01/08/16

CASTING

Manufacturing processes :-

↳ It is a process of converting raw material into a finished product.

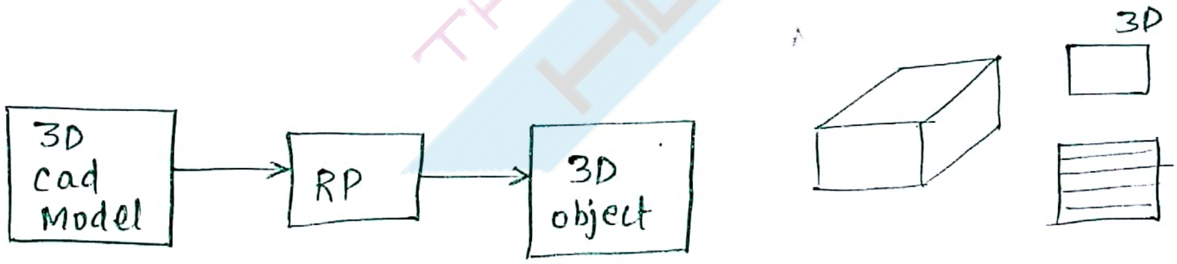
↳ It is a process of value addition to the raw material such that final product is having more value in the market when compare to raw material.

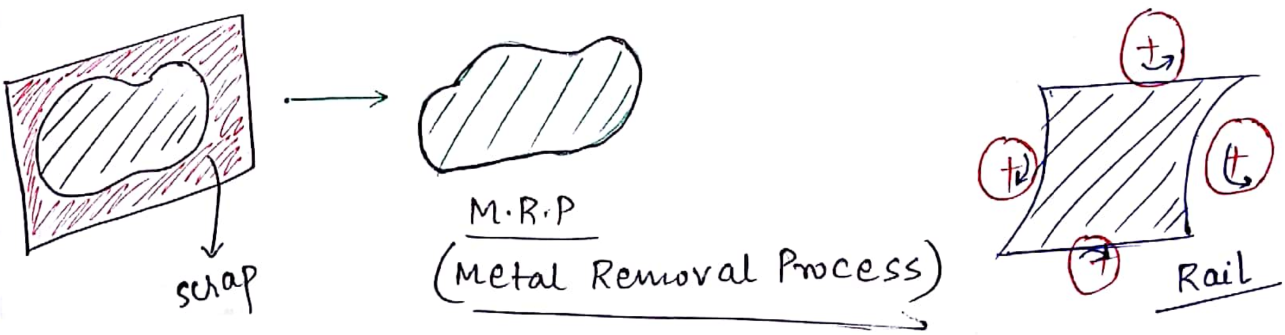
Classification :-

1. Casting → Basic / Primary
2. Forming
3. Fabrication process
4. Material Removal process

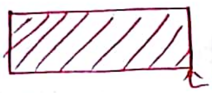
(2), (3) and (4) → Secondary

1. zero process → Forming, casting.
2. Additive " → welding, Rapid prototyping.
3. Subtractive " → Metal cutting, Machine Tools





Casting :- It is a process in which molten liquid metal will be allowed to solidify in a pre-defined mould cavity. After solidification, by breaking the mould required shape of the object can be produced.

① Pattern → 

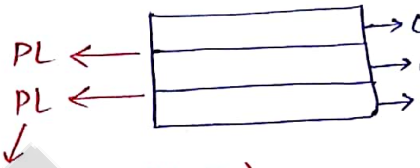
② Moulding sand.

③ Tools.

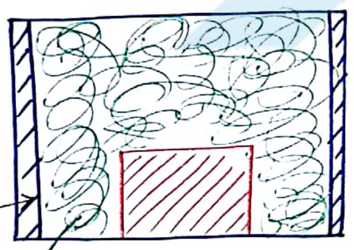
Mould Box :

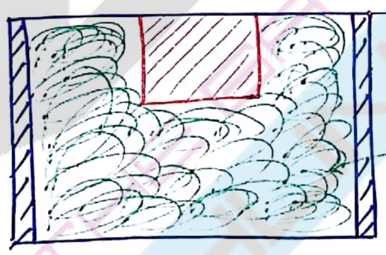
① Two Box

② Three Box



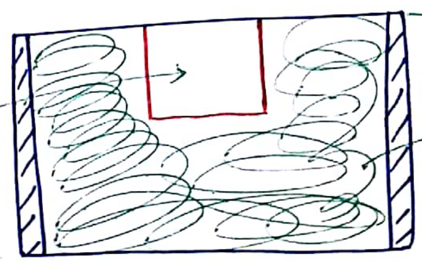
Process



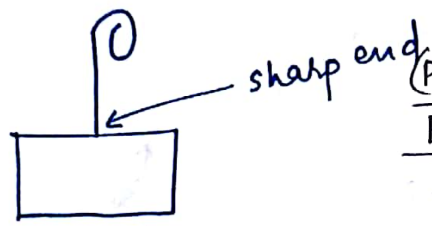


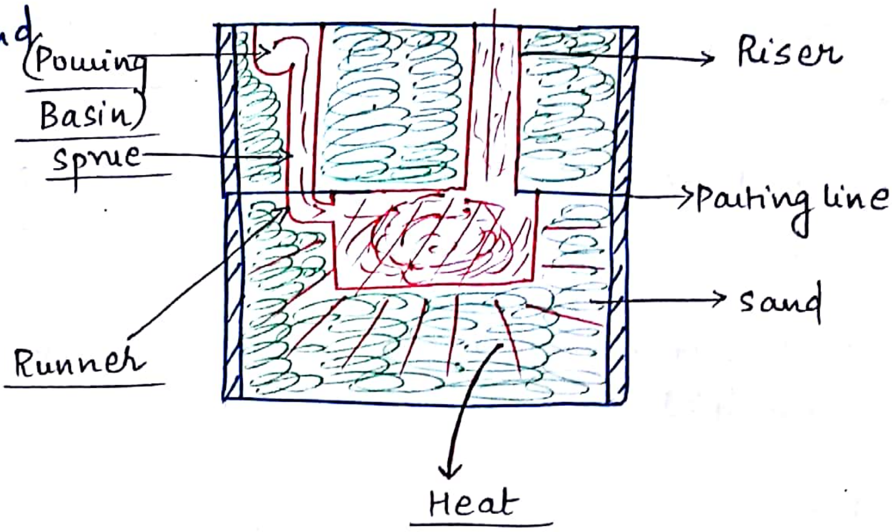
after Rotation (for easy removal of pattern)

⇓

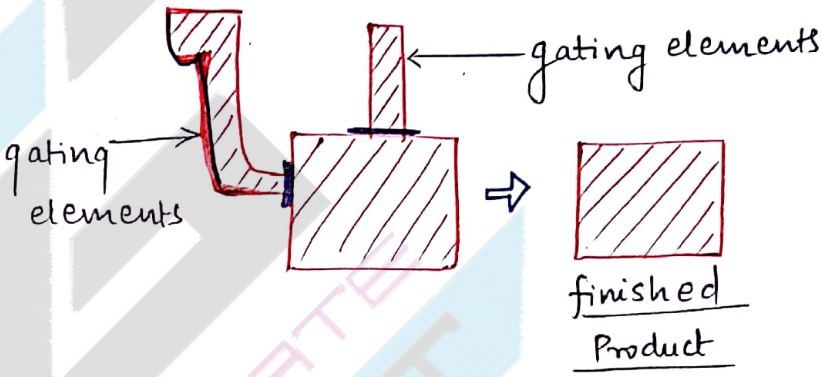


draw spike





⇩ after Breaking,



* Advantages

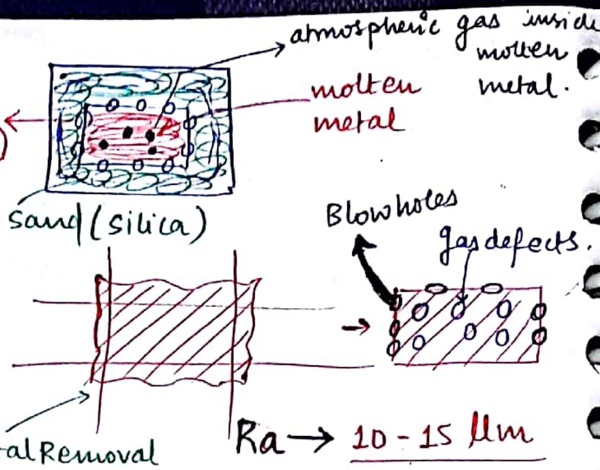
1. Complex-shaped → wax pattern.
2. less expensive
3. More Ductile material
4. Very large size objects → (a) machine Tool beds
   (b) Engine blocks
   (c) Gear box housing
   (d) Road Rollers.

SIR

1. Complex shape of the object can be easily produced.
2. It is a simple & less expensive process.
3. Ductile and Brittle materials can be produced.
4. large size objects can be produced by casting only.

Limitations of the casting process :-

1) Surface finish of the castings are very poor.



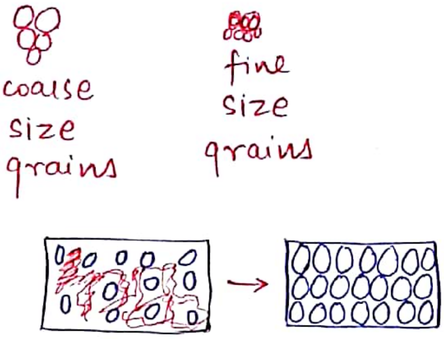
Ra → 10 - 15 μm

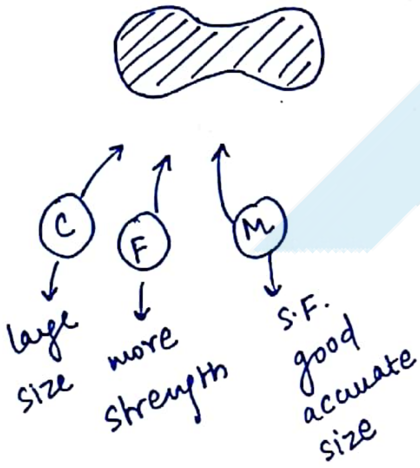
2) It is a labourious and time consuming process.

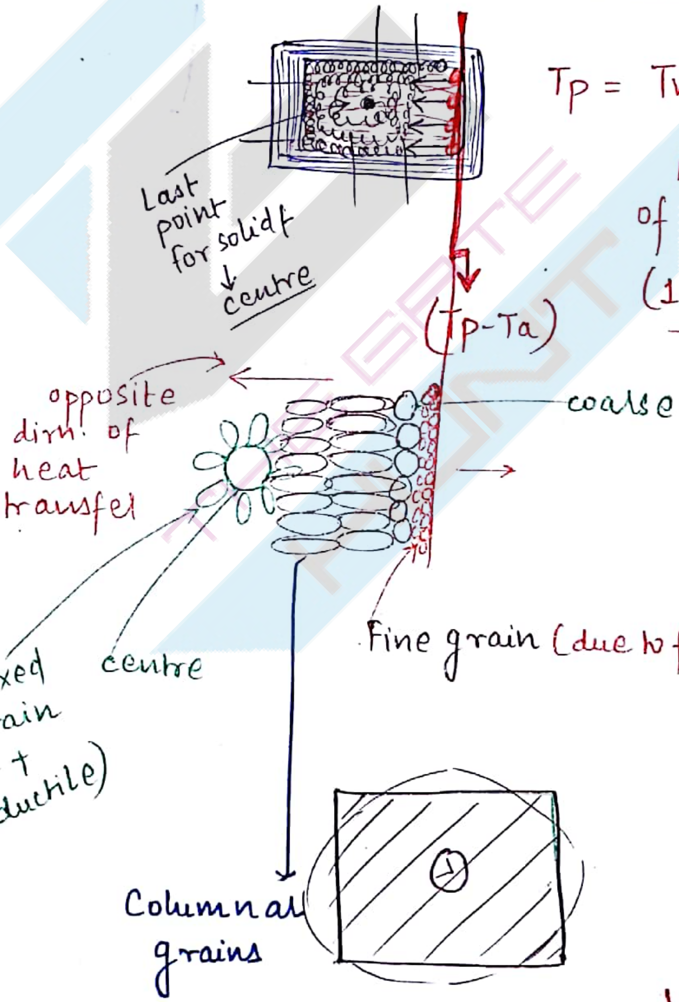
3) There is a possibility of gas defects can be expected.

hence allowance provided.

4) Casting objects are not having uniform mechanical properties due to non-uniform cooling.





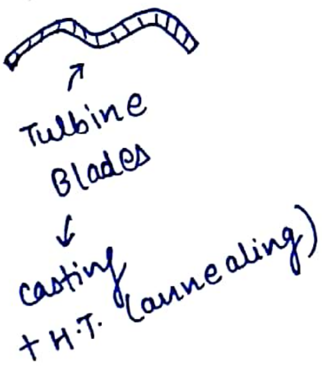


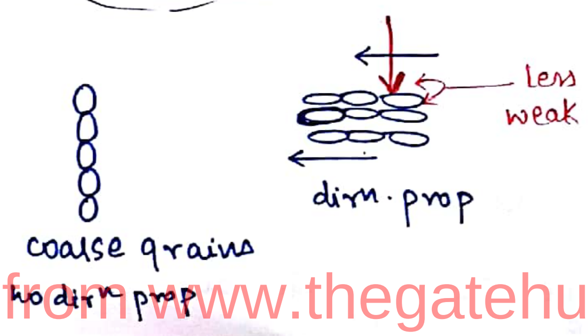
$T_p = T_m + \Delta t$

↓

Degree of superheat (100°-250°C)

$(T_p - T_a)$





* **Selection of the manufacturing process will depends on :-**

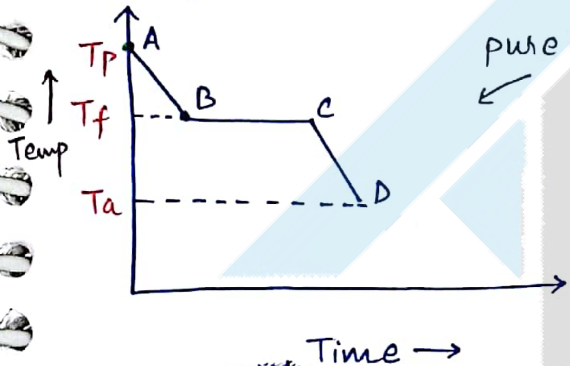
(a) shape and size of the object.
(b) Properties required by the object.
(c) Accuracy and surface finish required.
(d) No. of components to be produced.
(e) Cost of the object.

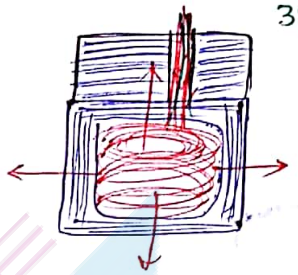
* **Patterns** :- Pattern is replica of final casting to be produced with some allowances.

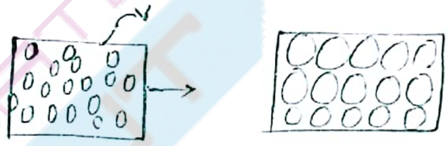
Allowances :- (1) shrinkage (or) contraction. (2) Draft (or) Taper. (3) Machining (or) Finish. (4) shake (or) Rapping (5) Distortion (or) camber. (6)

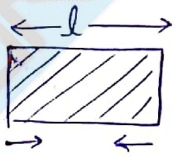
$V = 100\,cm^3 \rightarrow 97\,cm^3$ 3%

Shrinkage Allowance :-









$T_f \rightarrow T_a$

mm/m

when the ~~solid~~ liquid ~~liquid~~ metal is solidify in the cavity, there is a possibility of shrinkage of the material. Due to this size of the casting will be decreased.

when the solid ~~liquid~~ metal is cooled from freezing to ambient tempr. the shrinkage is ~~liquid~~ solid shrinkage.

when the liquid metal is cooled from pouring to freezing temperature, shrinkage is liquid shrinkage. During phase transformation, the shrinkage is solidification shrinkage.

liquid and solidification shrinkage can be compensated by providing riser. These are expressed as percentage of shrinkage volm. of the material. solid shrinkage can be compensated by providing shrinkage allowance on the pattern.

These values are expressed in terms of lineal dimensions.

Shrinkage values ← (Solid shrinkage values)

1. Bismuth → Negligible
2. White metal → 5mm/m
3. Cast Iron → 10mm/m
4. Aluminium → 13mm/m
5. Copper → 17 mm/m
6. Steel → 20 mm/m
7. Brass → 23mm/m

✓ Al → 6.5% more volm. of Riser

✓ Brass → " " of

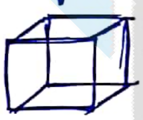
✓ Steel → Total shrinkage

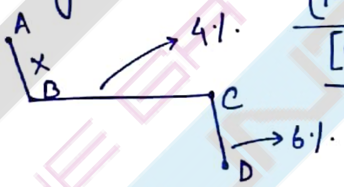
✓ 'Al' is having more liquid and solidification shrinkage which require more volume of the riser. Solid shrinkage is maximum for Brass which require large size pattern. Total shrinkage is maximum for steel.

Q. A cubical casting of 50mm size undergoes volumetric solidification shrinkage of 4%. and volumetric solid contraction of 6%. There is no riser is used and pattern making allowance is not considered. what is the final size of the casting.

Sol V.S.S. = 4%.

V.S.C. = 6%.





$(1-4\%)$ of 50^3

$[0.96(50^3)]$

$0.94[0.96(50)^3]$

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

$\boxed{a = 48.317 \text{ mm}}$

9|9|16

* GREY CAST IRON :-

In case of grey cast iron due to conversion of carbon into graphite flakes there is a possibility of expansion of the material in liquid and solidification state. Due to this there is no need of providing the riser. In solid state, there is a possibility of shrinkage of the material. To overcome this, shrinkage allowances is provided on the pattern.

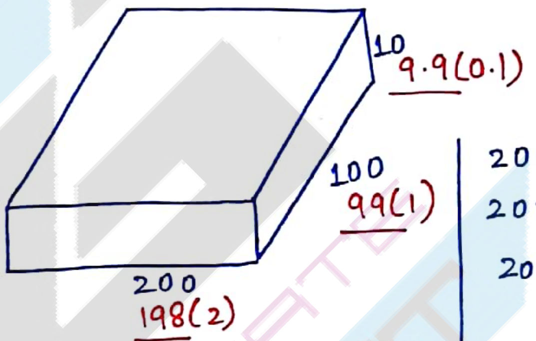
Q A grey cast iron block of dimensions 200, 100 and 10 mm^3 is produced by sand moulding process. pattern making allowances is 1%. What is the ratio of volume of the pattern to the volume of the casting

Sol>

$$\frac{\text{Volume of Pattern}}{\text{Volume of Casting}}$$

$$= \frac{(200+2)(100+1)(10+0.1)}{200 \times 100 \times 10}$$

$$= 1.03$$

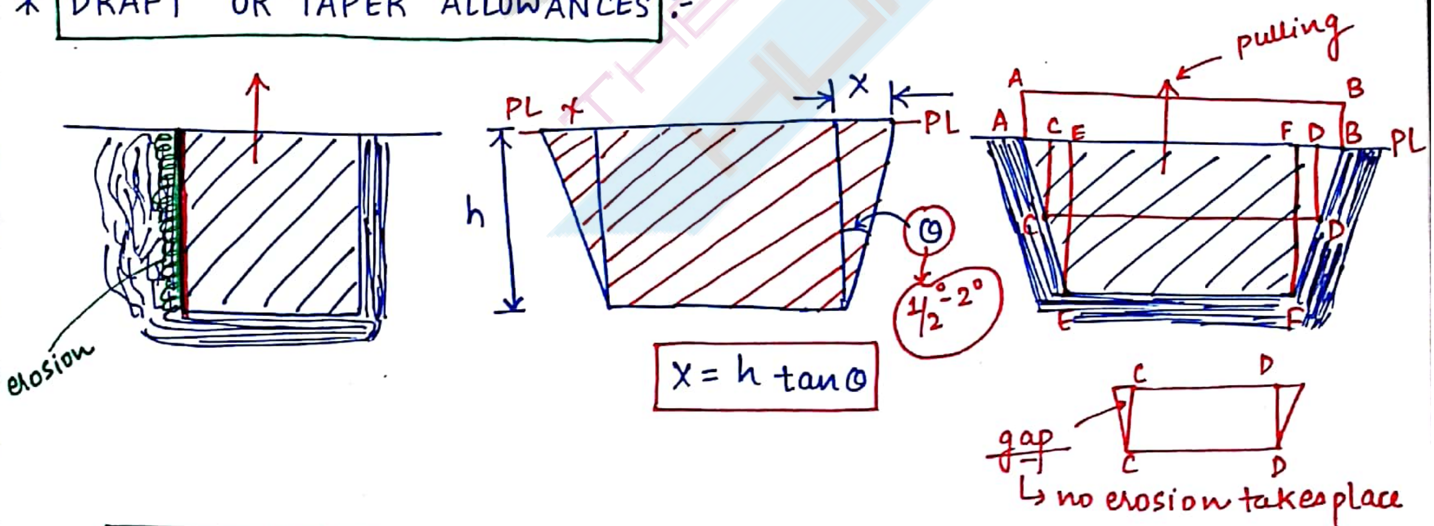


2 ∓ 200
1 ∓ 100
0.1 ∓ 10

$\boxed{1.03}$

200 − 1% → 2
202 − 1% → 2.02
202 . . . . . → 199.98
↓
0.02mm

* DRAFT OR TAPER ALLOWANCES :-

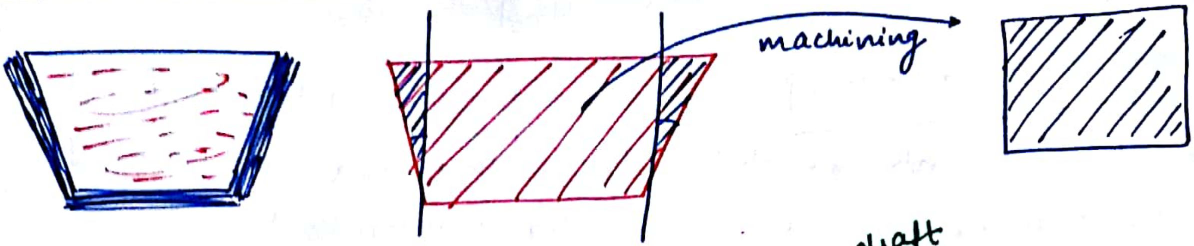


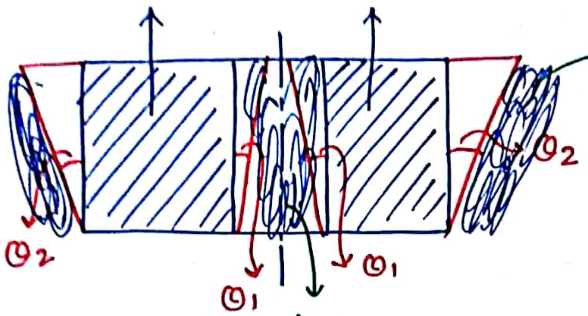
$\boxed{x = h \tan\theta}$

% contraction in case of GCI :-

$$\% V = 2(\% \text{ of carbon} - 2.8\%)$$

Before DA or TA.





more strength, Less draft means θ_2

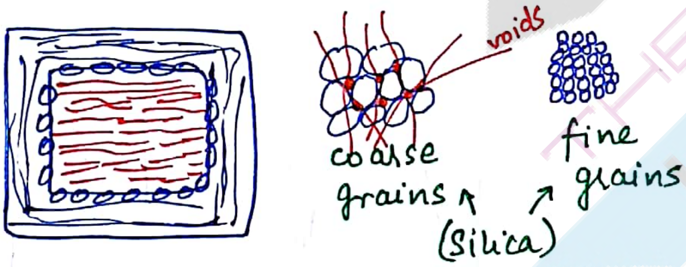
$\boxed{\theta_1 > \theta_2}$

less strength, more draft means θ_1

For easy removal of the pattern from the mould ~~front~~ or the vertical surface of the pattern to minimise continuous contact b/w pattern and mould surface, draft or Tapered allowances is provided.

