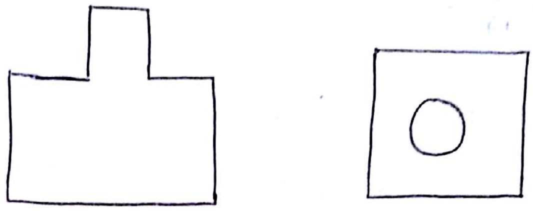
$$m_r = 1.2\, m_c$$ Imp (use)

$$m_r = \frac{d}{6} = \text{Constant}$$

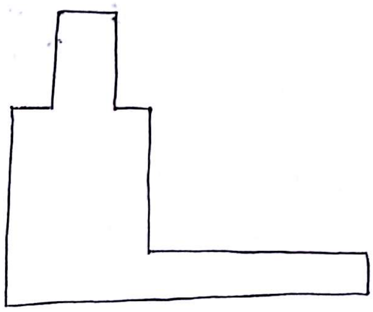
d = can be find

Position of Riser :

1) For uniform Thickness :-

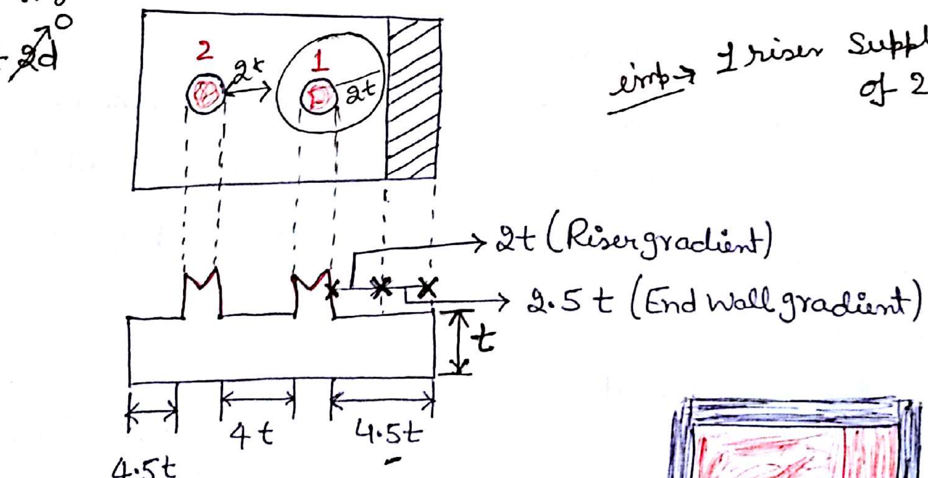


2) For Non-Uniform Thickness :-



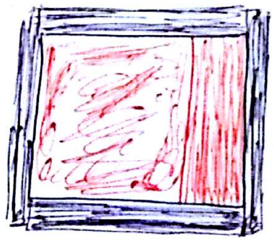
3) For Minimum Thickness & Max. Surface Area :-
e.g Plate, Slab, bars

$L = 13t + 2d$ (neglecting 2d → 0)



imp → 1 riser supplies surface area of 2 time thickness

NOTE
Due to large S.A, Heat Transfer Rate is very high and ↑ shrinkage so we have to provide more number of riser.



No Need of Riser liquid → (till 2.5t No Need of liquid from Riser b/c shrinkage is compensated by liquid metal at centre)

① With end Wall effect :-

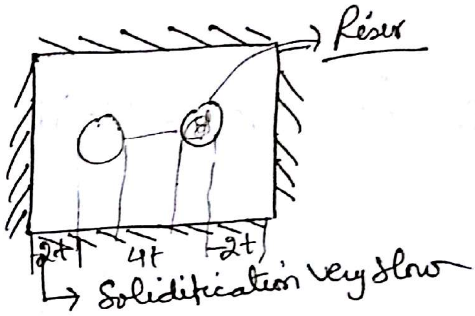
$L = 13t$ (two riser) — t here is thickness

$L = 9t$ (one Riser)

② Without end Wall effect :-

$L = 8t$ (two riser)

$L = 4t$ (one riser)



→ For a Simple Shape of the Casting, like a cube, one riser is Sufficient and it is provided on the top Surface of the mould at the Centre.

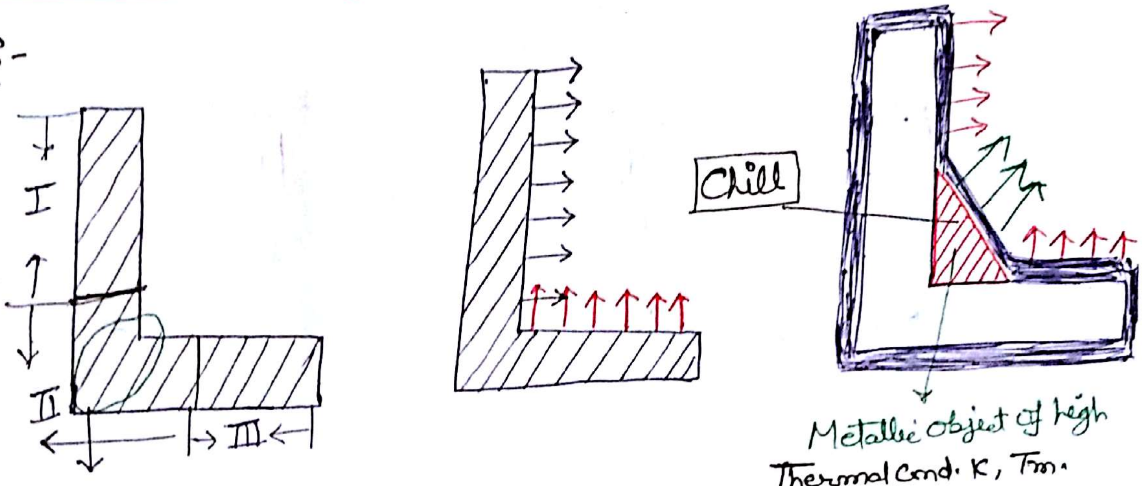
→ For non-uniform thickness of the Casting, riser is provided close to the higher thickness of the Casting.

→ For the Castings, with the min. thickness & max. Surface area one riser may not be Sufficient to Compensate, fast Rate of Shrinkage of the material. To overcome this, more no. of riser's are provided. Position of the first riser, from the Surface of mould is at a distance of 4.5 t.

Distance b/w two risers is 4t.

Chills & Padding:-

1) Chill:-



* Solid Shrinkage always toward the Center

1) Heat Rejection Area is less
2) liquid metal take long time to Solidify
   ↑ temp due to cross flow of Heat

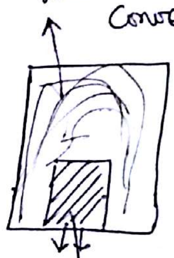
To overcome above, We Provide K, Tm of material to ↑ high ~~speed~~ Rate Heat Rejection (metallic object.

→ At, min. crossSections, in mould Cavities to maximize Heat Transfer Rate, metallic objects with high Thermal Conductivity and high melting Points metals are Provided. These are Known as chills.

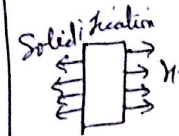
→ By providing the Chills, uniform heat Transfer, uniform Solidification, and directional Solidification Can be possible.

→ If the chill is external to the Surface of the mould, it is made up of high m.p. material.

→ If the Chill is internal to the Surface of mould, it is made up of Same material as the Casting.

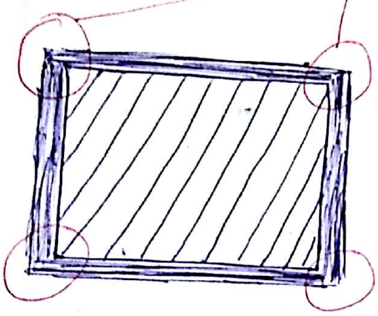


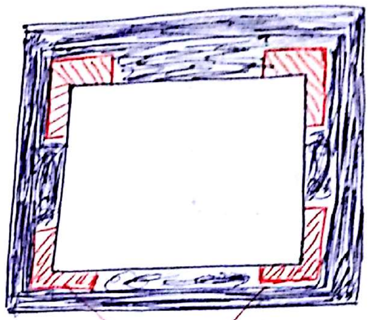
& Heat Rejection by Conduction is more than Convection



2) Padding :-

Weak Point.
H. Transfer Rate is min &
We have to maximise it





① minimize erosion
② maximize H.T. Rate
③ Solidification can be directional

(directional solidification)
↓
(Imp) ✓ High mechanical Property
uniform Solidification

→ At, critical crossections in the mould cavities, to minimize the erosion and to maximise the Heat transfer Rate, metallic objects with high thermal conductivity & with high melting Point material can be provided. These are known as Padding

→ By Providing chills, Padding & chaplets, uniform Solidification and directional Solidification, can be possible.

