

HANDWRITTEN
NOTES
OF

(CASTING)

BY

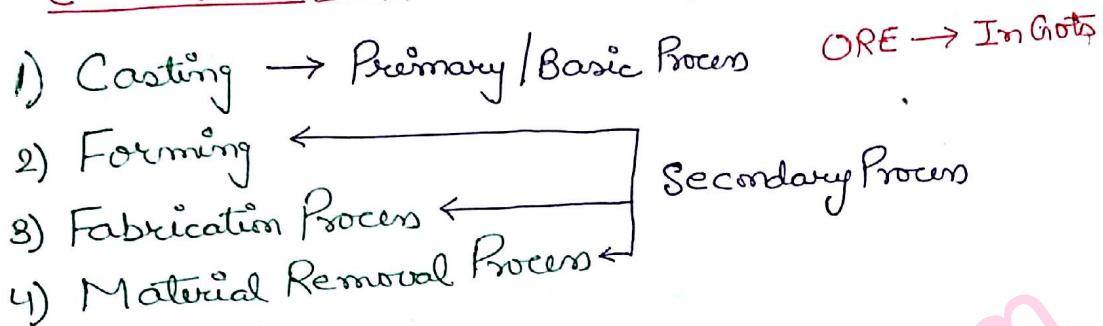
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Manufacturing Process

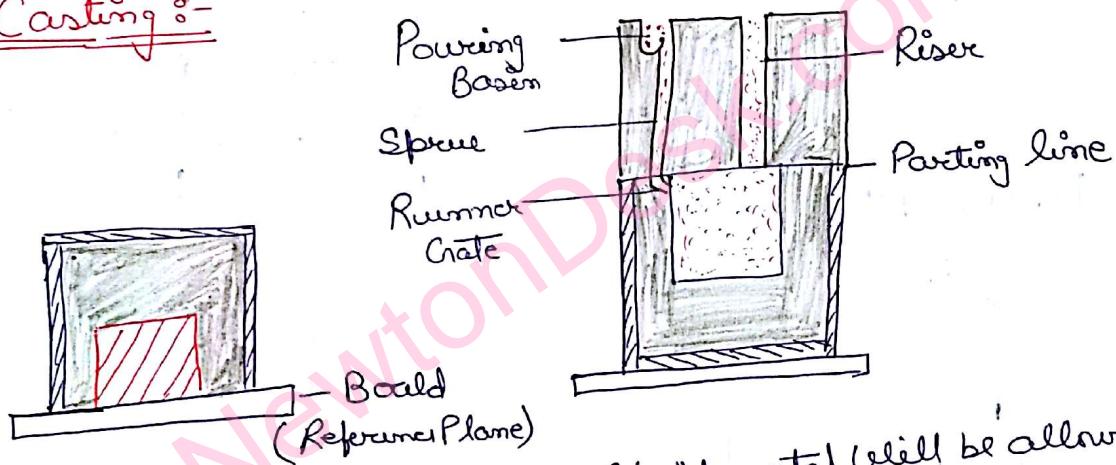
It is a process in which Raw material will be converted into a finished product.

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

Classification of Manufacturing Process



Casting :-



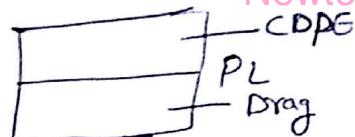
It is a process in which molten liquid metal will be allowed to solidify in a pre defined cavity (mold cavity).

Advantages :-

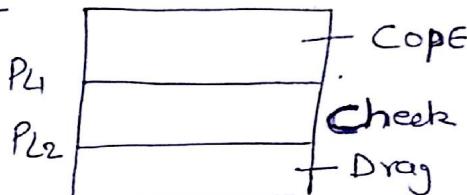
- 1) Complete shape of the object can be easily produced.
- 2) It is less expensive process.
- 3) Ductile & Brittle materials can be produced.
- 4) Large size object can be produced by Casting only. (150-200 tons)
 - e.g. Road roller, Machine Tool Beds, engine Block
 - Gear box housing

Mould Box:-

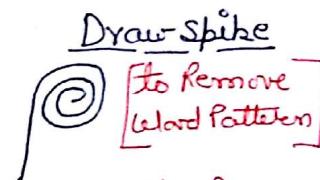
Two Box
Three Box



Three Box



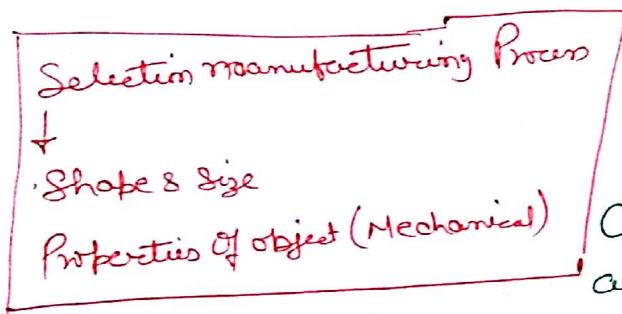
Two Box



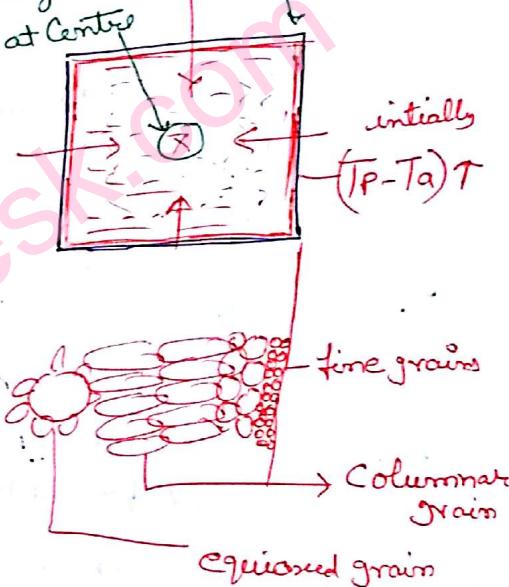
$$\text{Pouring Temp. } T_p = T_m + \Delta t \\ (100^\circ - 250^\circ)$$

Degree of Superheat

Limitations of Casting :-



Cooling is higher at Surface and lower at Centre



Draw Spike



use to remove Pattern from Mould.

grob

$$T_p = T_m + \Delta t$$

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 :-

→ exact Copy

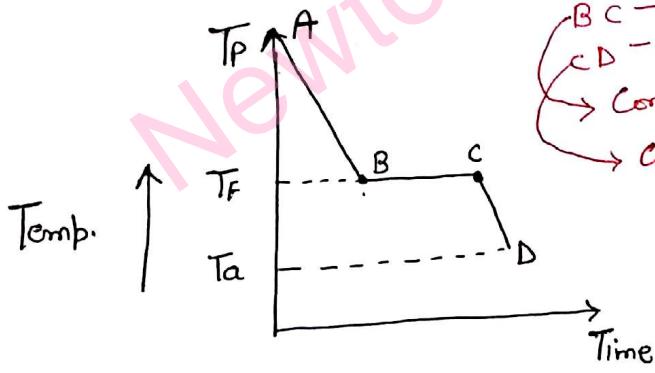
Pattern is the replica of final Casting to be Produced, with Some modifications. The modification are in the form of allowances.

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
 CD - Solid State - Solid Shrinkage
 → Compensated by Providing Riser
 → Compensated by ↑ size of Pattern

$\Delta l = l \alpha \Delta T$ ($\alpha \rightarrow \alpha$)
 $-\Delta l = l \alpha \Delta T$ Coefficient of
 linear expansion

(gmp)

Cooling Process

- 1) α is +ve \rightarrow Contraction
 - 2) α is 0 \rightarrow no change
 - 3) α is -ve \rightarrow Expansion
- Bismuth = 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_a) 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 :-**

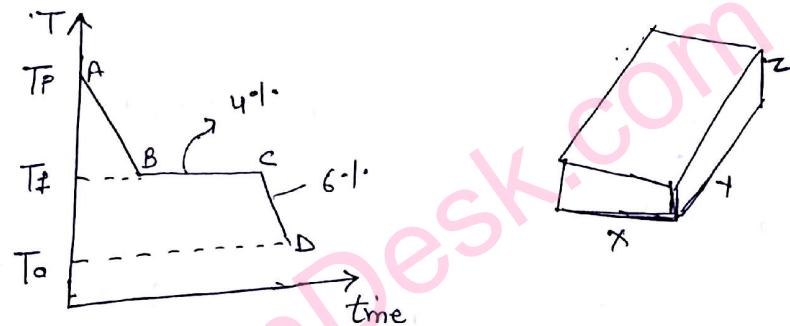
1) Bismuth & Invar	→ Negligible Shrinkage
2) White metal	→ 5mm/m Shrinkage
3) Cast iron (CI)	→ 10mm/m Shrinkage
4) Aluminium	→ 13mm/m
5) Copper	→ 17mm/m
6) Steel	→ 20mm/m
7) Brass	→ 24mm/m

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 solid contraction 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

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

$$\text{Vol. of material at } C = 0.96 \times (50)^3$$

$$\text{Vol. of material at } D = (0.96 \times (50)^3) 0.94$$

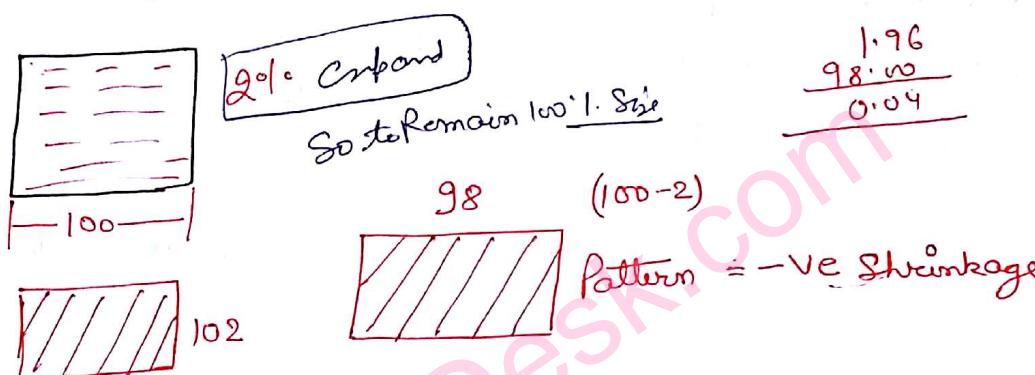
$$\text{Vol. of material at } D = 112800 \text{ mm}^3$$

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

(Ans) Produce by cupola furnace & Si NewtonDesk.com
 For grey Cast iron $\alpha \rightarrow -ve$
 Pig iron: iron & carbon both Separated
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).

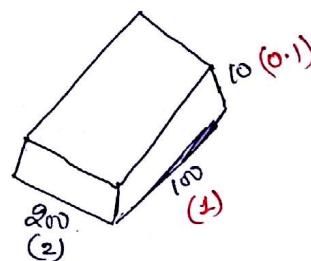
To overcome this, size of the Pattern will be reduced by Considering (-ve) Shrinkage allowances.



Qn) A Grey Cast iron block of dimension, $200 \times 100 \times 10 \text{ mm}^3$ 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) Volume of Pattern: $(200-2)(100-1)(10-0.1)$

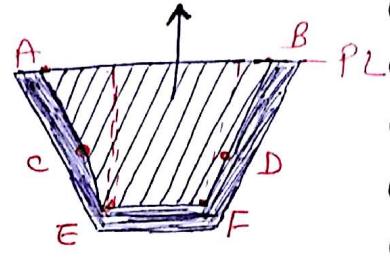
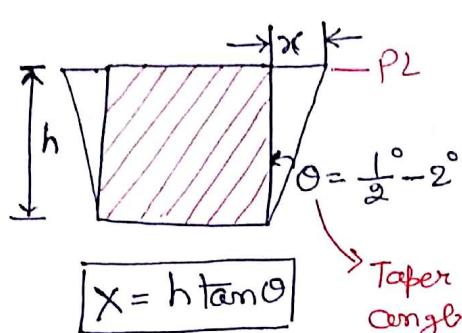
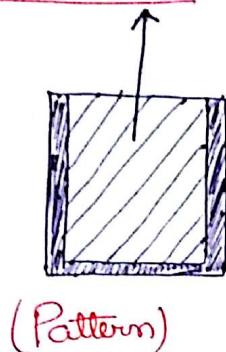
$$\begin{aligned} \text{Volume of Casting} &= 200 \times 100 \times 10 \\ &= 0.097 (< 1) \end{aligned}$$



> 1 for all other material
 = 1 (Bismuth)

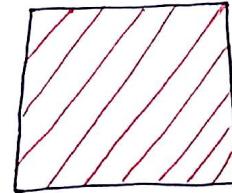
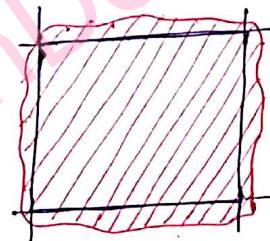
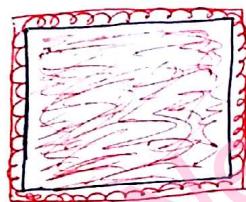
Draft or Taper Allowances :- for high height

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.

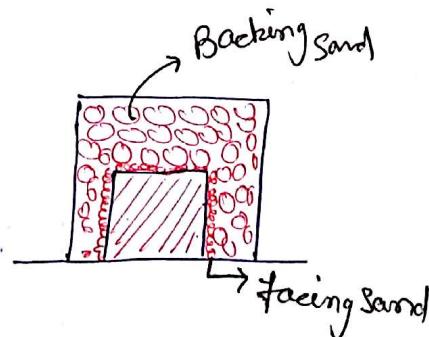
Machining or finish Allowances: (mm/surface)



Permeability
more Roughness

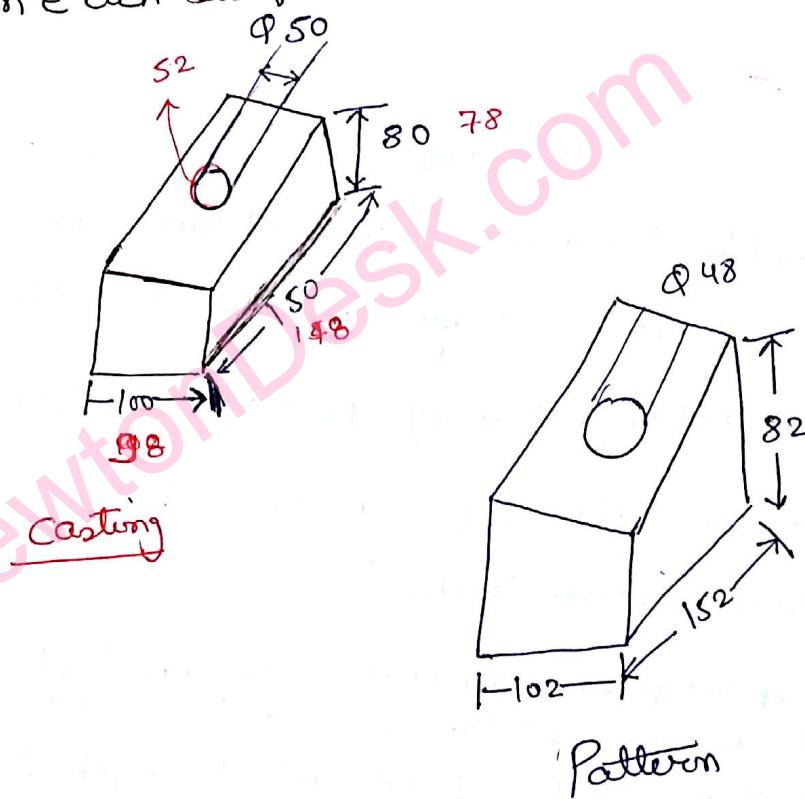
Silica grain
Surface finish

Surface finish $\propto \frac{1}{\text{Permeability}}$



- 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.

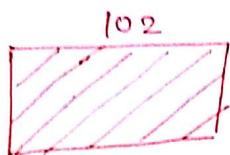
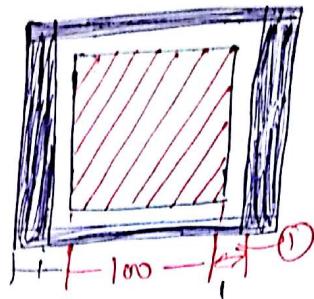
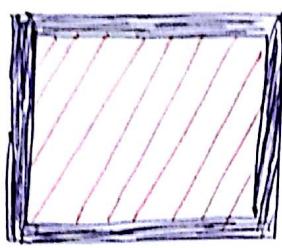
Q_n) Calculate, dimensions of the Pattern, for the casting shown, below, by ~~without~~ Considering machining allowance of 1 mm. on each surface.



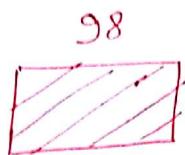
Shake (or) Rapping Allowances :-

(for short height)

(-ve) Allowances
Expansion.