External surface will require less draft when compare to internal surface.

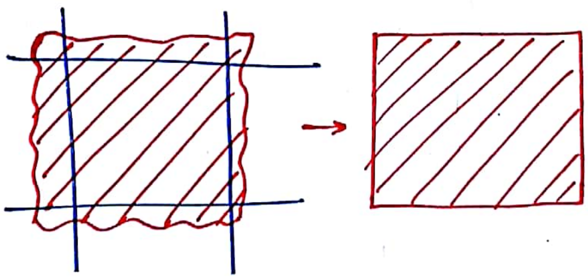
* MACHINING (OR) FINISH Allowances:-



mm/surface

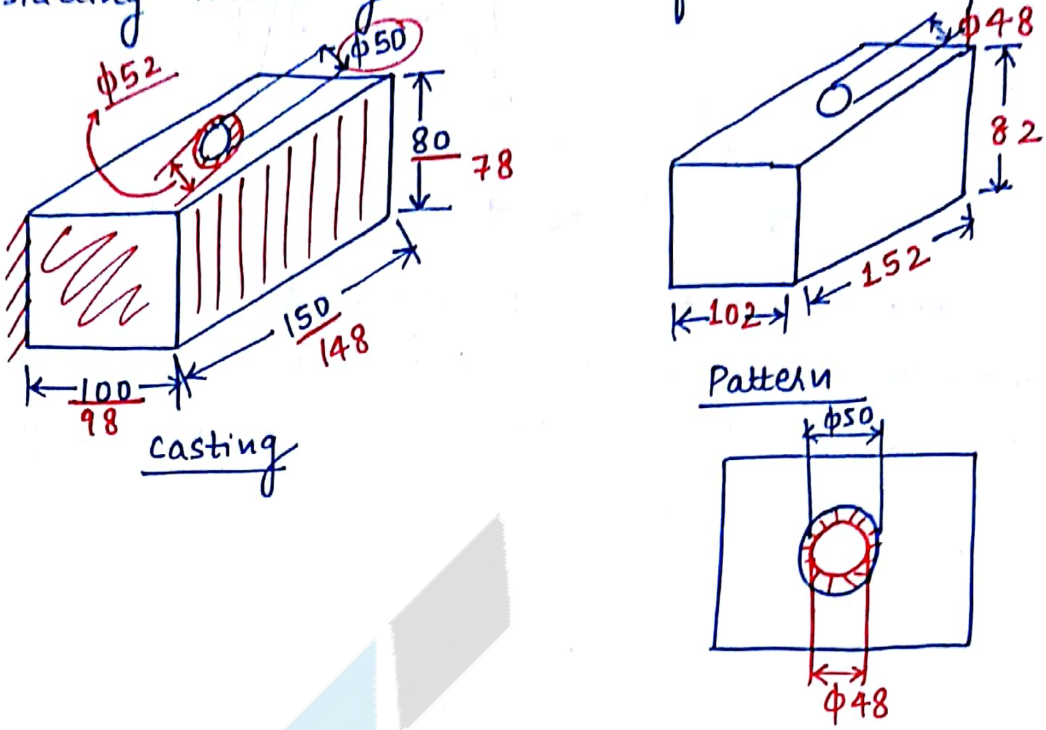
Ra → 10 - 15 μm

Roughness



Casting objects are not having smooth surface finish. To get smooth surface finish machining is req. Due to machining, size of the casting will be decreased. To overcome this, size of the pattern can be increased by providing machining allowance.

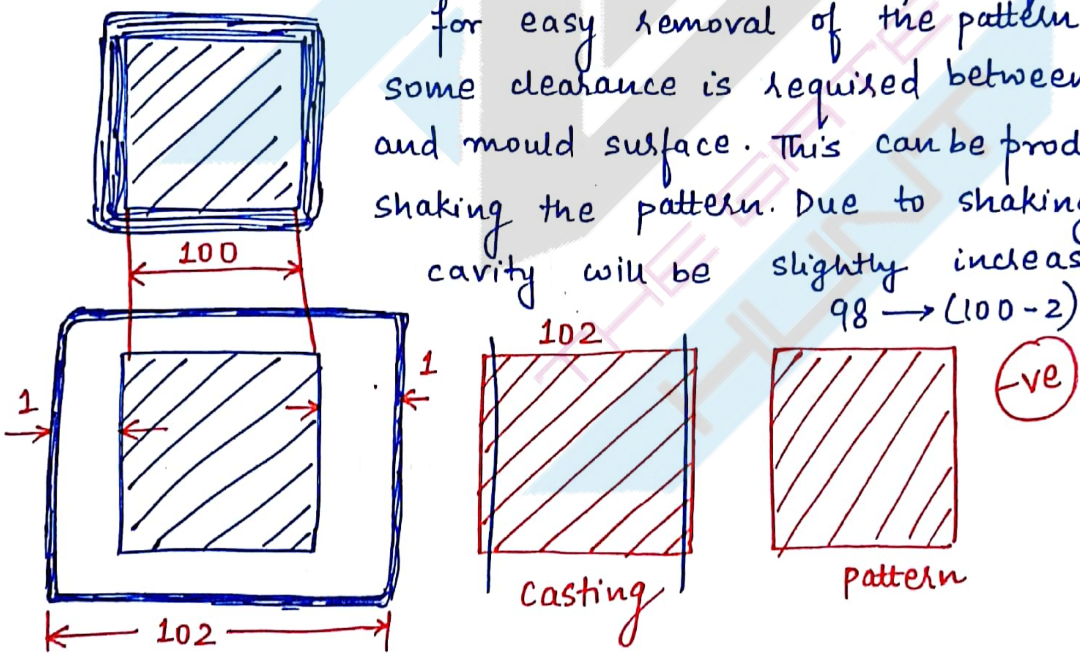
Q. Calculate dimensions of the pattern for the casting shown below by considering machining allowance of 1mm on surface



Sol

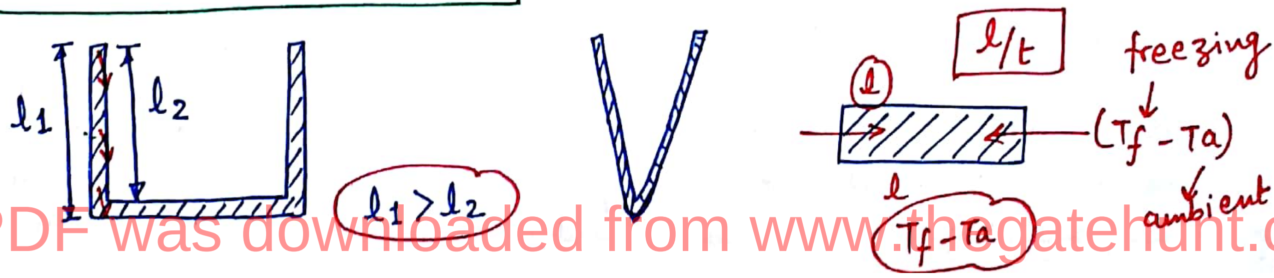
④ Shake (or) Rapping :- Due to ramming, moulding sand will be stick to the surface of the pattern. For easy removal of the pattern from the mould, some clearance is required between the pattern and mould surface. This can be produced by shaking the pattern. Due to shaking, size of the cavity will be slightly increased. To overcome

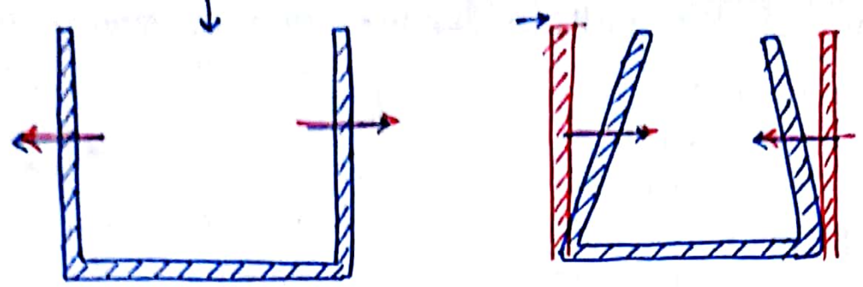
$98 \rightarrow (100-2)$



this size of the pattern can be reduced by providing shake allowance. It is a -ve allowance provided on the pattern.

⑤ DISTORTION OR CAMBER :-



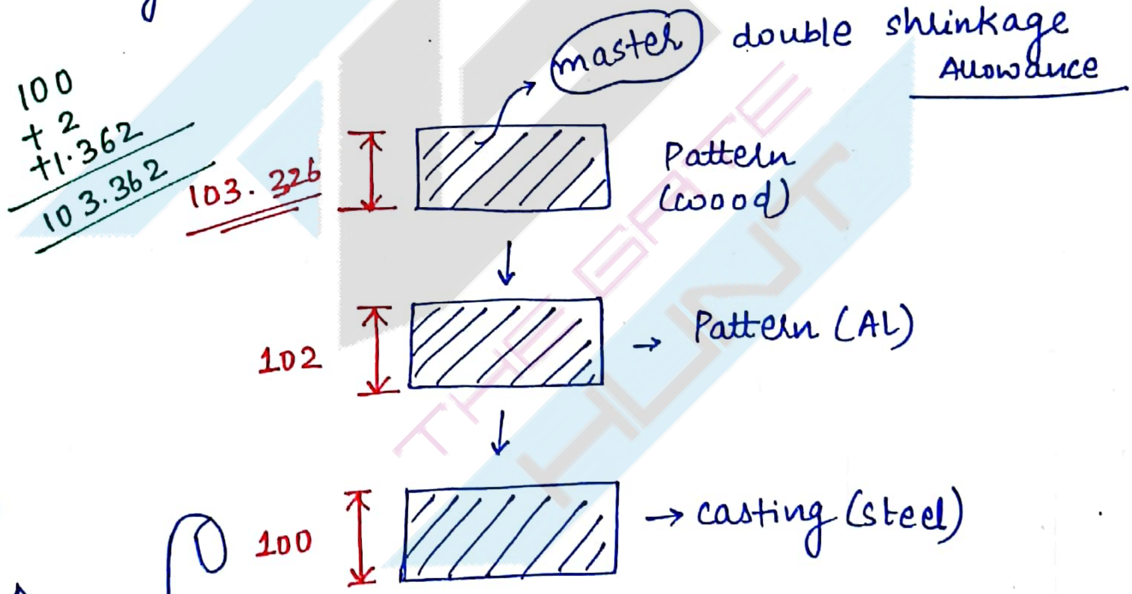


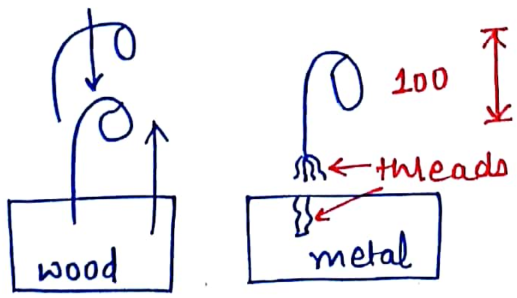
Depending on shape and size of the casting due to difference in lineal dimensions, there is a possibility of distortion of the casting. To overcome this, distortion allowances is provided on the pattern opposite to the direction of distortion. These values ~~still~~ will depends on length to thickness ratio (L/t) ratio.

* PATTERN ~~ALLOWANCES~~ Materials :-

① wood

② Metals and alloys :- Al, C.I., steels, Brass, etc.





① steel :- (20mm/m)

1000 mm ⟶ 20mm

100 mm ⟶ ? 2mm

② AL(13mm/m)

1000mm – 13

102mm – ?

1.326mm

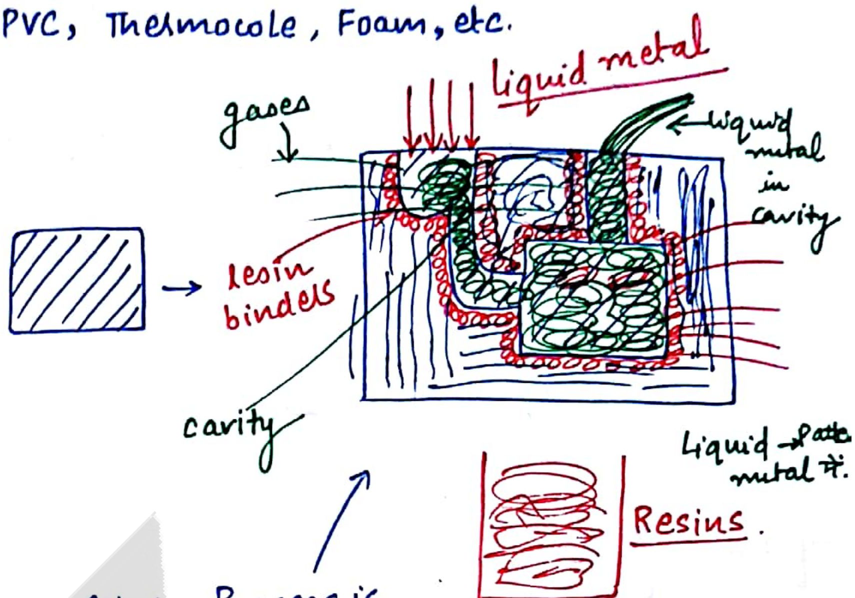
To produce more no. of castings in mass production, metallic patterns can be used. These are produced by wooden patterns. on the wooden patterns, shrinkage of the casting and shrinkage of metallic pattern both can be added. This is known as double shrinkage allowance. and wooden pattern is known as master pattern.

③ Plastics :- Polystyrene, PVC, Thermocole, Foam, etc.

230°C

Expendable Pattern
or
Disposable Pattern

used only once.



Whole Process is called FULL Moulding / Cavityless Moulding / EPC (Evaporative pattern casting).

[Pattern $\xrightarrow{heat}$ vapour]

✓ Wax ⟶ Investment , ~~Mercury~~ (Hg) ⟶ Mercast process.

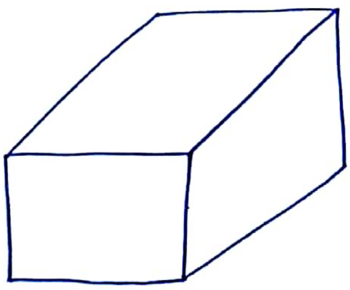
[wax $\xrightarrow{heat}$ liquid] cope reverse

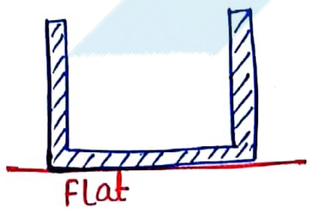
−39°C ← Freezing Temperature

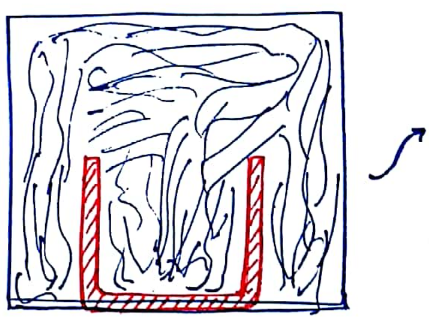
due to low freezing point conditions

* TYPES of PATTERNS :-

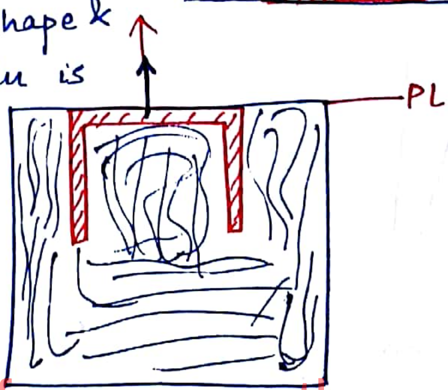
① Solid or Single piece :-



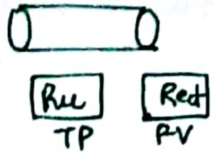


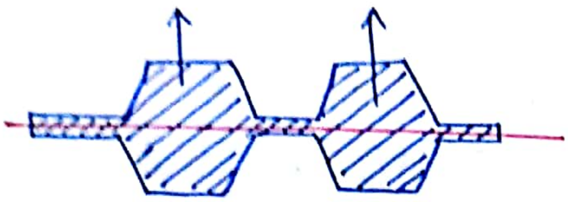


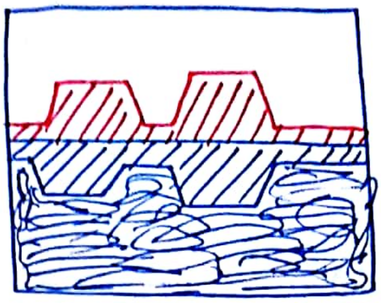
If the object is having simple in shape & size, one of the surface of the pattern is flat. solid or single piece pattern can be used. It is a simplest type of pattern.

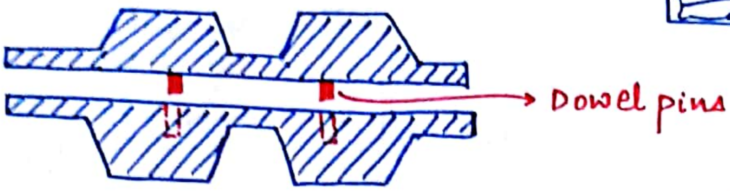


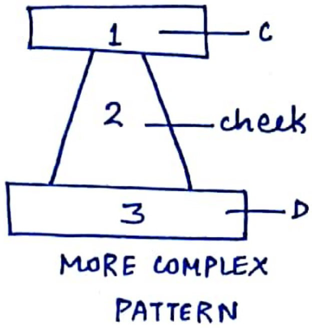
② SPLIT PIECE PATTERN :-

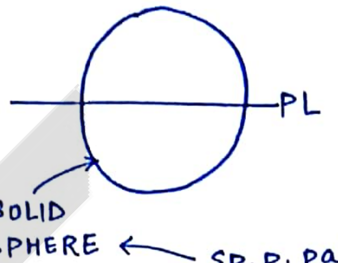












If the objects are having complex in shape and size pattern can be split along the parting line and they can be removed from cope and drag boxes separately.

SOLID SPHERE ← sp.p. pattern

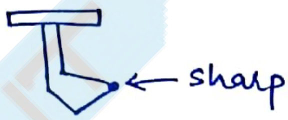
Blow moulding → hollow sphere

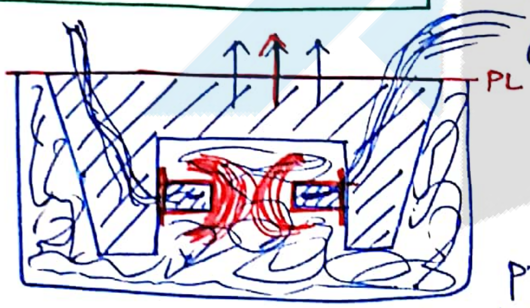
③ LOOSE PIECE Pattern :-

(1.) Projections

(2.) Undercuts

Lifter

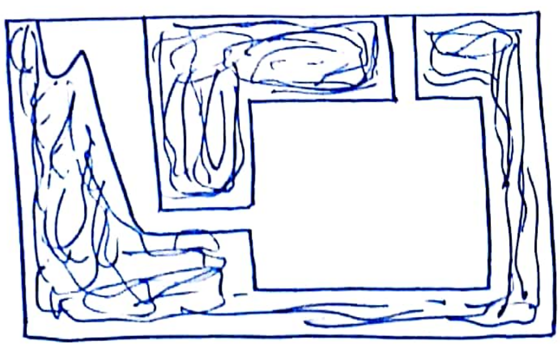


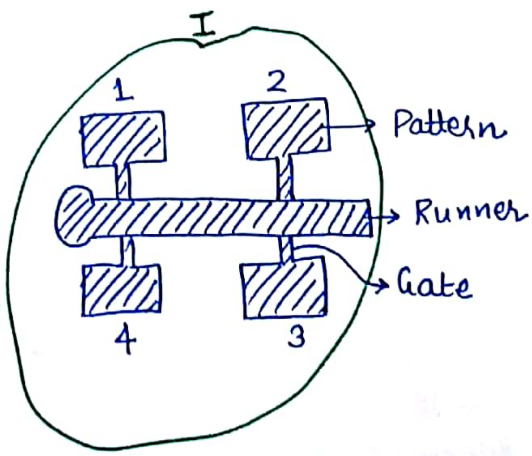


If the Patterns are having some internal projections or undercuts, loose piece pattern can be used. after removing the main part of the pattern, loose pieces can be removed from the mould to get the required cavity

10/9/2016

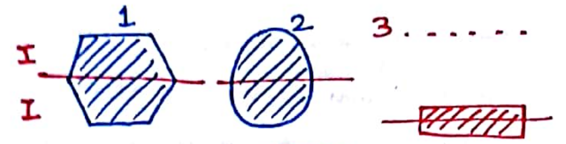
④ GATED PATTERN :-

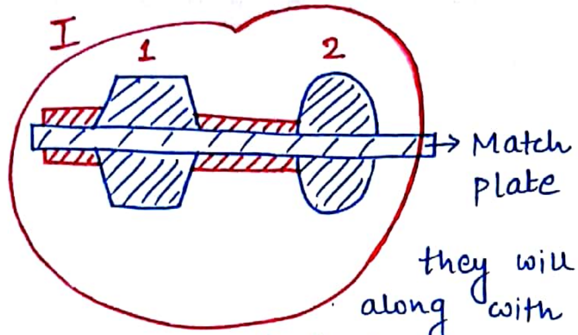


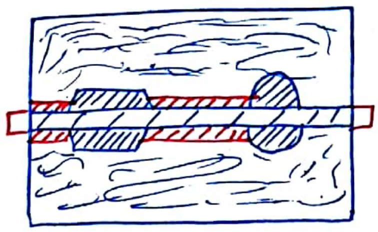


To produce runner and gate for each cavity in mass production manually will take more time. To overcome this no. of patterns along with gating elements will produce a single pattern known as gated Pattern.