Classification of Casting Techniques :-

1) **Expandable Moulds :**
   (Temporary Moulds)
   - → Sand Moulding
   - → Shell Moulding
   - → Investment Casting
   - → Full Moulding
   - → CO_2 Moulding

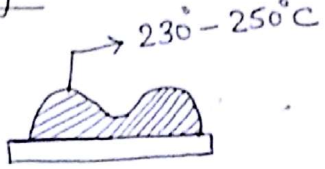
2) **Permanent Moulds :**
   (Metallic Moulds)
   - → Centrifugal
   - → Die Casting
   - → Slush Casting

3) **Continous Casting :-**

10-15 cm Method of Casting

Shell Moulding :-

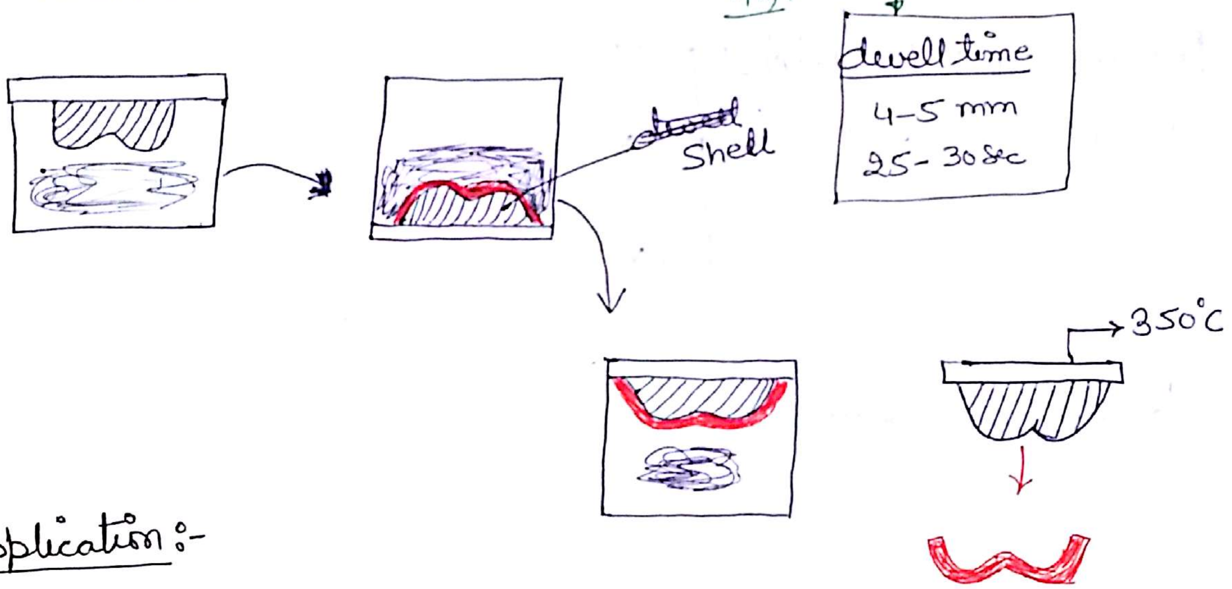
Pattern :



Moulding Materials :

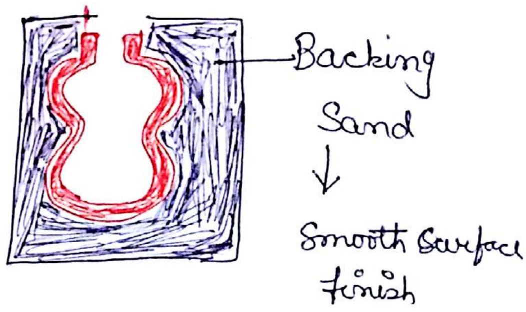
- Fine grain Silica Sand
- Phenolic Resins → [Phenol Formaldehyde urea formaldehyde] (Objective)
- Alcohol

Q) How shell thickness can be control



Application :-

1) Cylinder Head & cylinder block of I.C engines. (Hollow objects)
2) Rocker arm.
3) Valve Plates of Refrigerators.



NOTE :- min. amount of moulding material Wastage with good Surface finish

NOTE :- Permeability will be less

→ Pattern is Produced by Metallic material and it will be Heated upto 250°C.

→ Moulding Material is made in Contact with metallic pattern.

→ Due to heat from the pattern Phenolic resins will be activated, its bonding properties and moulding sand will be stick to the Surface of Pattern material in the form of Shell.
The Thickness of the Shell will depends on Contact time b/w Pattern & moulding material. This is Known as Dwell time.

→ After Getting Sufficient thickness of the Shell, Pattern & Shell will be Seprated from the mould box. They will be heated upto 350°C to increase the strength of the Shell.

→ By Seprating the Shell from the Pattern, no. of Shells Can be produced, they will be added together to get the required Shape of Cavity.

→ Better Surface finish Can be produced on casting.

→ It can be used for mass production.

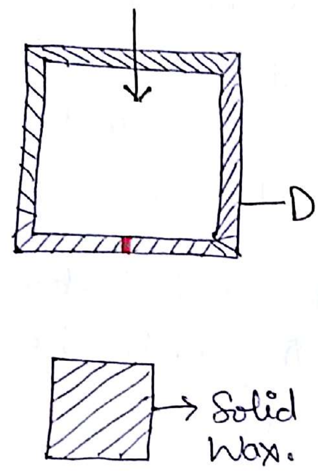
→ Size of the Casting are limited to 200-250 Kg.

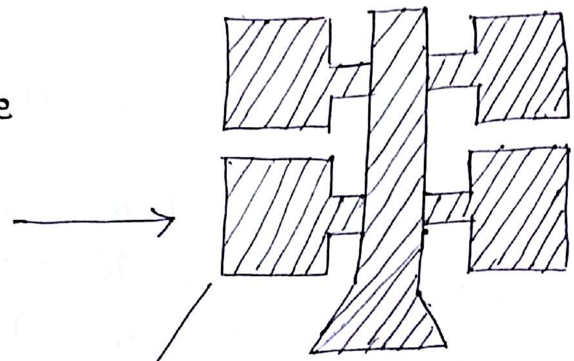
Investment Casting :- [Expandable Pattern & Expandable Mould] Question Objective

→ Lost Wax Process

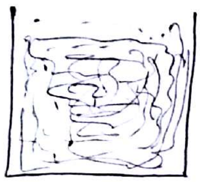
Pattern: Wax.

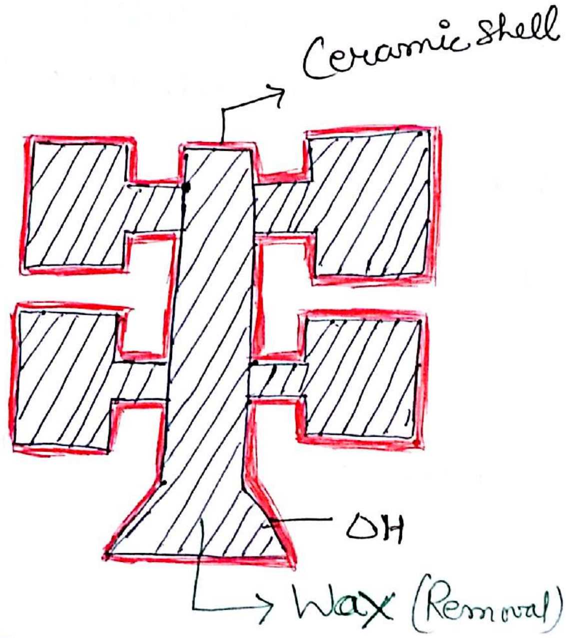
Pattern Assembly





Slurry Coatings



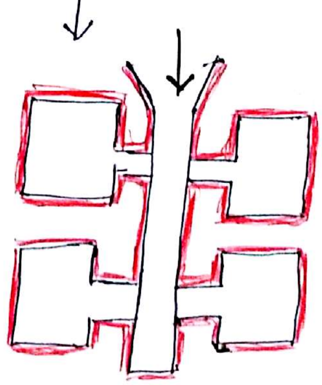


ethyle Silicate + Silica + Water — Good Bonding Property

↓

Adding fine grain Ceramic material

→ for Smooth Surface finish & due to High melting Point Materials (Imp)



Oven 650°C

To get this [illegible] This done bcz maybe some Wax Rest in Cavity

∴ To overcome gas defect due to fine grains Pattern must be Kept into Vaccume To Produce Highly Precise items

Applications

Pattern Remove in liquid form.

1) Gas Turbine blades
2) Jet engine Part → Very high temp
3) Medical Implant → titanium
4) dentures → Surgical element
5) Gold ornaments etc

→ Pattern is produced by Wax material.

→ No. of Patterns will be added, along with gating elements to produce Pattern Assembly.

→ Slurry Coatings are provided on the pattern, on to which, fine grains ceramic particles will be added to produce, required thickness of Ceramic Shell. By Heating the Ceramic Shell, Wax will be Converted into Liquid form, and it can be removed from the Shell to get the required shape of cavity, into which liquid metal will be allow to Solidify. By Breaking the Shell Casting Can be produced.