(With clearance)



(Pattern)

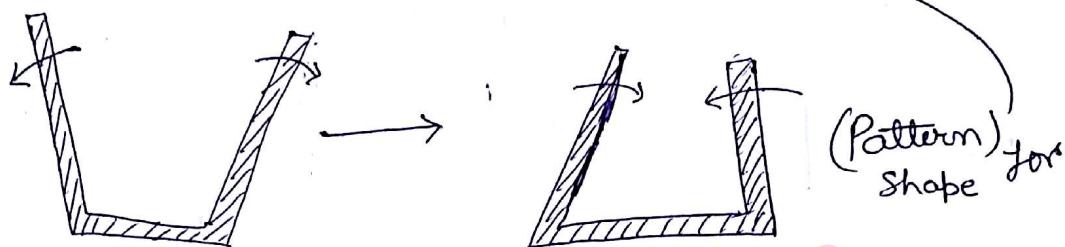
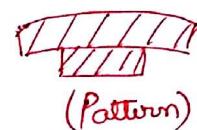
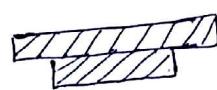
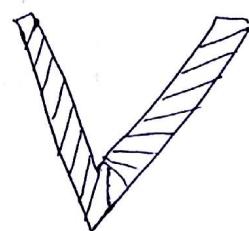
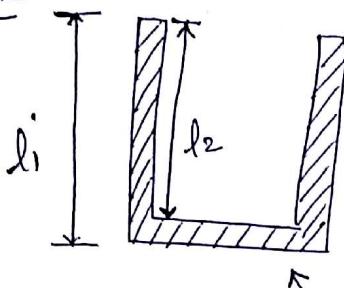
(100-2)
(-ve Allowances)

$$\frac{100+2 = 102}{100 - 100-2} \text{ Patt.}$$

- For, easy removal of the Pattern, Some clearance is required b/w Pattern and mould Surface.
- This can be produced by shaking the Pattern. i.e.
- Due to Shaking, Size of the Pattern will be slightly increased.
- To overcome this, Size of Pattern will be reduced by Considering Short Shake allowances. i.e (-ve) 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 ~~operator~~ level of the operator.

Distortion Allowance :- Zero Allowance

$$l_1 > l_2$$



- Depending on Shape & Size of the Casting, due to difference in Linear dimensions, there is a Possibilities of Shrinkage Stres 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 depends on, length to thickness Ratio.

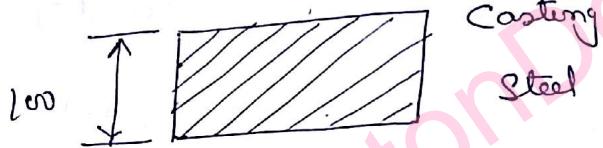
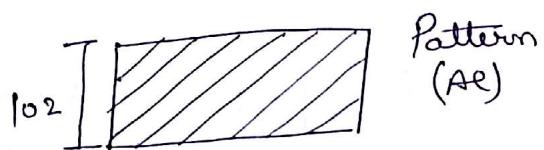
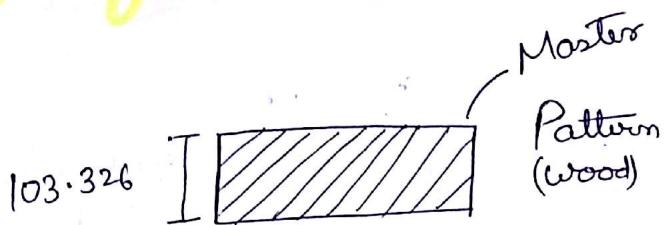
distortion depends on $\frac{l}{t}$

length to thickness Ratio

Pattern Materials :-

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

Int double allowances



Steel's Shrinkage
(20mm/m)

1m — 20mm

100 m — 2 mm

Aluminium Al = 13/mm

100 — 13mm

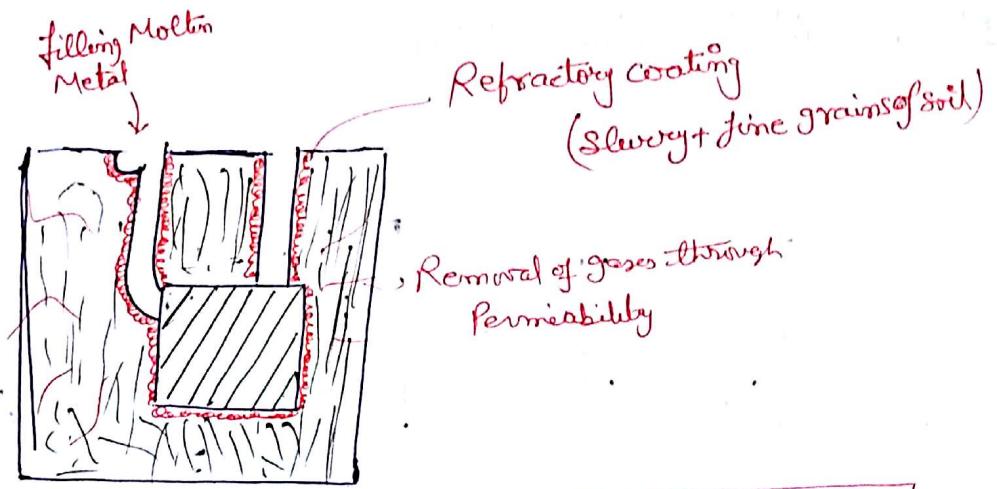
102 — 1.326 mm

Double Shrinkage Allowance :-

To produce no. of Casting in mass production, metallic patterns can be used. They can be produced by wooden patterns and wooden pattern. On wooden pattern, shrinkage of casting material & ^{mp} shrinkage of pattern material, both will be added & this is known as double shrinkage allowance. And wooden pattern is known as Master.

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3) Plastic: Polystyrene, PVC, foam, Thermoset etc.

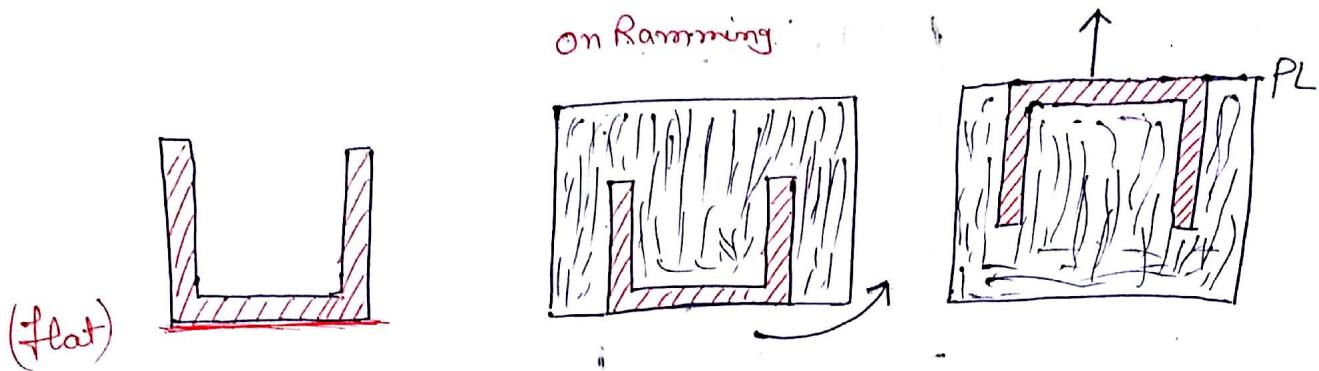


Wax — Investment C.
Hg — Mercury Cast Process
-39°C (F.P.)

Types of Patterns :-

1) Solid (or) Single Piece :-

(on Rotating)
Remove After Ramming

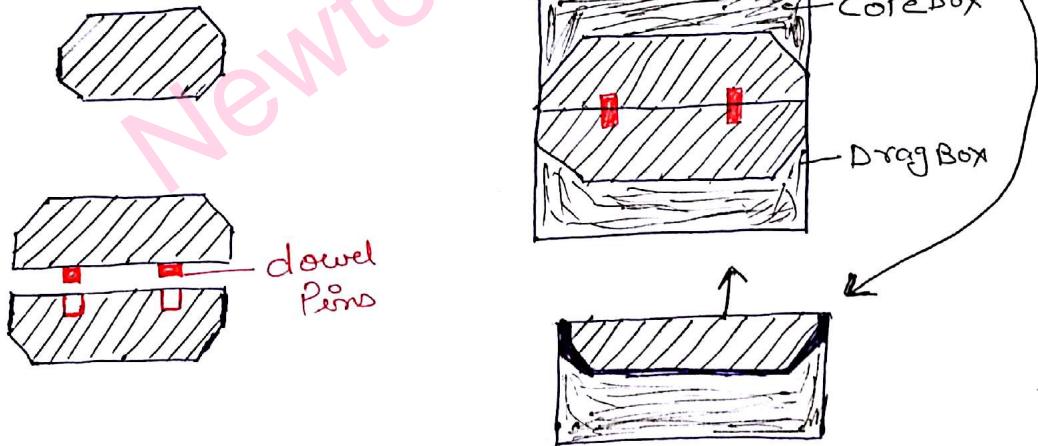


→ If the Object to be produced is Simple in shape & Size, Solid (or) Single piece pattern is used.

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

→ It is Completely Provided in the drag Box.

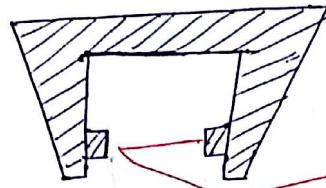
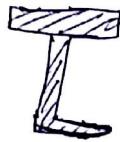
2) Split Piece Pattern :-



→ 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, Separately.

3) Loose Piece Pattern :-

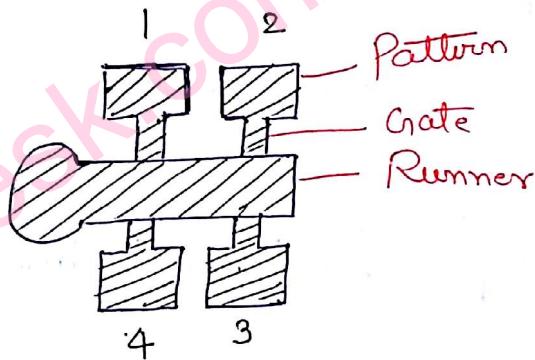
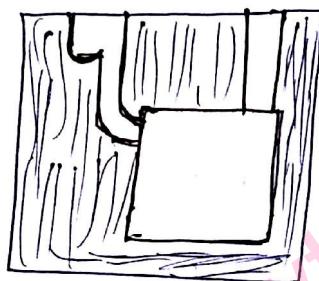
Pattern Removal
Tool



Projections and undercuts

- 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.

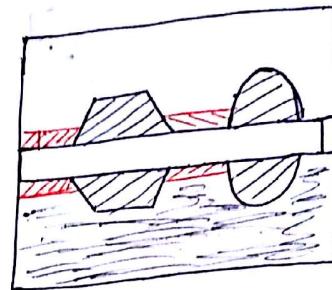
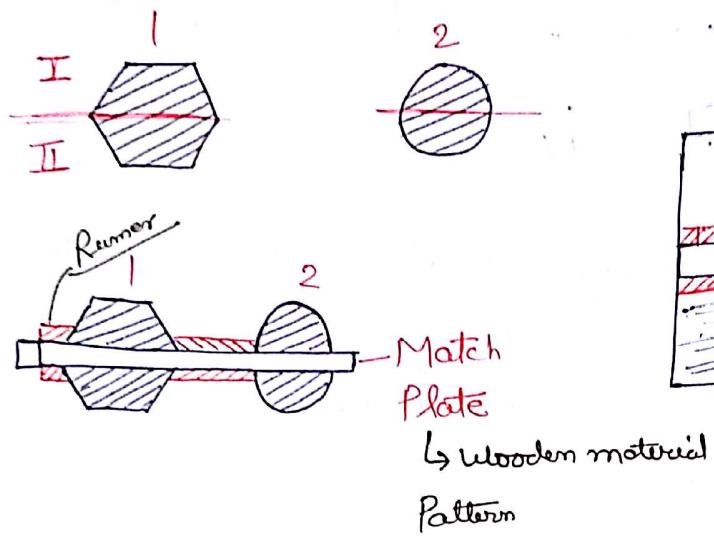
4) Gated Pattern :- (Runner + Gate)



- 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 :-

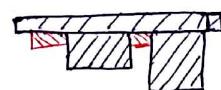
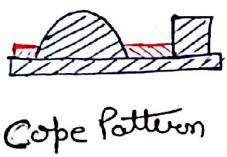
So sand will be filled & Paraffining Separately in Cope Box & Drag Box.



→ 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)



Drag Pattern

→ 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.

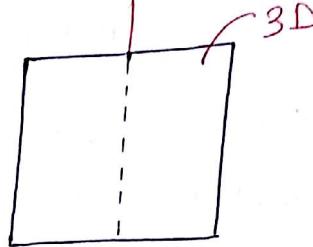
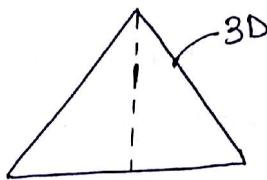
7) Sweep Pattern :-

Use: Symmetrical Shape of pattern

Rotating 2D Pattern to obtain full 3D Pattern.

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2D - 3D

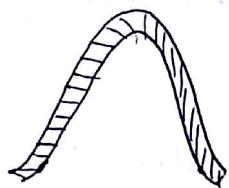
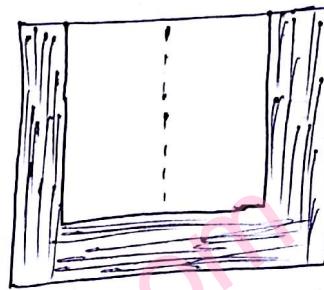
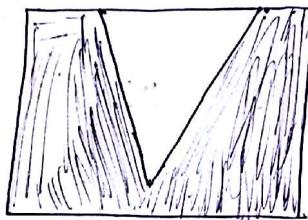
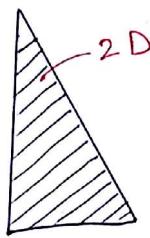


Loam Sand

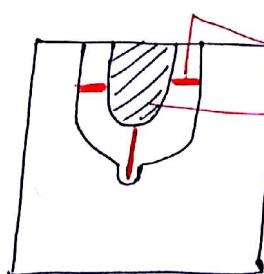
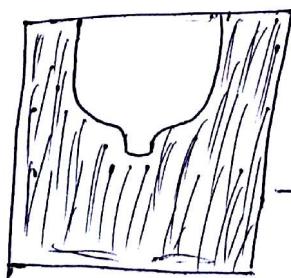
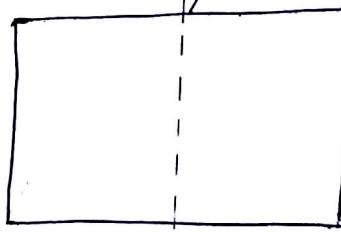
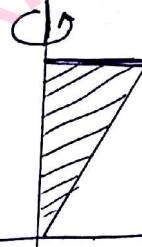
50% Silica

50% Clay

+
(40% Clay +
10% Water)



To obtain
Cavity in Mould



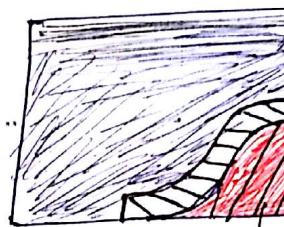
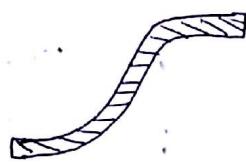
Chaplet (material same as casting material)

core

To support core chaplet is
there and core is made up of
Sand.