5 Match Plate Pattern :-

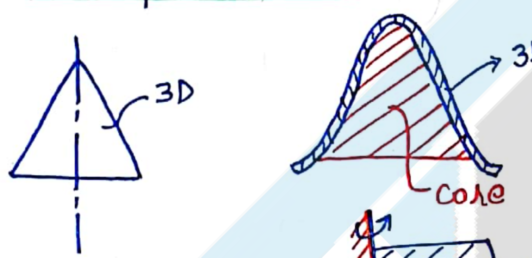


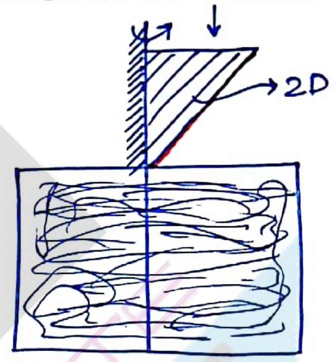




To produce complex shape of small size objects in mass production, no. of patterns can be split along the parting lines and they will be added on both sides of match plate along with gating elements. It can be used in mass production.

6 Sweep Pattern :-

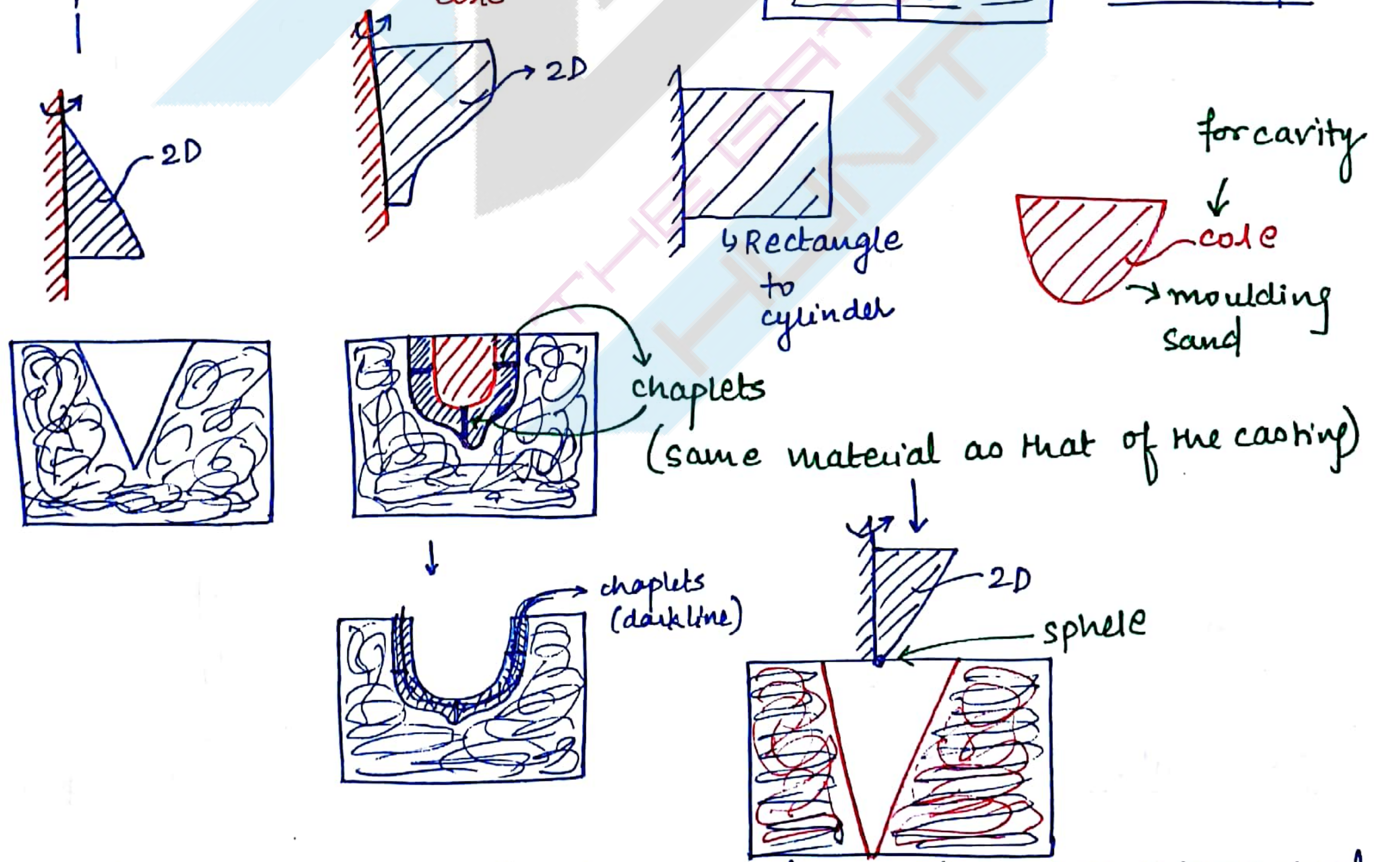




Loam sand :-

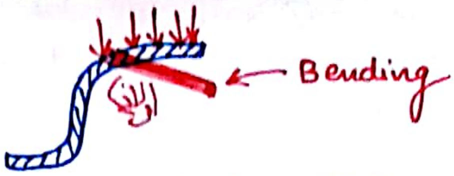
50% Silica

50% clay

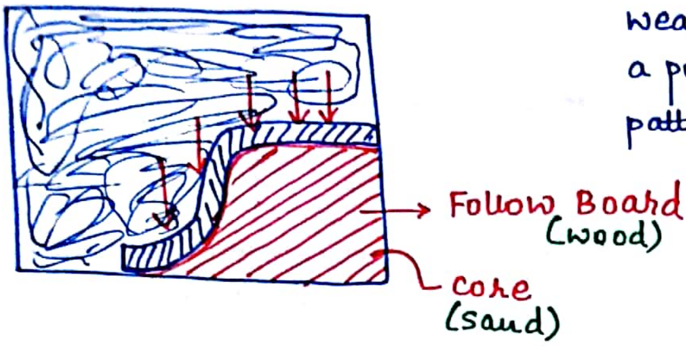


To produce complex shape of 3 dimensional mould cavities, 2 dimensional plane patterns will be rotated on the surface of the mould to produce 3D cavities. It is used for axis symmetric objects only. Examples :- cone, large size bells, cylinder, etc.

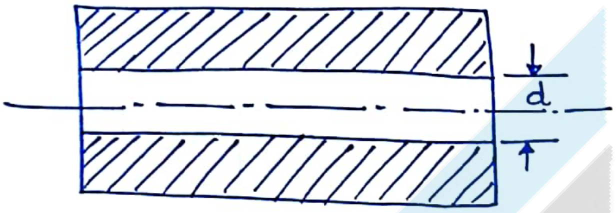
(f) **Follow Board Pattern** :-



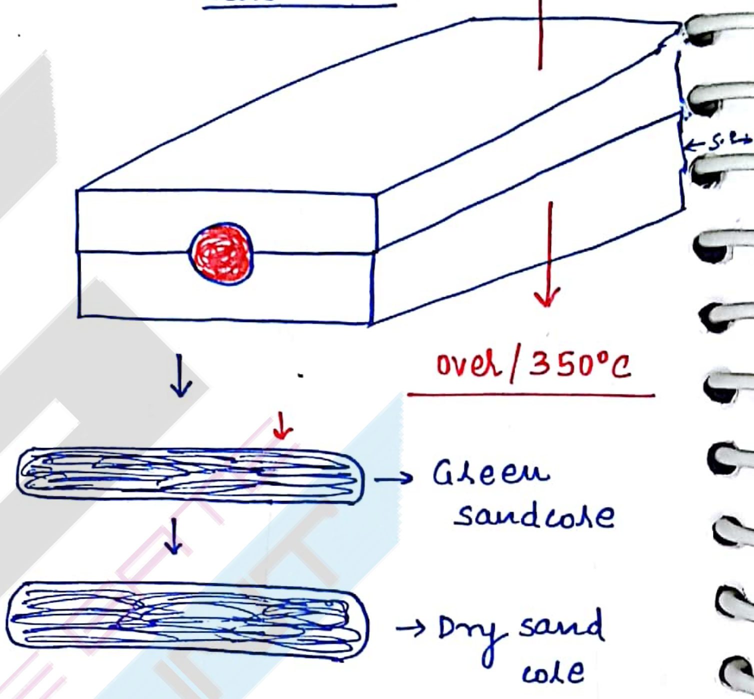
If the patterns are structurally weak, due to ramming force there is a possibility of breaking of the pattern. To overcome this, patterns are supported by providing follow board.

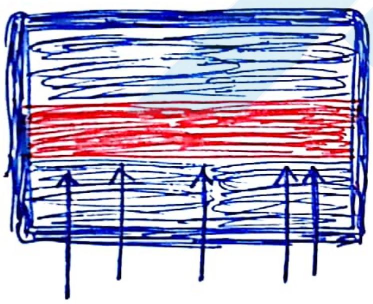


* CORE DESIGN :-



core boxes :-





Core sand

Moulding sand
+
organic resins
[Linseed oil, molasses, dextrin, etc]

Net Buoyancy Force (P) = wt. of liquid metal displaced − wt. of core

$$P = Vg\rho_m - Vg\rho_c$$

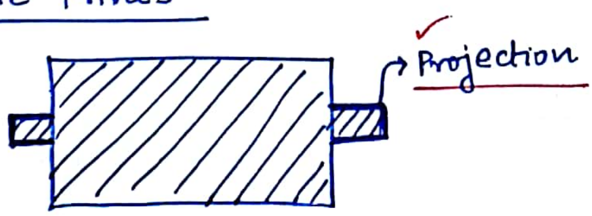
$$* \boxed{P = Vg(\rho_m - \rho_c)}$$

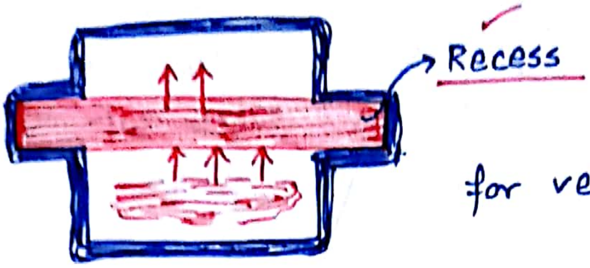
$V \rightarrow$ volume of the core

$\rho_m \rightarrow$ density of the molten liquid metal.

$\rho_c \rightarrow$ density of core material.

Core Prints





$P \le 3.5\,A_c$

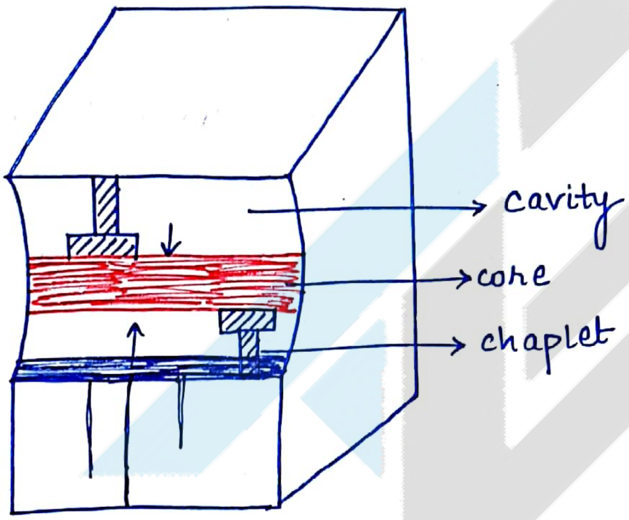
(cm) — area (surface) (core print)

for vertical core → chaplets not core prints.

✓ Core prints :- These are the projections on the pattern and recess inside the cavity to position the core properly.

✓ Chaplets :- These are the ~~mech~~ metallic objects used to support the core inside the cavity. These are produced by same material as the casting.

Horizontal core → Buoyancy Force dominating



Vertical core → Gravity dominating

Q A hollow casting is produced using a cylindrical core of H = D = 100 mm, density of the liquid metal is 2700 Kg/m³ and density of core metal is 1600 kg/m³, what is the net Buoyancy force on the core?

Sol

$P = Vg\rho_m - \rho_c Vg$

$P = Vg(\rho_m - \rho_c)$

$H = D = 100\,mm$

$\rho_m = 2700\ kg/m^3$

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

$P = \frac{\pi}{4}(100)^2(200) \times 10^{-9} \times 9.81\,(2700-1600)$

$P = \underline{8.47\,N}$

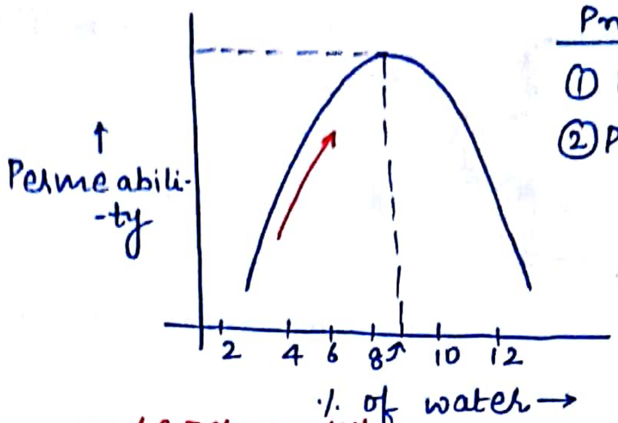
* MOULDING SAND :-

Silica - 70 - 85%

Clay - 10 - 20%

water - 2 - 8 %

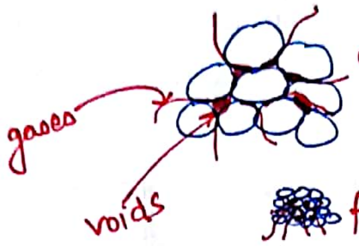
Additives - 1 - 6 %



Properties :-

① Refractoriness

② Permeability



coarse ← more permeability

Bentonite
Kalonite

* Properties of Moulding sand :-

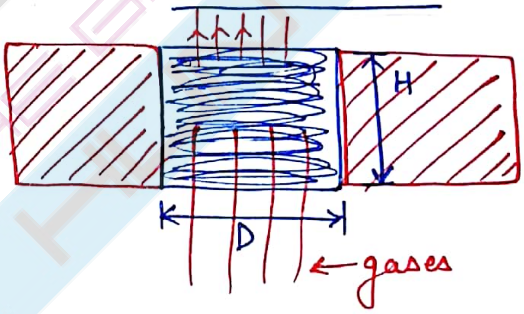
① Refractoriness :- ability of the moulding sand to withstand high tempr. of the liquid metal without fusion

② Permeability :- ability of the moulding sand to allow the gases to escape. It is expressed by permeability No.

$$\boxed{P_n = \frac{VH}{PAT}}$$

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

(AFS)
American F.S.



V → volume of the air passing through the specimen (2000 cm³)

H → height of cylindrical specimen (cm)

P → difference of pressure of air (gm/cm²)

A → c/s are of the specimen (cm²)

T → Time taken by the air to allow the gases to escape (min)

H = D = 2" (inch)
= 2 × 2.54
= 5.08 cm

P_n → 60 - 120 generally

$$P_n \rightarrow \frac{cm^3 \cdot cm}{\frac{gm}{cm^2} \cdot cm^2 \cdot min} = \frac{cm^4}{gm \cdot min}$$

Q Determine the permeability of the moulding sand it will take 1 min 25 seconds to allow 2000 cm^3 of air through a standard cylindrical specimen at a pressure diff. of 5gm/cm^2. (17)

Sol.

$$P_n = \frac{2000 \times 5.08}{5 \times \left(\frac{\pi}{4}\right)(5.08)^2 \times 1.46}$$

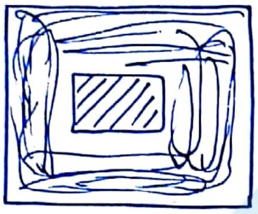
$$\boxed{P_n = 70.77}$$

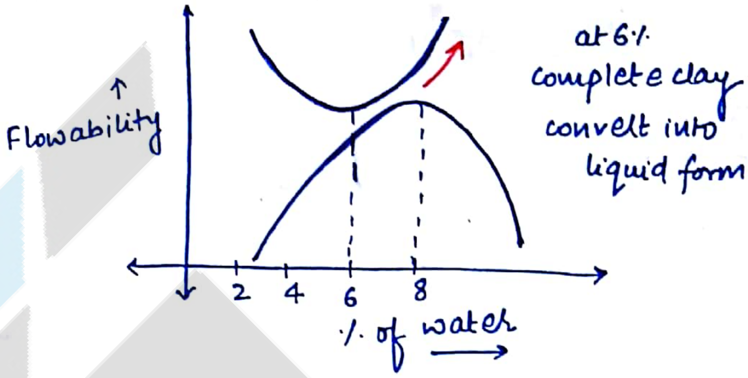
$P_n = \frac{VH}{PAT}$

$= \frac{2000 \times}{5 \times}$ 5.08cm

$= \frac{2000 cm^3 \times H}{5 \frac{gm}{cm^2} \times \frac{\pi}{4} D^2 \times 1.41}$

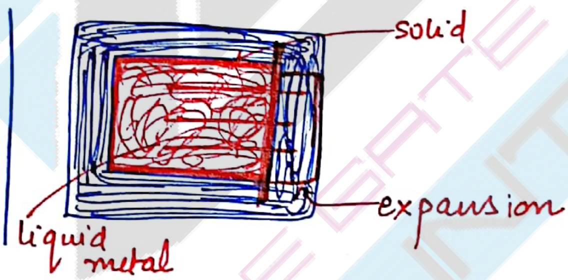
(3) **Flowability** :→ ability of the moulding sand to flow into all the corners of the mould Box due to ramming force.





(4) **Strength** :→

Green sand
Dry sand
Hot sand



→ To retain the shape and size of the cavity and to withstand forces applied by the liquid metal on the mould surface, mould must be having sufficient strength.

(a) **Green sand** :- If the moulding sand is having moisture, then it is called green sand. By evaporating the moisture, sand has become **dry**. After becoming the sand dry, still liquid metal is having more heat will ↑ the tempr. of the sand and it will become **hot**.

(5) **Hardness** :→ Mould hardness Number (0-100)

Average ,, ,, ,, ,, :- 60 - 80

Hardness is a surface property to minimize erosion and to withstand forces applied by the liquid metal. Mould must be having sufficient hardness. If the hardness is more than 80, permeability will be decreased. If the hardness is less than 60, dimensional stability of the casting will be decreased.

⑥ **Adhesive property** :- Bond formation b/w two different materials.

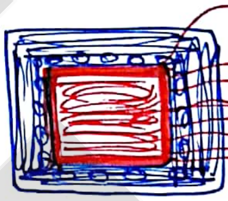
⑦ **Cohesive property** :- Bond formation b/w similar materials.

Moulding sand also requires sufficient thermal conductivity & low coefficient of linear expansion ('K', 'α').

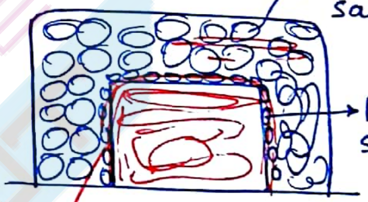
⑧ **Collapsibility** :- Ability of the moulding sand due to which mould surface will not provide any resistance due to solid contraction of the casting.

* Additives :-

1. Saw dust (or) wood flour } ↑ by (↓ HR<$). ↑ Collapsibility & Permeability

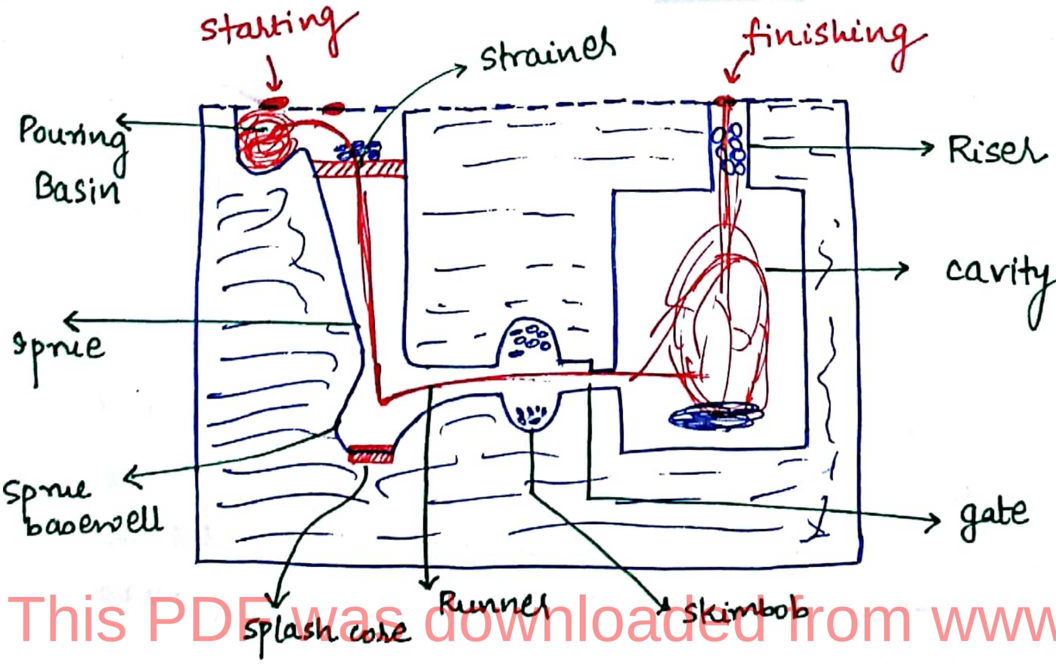


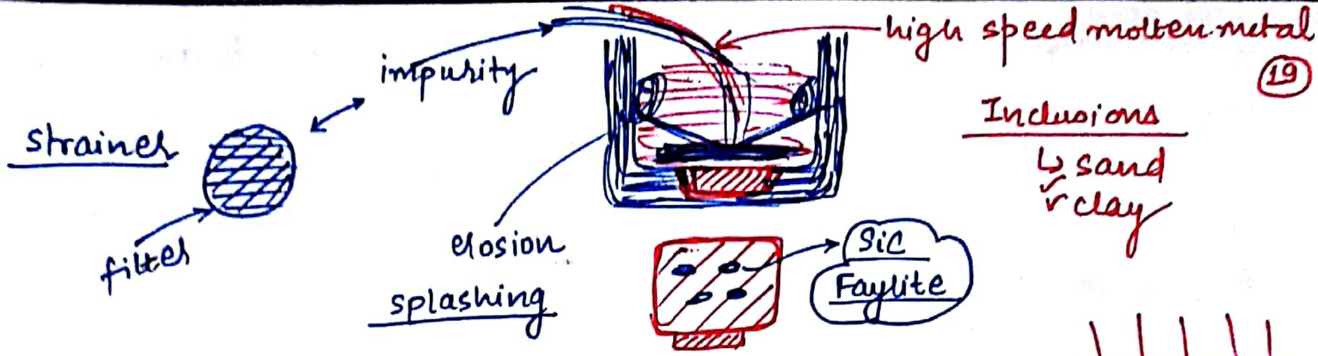
2. Linseed oil, Molasses, dextrin etc } (organic resin binders) Hardness and strength (↑ at high tempr)



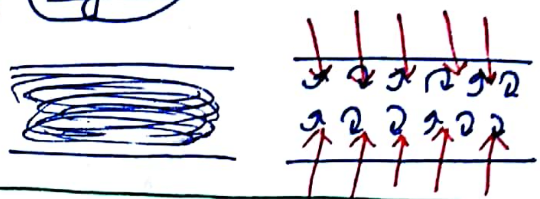
3. Coal dust } surface finish (of cavity)

* Elements of Gate Design :-





Inclusions
↳ sand
↳ clay



* Objectives of gating Design :-

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

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 and erosion.