→ Accuracy & Surface finish of Casting are very high.

→ It Can be used for mass production of Small Size Casting of 5-15 Kg only.

→ To minimize the gas defect, this process will be carried out under vaccume Conditions.

→ It is a expensive process.

Full Moulding :-

Large size, Complex Objects Producer

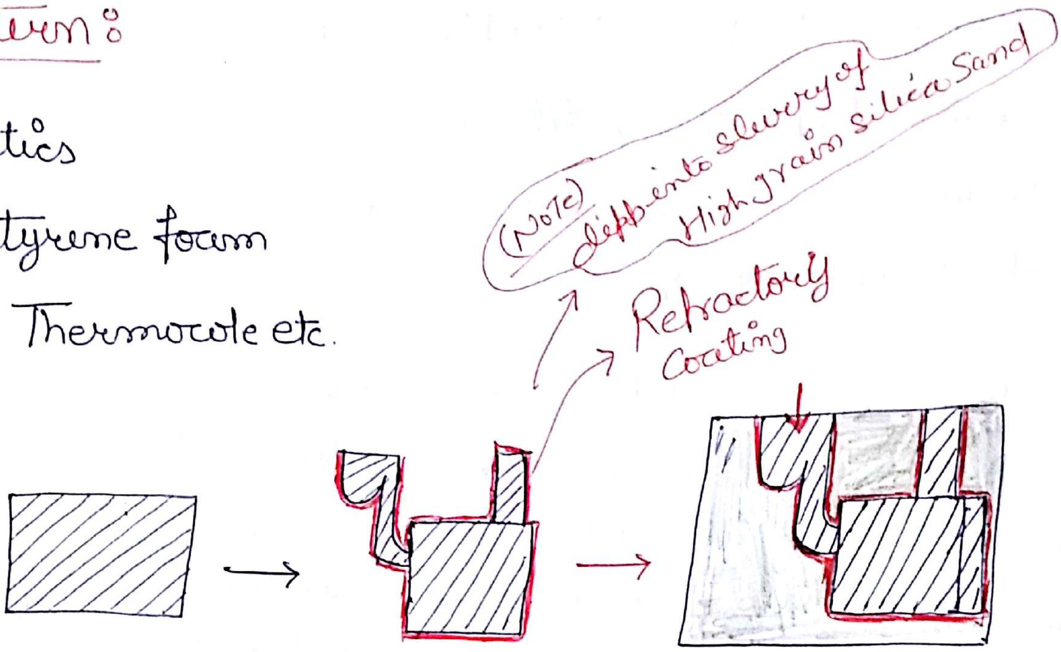
Imp Pattern Remove in gaseous is full Moulding

Pattern :

Plastics

Polystyrene foam

PVC, Thermocole etc.



Applications :-

1) Tooling
2) Fitting
3) Lock Components
4) Motor Casings

*** full Moulding / Cavity less moulding

bcz here / evaporative Pattern Casting /

Lost foam Process

> it using foam as Plastic material

→ Pattern is produced by Plastic material.

→ Gating elements will be, added onto the pattern.

→ By, adding Slurry Coatings on the Pattern, Silica Sand will be added on the Surface of the Pattern to produce, refractory Coatings.

→ By Keeping Inside the mould Box, moulding Sand will be filled to Support the ~~Shell~~ Refractory Coatings.

→ Liquid Metal will be directly allowed ~~ton~~ to the Pattern. Due to high temp. of liquid metal, Pattern will Stop evaporation & it will be converted into gaseous form.

→ By allowing the gases to escape, Cavity can be produced into which liquid metal can be filled Simultaneously.

→ After Solidification, By Breaking the mould, Casting can be Produced.

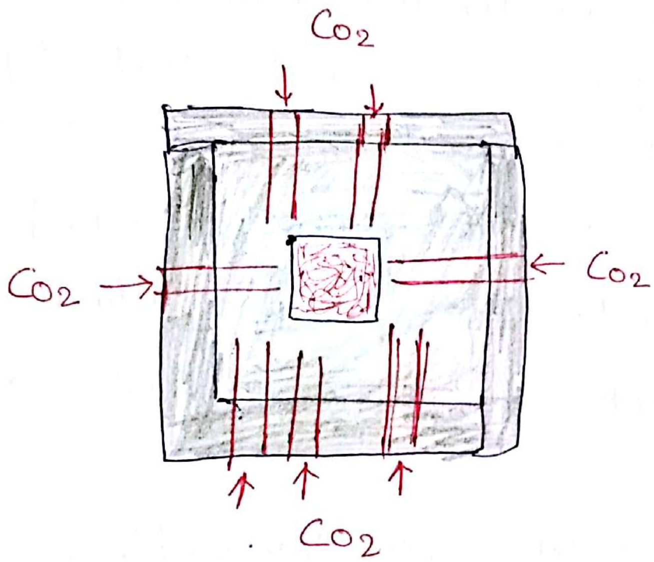
→ Large Size Castings with smooth Surface finish Can be Produced.

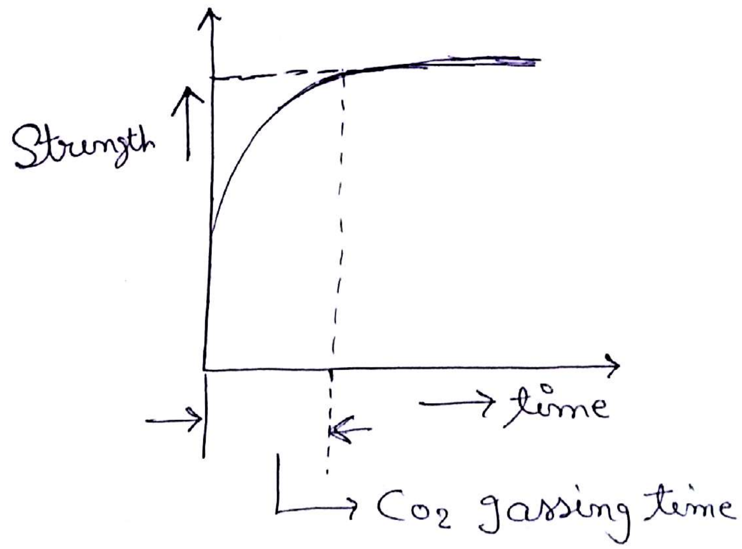
CO_2 Moulding :-

$Na_2SiO_3 \rightarrow$ 2-6 %

$Na_2SiO_3 + CO_2 \rightarrow SiO_2 + Na_2CO_3$

$SiO_2 \Downarrow$ Silicagel





→ Mould is Prepared by adding Sodium Silicate binder.

→ By, Creating Small Holes, CO_2 gas will be Supplied through the mould.

→ It will React with Sodium Silicate and produce silica-gel, which is having better bonding properties. Due to this, strength of the mould Can be increased.

→ Strength of the mould will depends on. time of Supplying of CO_2 in mould is Known as CO_2 gassing time.

→ This Technique is generally preferred to increase the Strength & Harrdness of large size moulds & cores.

Permanent Moulds :

* use to Produce axis symmetric object.

1) Centrifugal Casting.
2) True Centrifugal Casting.

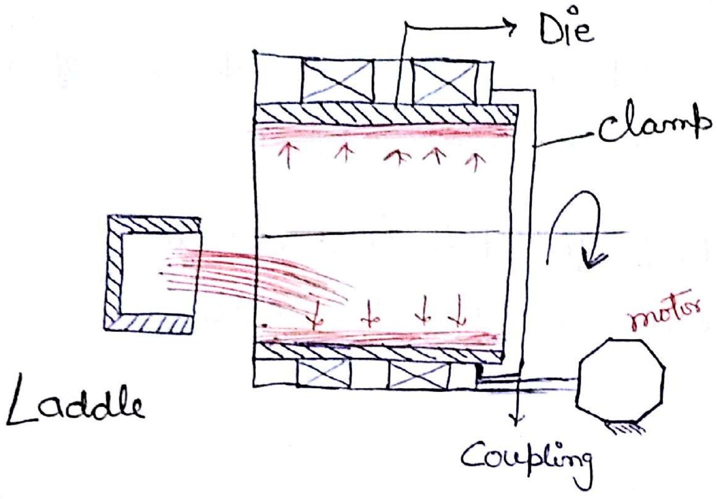
NOTE:

① $F_c \rightarrow$ Centrifugal force

$F_c = mR\omega^2 \quad F_c \propto m$

② F_g – gravity force

$F_g = mg$



③ No Possibility of gas defect.