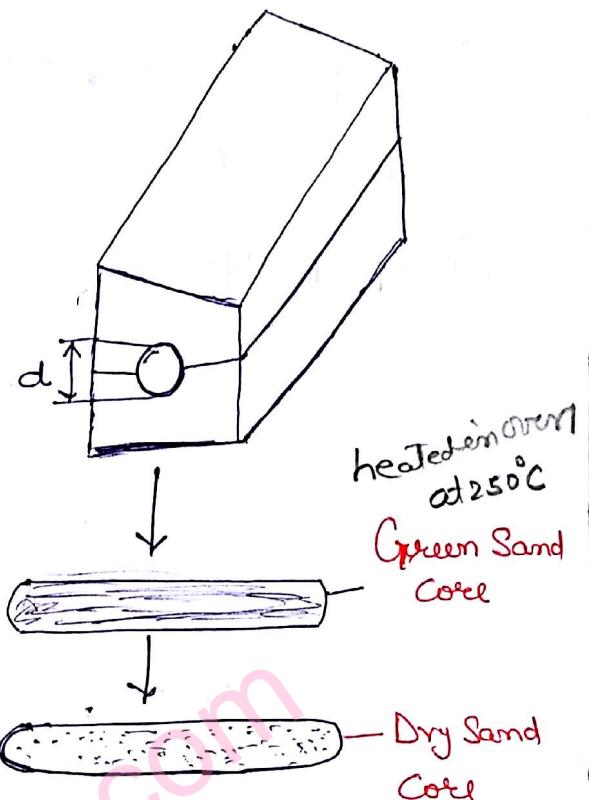
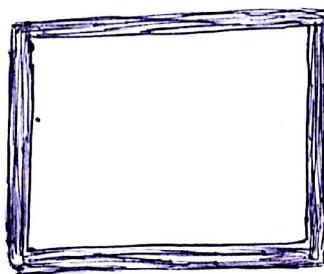
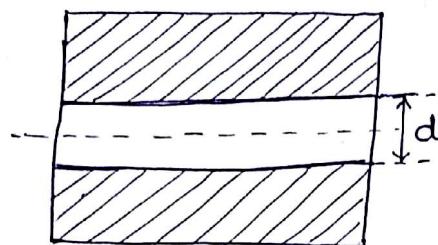
- To Produce Complex shape of 3D Cavity, 2D Plane Pattern will be rotated in the mould.
- It will be easy for Symmetrical shape of the Pattern only
- It is not the true shape of the Pattern.

8) Follow board Pattern :-



Follow Board
→ Provide Core Area to avoid gap.

- If the Patterns are Structurally Weak, due to Ramming force, there is a possibility of Breaking of the Patterns.
- To overcome this, Patterns are Supported, by Providing a follow Board.

Core Boxes :-Core Design :-Core Sand :-

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

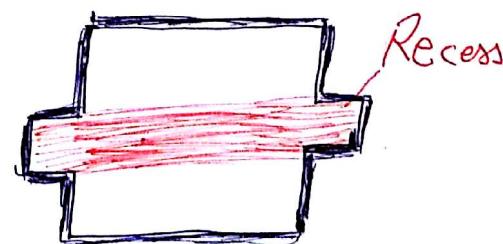
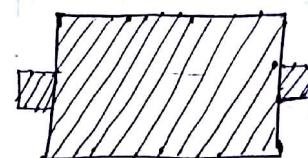
$$\text{Net Buoyancy} = \text{Weight of liquid} - \text{Weight of}$$

Force Metal displaced Core.

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

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

Core Print Points



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

↓
Core Volume

↓
Density of core material

Density of
Molten
Metal

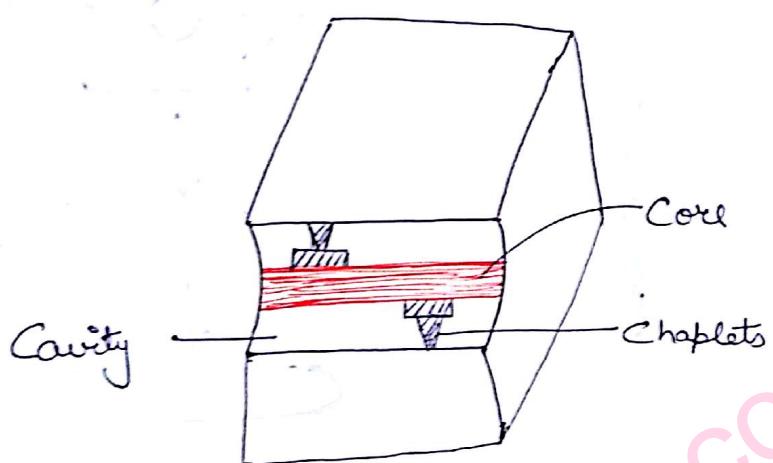
$$P = V_c g (\rho_m - \rho_c)$$

$$P \leq 3.5 A_c \rightarrow \text{Core Print Area}$$

(Surface area)

Core Prints:-

Core prints are the Projections on the Pattern and the Recars 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 on the core prints?

$$H = D = 100 \text{ mm}$$

$$\rho_m = 2600 \text{ kg/m}^3$$

$$\rho_c = 1600 \text{ kg/m}^3$$

$$[\text{Vol.}_c = \frac{\pi}{4} D^2 H]$$

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

$$[P = 7.704 \text{ N}] \text{ Ans}$$

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

V_c → Volume of Core

g — Gravity

ρ_m — Density of molten metal

ρ_c — Density of core material

$$\boxed{\text{Volume of Cylinder} = \frac{\pi}{4} D^2 h}$$

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 Refractoriness Temperature

Zirconium — 2700°C

Ceramic — 3500°C

Graphite — 4200°C

Refractoriness > 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 withstand high temp. of liquid metal without fusion.

2) Permeability % $P_n = 60 - 120$ } (Permeability number)

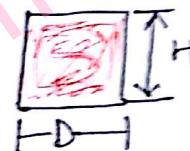
Ability of Moulding sand to allow the gases to escape is known as Permeability.

It is expressed by Permeability number.

$$P_n = 60 - 120$$

$$P_n = \frac{V_a H}{P A T}$$

grab



V = Volume air escape the job (2000 cm^3)

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

$$\begin{aligned} H &= D = 2'' \\ &= 2 \times 2.54 \end{aligned}$$

by American Foundry Society

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

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

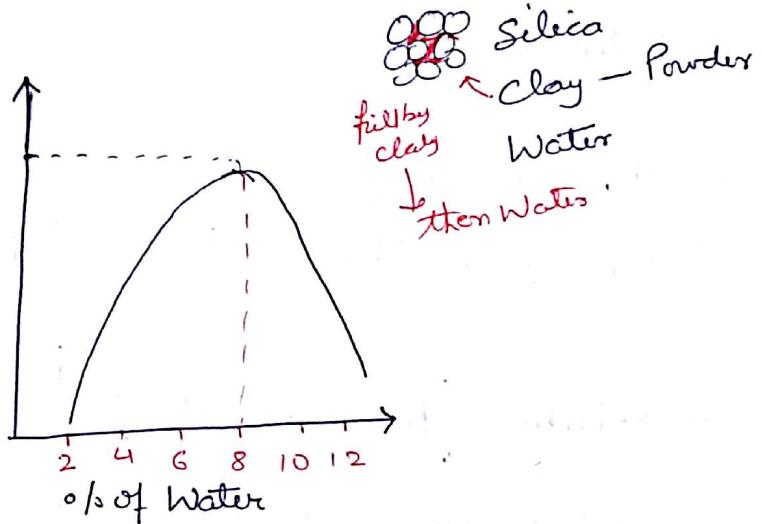
T = time taken to escape gas out the Specimen.

P_o = difference of Pressure (dyn/cm^2)

$$P_n = \frac{V_a H}{P A T}$$

Permeability v/s % of Water

Permeability



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

Qn) 2000 cm³ of air is allowed to Standard Cylindrical Specimen for 1.5 minutes. Manometer indicates pressure difference as 5 gm/cm². What is the Permeability of Moulding Sand.

Soln

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

$$P_m = 66.87$$

NewtonDesk.com

NewtonDesk.com

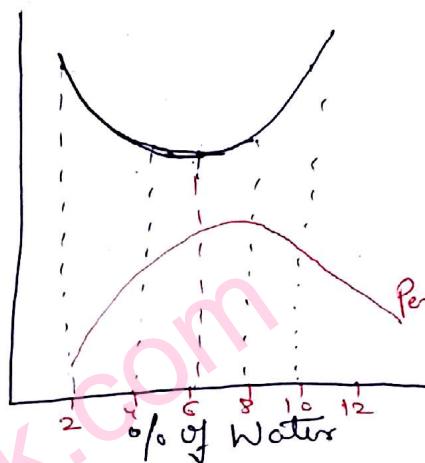
→ Flowability :-

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

It is also influenced by

Silica
Clay
Water

flowability

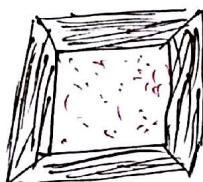


→ Strength of the Mould :-

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, around the cavity, Sand will become dry and strength of the mould is dry strength.

Hot Sand :

After the become the Sand dry, 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) | Permeability +
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.
H is a Surface Property.

→ if the mould Hardness is ↑ more than 80,
Permeability 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:

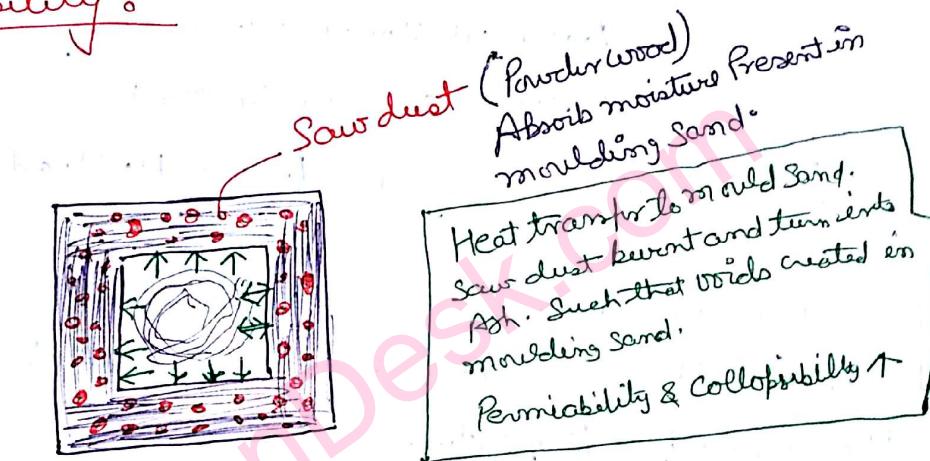
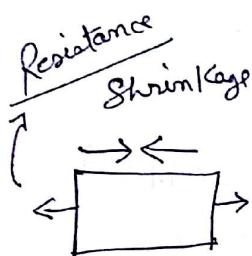
Bond formation b/w two different materials.

7) Cohesive Property:

Bond formation b/w same material

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

8) Collapsibility:



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

After Solidification cracks are formed on moulding sand.

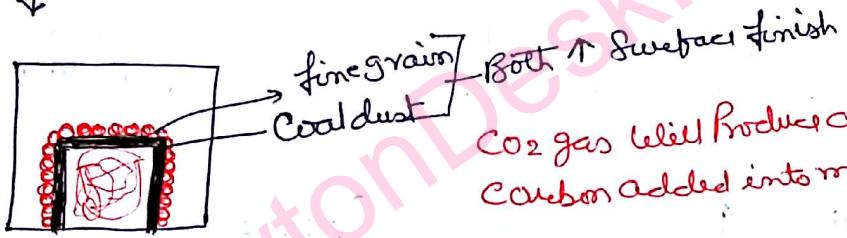
Collapsibility

Additives Used in moulding Sand :-

Saw dust
or
Wood Powder/Flour] Collapsibility & Permeability

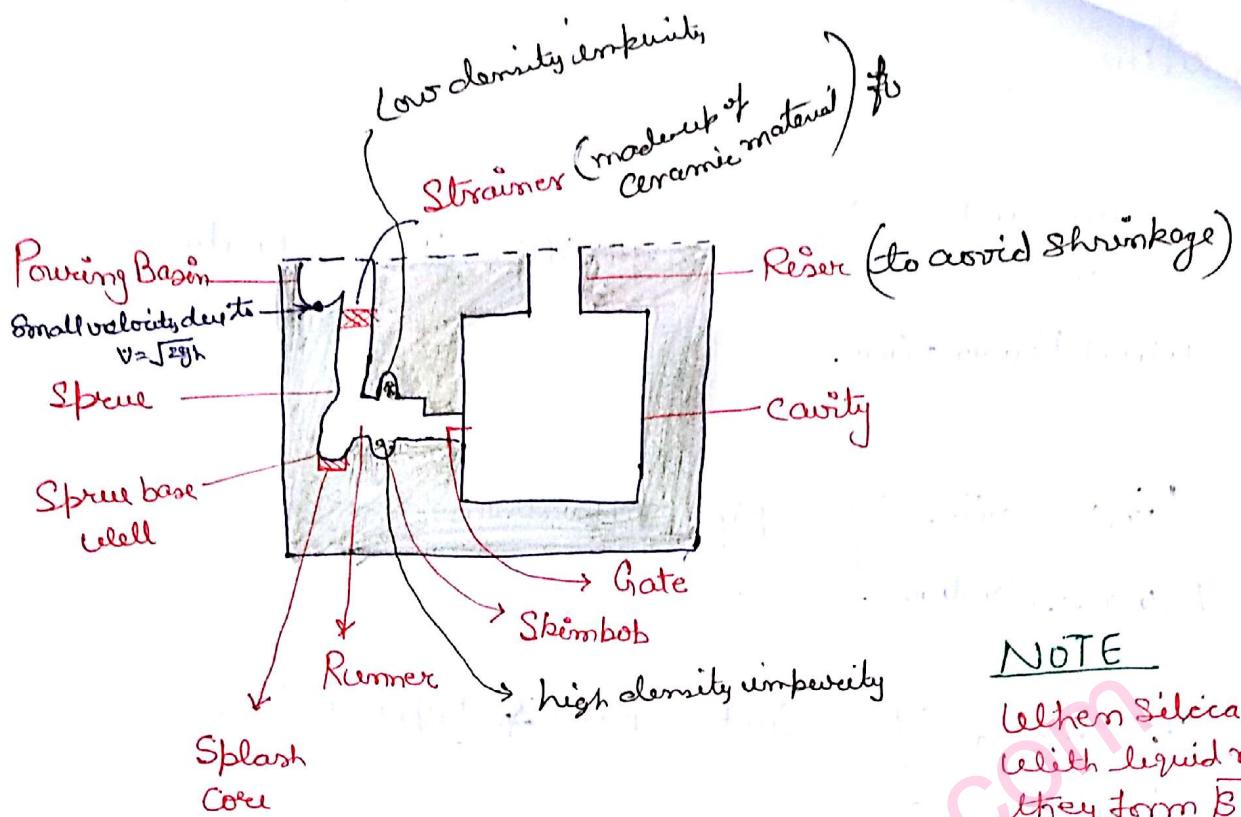
Linseed Oil,] Mould Hardners
Molasses, desctrin]

Coal dust &
Graphite] Surface finish & Refractoriness



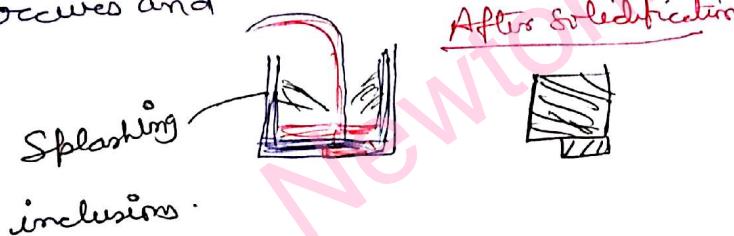
Both ↑ Surface finish
 CO_2 gas will produce after burning of carbon added into moulding sand.

Elements Of Gating Design :-

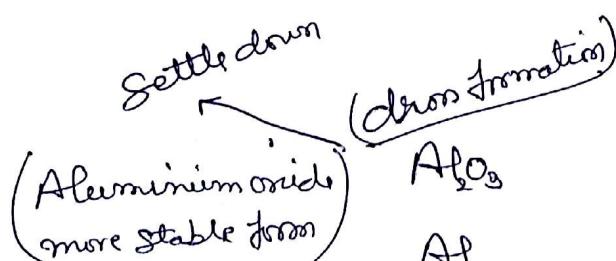


NOTE

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



Flow must be laminar



Density

3.6 gm/cm³ — Density more than
Pew liquid
2.7 gm/cm³

Reactivity with atmosp. gas is ↑ high

topsoil
spills
gases
for ferrous metal Reactivity with atmosp. gas is ↓ less
for ferrous metal enter into cavity with high velocity

NOTE

When Silicarneised
With liquid metal
they form SiC

Silicon Carbide
which are Hard &
Brittle

NOTE

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

Casting
Mould
System

for Steel, brass = 80-85%.

Al

Objectives of Gating Design:-

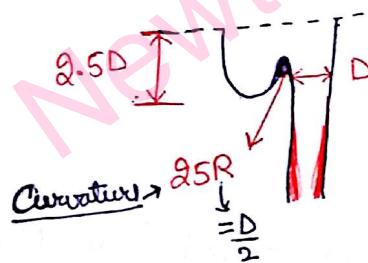
- 1) Design the gating elements, such that liquid metal can be enter into the cavity with optimum velocity, within a given time, without causing Turbulence, Splashing of liquid metal & mould erosion.
- 2) Design the gating element, such that pure liquid metal can be enter into cavity, without air aspiration effect.
- 3) Design the gating elements to produce max. Casting Yield.

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

V_c → Volume of Cavity

V_g → 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 sleeve, to minimise the erosion.

(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/m³. Assume height of the sprue as 20 cm. height of the pouring basin as 5 cm.