② Design the gating elements so that pure liquid metal can be enter into the cavity without air aspiration effect.

③ Produce the gating elements for maximum casting yield.

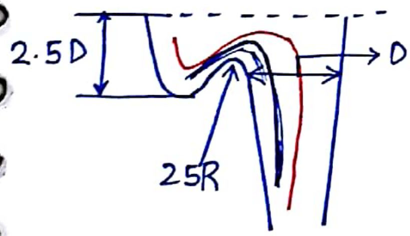
$$\text{Casting yield} = \frac{\text{Volume of casting } (V_c)}{V_c + \text{Vol}^m \text{ of gating elements } (V_g)}$$

$Al_2O_3 \rightarrow 3.8 \, gm/cm^3$.

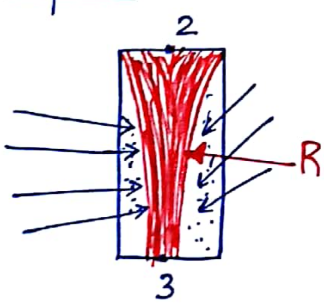
$Al \rightarrow 2.7 \, gm/cm^3$.

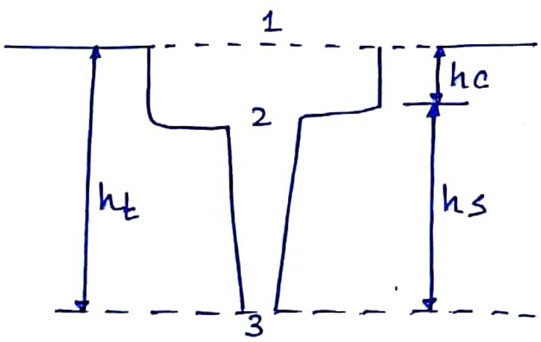
① Pouring Basin :-

Pouring Basin is designed to reduce the velocity of liquid metal which is enter into the sprue.



② Sprue :-





$v_3 >> v_2$

$Q = A_2 v_2 = A_3 v_3$

$A_3 << A_2$

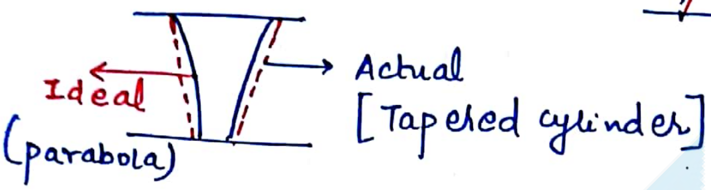
$V = \sqrt{2gh}$

$v_2 = \sqrt{2hg}$

$v_3 = \sqrt{2gh_t}$

$$\frac{A_2}{A_3} = \frac{v_3}{v_2} = \frac{\sqrt{2gh_t}}{\sqrt{2gh_c}} = \frac{\sqrt{h_t}}{\sqrt{h_c}} = \sqrt{\frac{h_t}{h_c}}$$

$$\boxed{\frac{h_t}{h_c} = \left(\frac{A_2}{A_3}\right)^2}$$



✓ **Air aspiration effect** :- Atmospheric gases can be absorbed into low pressure areas in the gating elements will form gas defects. This effect is known as A.A.E.

To avoid air aspiration effect, ideal shape of this sprue is parabola. To reduce the manufacturing difficulty, shape of the sprue is considered as Tapered cylinder.

Q> In a gating design, height of the sprue is 200 mm, x-s/c area of the sprue at the begining is 650 mm². discharge rate of liquid metal is 6.5×10^5 mm³/s. what is the x-s/c area of the sprue at the bottom.

Sol> $h_s = 200$ mm

$A_2 = 650$ mm²

$Q = 6.5 \times 10^5$ mm³/s

$A_3 = ?$

$Q = A_2 V_2$

$$v_2 = Q/A_2 = \frac{6.5 \times 10^5}{650} = 1000$$

$v_2 = \sqrt{2gh_c} = 1000$

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

$A_2 v_2 = A_3 v_3 =$

$\frac{h_t}{h_c}$ $v_2 = 1000$ ✓

$$\frac{200}{1m/s} = \left(\frac{A_2}{A_3}\right)^2 \quad 650$$

$0.05 = h_c$

$A_2 V_2 = A_3 V_3$ $h_c = 50.96$

$650 \times$

$v_2 = \sqrt{2gh_c}$

$v_3 = \sqrt{2gh_t}$

$v_3 = 1.98$ ✓

$h_t = h_s + h_c$

$= 200 + 50.96$

$= 250.96\ mm$

$$\frac{A_2}{A_3} = \sqrt{\frac{h_t}{h_c}} \qquad Q = A_2 v_2 = A_3 v_3$$

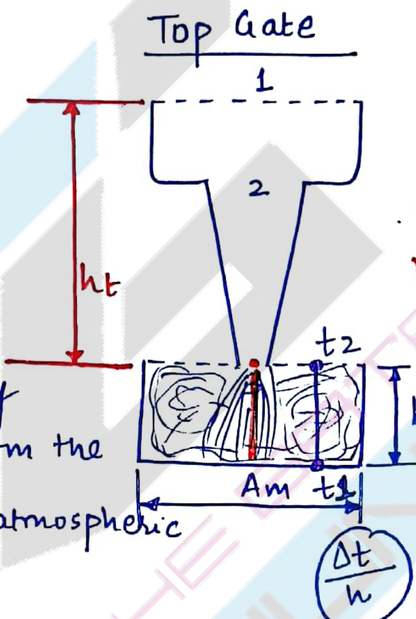
$$\frac{650}{A_3} = \sqrt{\frac{250.96}{50.96}}$$

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

* **GATE (Ingate)** :- It is the actual entry point through which liquid metal can be enter into the cavity.

TYPES :-

1. Top gate
2. Bottom gate
3. Parting line gate
4. step gate



$A_3 = A_g$

$v_3 = v_g = \sqrt{2gh_t}$

'favourable'

Tempr. gradient

- liquid metal is directly enter into the cavity from the bottom of the sprue at atmospheric pressure.
- velocity of the liquid metal in the cavity is very high.
- There is a possibility of turbulence and splashing of the liquid metal.
- It can be used for casting of ferrous materials.
- There is a possibility of favourable tempr. gradient of the liquid metal in the cavity.

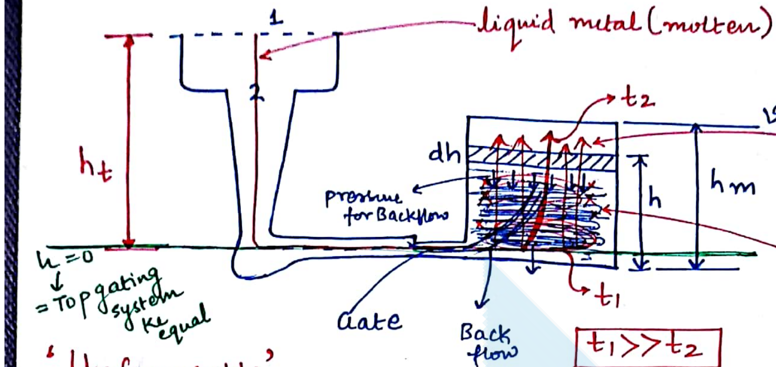
$$dt \cdot A_g v_g = A_m \cdot dh$$

gate — mould

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

$$\boxed{t_f = \frac{V_m}{A_g v_g}}$$

② Bottom Gate :-



Since it is moving in upward direction

$v_3 = v_g = \sqrt{2g(h_t - h)}$ because of pressure difference hence upar jayega

velocity of liquid metal is negligible in cavity. no chance of turbulence. no oxide formation. used for non-ferrous materials. not for ferrous materials

'Unfavourable'

temperature gradient $\frac{\Delta t}{h}$

$\boxed{t_1 >> t_2}$

hence liquid solidifies at t_2 faster than t_1

hence non-uniform cooling

✓ Liquid metal is enter into the cavity from bottom to top vertically in upward direction. velocity of the liquid metal in the cavity is negligible. ✓ There is no possibility of turbulence and splashing of the liquid metal. ✓ It can be used for casting of non-ferrous materials.

✓ There is unfavourable temperature gradient of the liquid metal in the cavity.

$$\therefore \; dt \cdot A_g v_g = A_m \cdot dh$$

$t = 0, h = 0$

$t = t_f, h = h_m$

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

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

$$\Rightarrow \boxed{t_f = 2 \cdot \frac{A_m}{A_g} \cdot \frac{1}{\sqrt{2g}} \left[\sqrt{h_t} - \underbrace{\sqrt{h_t - h_m}}_{0} \right]}$$

if $\boxed{h_t = h_m}$

$$t_f = 2 \cdot \frac{A_m}{A_g} \cdot \frac{1}{\sqrt{2g}} \cdot \sqrt{h_t} \times \frac{\sqrt{h_t}}{\sqrt{h_t}}$$ (23)

$$= 2 \cdot \frac{A_m}{A_g} \cdot \frac{h_m}{\sqrt{2gh_t}}$$

$$* \boxed{t_{f\,bottom} = 2\, t_{f\,top}}$$

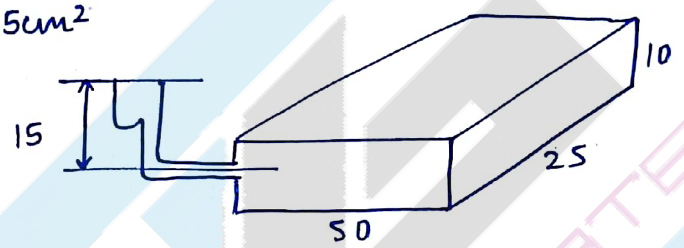
Q In a gating design dimensions of the cavity is $50 \times 25 \times 10\ cm^3$. It will be filled by providing gate on the top of the cavity with the pouring height of 15cm. area of the gate is $5cm^2$. time taken to fill the cavity is

Sol

$h_t = 15cm$

$A_g = 5cm^2$

$$\frac{50 \times 25 \times 10 \times 2}{\sqrt{2g15} \times 5}$$

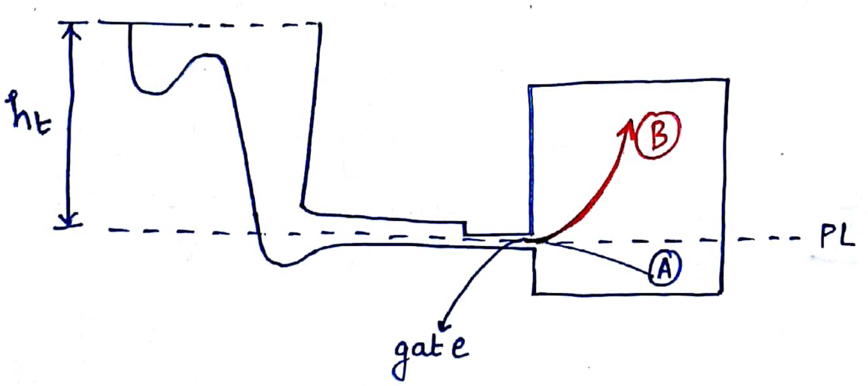


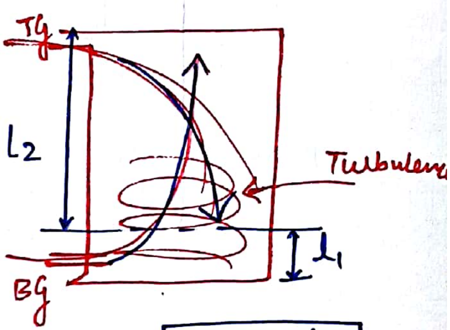
$$t_{ft} = \frac{V_m}{A_g v_g} = \frac{50 \times 25 \times 10}{5 \times \sqrt{2 \times 9.81 \times 15}} = \underline{14.57 sec}$$

$$t_{fb} = 2 \cdot \frac{A_m}{A_g} \cdot \frac{1}{\sqrt{2g}} \left(\sqrt{h_t} - \sqrt{h_t - h_m}\right) = 2 \times \frac{50 \times 25}{5} \times \frac{1}{\sqrt{2 \times 9.81}} \times \left(\sqrt{15} - \sqrt{15-10}\right)$$

$$= \underline{18.47 sec}$$

③ **Parting line Gate :-**

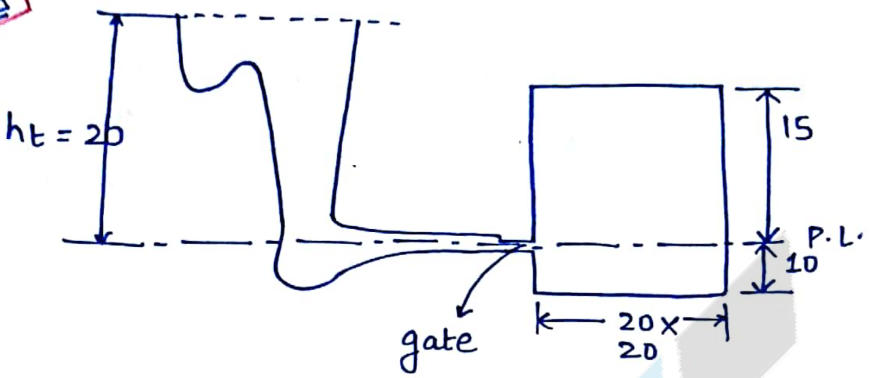




$$\boxed{l_1 << l_2}$$

✓ Gate is provided along the parting line such that below the parting line, cavity can be filled by assuming top gating system and above the parting line, it can be filled by assuming Bottom gating system. To get the advantage of both top and bottom gauge, it is a most commonly used type of gate.

Q



calculate cross-sectional Area of the gate = ? such that liquid metal can be filled into the cavity in 10 sec's.

Sol $t_f = t_{f_A} + t_{f_B}$

$h_t = 20$

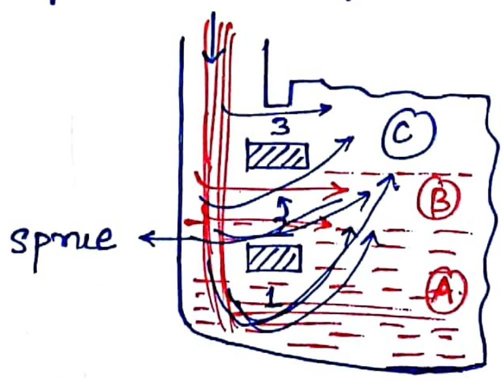
$$t_f = 2 \cdot \frac{300}{A_g} \cdot \frac{1}{4.42} \cdot \frac{\sqrt{h_t}^{\,4.47}}{2.23}$$

$$10 = \frac{V_m}{A_g v_g} + 2 \cdot \frac{A_m}{A_g} \cdot \frac{1}{\sqrt{2g}}\left(\sqrt{h_t} - \sqrt{h_t - h_m}\right)$$

$$10 = \frac{20 \times 20 \times 10}{A_g\sqrt{2 \times 981 \times 20}} + 2 \cdot \frac{20 \times 20 \times 1}{A_g\sqrt{2 \times 981}}\left(\sqrt{20} - \sqrt{20-15}\right)$$

$$\boxed{A_g = 6.05\,cm^2}$$

④ **Step Gate** :- To fill the molten liquid metal into very large size mould cavities, no. of gates are provided vertically in the form of step such that liquid metal can be filled into the cavity within a given time without causing turbulence and splashing of the liquid metal.

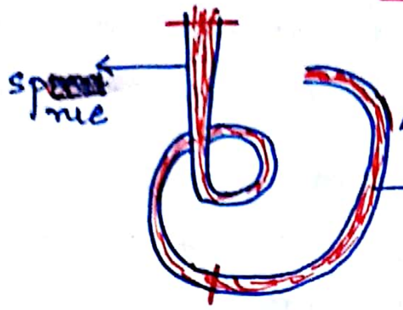


* **Fluidity** :-

Spiral test :- american Foundry society → AFS

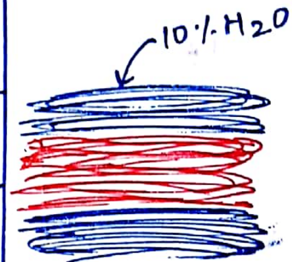
ASTM → american society of Testing of material

ours ← BIS



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 spiral test. Distance covered by liquid metal before solidification in a standard spiral will gives the value of fluidity.

Property		Fluidity
** * ① Pouring Tempr.	↑	↑
② Viscosity → Resistance to flow	↑	↓
③ Density	↑	↓
④ % of water in sand	↑	↓
⑤ surface finish of cavity	↑	↑



✓ more influence on the liquid metal → Pouring Tempr.

✓ Fluidity $\xrightarrow{\text{depend}}$ energy of atoms

But not viscosity.

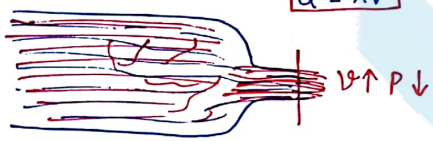
11/09/2016

* CHOKE AREA :-

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

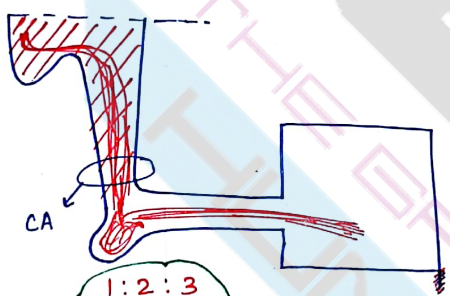
$m \rightarrow$ Mass of the casting.
$\rho \rightarrow$ density of the material.
$C_d \rightarrow$ coeffi. of discharge.
$t_f \rightarrow$ filling time required.
$h_t \rightarrow$ height of the liquid metal above the gate.

$Q = AV$



Unpressurised Gating :-

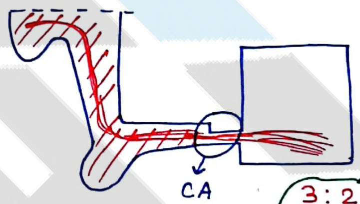
$CA = A_s$



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

Pressurised Gating :-

$CA = A_g$



3 : 2 : 1
2 : 2 : 1
1 : 1.5 : 0.5
also
1 : 2 : 1

$$C.Y. = \frac{V_c}{V_c + V_g}$$

casting yield

Choke area → it is a minimum cross-sectional area in all the gating elements. it will control the flow of the liquid metal which is enter into the cavity. it is the first parameter to be calculated in all the gating elements.

U.P. Gating :→ choke area is at the bottom of the spue. velocity of the liquid metal in the cavity is less. There is no Turbulence and splashing of the liquid metal. It can be used for casting of non-ferrous materials. There is a possibility of air aspiration effect.

casting yield is less.

P. Gating System :- choke area is at the gate. velocity of the liquid metal in the cavity is very high. There is a turbulence & splashing. used for ferrous materials. No air aspiration effect. casting yield is more.

* **Grating Ratio** :-

$A_s : A_r : A_g$

$1 : 2 : 3$

Q In a gating design, gating ratio is 3:2:1. it is used to produce a casting of mass 20 kg, density of the material is 2700 kg/m³, filling time required is 8.2 secs, height of the liquid metal above the gate is 200 mm. assuming Cd as 0.98. Calculate the dimensions of the sprue.

Sol

$A_s : A_r : A_g$

$GR = 3 : 2 : 1$

$m = 20\,kg$

$\rho = 2700\,kg/m^3$

$t_f = 8.2\,sec$

$h_t = 200\,mm$

$C_d = 0.98$

also, $A_r = 2A_g = 2 \times 4.65 = 9.3\,cm^2$

$A_r = \frac{\pi}{4} d_r^2 = 9.3 \Rightarrow \boxed{d_r = 3.44\,cm}$

* suppose $1 : 2 : 3$ ← qu. changing

$C_A = A_s$

$A_r = 2A_s$

$A_g = 3A_s$

$$C_A = \frac{m}{\rho t_f C_d \sqrt{2gh_t}} = \frac{20}{2700 \times 8.2 \times 0.98 \sqrt{2 \times 9.81 \times 0.2}}$$

$$\boxed{C_A = 4.65 \times 10^{-4}\, m^2}$$

$C_A = A_g = 4.65\,cm^2$

$A_s = 3A_g = 3 \times 4.65 = 13.99\,cm^2$

$A_s = \frac{\pi}{4} d_s^2 = 13.99 \Rightarrow A_s = 13.99$

$\Rightarrow \boxed{d_s = 4.21\,cm}$

* Solidification Time :-

Chvorinov's principle :-

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

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

V → amount of heat content / heat available

A → amount of heat transfer

K → depends on properties of the moulding material ($K, \alpha, \ldots$ etc)

$\alpha = \frac{K}{\rho C}$

K → Solidification factor

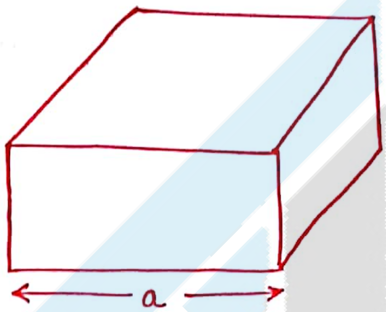
→ S/m^2

Example :- ① $t_s \propto \frac{1}{K}$ ← thermal conductivity

② $t_s \propto \frac{1}{\alpha}$ ← thermal diffusivity

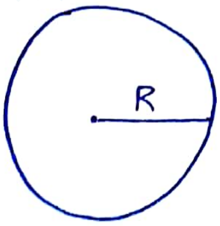
③ $t_s \propto$ "$1 \times C$" ← specific heat

① Cube :-



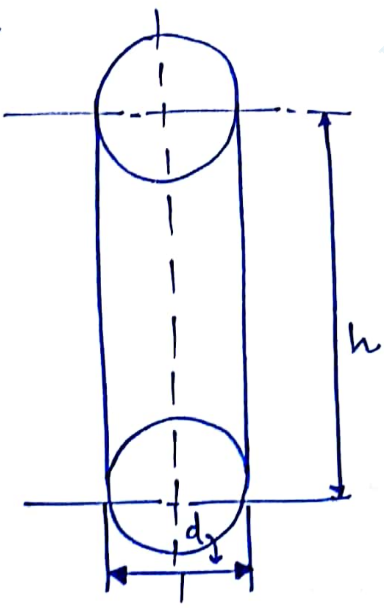
$$\frac{V}{A} = \frac{a^3}{6a^2} = \frac{a}{6}$$

② Sphere :-



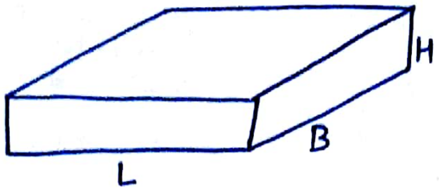
$$\frac{V}{A} = \frac{\frac{4}{3}\pi R^3}{4\pi R^2} = \frac{R}{3} = D/6$$

③ Cylinder :-



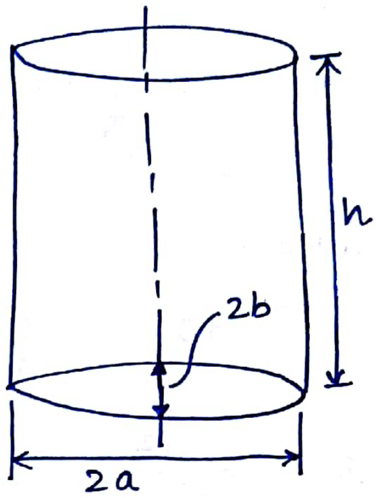
$$\frac{V}{A} = \frac{\frac{\pi}{4}d^2 . h}{2\frac{\pi}{4}d^2 + \pi d h}$$

④ **Slab :-**



$$\boxed{\frac{V}{A} = \frac{LBH}{2(LB + BH + HL)}}$$

⑤ **Elliptical cylinder :-**



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

Q A molten drop of liquid metal which is in spherical form with 3mm radius will solidify in 10 sec's. what is the solidification time of same molten drop with double the radius.