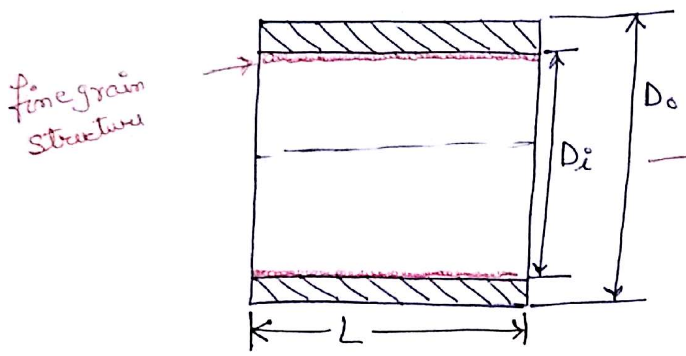
Basic Principal

Liquid metal getting solidify till that continuous Rotation.

→ Heat Rejection by Conduction

→ Forced Conduction.

→ due to fast Rate of Solidification or Heat Transfer, very fine grain will be develop & Strength & Hardness is more & high density i.e mass



$$V = \frac{\pi}{4}\left(D_o^2 - D_i^2\right)L$$

→ impurities (less density) Collected towards Centre

Q.A → Casting yield is 100%

Q.A → How liquid & Solid Shrinkage can be compensated?

A→ by providing more amount of liquid from laddle by next layer of Liquid.

if Liquid & Solid Shrinkage → is 3%

then Volume to be provided is 103 to get 100% casting.

→ Boaring operation inside to get finishing.

→ for long length (more than 5 m) mould be inclined at below 30°

Applications :-

1) Hollow Cylindrical pipes
2) Gun Barrels
3) Large Size bushes
4) Hollow propellor Shafts

$F = ma = mR_m\omega^2$

$a = R_m\left(\frac{2\pi N}{60}\right)^2$

$a = R_m\left(\frac{2\pi}{60}\right)^2 N^2$

→ To Produce Hollow Casting, without using the Core, this Technique Can be used.

→ Liquid metal will be enter into mould, which is under rotation.

→ Due to Centrifugal force, high density pure liquid metal Can be forced away from the Centre, less density slag will be Collected towards the Centre.

→ Due to fast rate of Cooling fine grain structure will be developed in the Castings, which are having more Strength and hardness.

→ There is no gating element used.

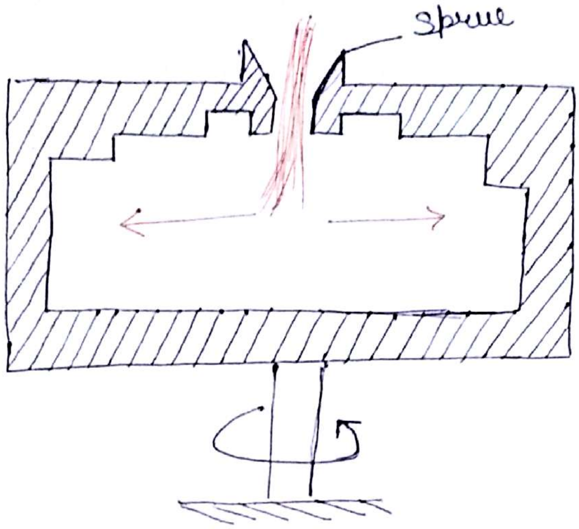
→ Casting Yield is 100%.

→ Production Rate is Very high.

→ Better Surface finish Can be produced by the Castings.

→ High initial investment Cost and it is used only for Hollow Symmetrical Objects.

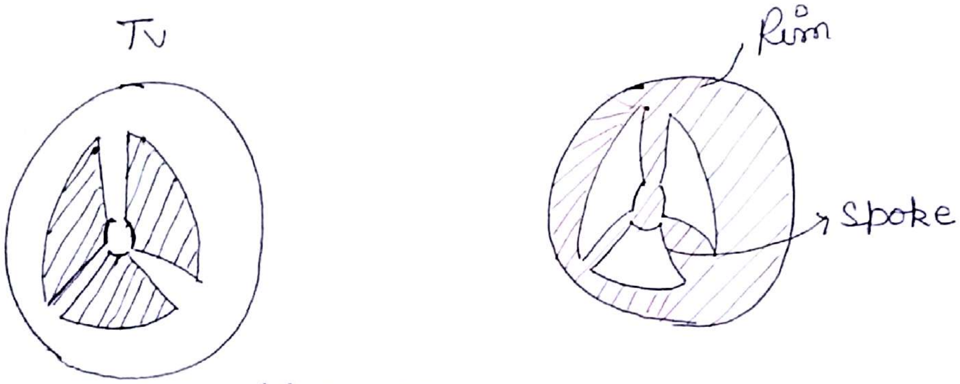
Semi Centrifugal Castings :-



Rotation → Vertical underaction of gravity

and casting due to Centrifugal force.
Liquid metal first hits outside Surface of Cavity and Progress toward Centre

* Projection are in die itself other than cylindrical object & Symmetric object are produces



:- Before filling liquid metal

imp → Casting Yield is less due to gating element (Sprue)

Why Semi centrifugal?
due to Vertical rotation and centrifugal action

Applications

1) Pulleys
2) Wheels
3) Spoked Wheels.

Two Wheels alloy Wheels

→ Die cavity is produced, along with sprue, and it will rotated about vertical axis.

→ Liquid metal will be enter in the centre of sprue, by means of gravity force. and it is forced away from the centre by means of centrifugal force.

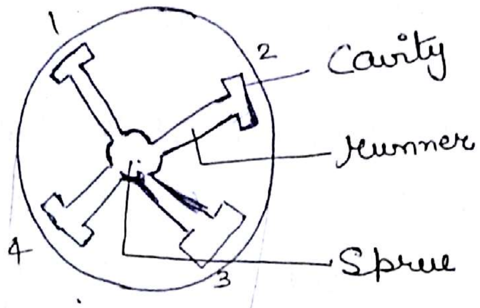
→ Liquid metal will start solidification at the outside surface and it is progressing towards the centre.

→ Less density impurities will be collected towards the centre.

→ Casting yield will be less, when compare to true centrifugal casting.

Centrifuging :- For unsymmetrical Casting

↳ Production for mass Production



NOTE

1) Depending on Size of Cavity Produced by changing ~~Size~~ dimension of runner.

* liquid metal enter into Cavity with non uniform Centrifugal force

* Casting yield will be less bcs no. of gating element are more. due to this we are not using this and in place die castie

→ To Produce unsymmetric objects in mass production, this technique is used.

→ No. of Cavity are produced on die along with gating elements & it will be rotated at a given Speed.

→ Liquid metal will be enter ~~at~~ into the Centre of Sprue, by means of gravity force & it is forced into the cavities with non-uniform Centrifugal force, Known as Centrifuging.

→ Axis of Rotation of mould & axis of object are not Coinciding.

→ Casting Yield will be less.

→

Applications

1) Patterns used in investment Casting made up of Wax material.

2)

Qn) A Hollow Casting is produced, which is having internal dia. of 0.5 m. & outside side dia. of 0.52 m. It is produced by Centrifugal Casting. Accelaration of the mould is 70g. What is rotational speed of the mould?

Soln) Given; $D_o = 0.52$ m

$D_i = 0.5$ m

$a = 70g$

$N = ?$

$$R_m = \frac{D_o + D_i}{4} = \frac{0.52 + 0.5}{4} = 0.251 \text{ m.}$$

$$\boxed{R_m = 0.251 \text{ m}}$$

$$F = ma = m R_m \omega^2$$

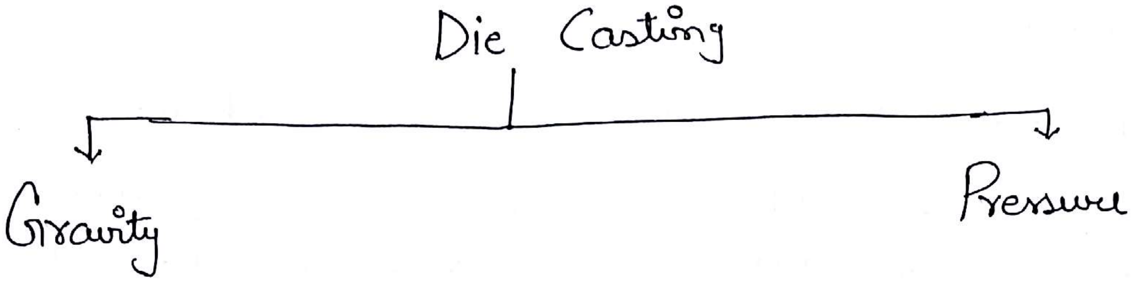
$$a = R_m \left(\frac{2\pi N}{60}\right)^2$$

$$a = R_m \left(\frac{2\pi}{60}\right)^2 N^2$$

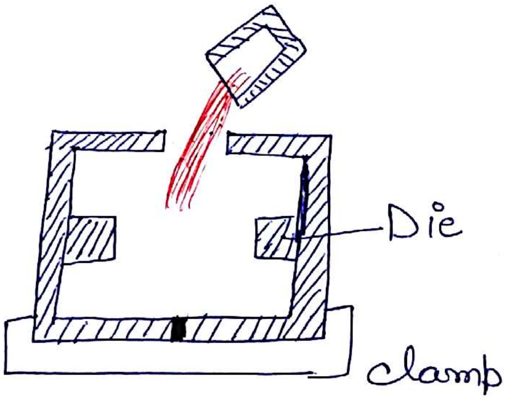
$$70 \times 9.81 = 0.251 \cdot \left(\frac{2\pi}{60}\right)^2 N^2$$

$$\boxed{N = 495.54 \text{ rpm}}$$ Ans

Die Casting:



Gravity Die Casting :-



NOTE:

No Rotation Of Mould
No Centrifugal force

* Casting under action of gravity force

Due to die – fast Solidification & Heat Rejection

→ Smooth Surface finish
→ Dimensional accuracy

Surface Roughness → 0.8 – 1.6 μm

→ fine grain Structure develop due to Solidification, Strength & Hardness

* metal having high fluidity are produced by this type of Casting. e.g Piston

→ Liquid metal is enter into the Cavity, by means of gravity force Only.