Soln

$$\dot{m} = 20 \text{ kg/s}$$

$$\rho = 7800 \text{ kg/m}^3$$

$$h_s = 20 \text{ cm}$$

$$h_c = 5 \text{ cm.}$$

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

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

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

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

$$Q = A_2 V_2$$

$$V_2 = \sqrt{2gh_c}$$

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

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

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

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

$$\boxed{d_2 = 5.64 \text{ cm}}$$

$$Q = A_3 V_3$$

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

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

$$V_3 = 221.47 \text{ cm/s}$$

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

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

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

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

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 $6.5 \times 10^5 \text{ mm}^3/\text{s}$. What is the cross sectional area of Sprue at the bottom.

$$h_s = 200 \text{ mm}$$

$$A_1 = 650 \text{ mm}^2$$

$$\phi = 6.5 \times 10^5$$

$$A_3 =$$

$$\phi = A_2 V_2$$

$$V_2 = \sqrt{2gh_c}$$

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

$$\frac{(650000)^2}{650} = \sqrt{2 \times 9.81 \times h_c}$$

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

$$3312.9 = \sqrt{h_c}$$

$$\phi = A_2 V_2$$

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

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

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

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

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

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

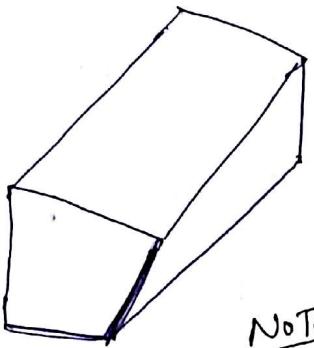
from Continuity

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

$$\phi = A V$$

Design of Runner :-

(1)



Note →

Trapezoidal cross section

Highest Coefficient discharge

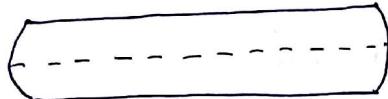
$$= 0.9$$

more surface area

~~more Surface area, more heat Rejection, & metal Solidity before getting into Cavity. So~~

(2)

To minimize used.



(Cylindrical Shape)

~~Circular Cross~~

section

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 (In gate)

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.t. 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:

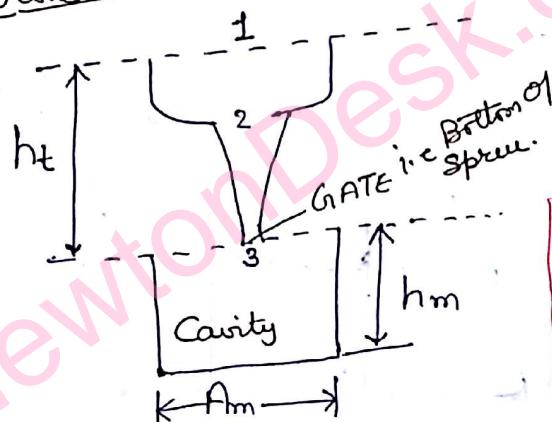
Note: Only use for ferrous material.

Time taken to fill cavity is less

steps very less

uniform solidification due to favorable

temp gradient $\frac{dt}{h} = \frac{dt}{dx}$



Note:
Preferred for large size cavity

$$A_3 = A_g$$

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

Note:
if $P_p \ll P_a$ then
air aspiration occurs

Note: if direct flow
Metal oxide form
Not use for non-ferrous (Non) material & aluminum

- 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 used 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

$$Q = A_g V_g = A_m \cdot V_3$$

Favorable →

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

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

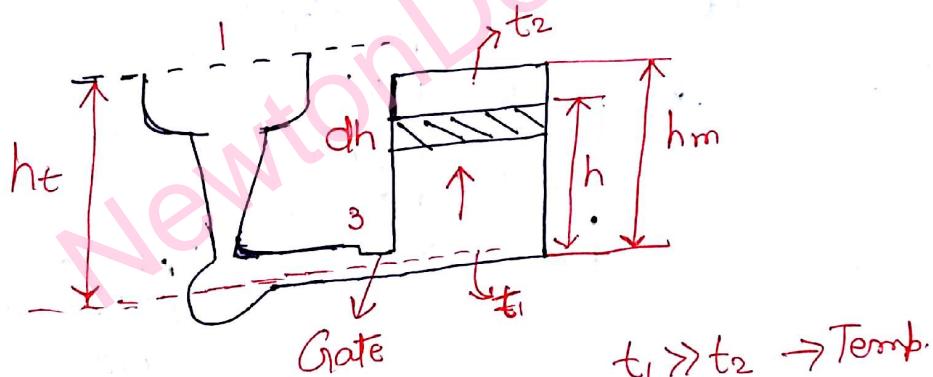
$$\text{GATE} \quad t_f = \frac{V_m}{A_g V_g} = \frac{V_m}{A_g \times \sqrt{2g} h_t}$$

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

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



$$t_1 \gg t_2 \rightarrow \text{Temp.}$$

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

$$dt \cdot A g V_g = A_m \cdot dh$$

$$\int_0^{t_f} dt = \frac{A_m}{A g} \int_0^{h_m} \frac{dh}{\sqrt{2g(h_t - h)}}$$

$$t=0 \quad h=0$$

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

$$t = t_f \cdot h^2 h_m$$

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

Ans

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

if

$$h_m = h_t$$

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

Now multiply by $\sqrt{h_t}$ on Numer. & Denominator

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

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

$$t_{fb} = 2 t_f$$

(Qn) In a gating design, dimension of cavity is given by $50 \times 25 \times 15 \text{ cm}^3$. Height of the liquid metal, above the gate is 15cm. Cross sectional area of the gate is 5 cm^2 .

Determine,

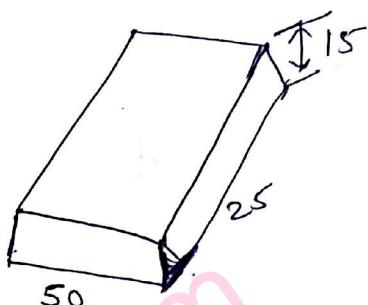
Time Required to fill the gravity using top & Bottom gate?

Soln

$$50 \times 25 \times 15 \text{ cm}^3$$

$$h_t = 15 \text{ cm}$$

$$A_g = 5 \text{ cm}^2$$



① Top gate

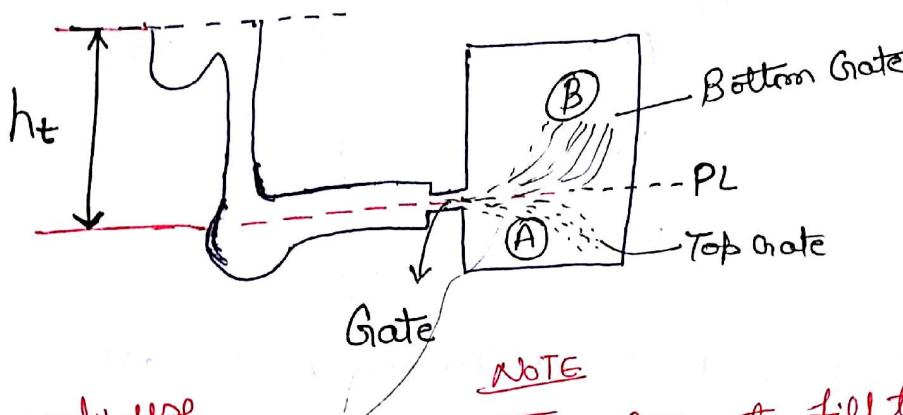
$$t_{ft} = \frac{V_m}{A_g V_g} = \frac{50 \times 25 \times 15}{5 \times 2 \times 9.81 \times 15} = 21.85 \text{ sec}$$

$t_{ft} = 21.85 \text{ sec}$

② Bottom Gate

$$t_{fb} = 2 \cdot t_{ft} = 2 \times 21.85 = 43.71 \text{ sec.}$$

3) Parting Line Gate :-

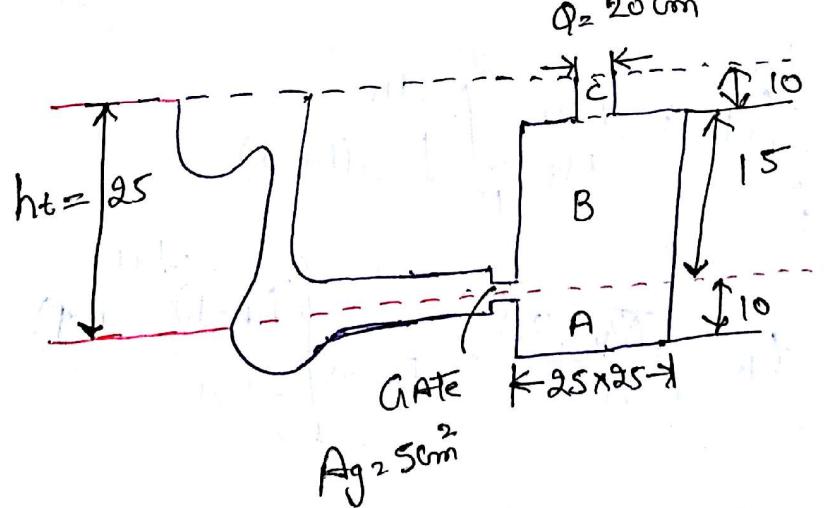


NOTE :-
Most Commonly used
gating System

- 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

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

$$dt = \frac{A_m \cdot dh}{A_g \sqrt{2g(h_t - h)}} \quad \begin{array}{l} \text{if } t=0 \ h=15 \text{ cm} \\ t=t_{fc} \ h=25 \text{ cm} \end{array}$$

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

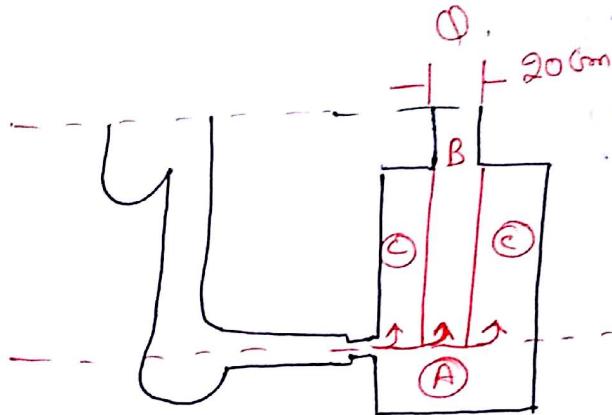
$$t_{fc} = \frac{\pi/4 (20)^2}{5} \times \frac{1}{\sqrt{2 \times 981}} \left[\frac{(h_t - h)^{-\frac{1}{2}+1}}{-\frac{1}{2}+1} \right]_{15}^{25}$$

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

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

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

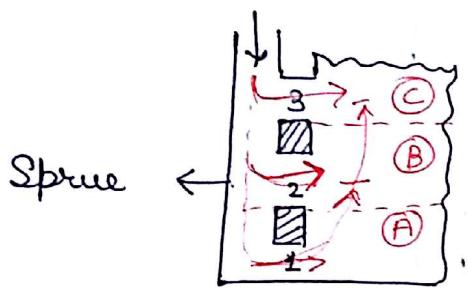
Short Method



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

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

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. Turbulence.

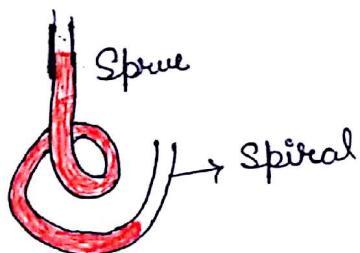
- To fill the molten liquid metal into very large size mould cavities, no. of gates are provided in the form of Step.
- liquid Metal can be gradually filling into the cavities, within a given time without causing turbulence & splash splashing of the liquid metal.

Fluidity:

AFS → American Foundry 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 determined, by conducting a spiral test.

→ Distance covered by the liquid metal before solidification in a standard Spiral

It will give the value of fluidity.

~~Property~~

~~Fluidity~~

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

✓ GMP Objective
- Which influences the fluidity most? (Property)

CHOKE Area :-

$$CA = \frac{m}{\rho t_f C_d \sqrt{2gh}}$$

- It is the min. cross-section area in all the gating elements.
- It will control the flow of liquid metal, which is enter into mould cavity.
- g is first parameter to be calculated in all the gating elements.

m → mass of Casting

ρ → density of material

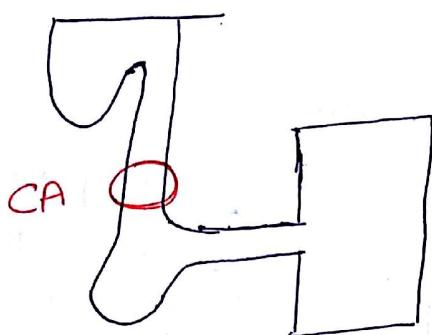
t_f → filling time Required

C_d → Coefficient of discharge

h_t → height of liquid metal above the gate.

Un-Pressurised Gating :-

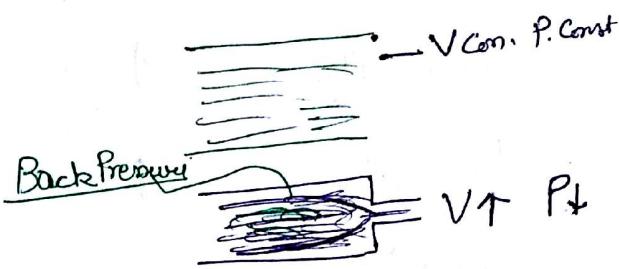
$$CA = As$$



1: 2: 4
1: 2: 3
0.5: 2: 15

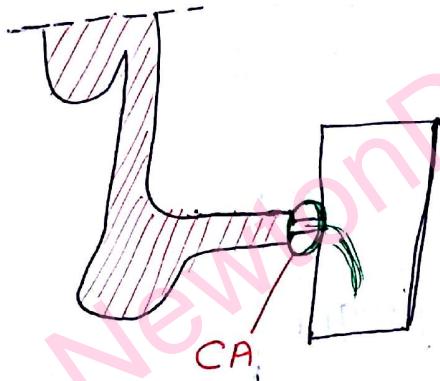
NOTE :-

- Used for non ferrous material like Al etc.

Pressurised Gating :-

Used for Ferrous material

NOTE
→ turbulence
Splashing
occurs due to ↑ V.



$$CA = Ag$$

Job interview

$$\uparrow \text{Casting} = \frac{V_c}{V_c + V_{g\downarrow}}$$

Yield

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

At the Back of gate
pressure is created on best
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

Up Pressurised Gating

- Choke Area is at the bottom of the Spue.
- Velocity of the liquid metal, which enter into Cavity will be less.
- There is no possibility of Turbulence & Splashing of liquid metal.
- 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 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

$$\begin{array}{l} 1 : 2 : 4 \\ 1 : 2 : 3 \\ 0.5 : 2 : 1.5 \end{array}$$

Unpressurised Gating used for Non ferrous

$$\begin{array}{l} 3 : 2 : 1 \\ 2 : 2 : 1 \\ 2 : 2 : 0.5 \end{array}$$

Pressurised Gating \rightarrow use for Ferrous

[2:1:2 \rightarrow Not exist because of chance of erosion]

[1:2:1 \rightarrow Pressurised Gating System]

(Q) In a gating design, gating Ratio is 1:2:3. Let us consider 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

$$\text{Gating Ratio} = 1:2:3$$

$$m = 30 \text{ kg}$$

$$\rho = 2600 \text{ kg/m}^3$$

$$t_f = 11.2 \text{ sec}$$

$$h_t = 250 \text{ mm}$$

$$C_d = 0.98$$

$$C.A = \frac{30}{2600 \times 11.2 \times \sqrt{2 \times 0.25} \times 0.98}$$

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

As it is unpressurised gating system.