Sol

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

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

$$\frac{t_{s_1}}{t_{s_2}} = \left(\frac{S_1}{S_2}\right)^2$$

$$\frac{10}{t_{s_2}} = \left(\frac{3}{6}\right)^2$$

$$\boxed{t_{s_2} = 40\,\text{sec.}}$$ Ans.

WB Q17

$K = 0.92 \times 10^6 \ s/m^2$

sphere → $d = 200mm$

$t \quad 0.92 \times 10^6 = K\left(\frac{D}{6}\right)^2$

SIR

$ts = K\left(\frac{V}{A}\right)^2 = K\left(D/6\right)^2 = 0.92 \times 10^6 \left(\frac{0.2}{6}\right)^2 = 1077.78 \, sec$

Q15 cube → l sphere → r

$a^3 = \frac{4}{3}\pi R^3$

SIR

$$\frac{(ts)_c}{(ts)_{sp}} = \frac{\left(\frac{V}{A}\right)_c^2}{\left(\frac{V}{A}\right)_{sp}^2} = \frac{(A)^2_{sp}}{(A)^2_c} = \frac{(4\pi r^2)^2}{(6l^2)^2} = \left(\frac{4\pi}{6}\right)^2 \cdot \left(\frac{r}{l}\right)^4$$

$$= \left(\frac{4\pi}{6}\right)^2 \left(\frac{3}{4\pi}\right)^{4/3}$$

$$= 0.694$$

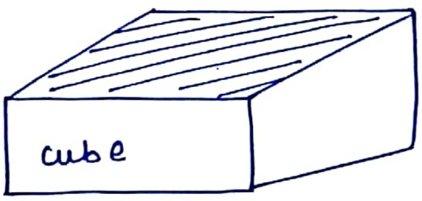
$V_{sp} = V_c$

$\frac{4}{3}\pi r^3 = l^3$

$\left(\frac{r}{l}\right) = \left(\frac{3}{4\pi}\right)^{1/3}$

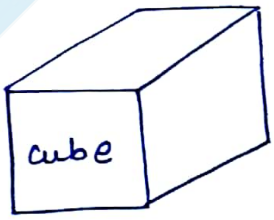
Q22 → HW

Q26 $ts \propto \left(\frac{V}{A}\right)^2$



①

$A = 5a^2$



②

$A = 6a^2$

$$\frac{ts_1}{ts_2} = \frac{(a/5)^2}{(a/6)^2} = \frac{36}{25}$$

Q29

$$\frac{(t_s)_{cylindrical}}{(t_s)_{cube}}$$

$(h = r)$

cube: $a = 2h$

$$\frac{\frac{\pi}{4}(2h)^2 h}{2\frac{\pi}{4}(2r)^2 + \pi(2r)h} = \frac{\frac{\pi}{\cancel{4}} \cancel{4}h^2 h}{2\frac{\pi}{\cancel{4}}\cancel{4}h^2 + 2h^2\pi}$$

$$\frac{\pi h^3}{2\pi h^2 + 2\pi h^2}$$

$$\frac{\cancel{\pi} h^{\cancel{3}}}{4\cancel{\pi} \cancel{h^2}}$$

$$\frac{h}{4}$$

$$(t_s)_{cube} = \frac{a}{6} = \frac{2h}{6}$$

$$\frac{h/4}{\frac{2h}{6}} \quad \frac{\cancel{h}}{4} \times \frac{\cancel{6}\,3}{\cancel{2h}} \quad 3/4 \text{ Ans}$$

$\boxed{0.56}$ ← Ans

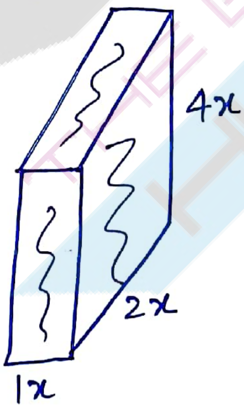
Q Two castings, one is a cube, another is a slab both are made up of same material and having same volume but the slab dimensions are in the ratio of 1 : 2 : 4. What is the ratio of solidification time of cube to the slab.

Sol $\boxed{V_c = V_s}$ ← given

$$\frac{8}{2(2+8+4)}$$

$$\frac{\cancel{8}\,\cancel{4}\,2}{\cancel{2}(\cancel{14})\,7} \quad \frac{2}{7}$$

$$\frac{(t_s)_c}{(t_s)_{SL}} = \frac{\left(\frac{V}{A}\right)_c^2}{\left(\frac{V}{A}\right)_{SL}^2}$$



$$= \frac{(A)_{SL}^2}{(A)_c^2} = \frac{(28x^2)^2}{(6a^2)^2}$$

$V_c = V_{SL}$

$a^3 = 8x^3$

$\boxed{a = 2x}$

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

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

$= 1.36$ Ans

$V = 1x \cdot 2x \cdot 4x$

$= 8x^3$

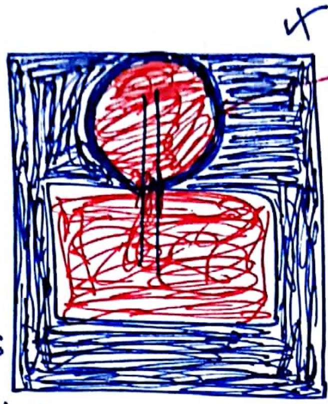
$A = 2(1x \cdot 2x + 2x \cdot 4x + 4x \cdot x)$

$A = 28x^2$

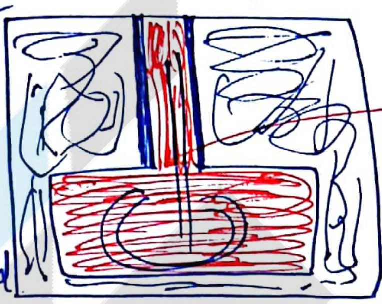
* Riser :-

$\left(\frac{A}{V}\right) \rightarrow$ cooling characteristics

$\hookrightarrow$ min.



For a given volume of the the riser sphere is having minm. surface area to the volume ratio but it's not considered as shape of the riser. This is due to availability of the liquid metal in the spherical riser is at the centre.



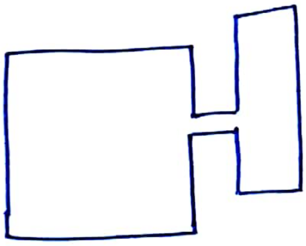
Cylinder will be considered as the shape of the riser.

Types of Riser's - (1) Side Riser.
(2) Top Riser.

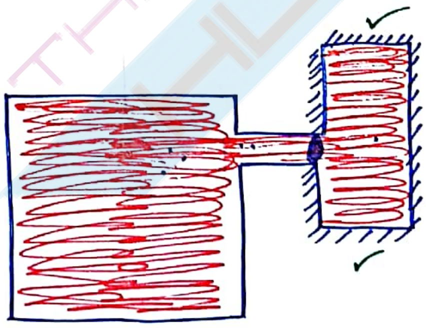
Solidification time $\rightarrow$ maxm.

our concern

(1) Side Riser

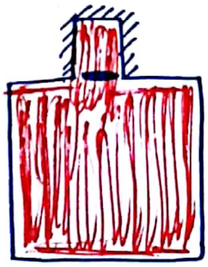


Redraw $\rightarrow$



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

(2) Top Riser



✓ more preferable.

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

* Optimum condition in case of :-

① Side Riser :-

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

$v \to$ constant

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

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

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

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

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

$$\left[V = \frac{\pi}{4}d^3\right]$$

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

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

$$d^3 = \frac{4V}{\pi} \neq 4 \times \frac{\pi}{4}d^3$$

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

$$\boxed{h = d}$$

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

② Top Riser

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

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

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

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

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

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

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

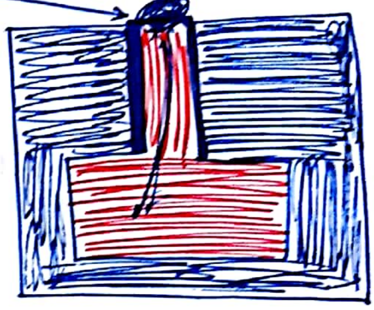
$$\boxed{h = d/2}$$

$$\boxed{(A/V) = \frac{6}{d}}$$

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

* Riser Design :-

① ⓐ vol. of Riser = 3 × % of shrinkage vol. of casting



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

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

$\boxed{h \,\&\, d}$

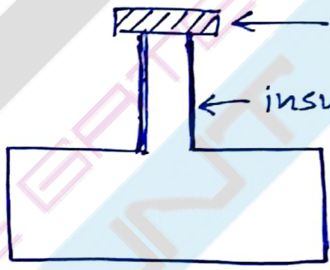
$$\boxed{\left(\frac{A}{V}\right)_c = \left(\frac{A}{V}\right)_r}$$

$\boxed{h \,\&\, d}$

$V = 100\,cm^3$
3%
$3\,cm^3$

$V_r = 3\,cm^3$

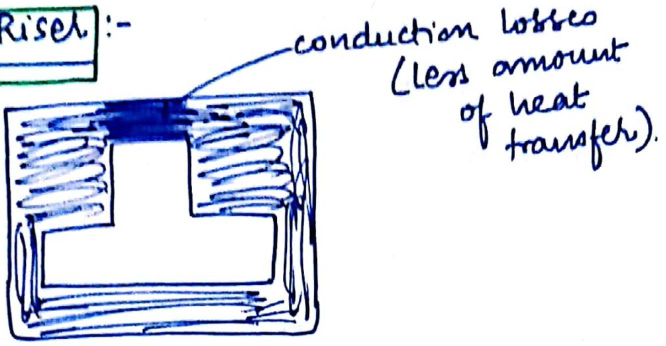
$V_r = 9\,cm^3$



Re-written

$V = 100\,cm^3$ 3% $3\,cm^3$ ① Insulating Material ② Exothermic material ③ $h = d$ & $h = d/2$ ④ Next Page	$V_r = 3\,cm^3$	$V_r = 9\,cm^3$

Blind Riser :-



Methods to ↑ the performance of the Riser :-

1. Insulating material
2. Exothermic material (heat Releases).
3. $h = d$ & $h = d/2$
4. Blind Riser

* Caine's Method :-

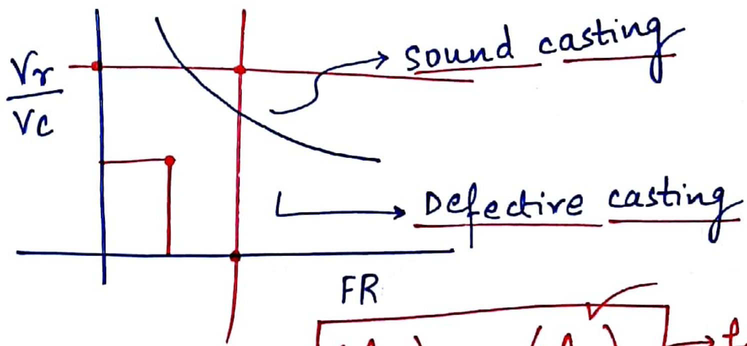
$$\text{Freezing Ratio (FR)} = \frac{\left(\frac{A}{V}\right)_c}{\left(\frac{A}{V}\right)_r}$$ → cooling characteristics

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

$X = FR$

$$\boxed{Y = \frac{V_r}{V_c}}$$

a, b, c are constants. → depends on properties of material.



✓ Simple shape of castings.

$$\boxed{\left(\frac{A}{V}\right)_c = \left(\frac{A}{V}\right)_r}$$ → for Recalculating of Def. casting

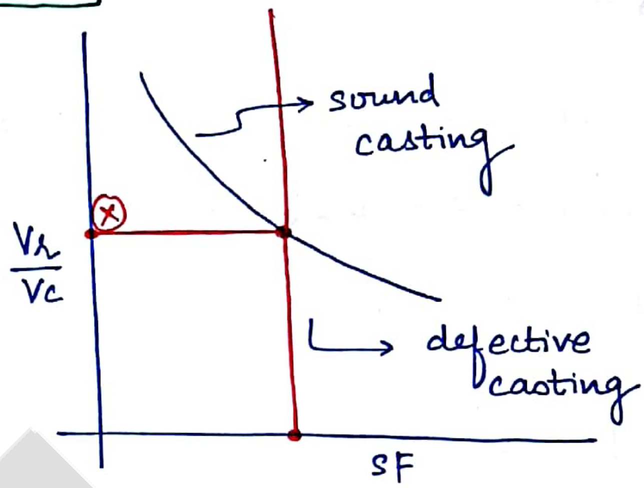
This method can be used for calculating the dimensions of the risers for simple shape of casting. for a complex shape of the casting, calculation of surface area to the volm. ratio is difficult.

③ Modified Caine's Method :- (Naval Research laboratory method) → for complex shape.

$$\boxed{\text{Shape Factor (SF)} = \frac{L+W}{T}}$$

L → Length
W → width
T → thickness

maxm. consider please



$\frac{V_r}{V_c} = X$ ← some constant value

$$\boxed{V_r = V_c X}$$

Gate 2015

SF	2	4	6	8	
$\frac{V_r}{V_c}$	1	1	0		

ⓐ **Cube** :- $SF = \frac{a+a}{a} = 2$

ⓑ **Sphere** :- $SF = \frac{D+D}{D} = 2$

ⓒ **Cylinder** :- $SF = \frac{H+D}{D} = \frac{H+D}{D}$

ⓓ **Slab** :- $SF = \frac{L+B}{H}$

(4) $\boxed{\text{Modulus Method}}$:- → simple shape of casting

$$\text{Modulus } (M) = \left(\frac{V}{A}\right)$$

$$\boxed{M_r = 1.2 M_c}$$

Riser   casting

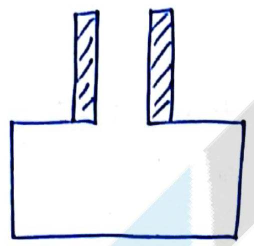
M_r = const.

$$M_r = d/6 = \text{const.}$$

WB / T1   Sol   cylindrical Riser ⟶ $25 \times 12.5 \times 5 \text{ cm}^3$

steel → 3%

r → (3)



* last line → underline please

SIR (T1) $25 \times 12.5 \times 5 \text{ cm}^3$

(a) $V_s = 3 \times \frac{3}{100}(25 \times 12.5 \times 5)$

$= 140.625 \text{ cm}^3$

$V_r = \frac{\pi}{4} d^3 = 140.625$

$$\boxed{h = d = 5.636 \text{cm}}$$ Ans :. shrinkage alone

(b) our curiosity → $\left(\frac{A}{V}\right)_c = \frac{2\,[25 \times 12.5 + 12.5 \times 5 + 5 \times 25]}{25 \times 12.5 \times 5} = 0.64$

$\left(\frac{A}{V}\right)_r = \frac{6}{d} = \frac{6}{5.636} = \underline{1.065}$

no use of this riser since solidification starts here first.

so,

$\left(\frac{A}{V}\right)_r = \left(\frac{A}{V}\right)_c$

$\frac{6}{d} = 0.64$

$$\boxed{d = h = 9.375 \text{cm}}$$

Q32 Caine's method

$\left(\frac{h}{d}\right)_c$

250x250x50

Side riser

$t = 50$ mm

$a = 0.10$, $b = 0.03$

$c = 1.00$

$250 \times 50\ mm^2$

SIR $250 \times 250 \times 50\ mm^3$

$a = 0.1$, $b = 0.03$, $C = 1$

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

$$X = FR = \frac{\left(\frac{A}{V}\right)_c}{\left(A/V\right)_R}$$

$$\left(\frac{A}{V}\right)_c = 2\left[\frac{250\times 250 + 250\times 50 + 50\times 250}{250\times 250\times 50}\right] = 0.056$$

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

$$\frac{\left(\frac{A}{V}\right)_c}{\left(\frac{A}{V}\right)_R} = \frac{0.056}{6/d} = X$$

$$Y = \frac{\frac{\pi}{4}d^3}{3125000}$$

$$\boxed{\frac{0.056}{6/d} = \frac{0.1}{\frac{\frac{\pi}{4}d^3}{3125000} - 0.03} + 1}$$

$$\frac{0.056\times d}{6} = 0.1 \text{ - - - - -}$$

$$\boxed{d = 128.4\text{mm}}$$

$\frac{1250000}{\pi d^3 - 75\times 10^5} + 1$

$-6250000 + \pi d^3$

$9.33\times 10^{-3}\ \pi d^3 -$

$\frac{\frac{\pi}{4}d^3 - 93750}{3125000}$

$\frac{\pi d^3 - 375000}{12500000}$

-0.03

$\pi d^3 - 375000\ 375000$

$\frac{\pi d^3 - 7500000}{12500000}$

0.1

30

SF	2	4	6	8	10	12
Riser volume / casting volume → $\left(\frac{V_r}{V_c}\right)$	1.0	0.70	0.55	0.50	0.45	0.27

L B H
$25 \times 15 \times 5\,cm^3$

~~2.57~~

$h = d$

SIR

$$\text{Shape Factor} = \frac{L+B}{H} = \frac{25+15}{5} = 8$$

$$\frac{V_r}{V_c} = 0.5$$

$$V_r = 0.5(25 \times 15 \times 5)$$

$$V_r = \frac{\pi}{4} d^3 = 937.5\,cm^3$$

$$\boxed{d = 10.61\,cm}$$

Q A cylindrical riser with $h = d$ is positioned on the top of cylindrical casting. $h = 100\,mm$ and d is $200\,mm$. Calculate dimensions of the using Modulus method. riser.

Sol

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

$\pi d h$

$$\frac{\frac{\pi}{4} h^3}{}$$

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

SIR $h = d$

$H = 100\,mm$

$D = 200\,mm$

$M_r = 1.2 M_c$

$$M_c = \left(\frac{V}{A}\right)_c = \frac{\pi/4\,(200)^2(100)}{2 \times \frac{\pi}{4}(200)^2 + \pi(200)(100)}$$

$$= 25$$

$$M_r = 1.2 \times 25 = 30$$

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

$h = d$

$M_r = d/5$

$M_r = d/5 = 30$

$d = 150\ mm$

Q28 $d = 6cm$, $h = 6cm$ > Riser

casting $7 \times 10 \times 2$

$t_s = 1.36\ min$

$t_R = 2$

$$\left(\frac{V}{A}\right) = \frac{LBH}{2(LB + BH + HL)}$$

SIR

$$\frac{(t_s)_c}{(t_s)_R} = \frac{\left(\frac{V}{A}\right)_c^2}{\left(\frac{V}{A}\right)_R^2} = \frac{\left(\frac{7 \times 10 \times 2}{2 \times (7 \times 10 + 10 \times 2 + 2 \times 7)}\right)^2}{\left(\frac{6}{6}\right)^2} = \frac{1.36}{(t_s)_r}$$

$$\boxed{(t_s)_r = 3 min}$$

T2 Side Risers → same volume.

cylinderical shape square parallelepiped.

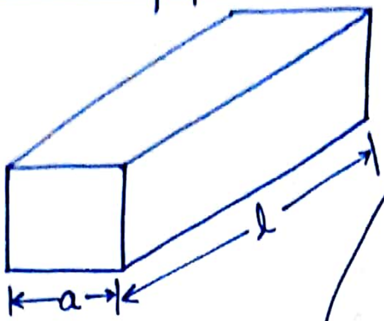
Optimum Side Risers (underline please)

① Cylinder

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

$\boxed{h = d}$

② Square Parallelopiped :-



$$A = 2a^2 + 4al$$

$$V = a^2 l \Rightarrow l = \frac{V}{a^2}$$

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

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

$$\frac{dA}{da} = 0 \Rightarrow 4a - \frac{4V}{a^2} = 0$$

$$V = a^3 = a^2 l$$

$$\boxed{a = l}$$

put $a = l$

$$\frac{(ts)_{cy}}{(ts)_{sp}} = \frac{\left(\frac{V}{A}\right)^2_{cy}}{\left(\frac{V}{A}\right)^2_{sp}} = \frac{(A)^2_{sp}}{(A)^2_{cy}} = \frac{(6a^2)^2}{\left(\frac{3}{2}\pi d^2\right)^2}$$

$$= \left(\frac{4}{\pi}\right)^2 \cdot \left(\frac{a}{d}\right)^4$$

$$= 1.17$$

$$V_{cy} = V_{sp}$$

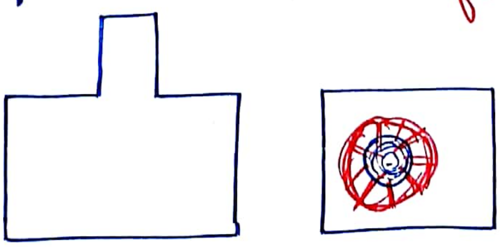
$$\frac{\pi}{4} d^3 = a^3$$

$$\left(\frac{a}{d}\right) = \left(\frac{\pi}{4}\right)^{1/3}$$

$$\boxed{(ts)_{cy} = 1.17\,(ts)_{sp}}$$

* Position of Riser

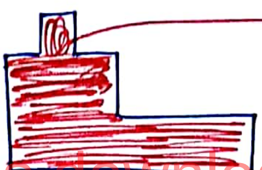
① Uniform thickness :- → simple shapes of casting



③ For min. Thickness and max. (SA) → surface area

[Next Page]

② For Non-uniform thickness :-



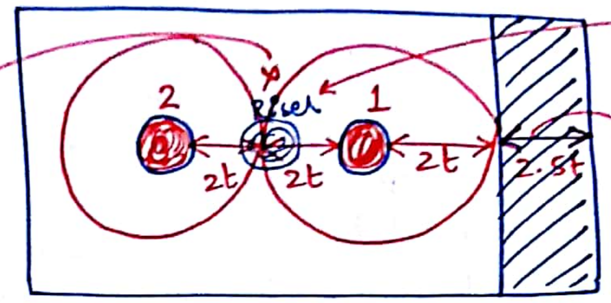
→ providing Riser to highest thickness of the casting.

since solidification reasons.