→ It is used to produce Simple Shape of the Casting, made up of high fluidity materials.

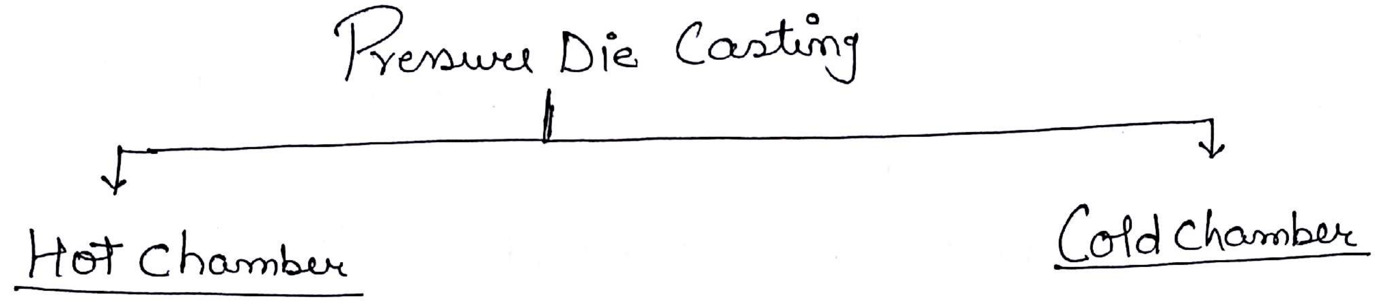
→ Surface finish and accuracy of the Casting are very high.

→ Due to fast rate of Solidification, fine grain structure will be developed in the Casting. Which are having more strength & Hardness.

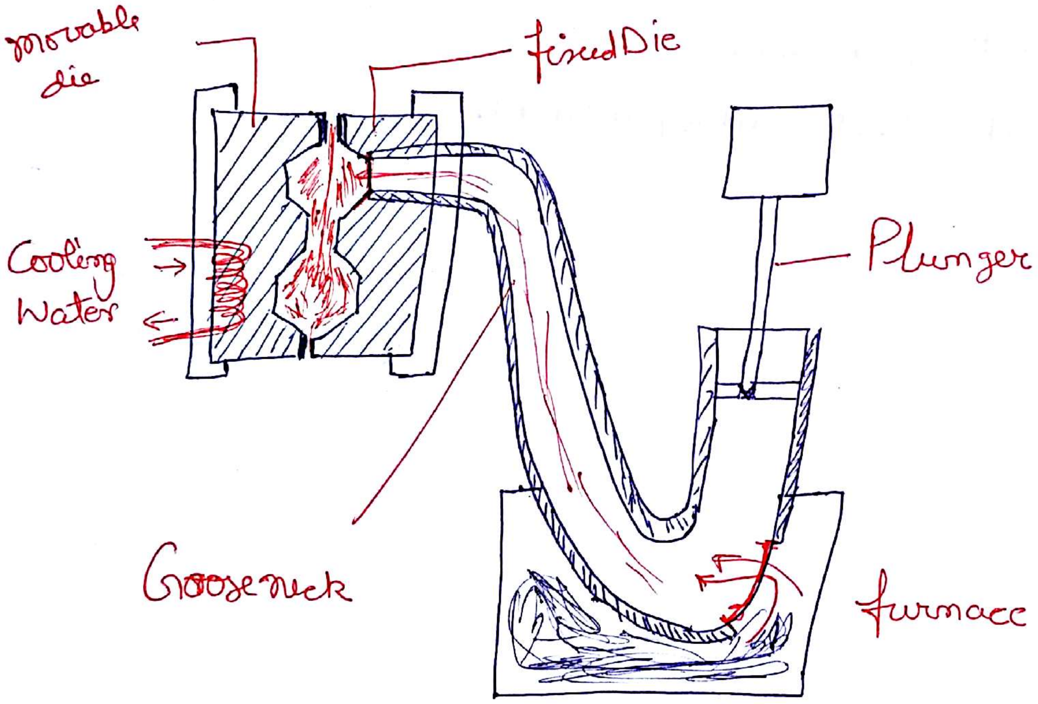
Applications

1) Pistons used in Automobiles, made up of Aluminium Alloys.

Pressure Die Casting:



Hot Chamber Die Casting:



GooseNeck life:

* Due to Continous Contact of gooseneck with liquid metal in furnace life of gooseneck is low so it is Compensated by using this process to low melting point casting

Aluminum is not used due to sticking

NOTE:
→ must maintain same Pressure untill Solidification

Qu * Liquid & Solid Shrinkange – Compensated by liquid metal in gooseneck no need of Riser

→ 150 - 200 Component / hour
↑ Production Rate

→ Liquid metal is forced into the cavity under external plunger force.

→ Furnace is integrated with casting unit.

→ Due to Continous Contact of the liquid metal with the goose neck it's life will be reduced.

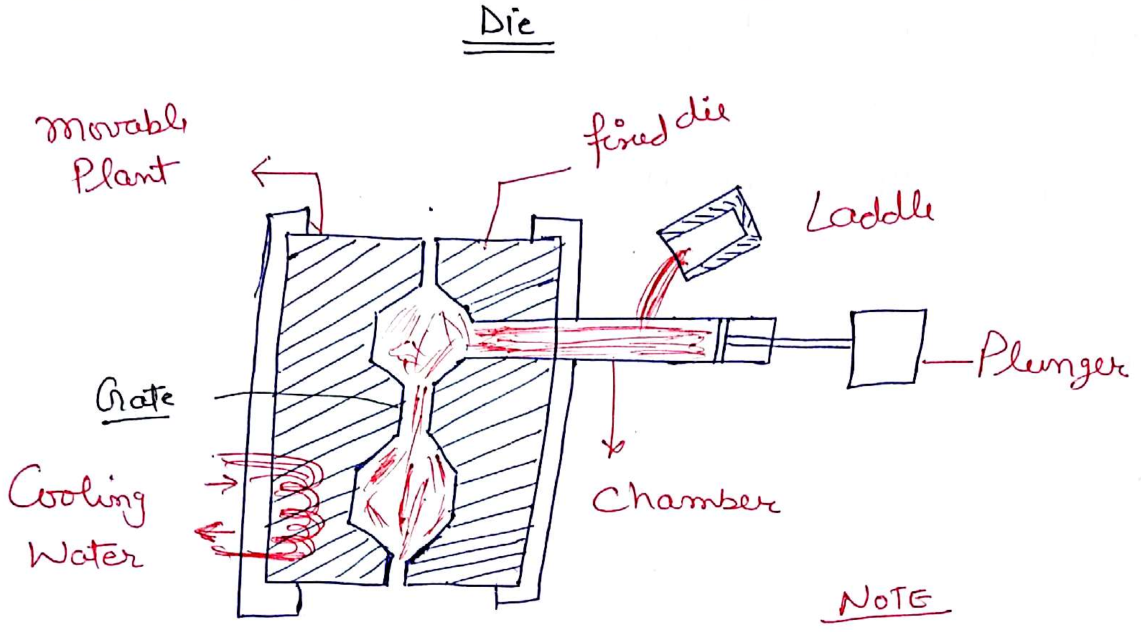
** → It can be used to produce, low melting point materials like lead, tin & Zinc.

→ Due to Sticking tendency of Aluminium, life of the goose neck will be reduced.
↑

→ It is not used in this Techinique.

→ Complex Shape of the object can be produced.

Cold Chamber Technique :-



NOTE

Vol. of Chamber = Vol. of Cavity

life of Chamber is high bcz Contact with liquid metal is Very less time.

* → Used for high melting Point material
  → Al, Cu, Brass (non ferrous material)

* Not for Ferrous material, bcz of high melting Point of Ferrous material

* Complex shape can be Produced

* Casting yield will be max bcz to gating element.

use for small size casting

→ Furnace is seprated from Casting unit.