1. 2:3
Area of ~~gate~~ Choke

$$CA = A_s = 4.75 \text{ cm}^2$$

$$A_g = 3 A_s$$

$$= 3 \times 4.75 = 14.25 \text{ cm}^2$$

$$\boxed{A_g = 14.25 \text{ cm}^2}$$

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

$$d_g = 4.25$$

dia of the gate

$$A_r = 2 A_s = 2 \cdot 4.75 \\ = 9.5 \text{ cm}^2$$

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

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

$$d_r = 3.47 \text{ cm}$$

Solidification Time :-

Chvorinov's Principle :-

NOTE :- NewtonDesk.com

①

$$(ts)_c > (ts)_C$$

conting

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

VOL	→ Amount of Heat available
Surface Area	→ Amount of Heat Transfer

$$\uparrow ts = K \left(\frac{V}{A}\right)^2 \quad \text{imb}$$

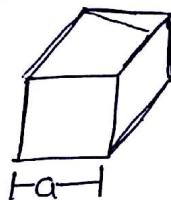
$K \rightarrow$ Solidification factor (S/m^2)

$$\rightarrow (S/m^2)$$

Volume to Surface area

$$\frac{V}{SA}$$

①



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

Cube

②

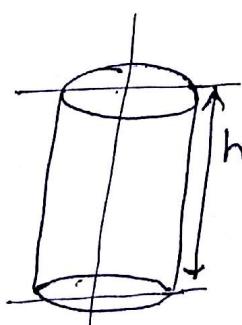
Sphere



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

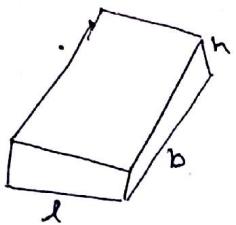
③

Cylinder



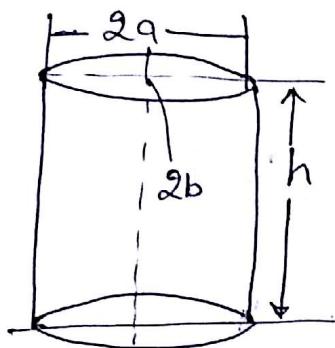
$$\frac{V}{SA} = \frac{\frac{\pi}{4} d^2 \cdot h}{2 \cdot \frac{\pi}{4} d^2 + \pi d h} =$$

(4)

Slab

$$\frac{V}{A} = \frac{l b h}{2(lb + bh + hl)}$$

(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 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?

$$r_1 = 2 \text{ mm} \quad ts_1 = 10 \text{ sec}$$

$$r_2 = 4 \text{ mm} \quad ts_2 = ?$$

$$ts \cdot \frac{V}{A} =$$

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

$$\frac{ts_1}{ts_2} = \left(\frac{r_1}{r_2}\right)^2$$

$$\frac{10}{ts_2} = \left(\frac{2}{4}\right)^2$$

$$ts_2 = 40 \text{ sec}$$

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

$$ts_1 = 5 \text{ min}$$

8 times heavier than

$$ts_2 = ?$$

$$m_2 = 8m$$

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

$$V_2 S_2 = 8 V_1 S_1$$

$$V_2 = 8V_1$$

$$a_2^3 = 8a_1^3$$

$$a_2 = 2a_1$$

$$\frac{ts_1}{ts_2} = \left(\frac{a_1}{a_2}\right)^2$$

$$\frac{5}{ts_2} = \left(\frac{a_1}{2a_1}\right)^2$$

$$ts_2 = 20 \text{ min}$$

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

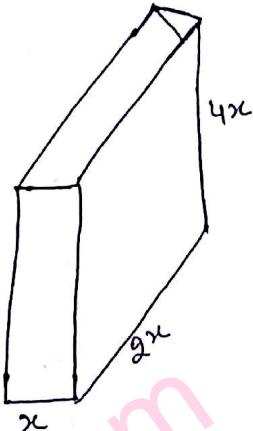
$$V = 1x \cdot 2x \cdot 4x = 8x^3$$

$$\begin{aligned} A &= 2(1x \cdot 2x + 2x \cdot 4x + 4x \cdot 1x) \\ &= 28x^2 \end{aligned}$$

$$V_C = V_{Sl}$$

$$a^3 = 8x^3$$

$$a = 2x$$



$$\frac{(ts)_{\text{Cube}}}{(ts)_{\text{Slab}}} = \frac{\left(\frac{V}{A}\right)_C^2}{\left(\frac{V}{A}\right)_{\text{Slab}}} = \frac{A_{\text{Sl}}^2}{(A_C)^2}$$

$$\begin{aligned} &= \frac{(28x^2)^2}{(6a^2)^2} = \left(\frac{28}{6}\right)^2 \left(\frac{x}{a}\right)^4 \\ &= \left(\frac{28}{6}\right)^2 \cdot \left(\frac{x}{2x}\right)^4 \\ &= 1.36 \end{aligned}$$

Riser :-

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

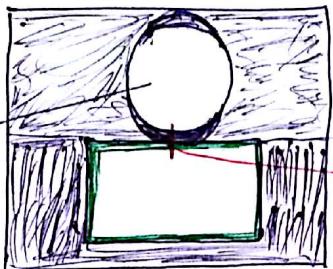
min

→ Solidification time \rightarrow more

→ Rate solidification in Riser is less
in Cavity is high

Not used

due to thermal conductivity
molten metal get
solid at Center
force and molten
liquid at Center.
So if shrinkage occur
it will not supply
molten metal to cavity

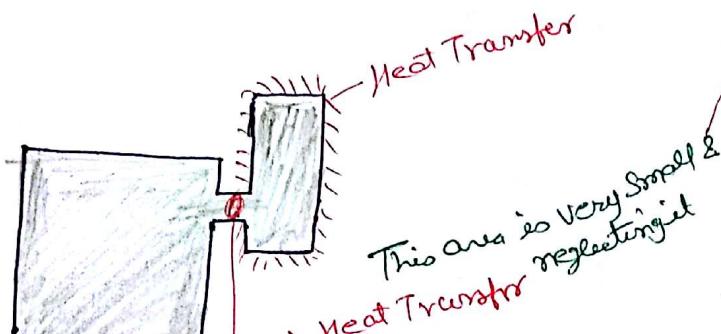


Cylinder \rightarrow Riser Preferred

→ 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.

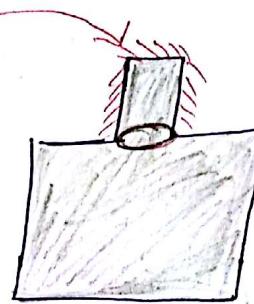
Types Of Riser :-

(1) Side Riser (For high depth)



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

(2) Top Riser



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

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 :-

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

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

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

Assuming volume as constant

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

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

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

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

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

$$\boxed{h = d}$$

Area to Volume Ratio

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

Putting $h=d$

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

Top Riser

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

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

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

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

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

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

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

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

Putting $h = d/2$

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

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

Riser Design :-

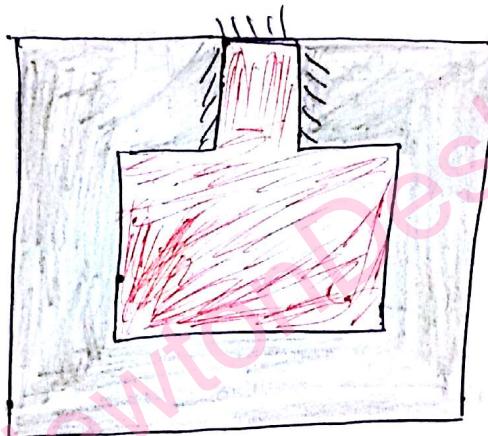
i) (a) Volume of Riser = $3 \times \%$ of Shrinkage vol. of Casting

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

$$\downarrow$$

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

$$(h \& d)$$



→ Insulator material

→ Exothermic material

↳ (Thermite 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

$$X = \frac{a}{y-b} + c$$

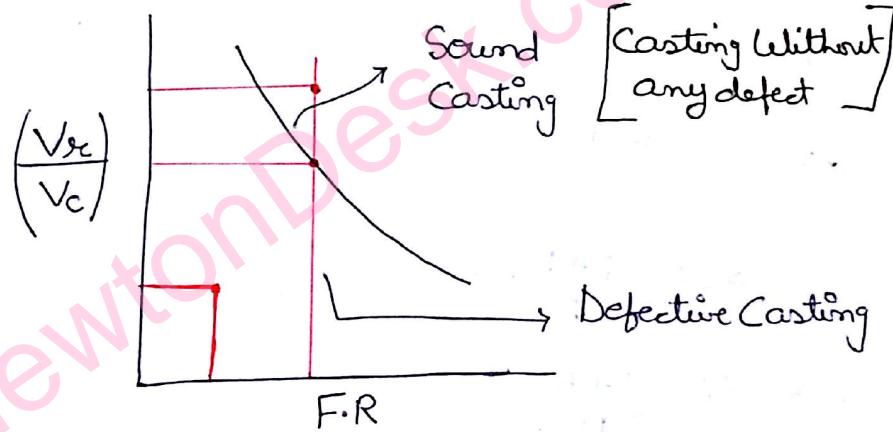
$$X = F.R$$

NOTE 2

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

$$Y = \frac{V_r}{V_c} \quad a, b, c \text{ are Constants}$$

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



- 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 \rightarrow Max, L, W, T

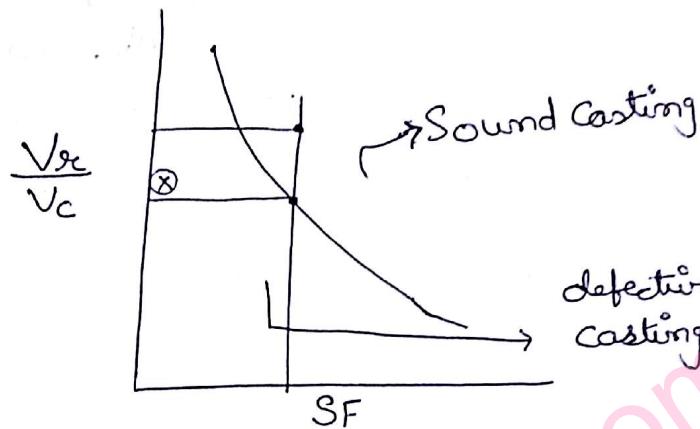
for Hollow \rightarrow mean effective value

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

L \rightarrow Length

W \rightarrow Width

T \rightarrow Thickness



Shape factor:

$$① \text{ Cube: } \rightarrow SF = \frac{a+a}{a} = 2$$

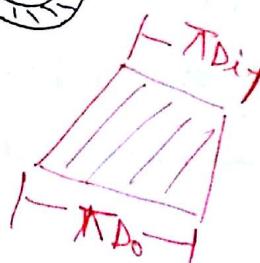
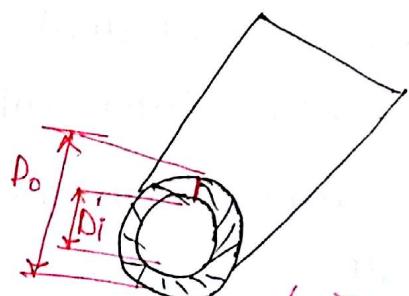
$$② \text{ Sphere (solid)} \rightarrow SF = \frac{D+D}{D} = 2$$

$$③ \text{ Slab} \rightarrow SF = \frac{L+B}{H}$$

$$④ \text{ Cylinder} \rightarrow SF = \frac{H+D}{D}$$

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

$$\begin{aligned} \frac{V_{r2}}{V_c} &= X \\ V_{r2} &= V_c \times X \\ V_r &= \frac{\pi}{4} d^2 \cdot h \\ \text{h & d Cambi find} \end{aligned}$$



4) Modulus Method :-

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

$$\boxed{m_r = 1.2 m_c}$$

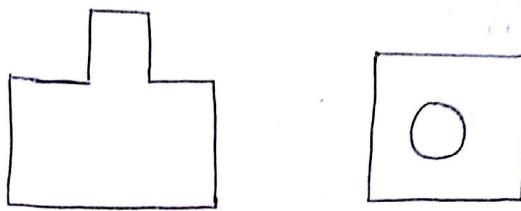
~~not use~~

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

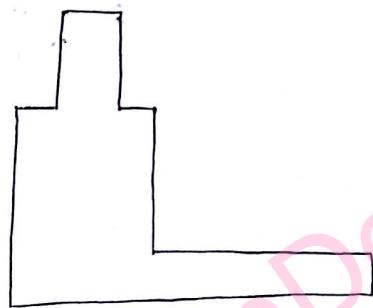
$$\boxed{d = \text{can be find}}$$

Position of Riser :-

1) For Uniform Thickness :-



2) For Non-Uniform Thickness :-

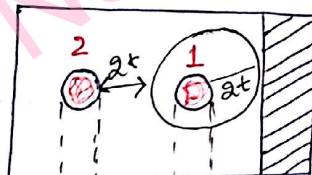


3) For Minimum Thickness & Max. Surface Area :-

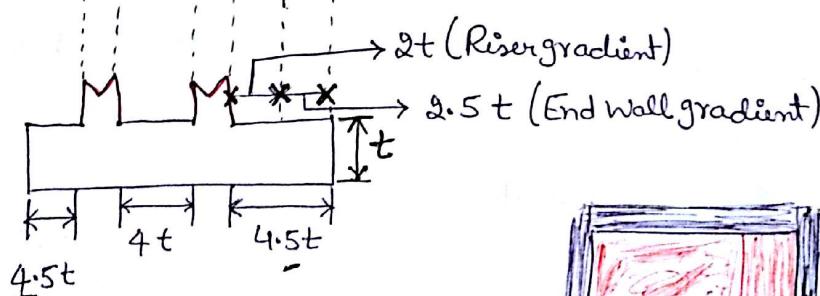
e.g. Plate, Slab, bars

$$L = 13t + 2d$$

neglecting



implies → riser supplies surface of 2 times thickness



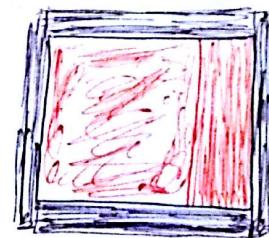
NOTE

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 line



till $2.5t$ No Need of liquid from Riser
big shrinkage is compensated by liquid metal at Centre

① With end Wall effect :-

$$L = 13t \quad (\text{two riser})$$

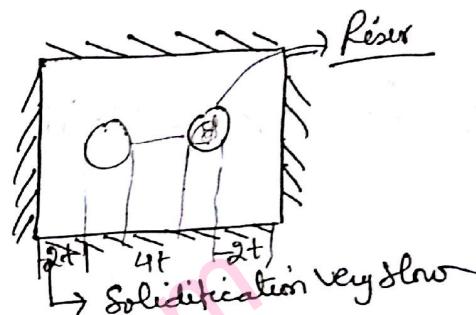
There is thickness

$$L = 9t \quad (\text{one riser})$$

② Without end Wall effect :-

$$L = 8t \quad (\text{two riser})$$

$$L = 4t \quad (\text{one riser})$$

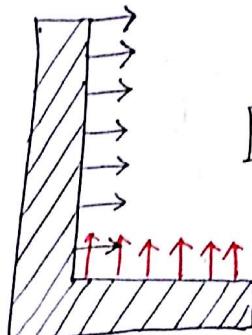
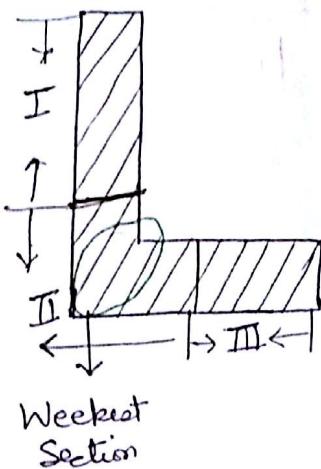


- For a Simple Shape of the Casting, like a cube, One riser is Sufficient and it is provided on the top surface of the mould at the Centre.
- For non-uniform thickness of the Casting, riser is provided close to the higher thickness of the Casting.
- For the Castings, with the min. thickness & max. Surface 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 $4.5t$.

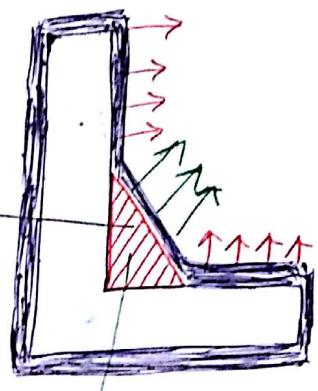
Distance b/w two risers is $4t$.

Chills & Padding:-

1) Chill:-



Chill



Metallic object of high Thermal cond. K, T_m .

* 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

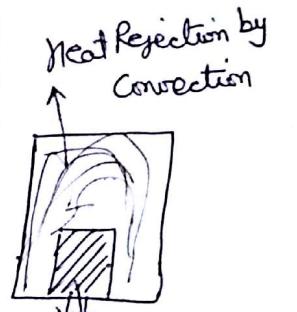
To overcome above, we provide K, T_m of material to ↑ high speed Rate of Heat Rejection (metallic object).

→ 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.

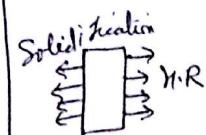
→ If the chill is external to the Surface of the mould, it is made up of high m.p. material.