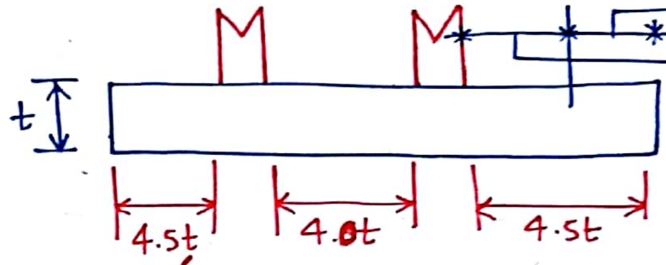
$L = 13t + \cancel{2d}$

$\boxed{L = 13t}$ ✓

not single ✓ not preferable



not sufficient to compensate fast rate of shrinkage of the casting hence more risers 1, 2.

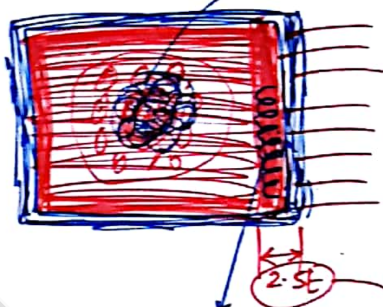


2.5t (Endwall gradient)

2t → (Riser gradient)

thickness of the casting

shrinkage cavities



shrinkage

no need to compensate the shrinkage for getting the liquid metal from the Risers.

① **with Endwall ~~Def~~ effect :-**

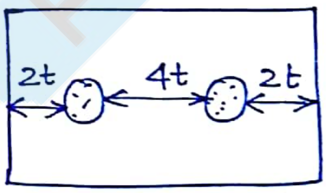
$L = 13t$ (Two Risers)

$L = 9t$ (one Riser)

② **without Endwall Effect :-**

$L = 8t$ (Two Risers)

$L = \underline{4t}$ (one Riser)



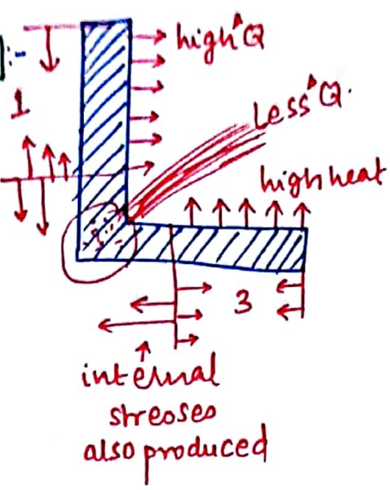
for simple shape and uniform thickness of the castings, one riser is sufficient to compensate the shrinkage. It is positioned on the surface of the mould at the centre.

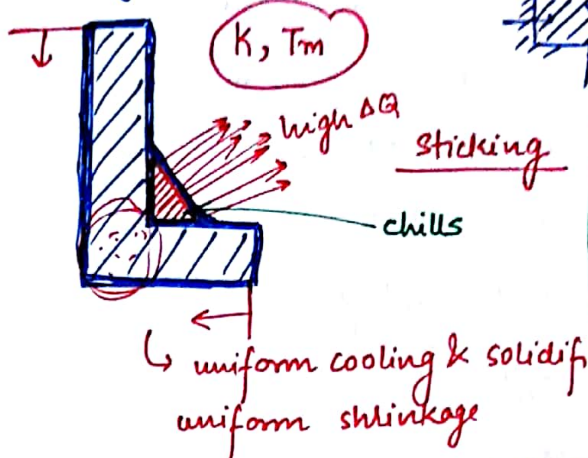
for non-uniform thickness of the castings, riser is provided close to higher thickness of the casting.

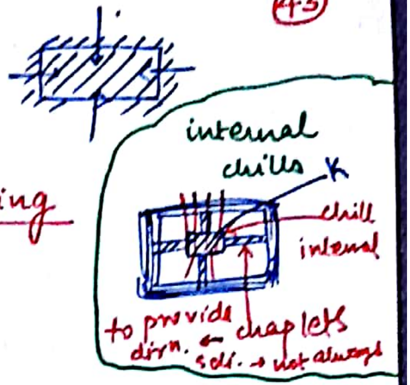
for a minm. thickness and maxm. surface area of the castings due to fast rate of shrinkage more no. of risers are required.

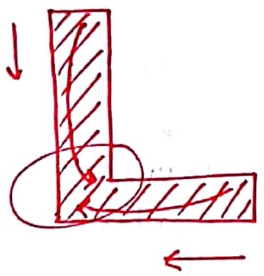
* Chills and Padding :-

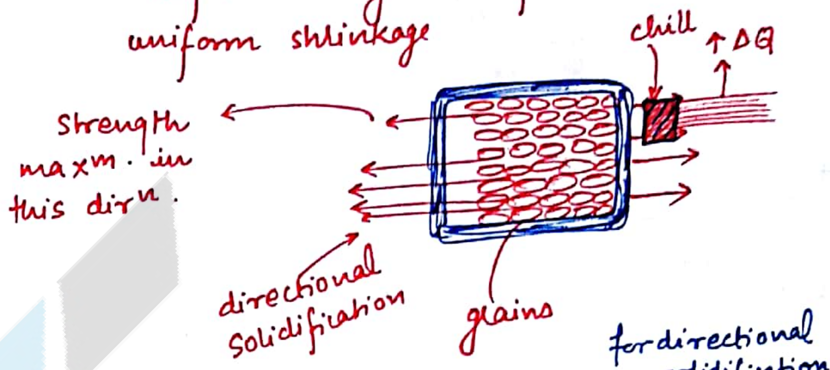
Chills :-

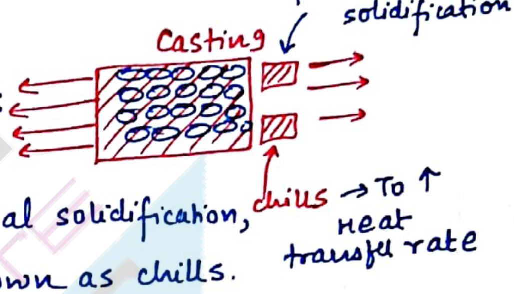








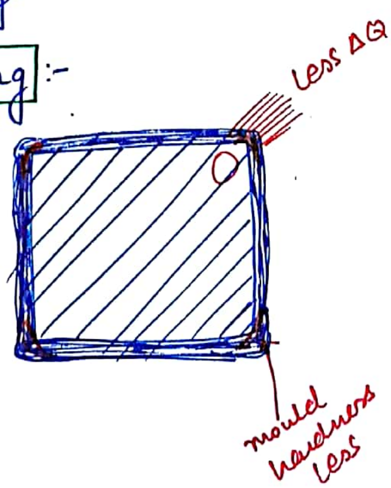


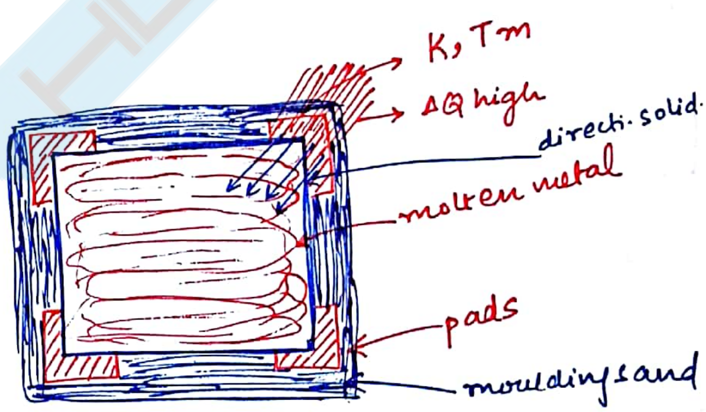


✓ At minimum x-s/c's in the mould cavities to maxm. the heat transfer rate and to provide uniform solidification and directional solidification, metallic objects are provided. These are known as chills.

✓ If the solidification will taking place in single direction, it is called directional solidification. along the direction of grain growth, strength is maximum.

Padding :-





✓ at critical x-s/c in the mould cavity (means corners) to minimize erosion and to maximize heat transfer rate and to provide directional solidification, metallic objects are provided. These are known as padding. * By providing chills and padding, directional solidification can be possible.

NOTE :- If the chaplets are providing to support the internal chill, they will also provide directional solidification.

IES Qn. Directional solidification.

① chills and padding → most appropriate ans.

② chills and chaplets

③ chaplets and padding

④ chills, chaplets and padding.

if option ① is not given, then ④ is appropriate ans.

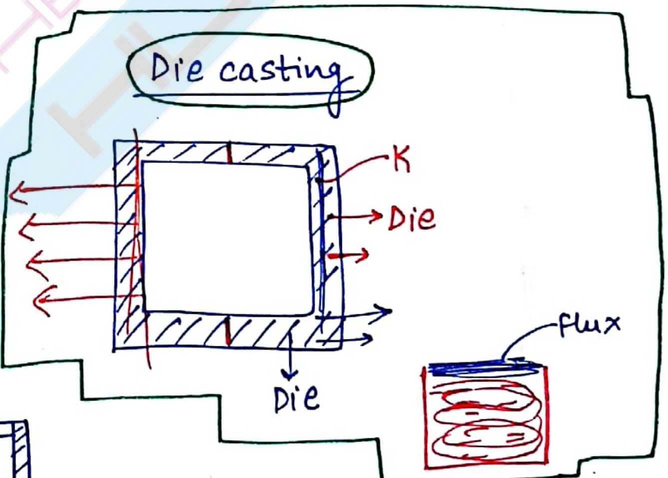
Solid
↓
more Heat transfer
than
↓
liquid
↓
since high K
↓
high ΔQ in conduction
↓
than convection, Radiation.

* Classification of Casting Techniques :-

1) **Expendable Moulds** (Temporary Moulds) :-
- → sand casting
- → shell moulding
- → Investment casting
- → Full moulding
- → CO_2 moulding

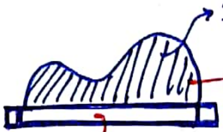
② **Permanent Moulds** (Metallic Moulds) :-
- → centrifugal
- → Die casting
- → slush casting
- → squeeze casting

③ **Continuous Casting**



* SHELL MOULDING :-

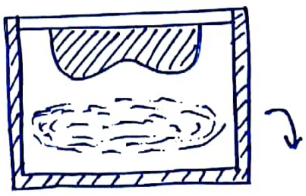
Pattern



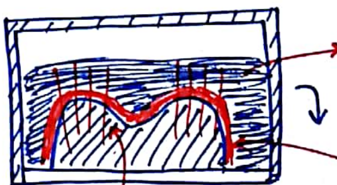
Moulding Material :-

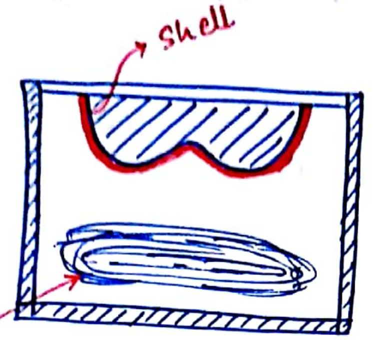
Finegrain silica,
phenolic resins, → thermosetting plastic resins with Reaction to silica sand.
Alcohol, etc.

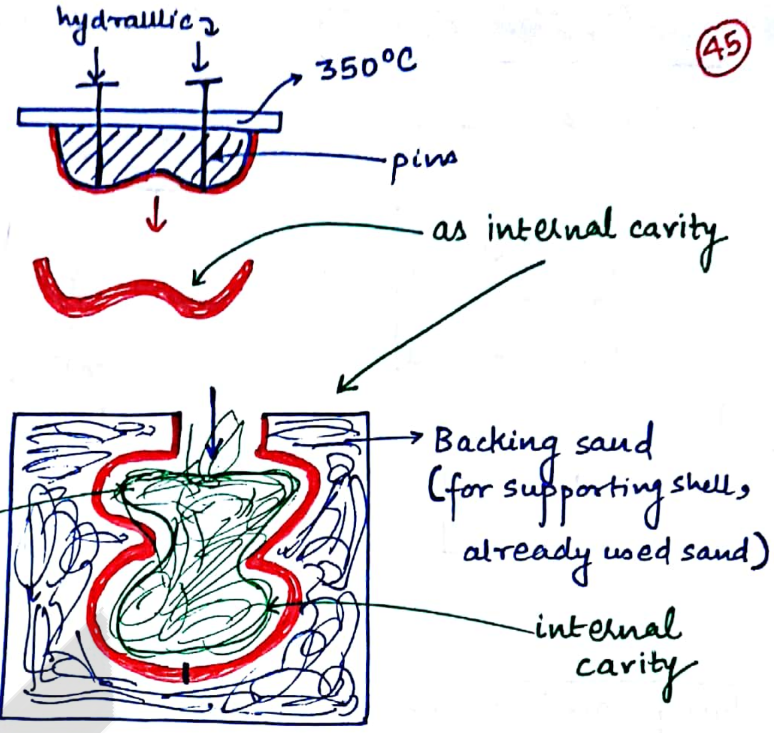
not using clay



dwell time







Resin binders → ① strength, hardness of shell ↑.
② —"—"— ↓ at very high Temp^r. (पिघलने)

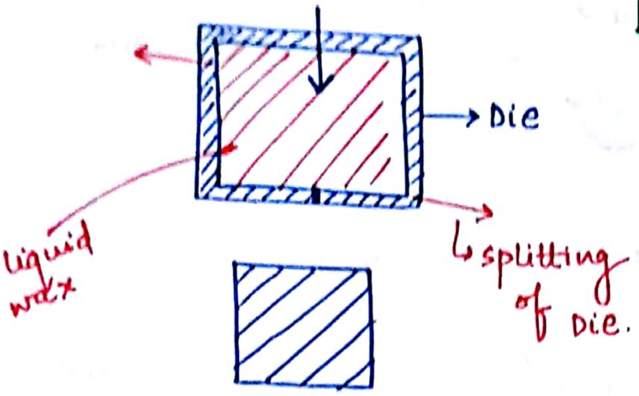
Applications :- ① cylinder Blocks of air cooled I.C. Engines,
② Rocker arms.
③ Valve plates of Refrigerators.

✓ To produce better surface finish and accuracy when compared to sand moulding, this technique can be used. Pattern is produced by metallic material and it can be heated upto 250°C. ✓ Moulding material is made in contact with heated metallic pattern. Due to heat from the pattern by activating the bonding properties of phenolic resins, moulding sand will be stick to the surface of pattern in the form of shell. Thickness of the shell will depends on contact time between pattern and moulding material known as dwell time. After getting required thickness, shell and pattern can be separated from the mould and they will be heated upto 350°C to increase the strength of the shell. By separating the shells from the pattern, they will be added together to get the required cavity into which liquid metal will be allowed to solidify.

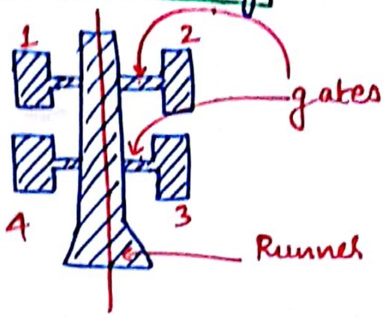
✓ Very complex shape of objects are difficult to produce. It is a time consuming process. Size of the castings are limited to 200kg.

* **Investment Casting** :- precision casting, more complex shapes.

Pattern → wax



Pattern Assembly :-



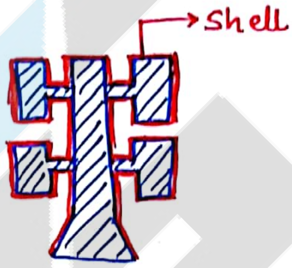
'Stuccoing process' → ceramic shell

Slurry and ceramic coating :-

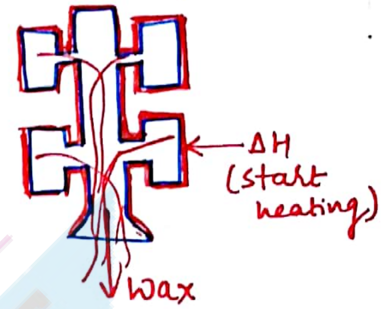
Slurry :- viscous material

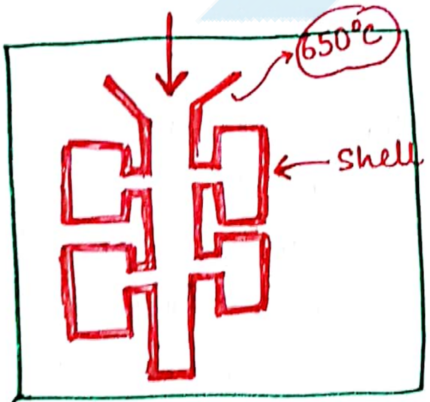
silica flour
Ethyl silicate
water

binder



Dewaxing :-





vacuum chamber
(since for limiting gas defects because of fine grains).

Applications :-

< 10kg

- Gas Turbine blades, → nimonic alloys
- Jet Engine parts,
- Dentures, → stainless steel
- Medical Implants, → Titanium alloys
- Gold ornaments, etc.

Requires smooth surface finish & precised.

high M.P., high strength

ONLY ONE TIME → . PATTERN
. CERAMIC

Hence, "Expendable pattern"
"lost wax pattern"

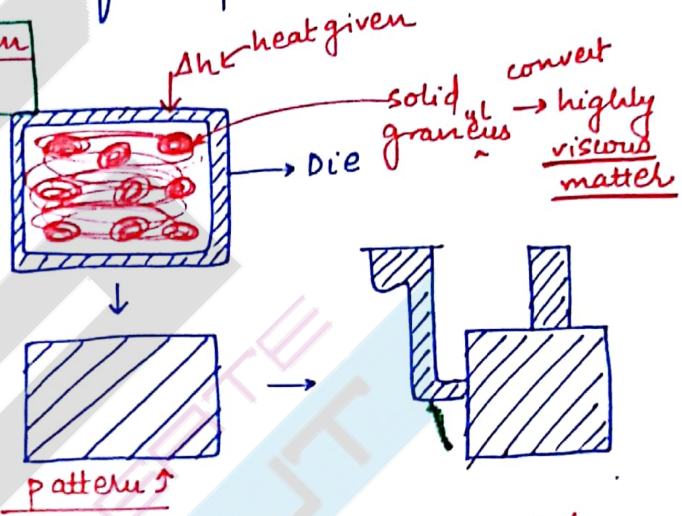
HIGH M.P. Materials, MORE COMPLEX CASTINGS.
↳ not by Die casting (∵ for low M.P. material)

✓ To produce complex shape of the objects which are made up of high Melting point and high strength materials, this technique can be used. ✓ Pattern is produced by wax material. To increase the production rate along with gating elements will produce a pattern assembly. By adding the slurry coatings, ceramic particles will be added around the pattern to produce a ceramic shell. By heating the ceramic shell, wax pattern can be removed to get the required cavity into which liquid metal will be allowed to solidify. after solidification by breaking the mould, required shape of casting can be produced by separating the gating elements. To minimize the gas defects, this process will be carried out under vacuum conditions. cost of the process will be high.

* **FULL MOULDING** → cavityless / Evaporative pattern casting or Lost Foam process

Pattern :- Plastics
- Polystyrene,
- Foam, PVC,
- Thermocole, etc

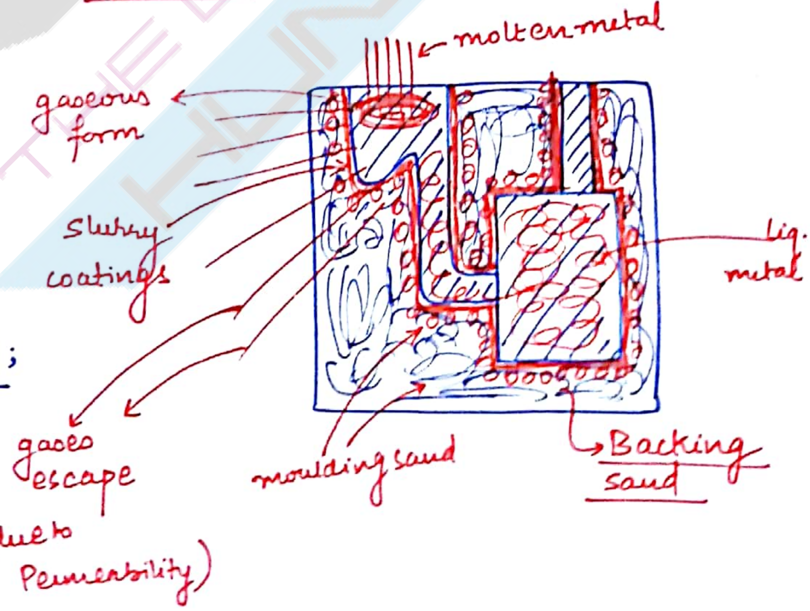
easily evaporated



✓ Complex shape

✓ low M.P. material

Applications :- Motor casings,
Tooling,
Fitting,
Lock components;

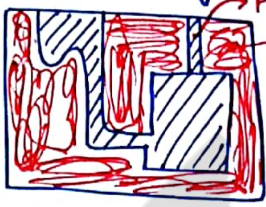


✓ EXPANDABLE PATTERN
- ↙ Full moulding
- ↘ investment casting.

✓ Pattern is produced by plastic material. Gating elements will be added on the pattern. By adding slurry coatings, moulding sand will be added around the pattern to produce a shell. It will be provided inside the mould by supporting backing sand. Liquid metal will be directly allowed on to the pattern due to high temperature, pattern will start evaporation and evaporated gases can be allowed to escape through the mould and cavity can be created into which liquid metal will be allowed to solidify. It can be used for complex shape. cost of the process is less. Generally used for low M.P. materials. If the moulding metal is replaced by plaster of paris, then it is called plaster moulding.

PLASTER MOULDINGS →

moulding material
↓
POP



used for low M.P. materials

POP → not having sufficient refractoriness
1000°C
also —"—"— permeability
less

Chances of Gas Defects.

✓ Used for Low Melting Point and Non-Ferrous Materials.