→ used to produce high melting point non ferrous materials like, Al, Cu, Brass.

→ Contact of the liquid metal with chamber is very less.

→ Production Rate is very high.

→ Size of the Casting are limited to 5-20 Kg.

Applications:

1) Carburettors
2) Crank Cases
3) Valve bodies
4) fuel injection Pump Parts
5) Toilet fixtures
6) Kitchen Wares → Pressure cooker.

Qn) Compare Die casting and Investment Casting w.r.to following.

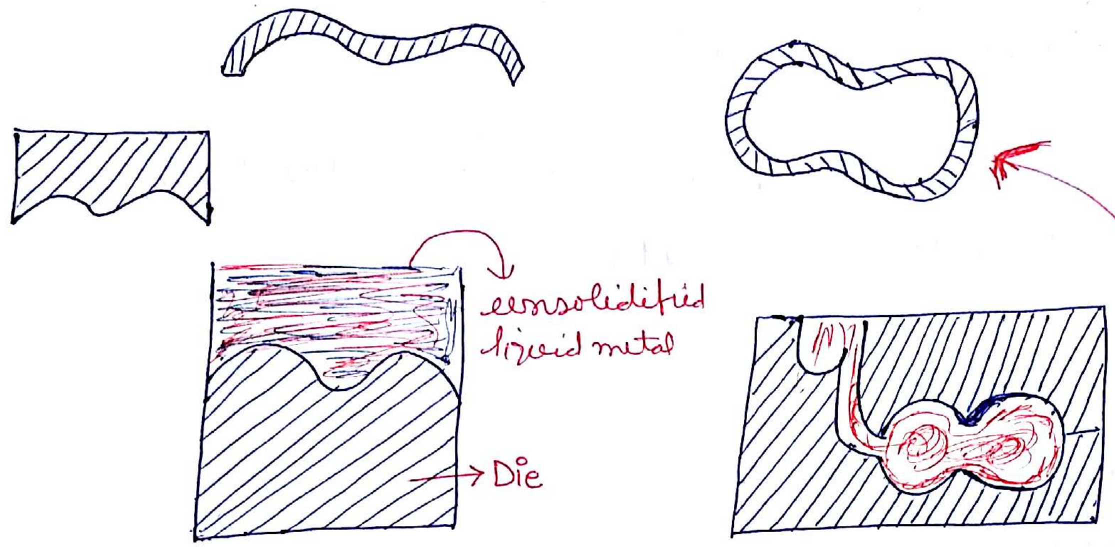
1) Production Rate
2) Complexity of the Object
3) melting point temp. of the material

Soln)

	Die casting	Investment Casting
Production rate	High	Low
Complexity of the object	Low	high
melting Point temp of the material	Low	high

Slush Casting :-

use → Low melting Non ferrous material



On rotating liquid comes out through gating element. bcz. only outer surface get solidified and at centre there is liquid metal. Soon rotating we get what we desired for

Application:

1) Hollow thin Casting
2) Hollow Statues
3) Toys
4) Decorative Item
5) Thin Ornament
6) Lamp Shades etc.

Note

$$t_s \propto \left(\frac{V}{A}\right)^2$$

$$t_s \propto (t)^2$$ for linear dimension

t → thickness

$$\boxed{t = C_1\sqrt{t_s} + C_2}$$

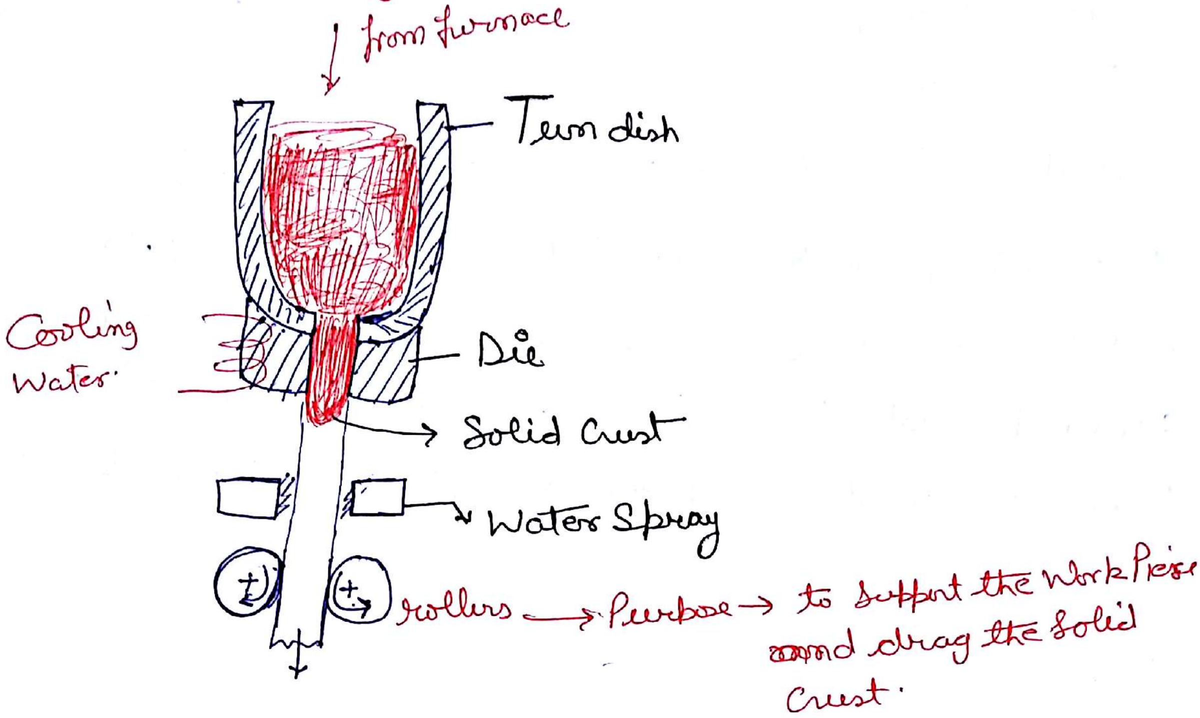
→ To Produce thin Sections and hollow thin Sections of required thickness, without using the Core. This Technique Can be used.

→ Liquid metal will be allow to Solidify on the die.

→ After getting the required thickness of the Casting, by rotating the die, unsolidified metal Can be seprated from Solidified metal. This is Known as Partial Solidification.

Generally used for non-ferrous low melting point materials.

Continous Casting:



Application

1) long length bar
2) rods
3) Slab etc.

grain Structure	depend on	Cooling rate

Production rate ↑ high

Limitation → Set up cost is more

*** Major steel industry used this

→ To Produce long length metallic objects, in mass Production, Continously from the liquid metal, this Technique Can be used.

→ Liquid metal will be allowed through the die.

→ Output of the Dies is Solid crust, on which Water will be sprayed to cool the material at a faster rate.

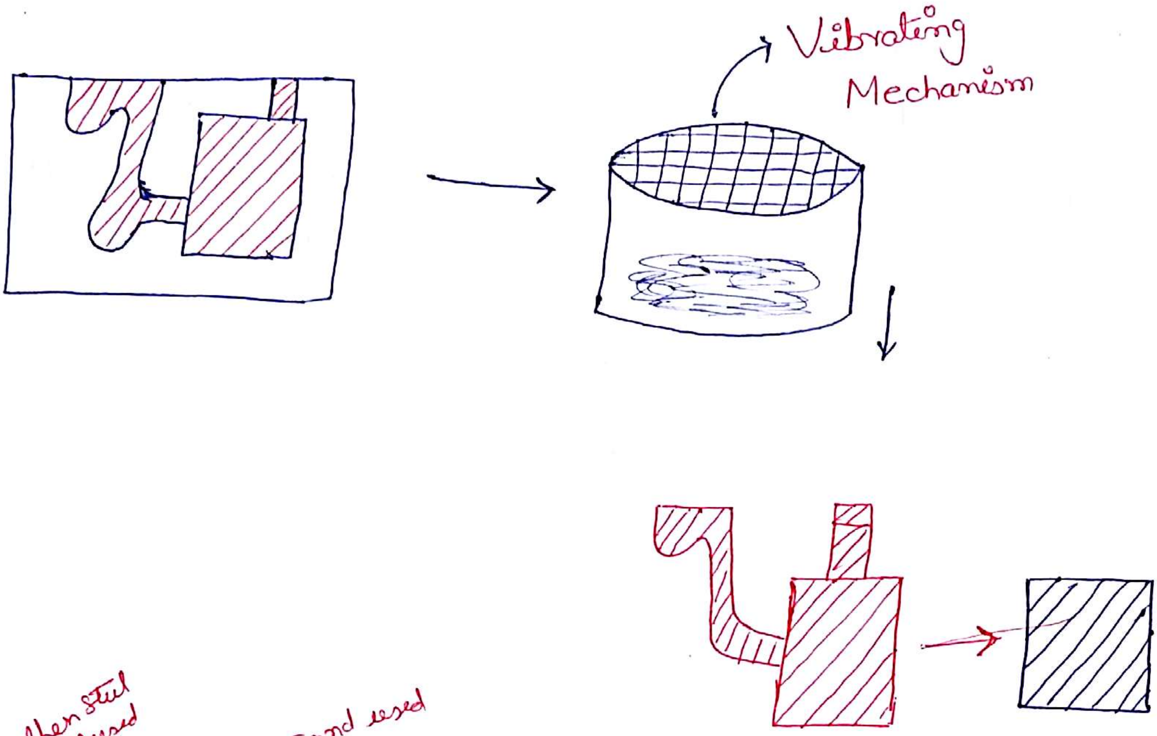
→ Depending on properties required by the object, different Cooling rates are provided on the workpiece material.