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



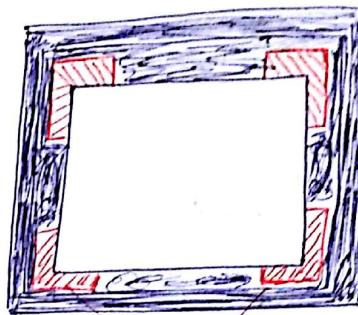
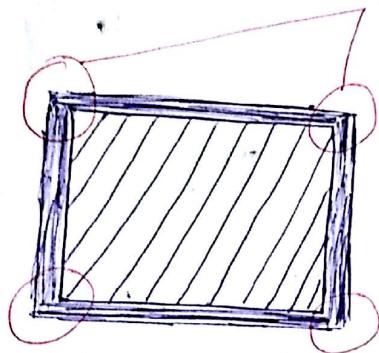
But Here H.R by Conduction

& Heat Rejection by Conduction is more than Convection



2) Padding :-

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



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

(directional solidification)
+
(Ans) ✓ High mechanical Property
uniform solidification

→ At critical cross-sections 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 :-

NewtonDesk.com

1) Expandable Moulds :

(Temporary Moulds)

- Sand Moulding
- Shell Moulding
- Investment Casting
- Full Moulding
- CO₂ Moulding

2) Permanent Moulds :

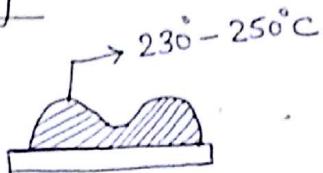
(Metallic Moulds)

- Centrifugal
- Die Casting
- Slush Casting

3) Continuous Casting :-

Shell Moulding :-

Pattern :-



Moulding Materials :-

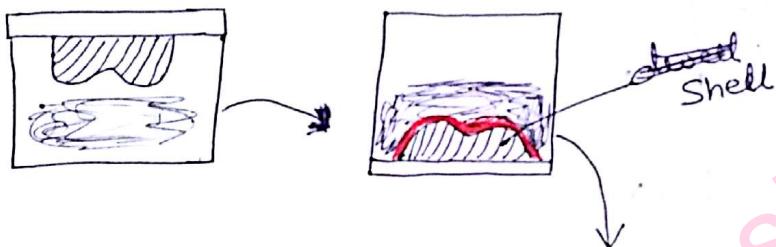
Fine grain Silica Sand

Objective

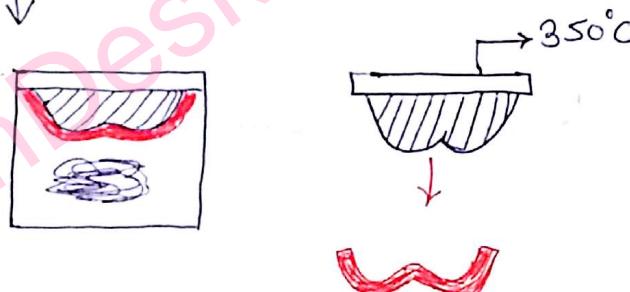
Phenolic Resins → [Phenol Formaldehyde urea formaldehyde]

Alcohol

(Q) How shell thickness can be controlled

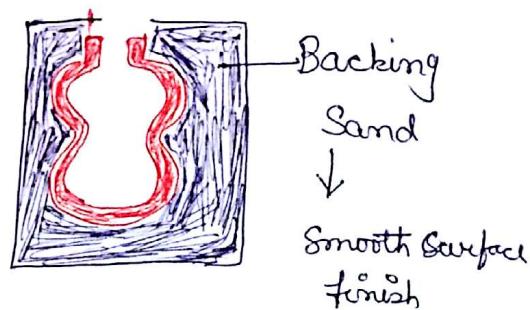


Devell time
4-5 mm
25-30 sec



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 separated from the mould box. They will be heated upto 350°C to increase the strength of the Shell.
- By separating 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 :-

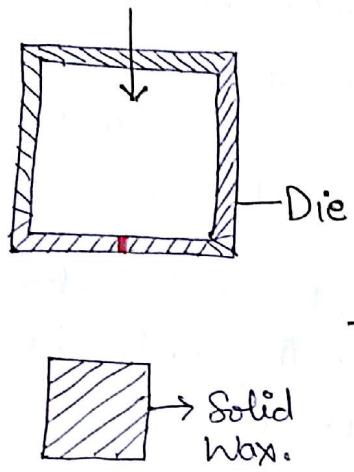
Expandable Pattern &

Expandable Mould

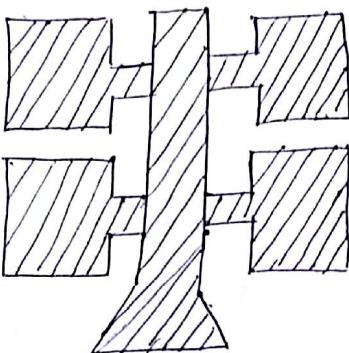
Pattern & Wax.

Lost Wax Process

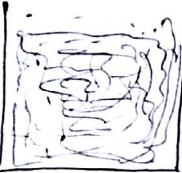
Question
Objectives



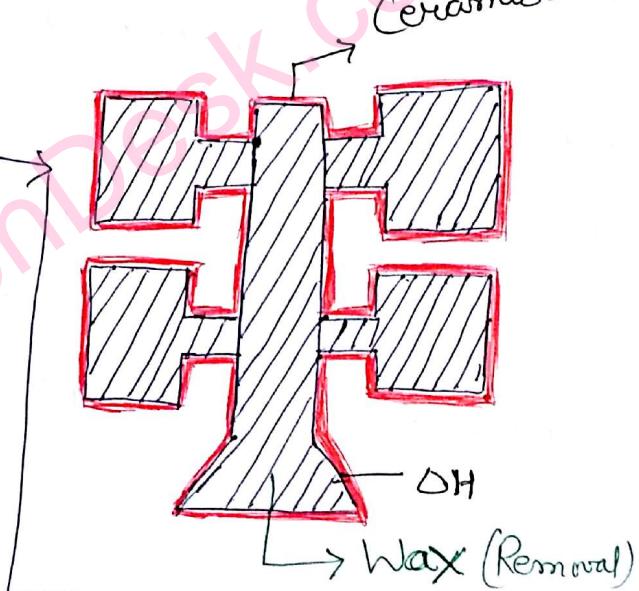
Pattern Assembly



Slurry Coatings

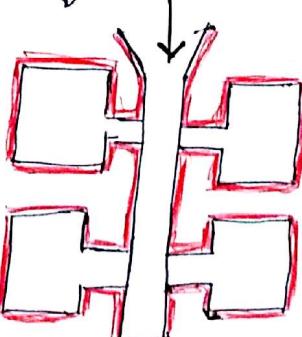


Ceramic Shell



Ethylen Silicate +
Silica + Water

Adding fine grain Ceramic material for smooth surface finish due to high melting point materials



Oven 650°C
To get this may this done by maybe some wax restriction cavity

o To overcome gas defect due to fine grains
Pattern must be kept into Vacuum To produce highly precise items

ApplicationsPattern Removal 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 vacuum conditions.
- It is an expensive process.

Full Moulding :-

Large Size, Complex Object Producer

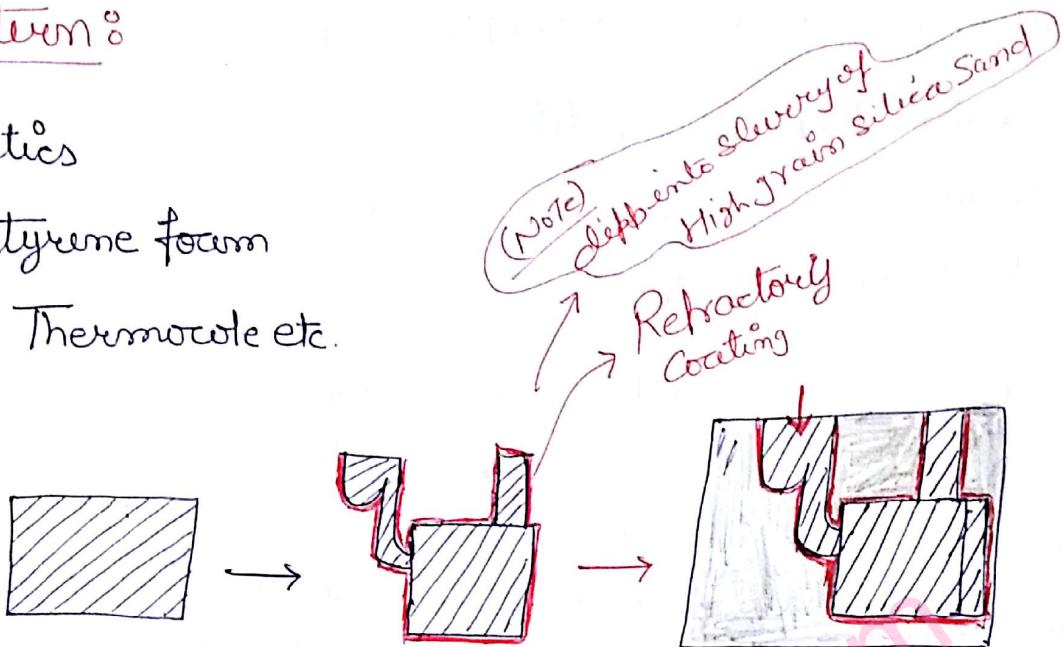
2nd Pattern Removal in gasero is full Moulding

Pattern :-

Plastics

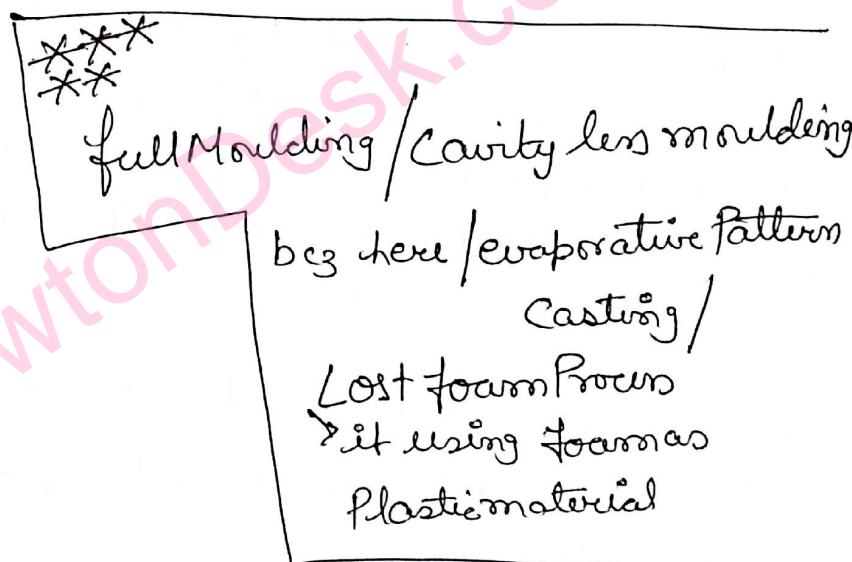
Polystyrene foam

PVC, Thermocote etc.



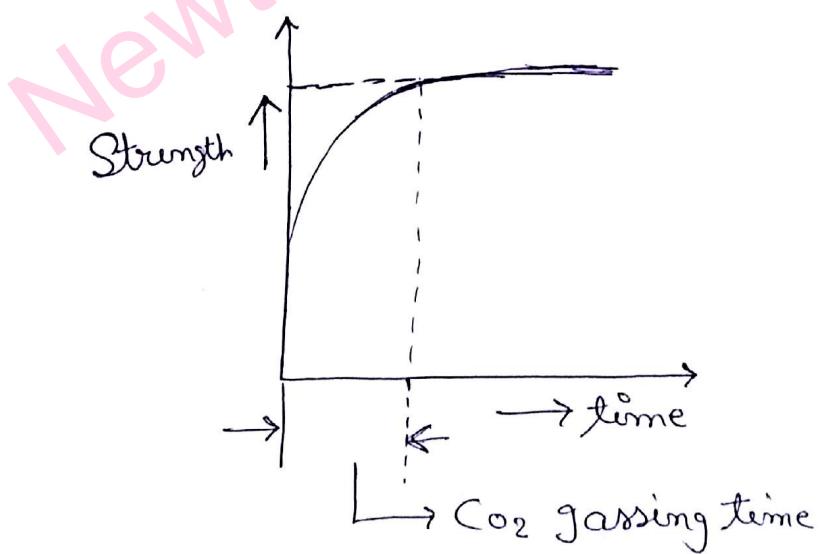
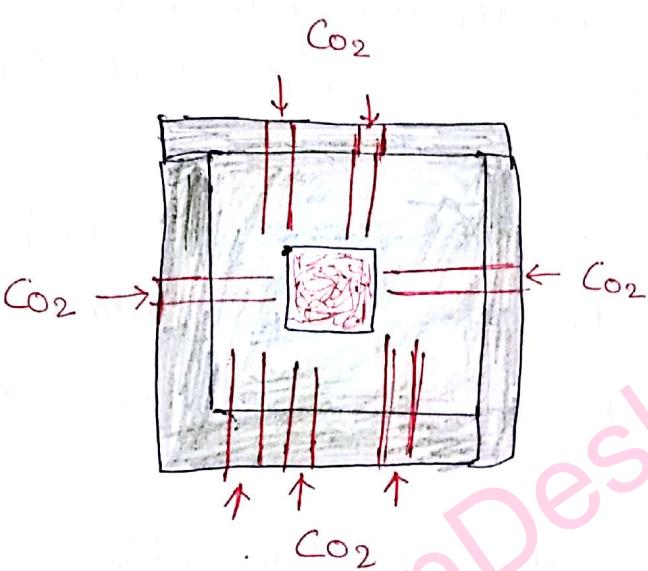
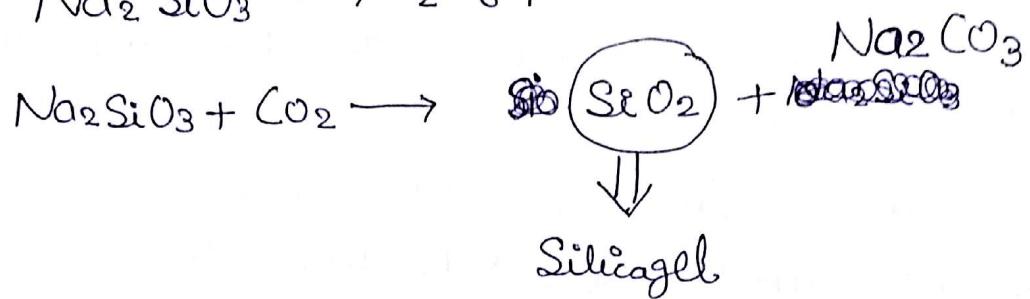
Applications:-

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



- 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 ~~still~~ Refractory Coatings.
- Liquid Metal will be directly allowed 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 mold, Casting can be Produced.
- Large Size Castings with Smooth Surface finish can be Produced.

CO₂ Moulding :-

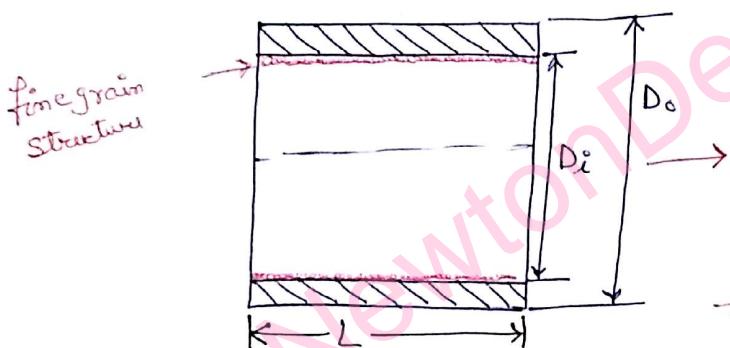
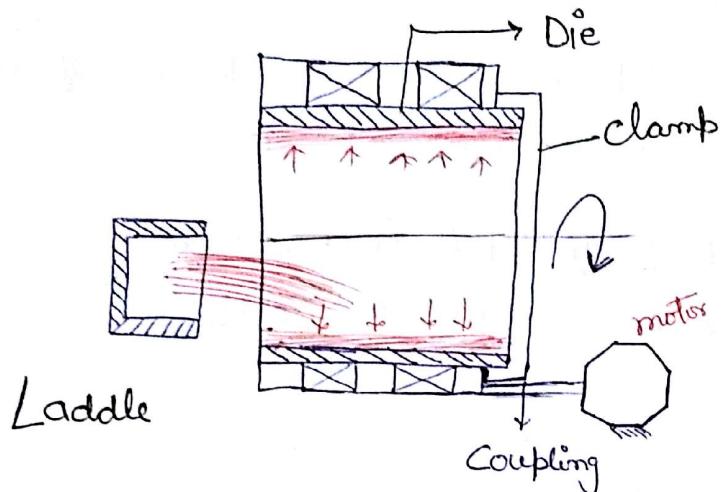


- Mould is Prepared by adding Sodium Silicate binder.
- By, Creating Small Holes, CO_2 gas will be Supplied through the mould.
- It will React with Sodium Silicate and produce silica-gel, which is having better bonding properties. Due to this, strength of the mould can be increased.
- Strength of the 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 & Hardness of large size moulds & cores.

Permanent Moulds :-

* used to produce axis Symmetric Object.

- 1) Centrifugal Casting.
- 2) True Centrifugal Casting.



- NOTE :-
- ① $F_c \rightarrow$ Centrifugal force
 - $F_c = m R \omega^2$ $F_c \propto m$
 - ② F_g - gravity force
 - $F_g = mg$

- ③ No Possibility of gas defect.