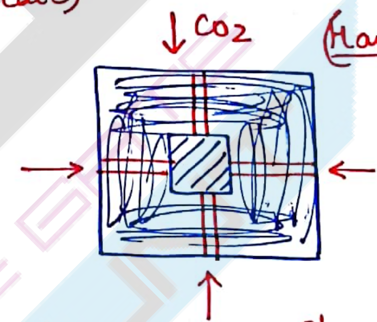
* $\boxed{CO_2 \text{ Moulding}}$:-

Binder (sodium silicate)

$Na_2SiO_3 \rightarrow 2\text{-}6\%$

$Na_2SiO_3 + CO_2 \longrightarrow SiO_2 + Na_2CO_3$

⇓
silica gel
↳ gum type
excellent Bonding

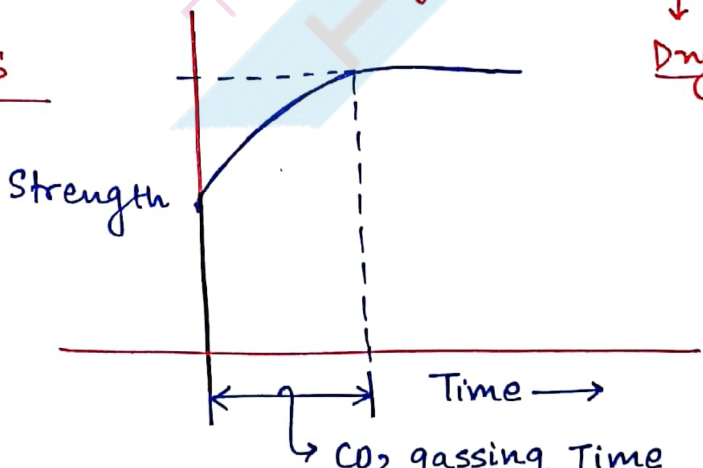


(Hand Ramming)
only

✓ ↑ strength & hardness of

LARGE SIZE MOULDS
↓
[M/c Beds]

strength → 1.4 MPa
↓
Dry strength



To increase the strength and hardness of large size mould and core, this technique can be used. mould is prepared by adding sodium silicate binder. By creating some holes inside the mould, CO_2 gas will be supplied. It will react with sodium silicate and produce silica gel which is having excellent Bonding properties. Due to this, strength and hardness of the mould can be ↑. The strength of the mould will depends on time of supplying CO_2 gas to the mould known as CO_2 gasing time. It is generally used for preparing large size moulds like machine Tool Beds, Rod Roller, etc.

Q In a sand Moulding process, it is decided to replace spherical riser with ~~h/~~ ~~d~~D = 200 mm. using a cylindrical riser with ~~h/~~ ~~D~~ h = d. under identical solidification time, what are the dimensions of cylindrical riser.

Sol SIR $\underline{D = 200\,mm}$ (h = d)

$$(t_s)_{sp} = (t_s)_{cy}$$

$$\cancel{K}\left(\frac{D}{6}\right)^2 = \cancel{K}\left(d/6\right)^2$$

$$\boxed{D = d = 200\,mm}$$

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

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

~~$= \frac{\pi}{2}(200)^2$~~

Q A cubical casting will solidify in 4 minutes. what is a solidification time of same cubical casting which is 8 times heavier than original casting is?

Sol

$$m_2 = 8m_1.$$

$$V_2 \cancel{\rho_2} = 8V_1 \cancel{\rho_1}$$

$$V_2 = 8V_1$$

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

$$\boxed{a_2 = 2a_1}$$

$$\frac{(t_s)_1}{(t_s)_2} = \left(\frac{a_1}{a_2}\right)^2$$

$$\frac{4}{t_{s_2}} = \left(\frac{\cancel{a_1}}{2\cancel{a_1}}\right)^2$$

$$\boxed{t_{s_2} = 16\,min}$$

~~$\frac{(t_s)_{c_1}}{(t_s)_{c_2}} = \frac{\left(\frac{V}{A}\right)^2_{c_1}}{\left(\frac{V}{A}\right)^2_{c_2}}$~~

~~$\rho = \frac{m}{V}$~~

~~$\frac{m_1}{\rho}$~~ ~~m~~

Q A casting of dimensions $\underline{200 \times 100 \times 10\,mm^3}$ is produced by using a cylindrical riser with $\boxed{h = d}$ what is the freezing ratio of the mould.

$(\cancel{d}/6)$ $\boxed{V \to \frac{200 \times 100 \times 10}{}}$

Sol

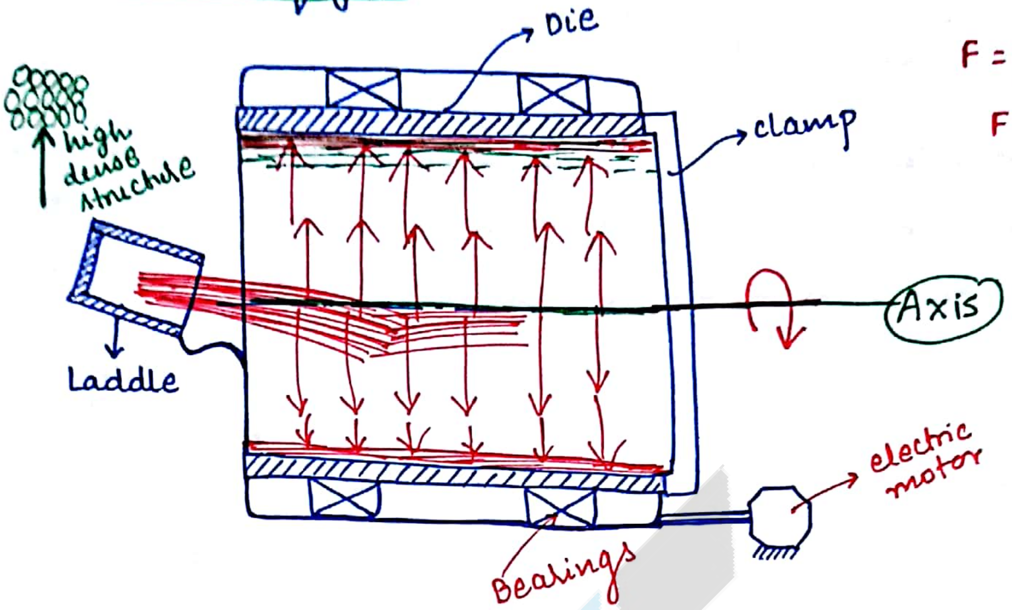
$$\text{Freezing Ratio} = \frac{\left(\frac{A}{V}\right)_c}{\left(\frac{A}{V}\right)_r} = \frac{(V/A)_r}{(V/A)_c} \to \frac{(d/6)}{\left(\frac{200 \times 100 \times 10}{2 \times (200 \times 100 + 100 \times 10 + 10 \times 200)}\right)}$$

$$= 0.038\,d$$

* CENTRIFUGAL CASTING :-

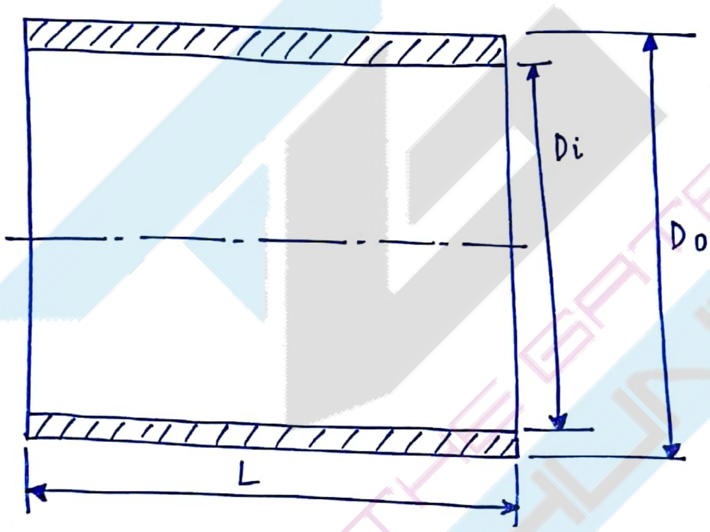
13/09/2016

(a) True centrifugal :-



$F = mR\omega^2$

$F \propto \rho$



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

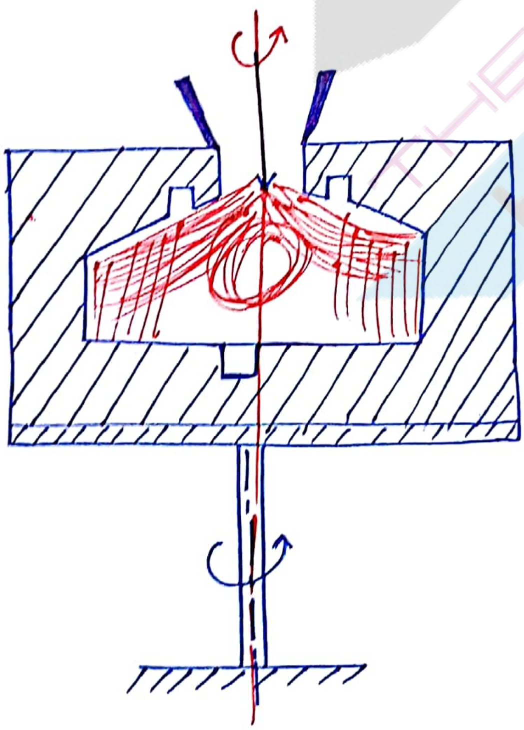
Applications :- Hollow cylindrical pipes
Gun barrels
cylinder liners
propeller shafts, etc.

$$F = ma = mR_m\omega^2 \quad , R_m = \frac{R_o + R_i}{2}$$

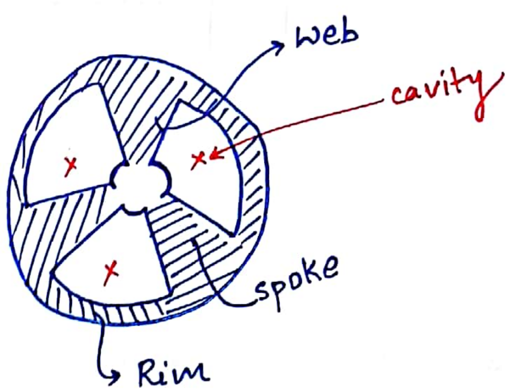
$$\boxed{a = R_m\left(\frac{2\pi N}{60}\right)^2}$$

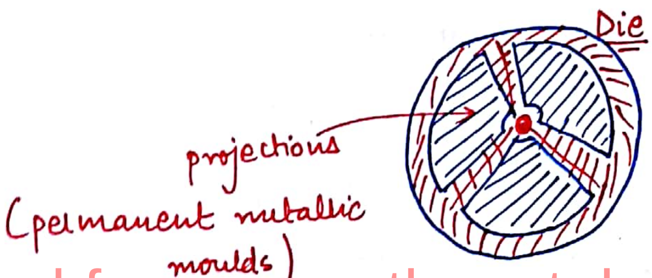
To produce hollow symmetrical shape of the objects in mass production without using the core, this technique can be used. Liquid metal will be allowed into the mould which is under rotation. due to centrifugal force, high density pure metal can be forced away from the centre & less density impurities will be collected towards the centre. Due to fast rate of cooling, fine grain structure will be developed in the casting which are having more strength and hardness. liquid metal is getting solidify when the mould is under rotation. Due to centrifugal force, high dense structure can be produced. There is no gating elements used. Casting Yield is 100%. It is used for hollow symmetrical shape of the objects only.

(b) Semi- Centrifugal casting :-



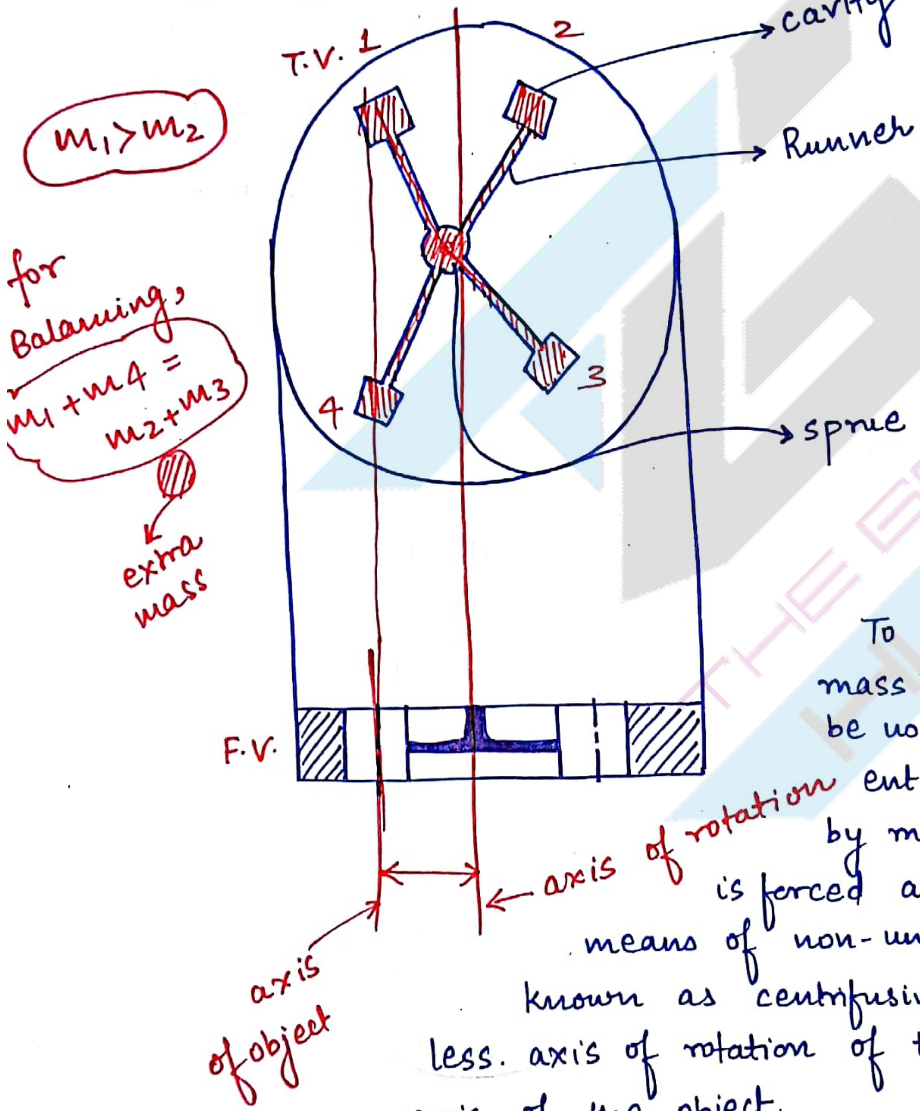
Applications :-
- Pulleys
- wheels
- spoked wheels, etc.





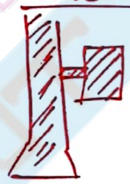
To produce the objects which requires more material in outside when compared to inside, this technique can be used. liquid metal can be enter into the mould which is under rotation. Due to gravity force, liquid metal will be entered at the centre of cavity and it is forced away from the centre by means of centrifugal force. liquid metal will be first solidify at the surface and slowly it is progressing towards the centre. high density pure structure at the outside and less ρ impurities will be collected towards the centre.

© Centrifuging :-



casting Yield → 60-70%

Investment casting



To produce unsymmetrical objects in mass production, this technique can be used. liquid metal can be enter into the centre of the sprue by means of gravity force and it is forced away from the centre by means of non-uniform centrifugal force known as centrifusing. casting yield will be less. axis of rotation of the mould not coincides with axis of the object.

Applications :- ✓ Patterns used in investment casting made up of wax.

Q A hollow casting of 600 mm outside radius and 500 mm inside radius is produced by True centrifugal casting. acclr. of the mould is 70g. what is the rotational speed of the mould.

Sol

$R_o = 0.6m$, $R_i = 0.5m$ } $R_m = 0.55m$

$a = g \cdot 70$

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

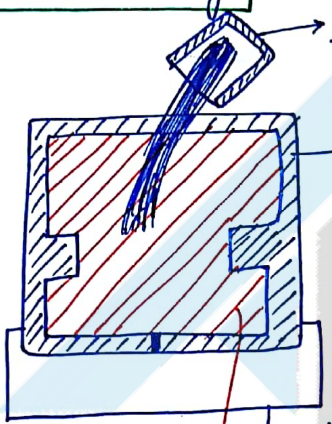
$a = R_m \left(\frac{2\pi N}{60}\right)^2$

$70 \times 9.81 = 0.55 \left(\frac{2\pi N}{60}\right)^2$

$N = 337.42$ rpm

* **DIE CASTING** – Gravity, pressure

Gravity Die casting :-



Die → for produce more no. of casting (same die can be used)

2 splits of the die after solidification

complex ✗ simple shape → fast cooling → fine grain structure.

fast cooling (Completely fill होने के पहले solidif. starts).

fast rate of solidification.

Permeability Less → Gas defects → To Remove → Vacuum (solid objects) → provide core (hollow objects).

Simple Shapes of Casting.

liquid metal can be enter into the cavity by means of gravity force only. It is used to produce simple shape of the castings only. accuracy and surface finish of the castings are very high. It can be used for Mass production. Due to fast rate of cooling, fine grain structure will be developed in the casting which are having more strength and hardness. It is used to produce better surface finish of the objects.

Applications :- (a) pistons used in automobiles made up of Al alloys.

* PRESSURE DIE CASTING

- Hot chamber.
- cold chamber.

Hot chamber Die casting :-

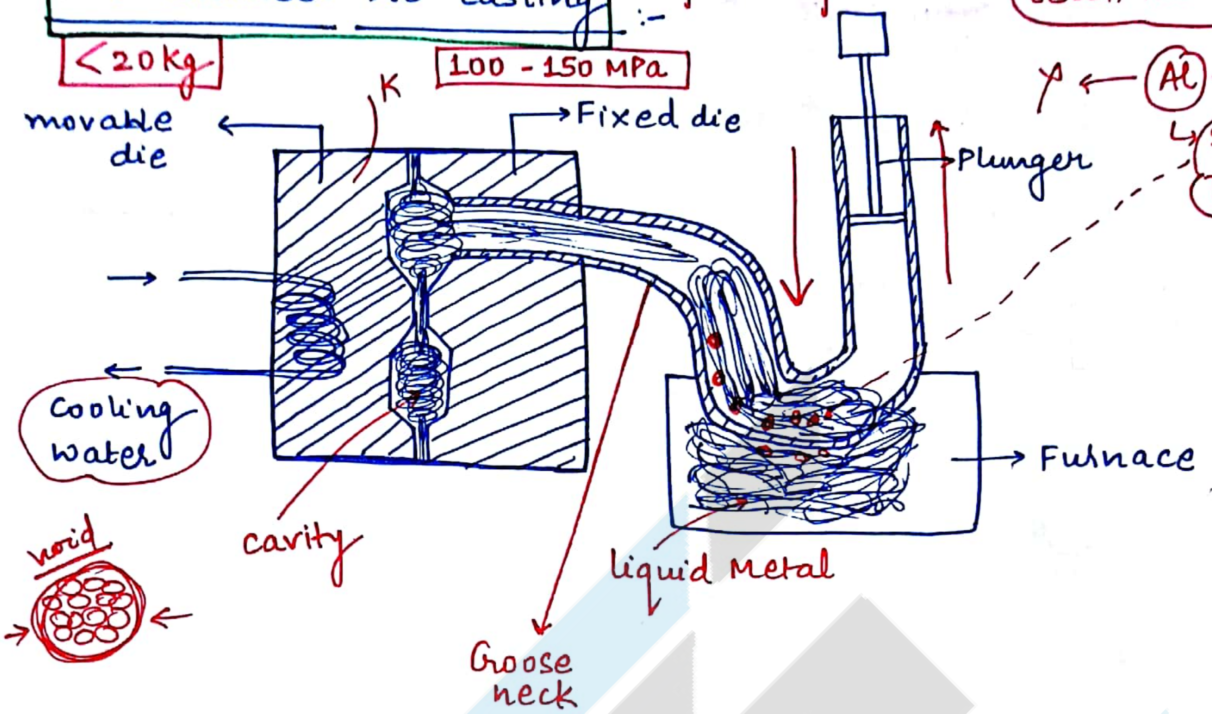
Complex shape

Lead, Tin & zinc

< 20 kg

100 - 150 MPa

X ← Al → low MP
↳ Sticking Tendency

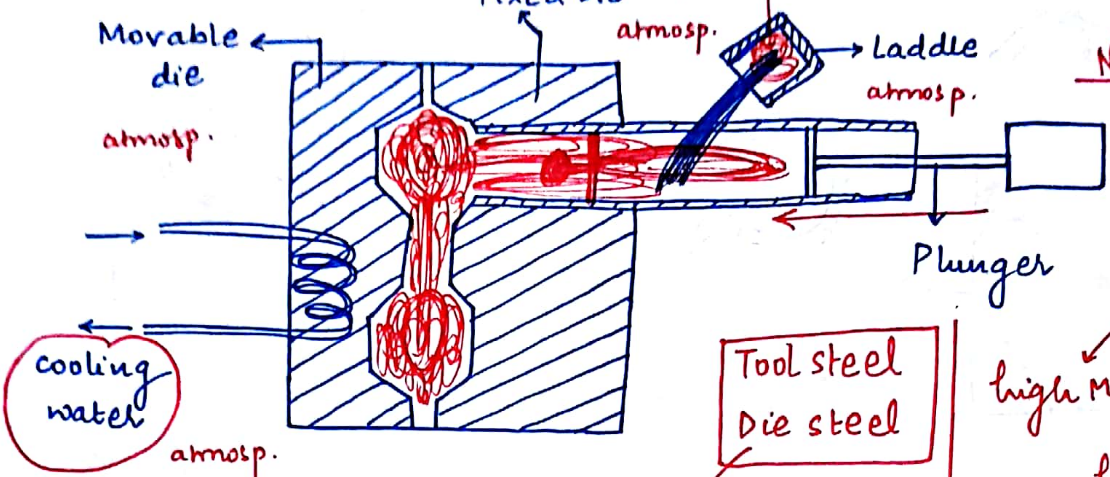


✓ small size castings → 150-200 castings/hr and high production rate and also for mass production.

Liquid metal will be enter into the cavity under external plunger force. furnace is integrated with die. It is used to produce complex shape of the objects which are made up of low M.P. materials like lead, Tin & zinc. liquid metal is getting solidify under pressure. Due to this, high dense structure can be produced. It can be used for mass production. Due to fast rate of cooling, fine grain structure will be developed in the casting which are having more strength and hardness. Due to sticking tendency of Al, it is not used in hot chamber die casting.

* Cold Chamber Die casting :-

Al, Cu, Brass, etc.



Non-Ferrous Material

Not used for Ferrous Material

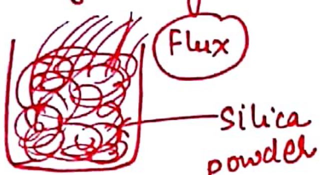
high MP → like steel

for which Titanium alloy die can used.

Tool steel
Die steel

→ Die material

Degassing



Furnace is separated from the die. liquid metal will be filled into the chamber and it will be forced into the cavity under external plunger force. It can be used to produce high M.P. non-ferrous materials like Al, Cu & Brass. It can be used for mass production. Better mechanical properties can be possible in the casting.