→ Production Rate is very high.

→ Initial Set up cost is more.

Cleaning of Casting :-

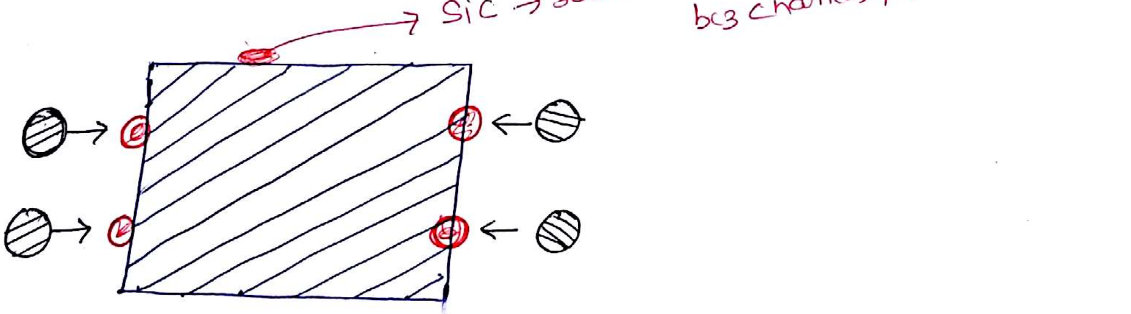
1) Fettling :-



b) Shot / Sand blasting

When steel Ball used — Shot

Coarse Sand used — Sand



1) Hardened Steel ball of &
   Ø 3-5 mm

2) Coarse Grain Sand.

Fettling

It is the process of breaking the mould, using Vibrating mechanism, and seprating the gating element from Casting is Known as fettling.

Shot / Sand blasting:

To remove the Silica Sand Particles, which are Fused on the Surface of Casting, Hardned Steel balls will be forced on casting along with air Pressure, is Known as shot blasting.

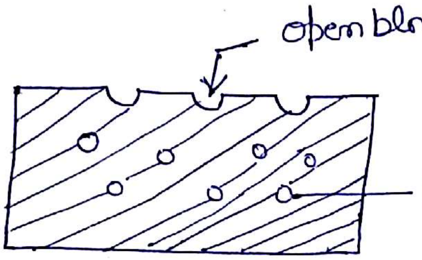
If Coarse grain Silica Sand is used for cleanning of the Casting, then it is called Sand blasting.

Casting Defects:-

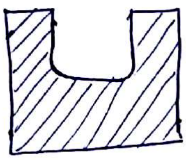
1) Gas Defects
2) Moulding Sand & Methods
3) Grating Design
4) Pouring Metal defects
5) Metallurgical defects
6) Other defects.

1) Gas Defects :

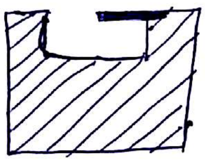
a) Blow holes & Open blows :-



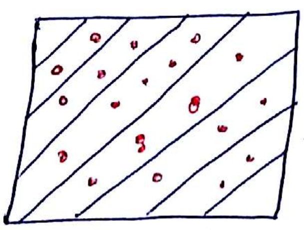
b) Scar : ← Shallow blow, and flat

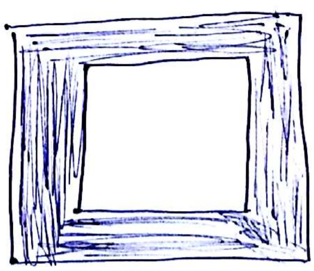


c) Blister : Scar Cover by thin layer is called blister



d) Pin hole Porosity :





a) blow holes & open holes :

Gas Defects, which are formed inside the Casting are Known as blow holes &
at top Surface of Casting Known as open ~~holes~~ blows.

b) Scar :-

A Shallow blow, which is formed on flat Surface Of Casting

c) blister :

It is the Scar Covered by thin layer of metal.

D) Pin hole Porosity :

Small Size gas defects, which are formed due to Hydrogen gas (H_2). Known as pin hole Porosity.

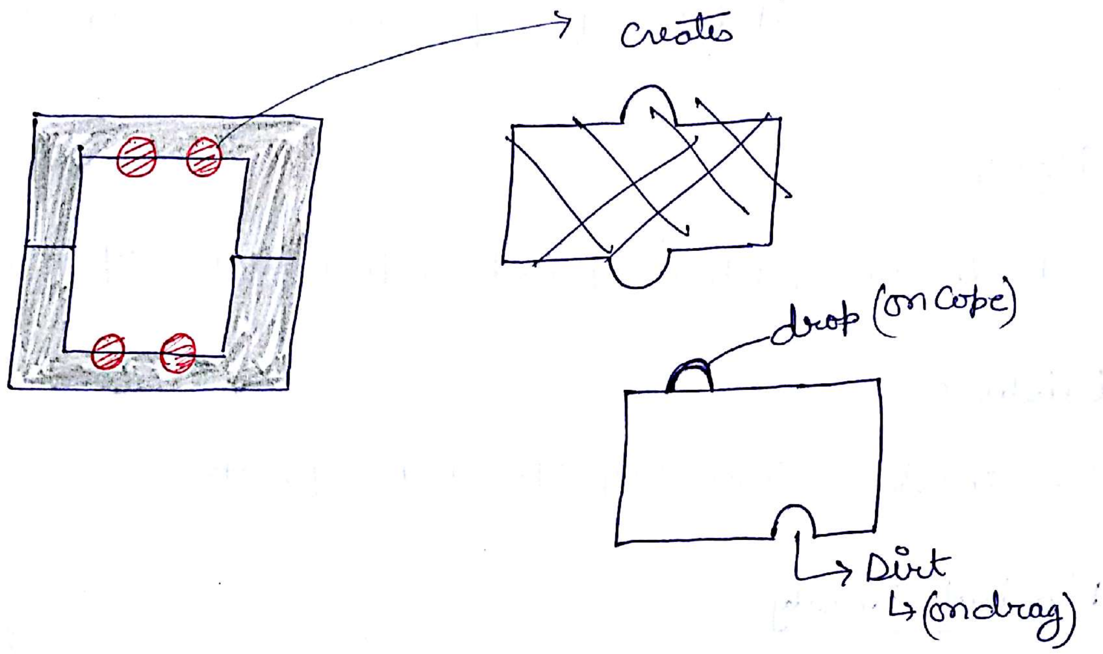
$$2H_2O \rightarrow 2H_2 + O_2$$

Remedies :

1) Heat the liquid metal in furnace up to pouring temp. only.
2) Convert Green Sand mould into dry Sand mould, before filling the metal. into the cavity.
3) Select the moulding Sand Such that it is having good Permiability
4) Provide Vent holes.

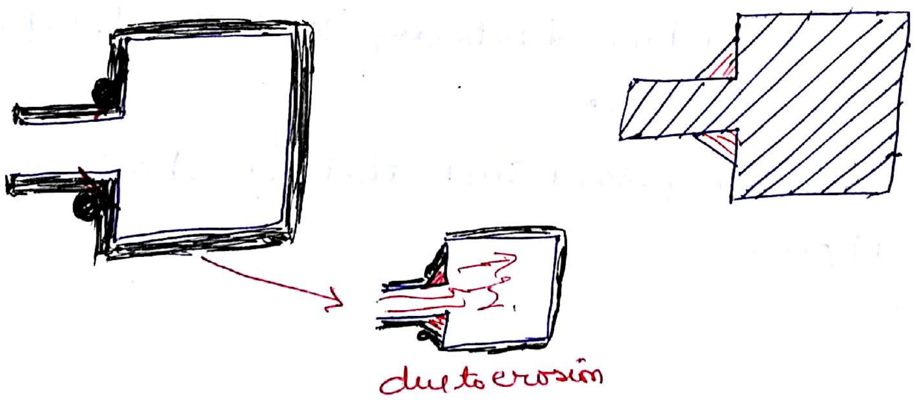
3) Moulding Sand & Methods:

a) Drop & Dirt:



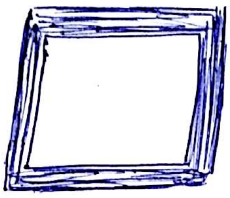
→ Due to improper Ramming, if the Silica Sand will be drop from Cope box to drag box will form a defect on the top surface of the Casting Known as drop & bottom surface of the Casting Known as Dirt.