Basic Principle

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 developed & Strength & Hardness is more & high density i.e. mass

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

→ Impurities (less density)
Collected towards Centre

Applications :-

- 1) Hollow Cylindrical pipes
- 2) Gun Barrels
- 3) Large size bushes
- 4) Hollow propeller Shafts

d. A → Casting yield is 100%

d. A → How liquid & solid Shrinkage can be compensated?

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

d. Liquid & Solid Shrinkage → is 3%
then Volume to be provided is 103
to get 100% casting.

→ Boiling operation inside to get finishing.

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

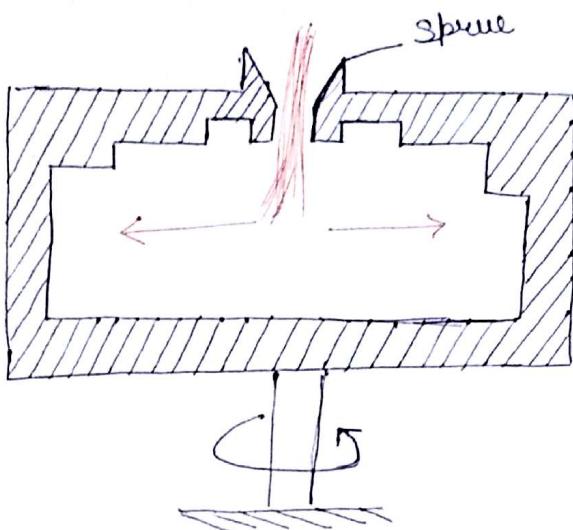
$$F = m \alpha = m R_m \omega^2$$

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

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

- 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.

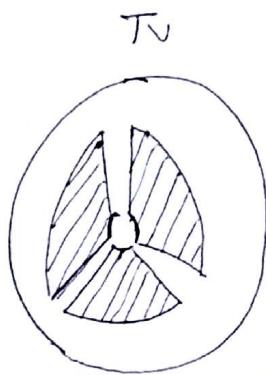
Semi Centrifugal Castings :-



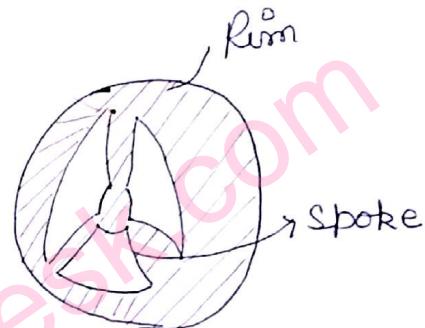
Rotation \rightarrow Vertical
underaction of
gravity

and Casting due to
Centrifugal force.
Liquid metal first fills
outside surface of cavity
and progresses toward centre

* Projection are in die
itself other than cylindrical
object & symmetric object
are produced



:- Before filling liquid metal



impt Casting yield is less due
to gating element (sprue)

Why Semi centrifugal?
due to vertical rotation and
centrifugal action

Applications

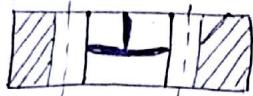
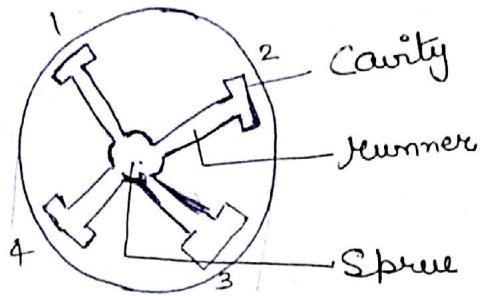
- 1) Pulleys
- 2) Wheels
- 3) Spoked wheels.

Two wheels alloy wheels

- Die Cavity is produced, along with Sprue, and it will be 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~~ circumference 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 instead die casting

- To Produce unsymmetrical objects in mass production, ~~Newton~~ ^{the} 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. Acceleration of the mould is 70g. What is rotational speed of the mould?

Soln)

$$\text{Given; } D_o = 0.52 \text{ m}$$

$$D_i = 0.5 \text{ m}$$

$$a = 70g$$

$$N = ?$$

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

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

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

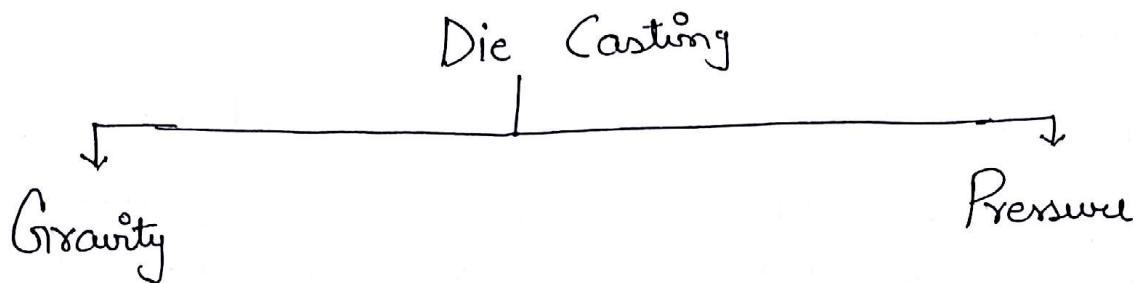
$$a = R_m \left(\frac{2\pi N}{60} \right)^2$$

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

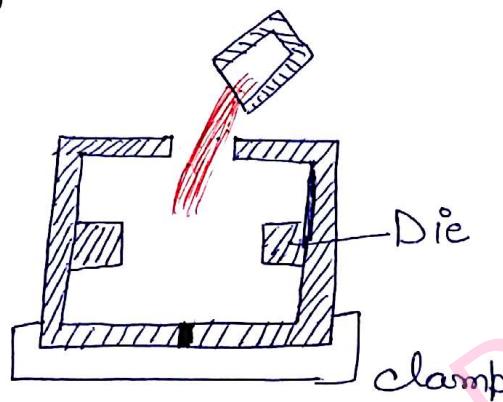
$$70 \times 9.81 = 0.251 \cdot \left(\frac{2\pi}{60} \right)^2 N^2$$

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

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 $\rightarrow 0.8 - 1.6 \text{ } \mu\text{m}$
- Fine grain structure develops 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 :

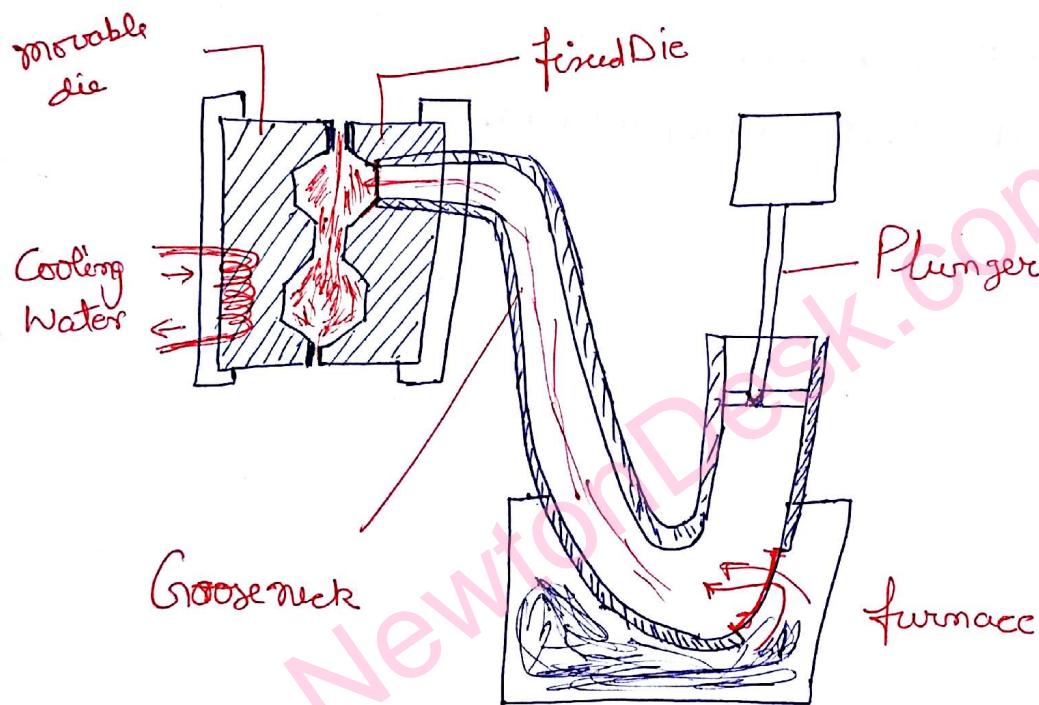
NewtonDesk.com

Pressure Die Casting

Hot Chamber

Cold chamber

Hot Chamber Die Casting :



* Gooseneck life:

Due to continuous contact of gooseneck with liquid metal in furnace
life of gooseneck is low
so it is compensated by
using thin process to low
melting point casting

Aluminum is not used
due to sticking

Note:

→ must maintain Barne Pressure
until Solidification

* Liquid & Solid Shrinkage - Compensated
by liquid metal in gooseneck
no need of Riser

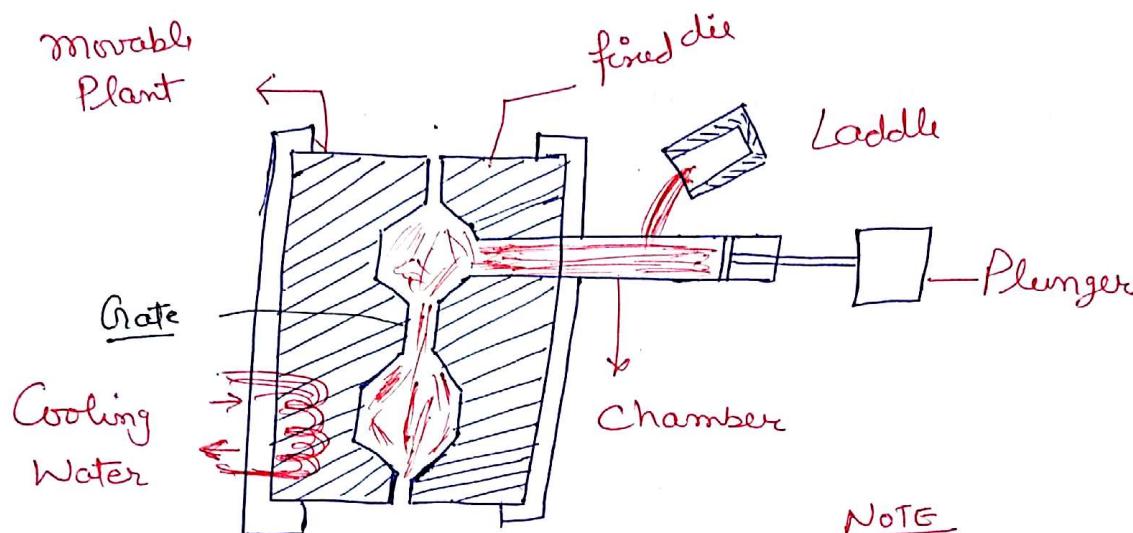
→ 150 - 200 Component / hour
↑ Production Rate

- Liquid metal is forced into the cavity under external plunger force.
- Furnace is integrated with casting unit.
- Due to continuous contact of the liquid metal with the goose neck its 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 Technique.
- Complex shape of the object can be produced.

Cold Chamber Technique :-

NewtonDesk.com

Die



NOTE

$$\text{Vol. of Chamber} = \text{Vol. of Cavity}$$

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 separated 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 Carburetors
- 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.t following.

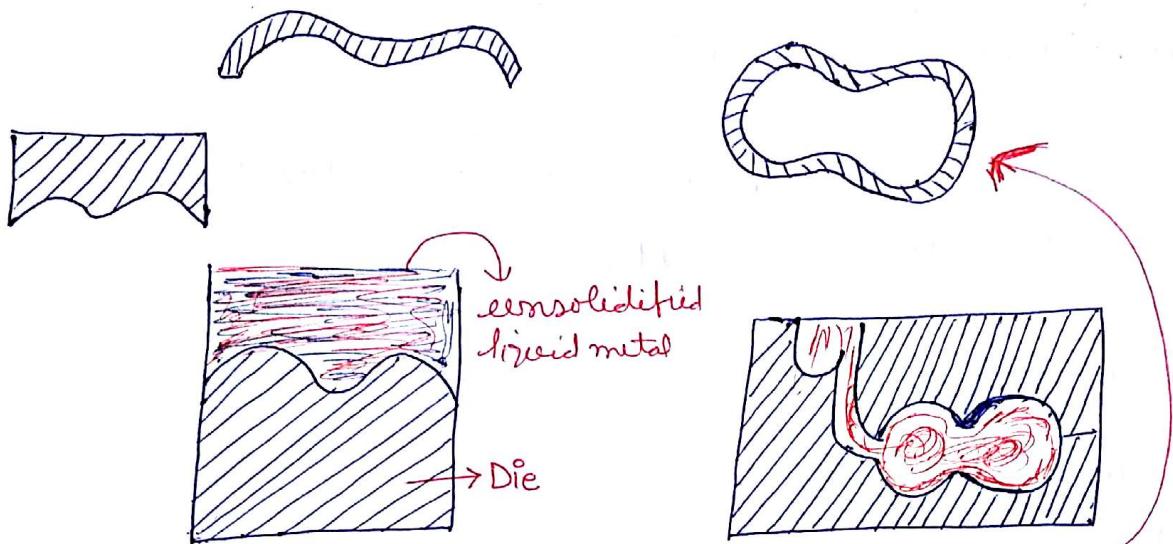
- 1) Production Rate
- 2) Complexity of the Object
- 3) melting point temp. of the material

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 :-

else \rightarrow Low melting Non fusible material



Applications:-

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

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

Note

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

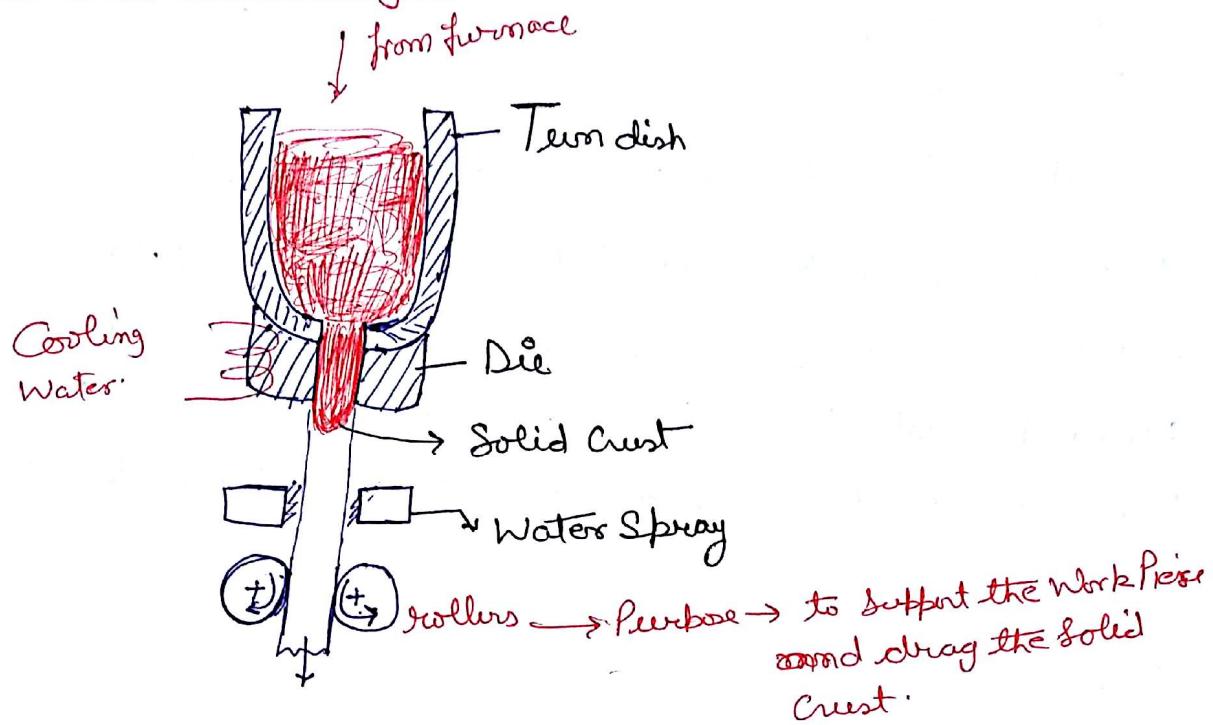
$$ts \propto (t)^2 \text{ for linear dimension}$$

$t \rightarrow \text{thickness}$

$$t_s = C_1 \sqrt{ts} + C_2$$

- To Produce thin Sections and hollow them ~~Section~~ 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 separated from Solidified metal. This is known as Partial Solidification. Generally used for non-ferrous slow melting point materials.