Applications:- Both for HCDC & CCDC :-

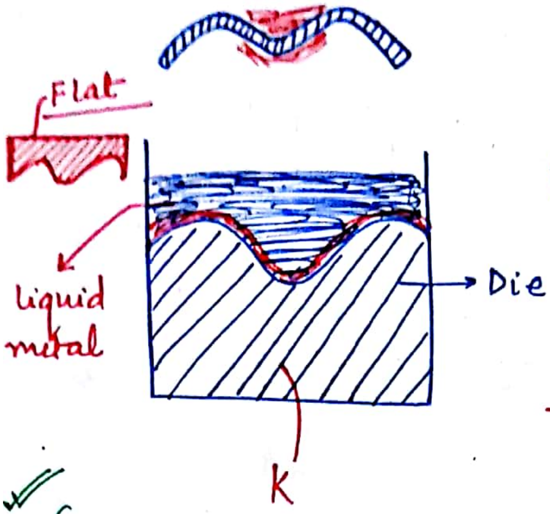
1. Carburators, crank cases, valve Bodies.
2. Fuel injection pump parts.
3. Toilet Fixtures.

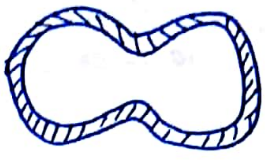
Q.> Compare die casting and investment casting with respect to following :- (a) production rate.
(b) Complexity of object.
(c) M.P. Tempr. of material.

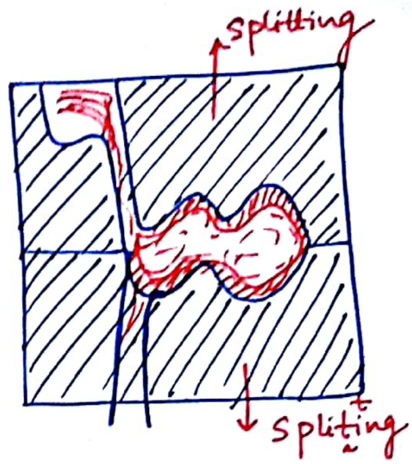
Ans.>

	Die	Investment
① Production Rate	High	Low
② Complexity of object	Low	High
③ M.P. Tempr. of material	Low	high

* SLUSH CASTING :-







✓ No CORE.

✓ Low M.P. – non ferrous metals

Applications :-

- Thin castings
- Hollow Thin castings
- Hollow statues
- Toys
- Decorative Items – flower pots
- lamp shades
- Thin ornaments, etc

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

$t_s \propto (t)^2$ ($t \rightarrow$ thickness) of the casting.

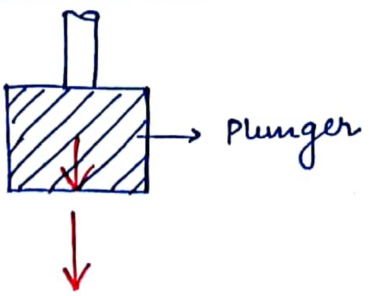
$$\boxed{t = C_1\sqrt{t_s} + C_2}$$

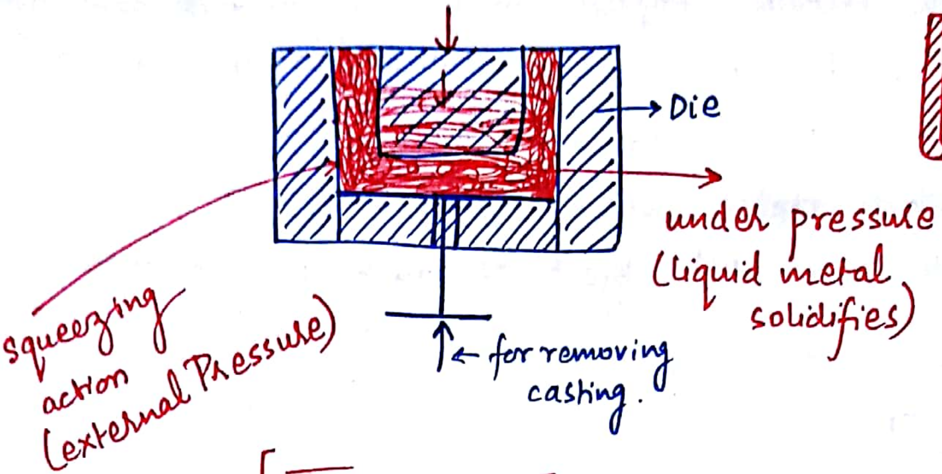
($C_1, C_2 \rightarrow$ constants depends on properties of casting)

($t_s \rightarrow$ solidification time required).

To produce thin castings and hollow thin castings without using the core, this technique can be used. liquid metal will be allowed to solidify on the die. After getting required thickness by rotating the die, unsolidified metal can be separated from solidified metal. It is known as partial solidification.

* SQUEEZE CASTING :-





✓ Plunger → only ↑ pressure of liquid Metal.

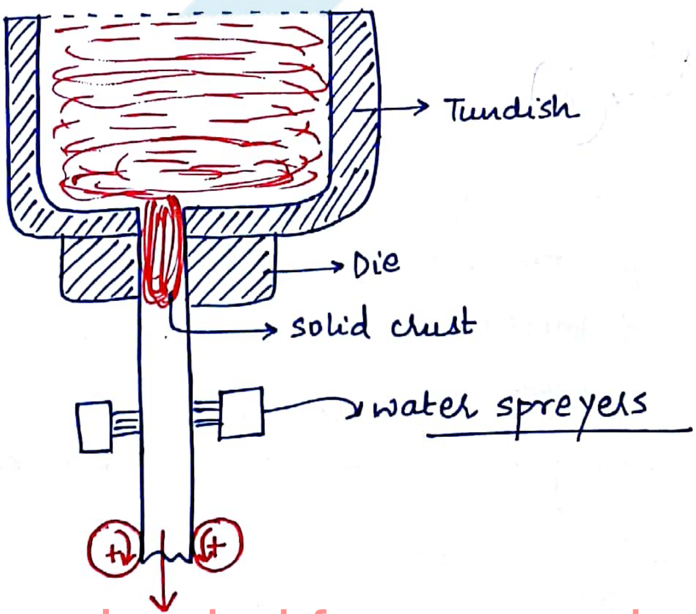
[IMPACT EXTRUSION ← (similar to)]

liquid metal is filled into the die cavity by applying external force using the plunger. liquid metal will enter in to the gap b/w die and plunger and the liquid metal is getting solidify due to the pressure from the plunger. high ~~grain~~ dense structure with better mechanical properties can be produced. Plunger will decide the shape and size of the casting. it is the combination of casting & forging.

Applications:- ① Break shoes made up of Aluminium.
② Bushes made up of Brass and Bronze.

* CONTINUOUS CASTING:-

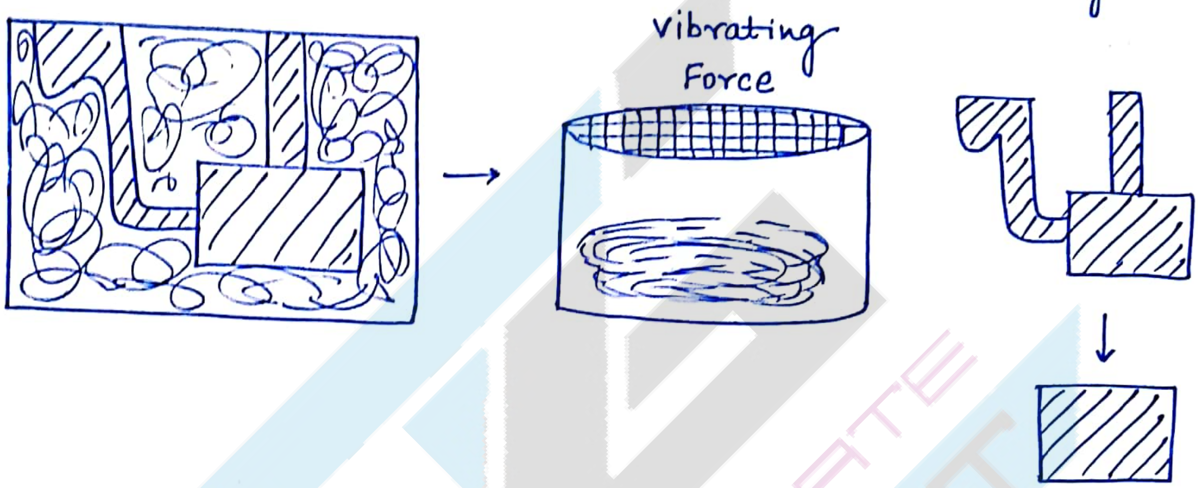
long length bars, rods, blooms, etc.



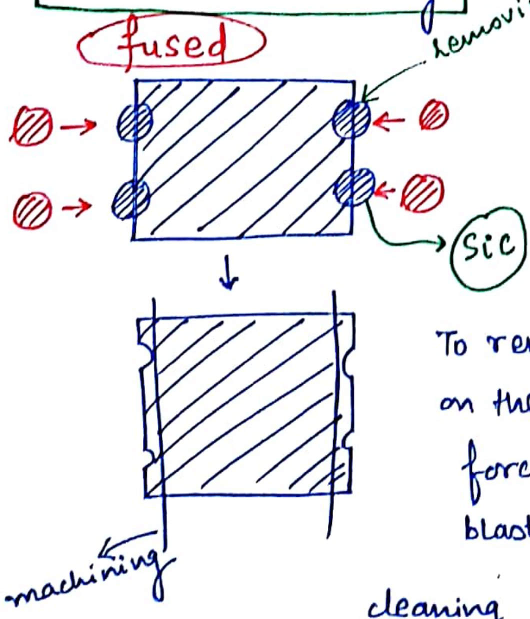
To produce large length metallic objects continuously in mass production, this technique can be used. liquid metal will be stored in the tundish and it will be allowed through the die. The output of the die is a solid ~~crust~~ on which water will be sprayed to cool the material at a faster rate to produce a solid object. It can be used in mass production.

* Cleaning of Castings :-

① **Fettling** :- It is a process of breaking the mould by providing the vibrating mechanism & separating the gating elements from the casting.



② **Shot/Sand Blasting** :- removing silica sand.



Shot peening

① Hardened steel balls of ϕ 3-5mm

② Coarse grain sand.

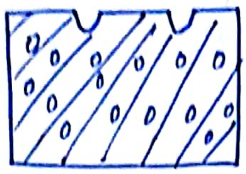
To remove the Silica sand particles which are fused on the surface of the casting, steel balls will be forced on the surface of the casting known as shot blasting. If coarse grain sand will be used for cleaning of the casting, then it is called sand Blasting.

* CASTING DEFECTS :-

① Gas Defects :-

ⓐ Blow holes and open blows :-

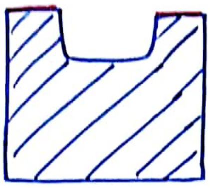
→ gas defects which is formed on the surface of the casting are open blows and which are formed inside the castings are blow holes.



A shallow

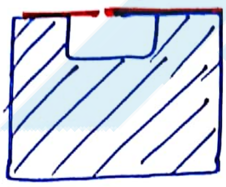
ⓑ Scar

→ A shallow Blow which is formed on the surface of the casting.



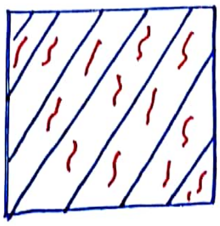
ⓒ Blister

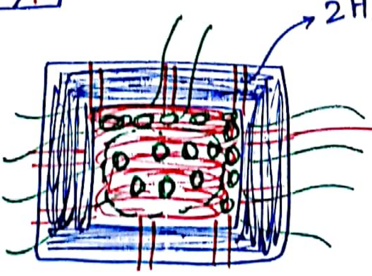
→ It is a scar covered by thin layer of metal is blister.



ⓓ Pinhole Porosity

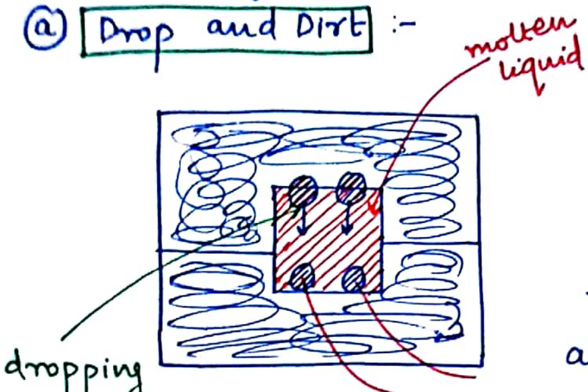
→ small size gas holes which are formed due to hydrogen gas is known as pin hole porosity.

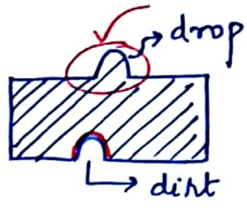




* ③ Moulding Materials and Methods :-

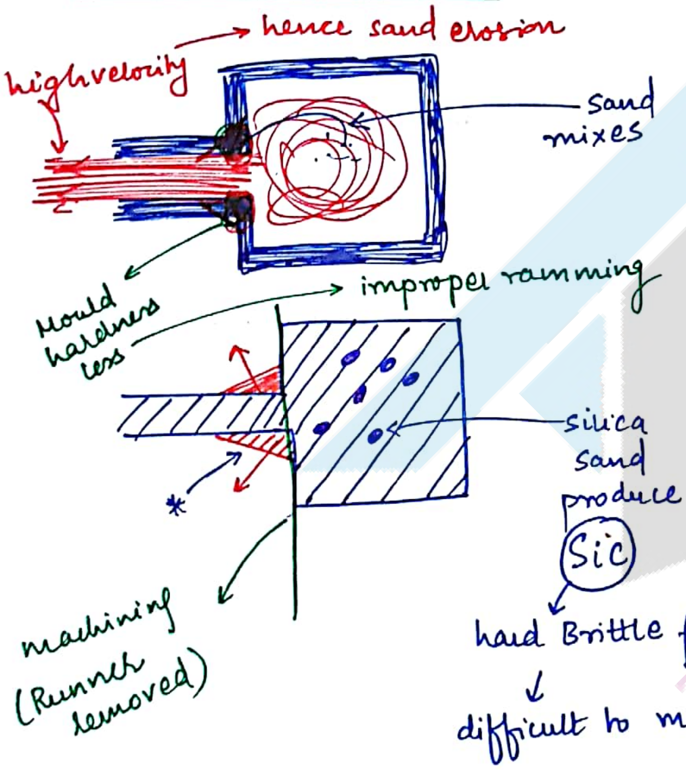
ⓐ Drop and Dirt :-





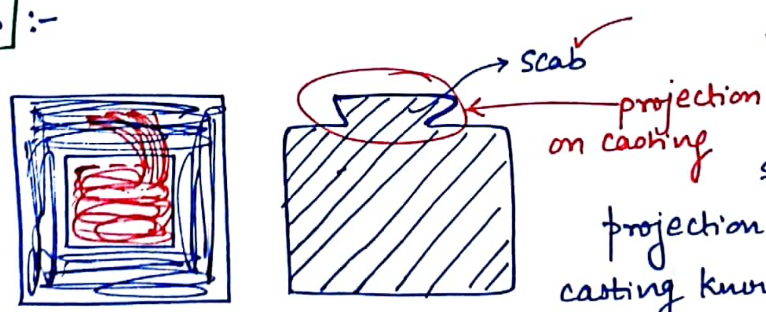
due to improper ramming, if the moulding sand will be dropped from cope box to drag box will form a projection on the surface of the casting known as Drop. at the bottom surface of the casting, a cavity is formed known as Dirt.

ⓑ Cuts and Washes :-



Due to improper ramming and gating design, if the moulding sand will be eroded from the mould surface and washed into the cavity will form some * projections on the casting known as cuts and washes.

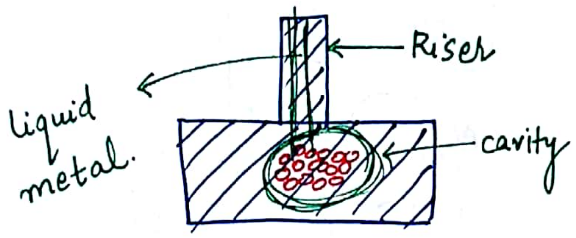
ⓒ Scab :-



Due to improper ramming, if the liquid metal can be penetrated into loose sand layers will form a projection on the surface of the casting known as scab.

③ Grating Design :-

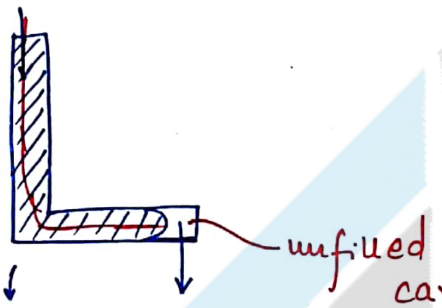
ⓐ Shrinkage cavities :-



Due to improper riser design, cavities formed due to shrinkage of the material is known as shrinkage cavities.

④ Pouring Metal Defects :-

ⓐ Misrun :-

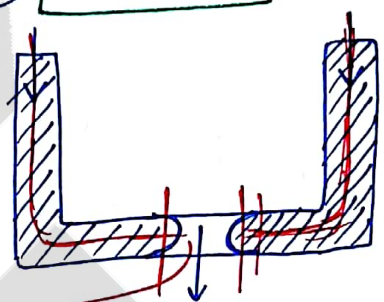


Due to insufficient fluidity, and pouring tempr. before reaching the cavity, the liquid metal is getting solidify will form a defect known as misrun.

ⓑ Cold shuts :-

Two streams

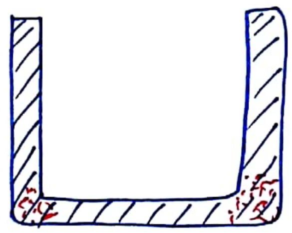
fuse



Two streams of liquid metal will not fuse properly will form a discontinuity in the casting.

⑤ Metallurgical Defects :-

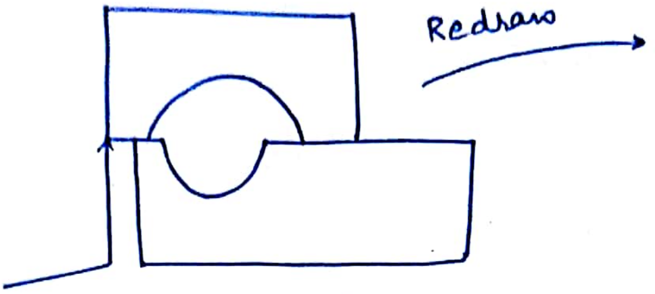
ⓐ Hot tears/cracks

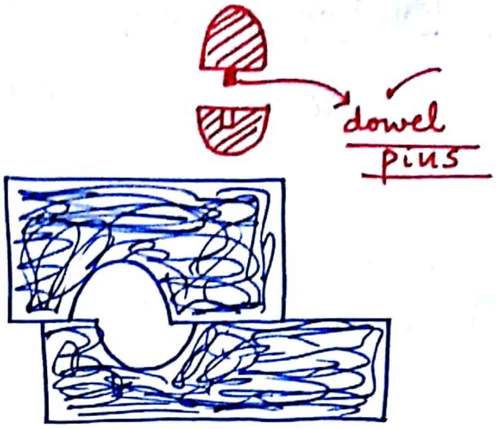


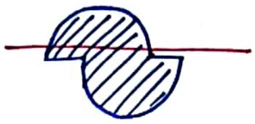
Due to non-uniform cooling, non-uniform shrinkage stresses can be developed in the casting. if the stresses will be more than the strength of the materials, cracks will be formed. These are known as Hot tears. To overcome this, chills and padding can be provided.

⑥ Other Defects :-

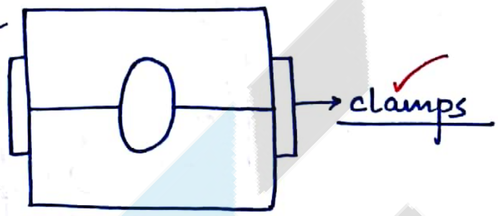
ⓐ Mould shift :-





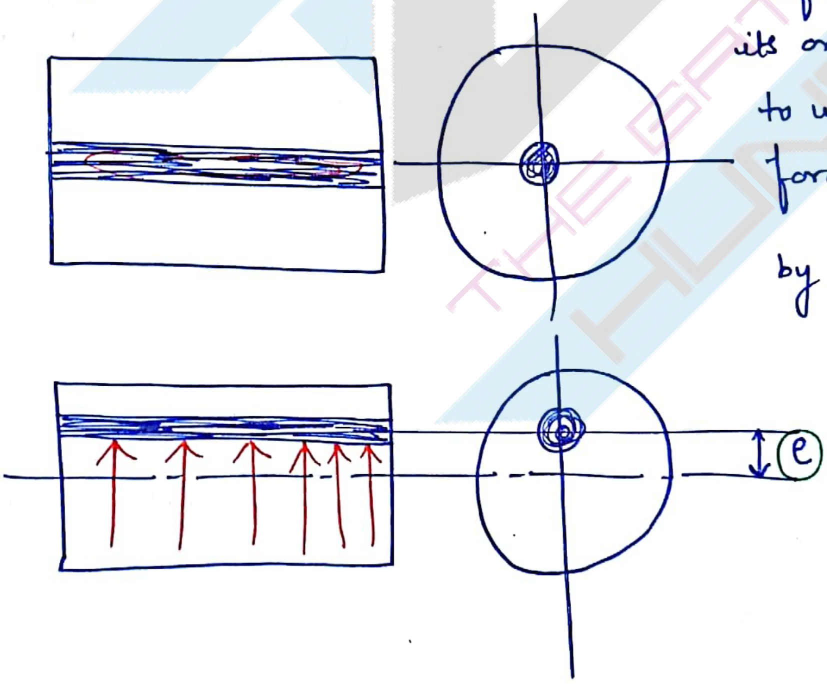


Due to improper positioning of cope box on the drag box, there is a mismatch in the casting along the parting line.
This can be overcome by providing dwell pins and clamps.



ⓑ Core - shift :-

Shifting of the core from its original position due to upward Buoyancy force.
This can be overcome by providing core prints and chaplets.



14/9/2016

Types of Furnace (only IES)

① Crucible ✓

② Cupola Furnace.

charge :-
ORE → PIG Iron
+
Flux → $CaCO_3$
+
coke → coke

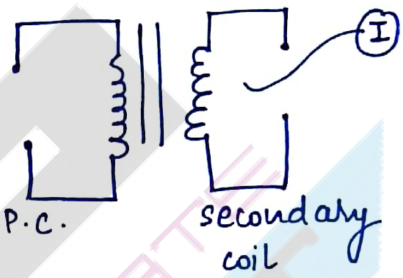
Charge → Fe_2O_3 and Fe_3O_4
↓
Blast Furnace
↓
PIG Iron
↓
Cupola
↓
C.I.

✓ if operating tempr. is high
↳ [HOT BLAST CUPOLA]

✓ Steel require more tempr. than C.I.

③ Electric arc Furnace

④ Induction Furnace → P = VI



⑤ Reverberatory furnace.

NOTES & PPTS :- https://goo.gl/tp2Kj1

✓ welding → Edison Tech centre