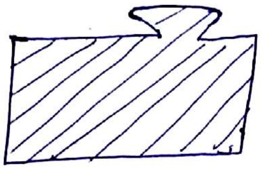
b) Cuts & Washes:- improper Ramming or Gating Design



→ At a minimum cross sections in the mould Cavity due to improper Ramming and Gating design, moulding sand will be eroded from the surface will form a defect known as cuts & Washes.

c) Scab: loose sand due to improper Ramming in Cope box

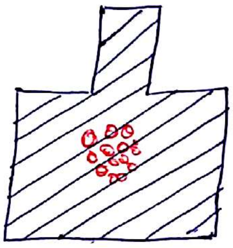




→ Due to Improper Ramming, the liquid metal will be Penetrated into loose sand layers, in the Cope box will form the projections on the top Surface of Casting Known as Scab.

3) Gating Design:

a) Shrinkage Cavities: Causes due to Improper Riser design (Obj)

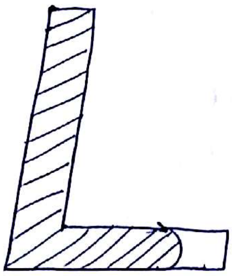


Due to Improper riser Design cavities form due to Shrinkage of the material is Known as Shrinkage Cavaties.

4) Pouring Metal Defects

Objective 2-4 times Gate, Match d Column

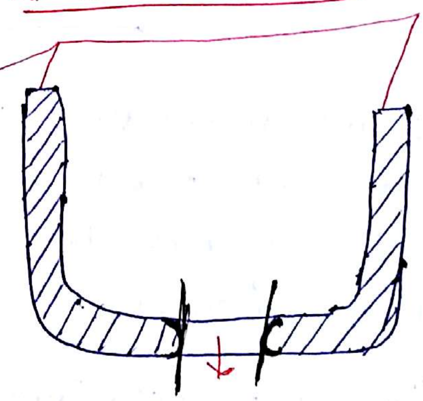
a) Misrun:-



(b) Cold Shuts

imp
Two stream of liquid metal not fusing

lack Pouring & fluidity



To overcome Heat liquid metal in furnace up to Pouring temp & Gating Design improve

(1) Misrun

Due to lack of fluidity, before reaching extreme end of cavity, if the liquid metal ~~Stop~~ Start Solidification will form a defect known as Misrun.

b) Cold Shuts:

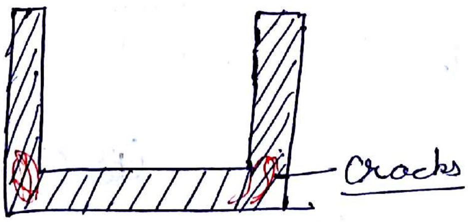
Two steams of liquid metal will not fuse properly, will form a discontinuity in the casting known as Cold Shuts.

Remedies:

1) Heat the liquid metal in the furnac up to Pouring temp.
2) Design the gating elements properly.
3) increase the surface finish of the cavity.

5) Metallurgical Defects:

a) Hot tears/Cracks:

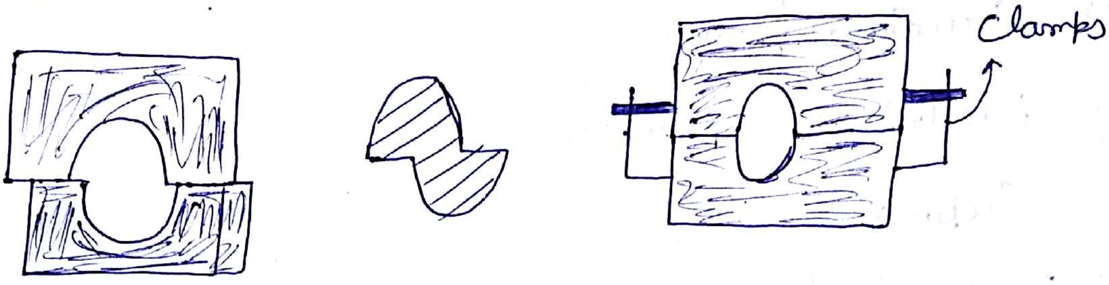


→ Due to non uniform cooling, internal stresses will be developed in the casting. if this stresses will be more than the strength of material, crack can be expected in casting and are known as Hot tears/Cracks.

This can be over come by providing chills & padding.

(6) Other Defects:

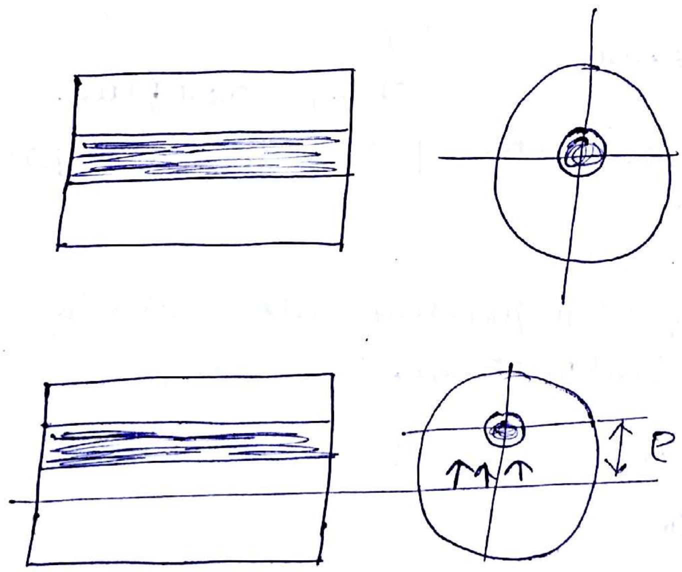
a) Mould Shift:



→ Due to improper positioning of Cope box and the drag box There is a mismatch along the Parting line in the Casting Known as mould Shift.

This Can be overcome by Providing dowel pins & clamps.

b) Core Shift:



Shifting of the core from its original position due to upward Buoyancy force is known as Core Shift.

This Can be over come by providing core prints & chaplets.

Objective

Furnace :-

1) Crucible furnaces
2) Electric Arc furnac
3) Cupola
4) Induction furnace
5) Reverberatory furnace

1) Crucible Furnac : Small quantity → Low m.P NonFerrous material

→ This furnace is used for melting of small quantities of the liquid metal in small size foundaries for melting of Low melting Point non ferrous material.

Charge = Ore + Flux + Coke

2) Electric Arc Furnac :- Large quantity + ferrous material + No Pollution.

Heavy steel Casting ← use

Charge = Ore + flux.

In Heat generation for melting of charge can be produced by using electric arc.

It is used for melting of Large quantities of the materials, with high melting point like steel material.

③ Cupola : used for Cast iron

Imp

Charge → Ore + Flux + Coke

Ore: Fe_2O_3 or Fe_3O_4

↳ Blast furnace → Pig iron → Cupola → Cast iron

Pig iron: Purest form, Soft.

7.

Charge
⇓
ORE → Pig iron
+
Fluxe → $CaCO_3$ (lime stone)
+
Coke → (To Heat)
(Pulverised form of Carbon)

→ It is used to produced cast iron by melting Pig iron. By collecting the heat from flue gases, atmospheric air which is supply to the furnace, can be heated to 200 - 450°C. is known as Hot blast cupola.

→ Operating temperature of Hot blast cupola is greater than conventional cupola.

Metal : Fuel.

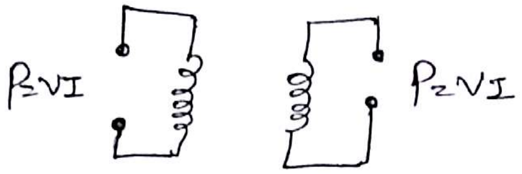
Melting / charge Ratio : 4:1 → 12:1

for Cupola furnace is melting / charge Ratio = 10:1

Hot Blast Cupola can be used in Steel foundary but Cupola is not.

4) Induction furnace :- using generally.

Charge → ore + flux



$H = I^2RT$

* Heat generation Here depend on current.

→ for both ferrous & non ferrous material.

→ By Providing the flux inside the crucible, heat will be generated by supplying high rate of current to copper tubes which wrapped on crucible.

→ It will be used for melting of low melting Point & high melting point ferrous & non ferrous materials with smaller & large Quantities

→ Fast Rate of Heating Can be possible.

→ Space required will be less.

→ Cost of melting is high.

5) Reverberatory Furnace :-

Oil & gas are used to burning inside furnace under action of burner.

→ Heat Required for melting of Charge can be produced by using ~~Valve~~ Wall mounted burners.

→ Space Required will be max.

→ Heat Transfer losses are more.

→ Cost of melting is less.

→ used for melting of Ferrous & non ferrous material in larger Quantity.