Continuous 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, Norman Production, Continuously 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.

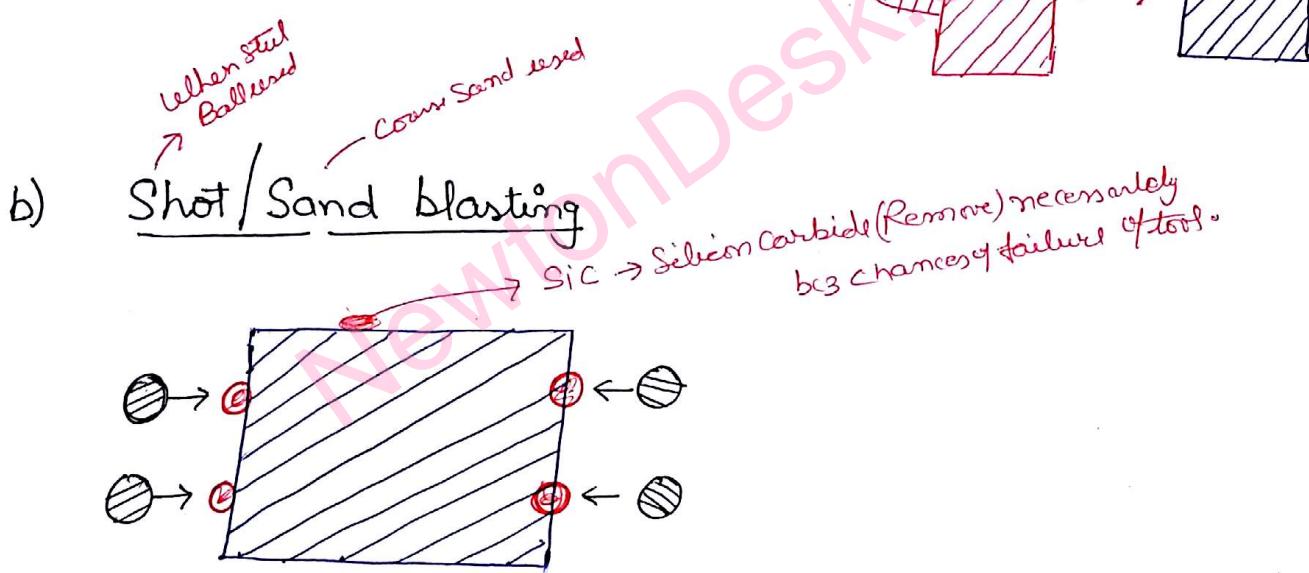
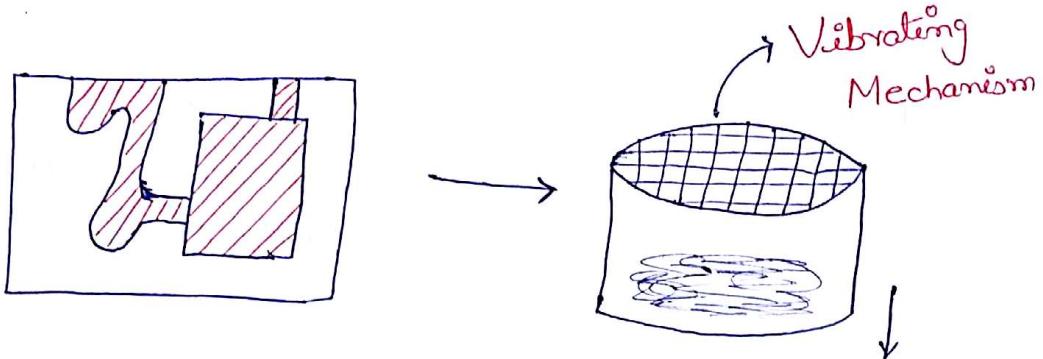
→ Depending on properties required by the object, different Cooling rates are provided on the Workpiece material.

→ Production Rate is very high.

→ Initial Set up cost is more.

Cleaning Of Casting :-

i) Fettling :-



1) Hardened Steel ball of &

\varnothing 3-5 mm

2) Coarse Grain Sand.

Fettling

It is the process of breaking the mould, using vibrating mechanism, and separating 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, Hardened Steel balls will be forced on casting along with air pressure, is known as shot blasting.

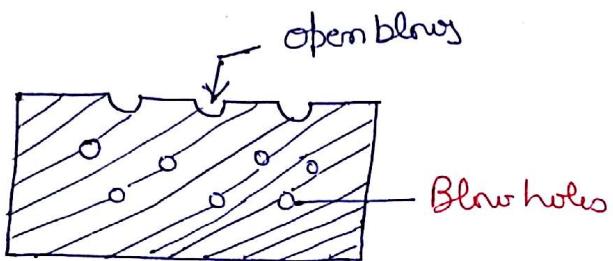
If Coarse grain Silica sand is used for cleaning of the Casting, then it is called Sand blasting.

Casting Defects :-

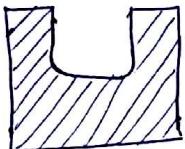
- 1) Gas Defects
- 2) Moulding Sand & Methods
- 3) Gating Design
- 4) Pouring Metal defects
- 5) Metallurgical defects
- 6) Other defects

1) Gas Defects :

a) Blow holes & open blows :-

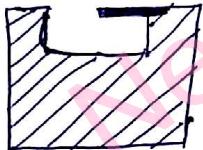


b) Scar : ← Shallow blow, and flat

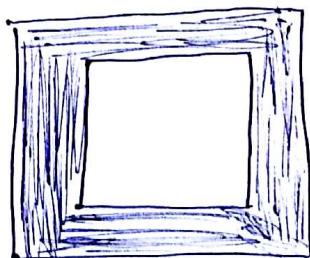
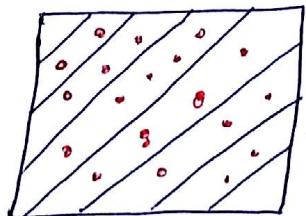


c) Blister:

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~~ blow.

b) Scars:-

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.

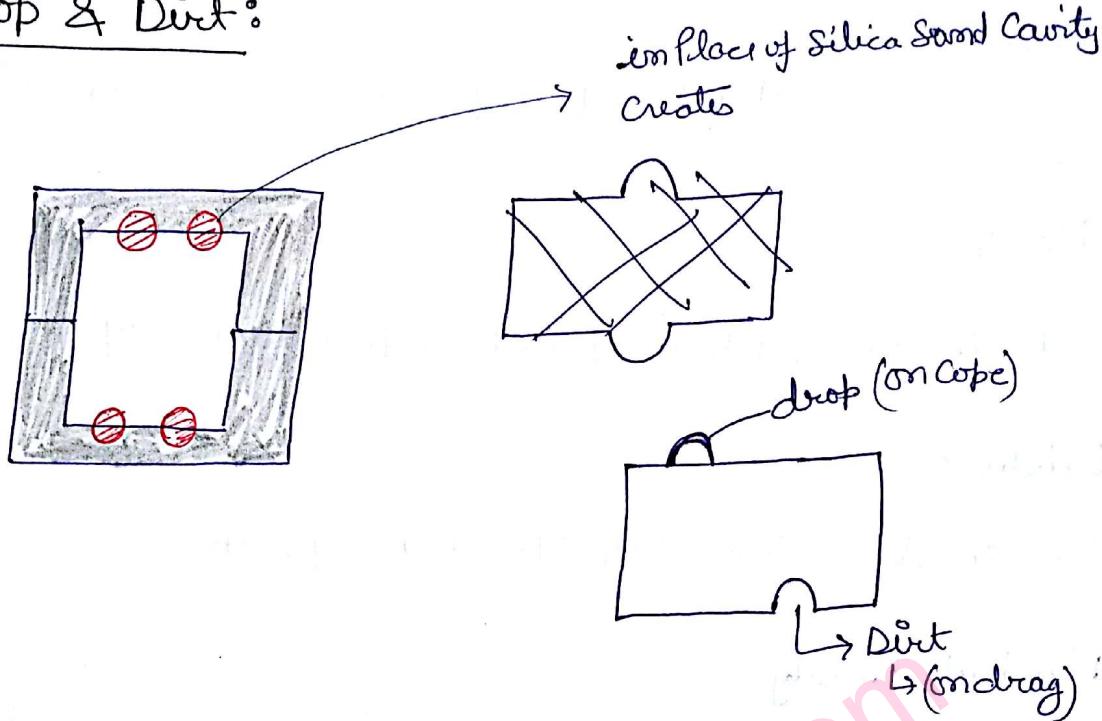


Remedies :

- 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 Permeability
- 4) Provide Vent holes.

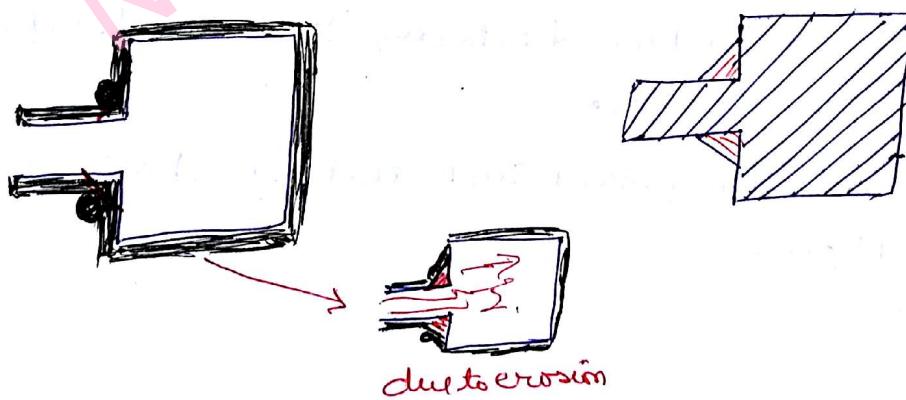
3) Moulding Sand & Methods:

a) Drop & Dirt:



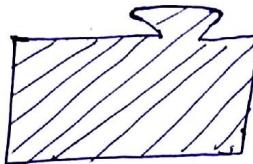
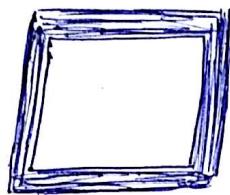
→ Due to improper Ramming, if the Silica Sand still bedrop from Cope box to drag box will form a defect on the top Surface of the Casting Known as drop & bottom Surface of the Casting Known as Dirt.

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.

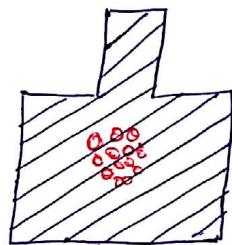
c) Scab: loose sand due to improper Rammimg in Copebox



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

3) Gating Design:

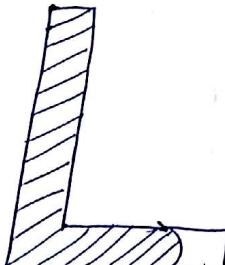
a) Shrinkage Cavities:
Causes due to Improper Riser design (obj)



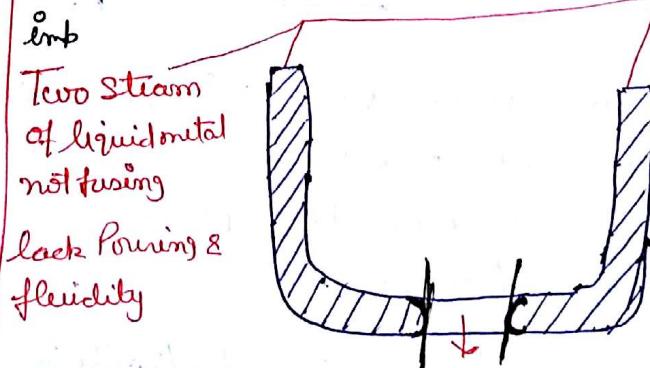
Due to Improper riser Design Cavities form due to Shrinkage of the material is Known as Shrinkage Cavities.

4) Pouring Metal Defects *Objectives 2-4 times
Gate, Match d column*

a) Misrun:-



(b) Cold Shuts



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:

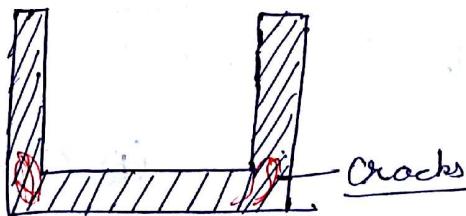
Two streams of liquid metal will not fuse properly, will form a discontinuity in the Casting Known as Cold Shuts.

Remedies:

- 1) Heat the liquid metal in the furnace 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:

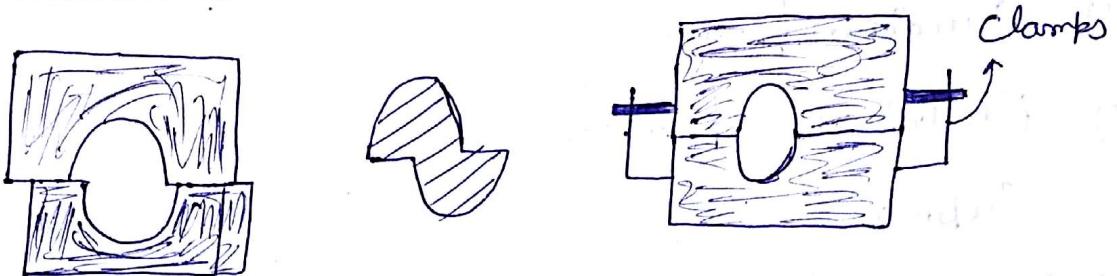


→ Due to non uniform Cooling, internal stresses will be developed in the Casting. If these stresses will be more than the Strength of material, Crack can be expected in casting and are Known as Hot tears / Cracks.

This can be overcome by Providing Chills & Padding.

⑥ Other Defects:

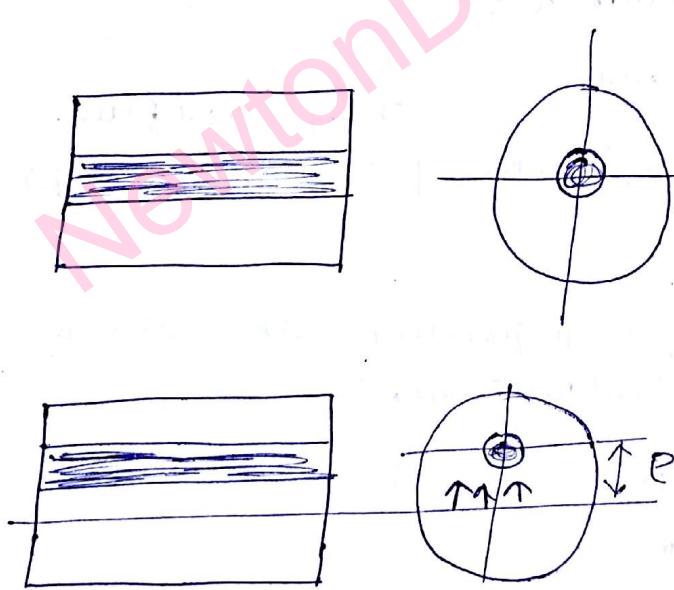
a) Mould Shift:



→ 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 dwell 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 overcome by providing core kevins & chablets.

Furnace :-

Objective

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

1) Crucible Furnace: Small quantity \rightarrow Low m.p NonFerrous material

\rightarrow This furnace is used for melting of small quantities of the liquid metal in small size founders for melting of low melting point non ferrous material.

Charge = Ore + Flux + Coke

2) Electric Arc Furnace :- Large quantity + ferrous material
Heavy steel castings else + No Pollution.
 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 :- Fe_2O_3 or used for Cast iron

~~ore~~ Fe_3O_4

Charge \rightarrow ore + Flux + Coke

\hookrightarrow Blast furnace \rightarrow Pig iron \rightarrow Cupola \rightarrow Cast iron

Porous form
Soft.

Charge
 ↓
 ORE → Pig iron
 +
 Fluorite → CaCO_3 (Lime Stone)
 +
 Coke → (To heat)
 (Pulverised form of Carbon)

→ It is used to produce Cast iron by melting Pig iron.
 By collecting the heat from flue gases, atmospheric air which is supplied to the furnace, can be heated to $200 - 450^\circ\text{C}$. It is known as Hot blast cupola.

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

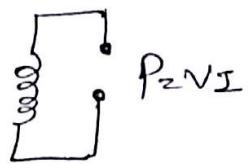
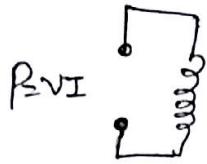
Metal : Fuel.
Melting / charge Ratio : $4:1 \rightarrow 12:1$

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

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

4) Induction furnace :- using generally.

Charge \rightarrow ore + flux



$$H = I^2 R T$$

~~Heat generation~~ Heat generated
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 both 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 ~~the~~ 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.