Toppersnotes
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IES/GATE

MECHANICAL ENGINEERING

VOLUME - 5

PRODUCTION ENGINEERING - 1

SIERRA INNOVATIONS

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Production Engineering – 1

PRODUCTION ENGINEERING -I

Manufacturing

It is prove of Converting raw material into a finished object It is a process of value addition to the raw material.

Classification of Manufacturing

- Shopping or forming (zero procon)
- (Welding) Joining Procom (Positive procen)
- Removal Procen /Metal cutting) (Negative Procen)
- Regenerative manufacturing Rapid Prototyping

Regenerative manufacturing or Rapid prototyping:-

(Printouts attached)

MECHANICAL ENGINEERING

Manufacturing

It is process of converting raw material into a finished object. It is a process of value addition to the raw material

Classification of manufacturing

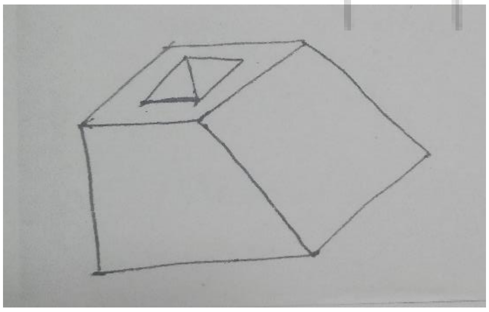
1. Shaping Or forming (Zero Process)
2. Welding Joining Process (Positive Process)
   (Positive Process)
3. Removal Process (Metal Cutting)
   (Negative Process)
4. Regenerative manufacturing or rapid prototyping.

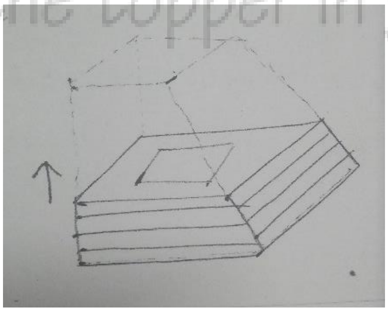
Regenerative Manufacturing or rapid prototyping: - (Only For Interview)

Producing of solid products in layer by layer from raw material in different forms.

1. Liquid- eg. Stereo lithography
2. Powder- eg. Selective Sintering
3. Sheet- eg. LOM (laminated Object Manufacturing)
4. Wire- eg. FOM (Fused Deposition Modelling)

Very Rapid, Accurate and used for rapid prototyping and tooling.





Advantages:-

1. Process is independent of part feature
2. No blanks are requires.
3. Tools Process
4. Easily Automotive Possible

Machining:-

Machining is an essential process of finishing by which jobs are produced to the desired dimensions and surface finish by gradually removing the excess material from the preformed blank in the form of chips with the help of cutting tools moved past the work surface.

Machining is a removal process.

Machining aim to:-

1. Fulfil its functional requirements.
2. Improve its performance.
3. Prolong its services

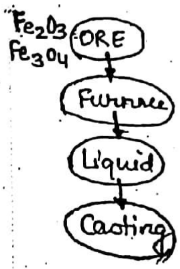
Drawback in marketing:-

Loss of material in the form of chips.

Slow process (Low Productivity)

CHAPTER :- 1 CASTING

* **Manufacturing** :- It is a process of converting raw materials into a finished object. It is a process of value addition to the raw material.



- **Classification Of Manufacturing** :-
  i) Casting
  ii) Forming
  iii) Fabrication process
  iv) Material removal process.
- **New Techniques** :- i) Zero ii) Additive iii) Subtractive processes.

i) **CASTING** :-

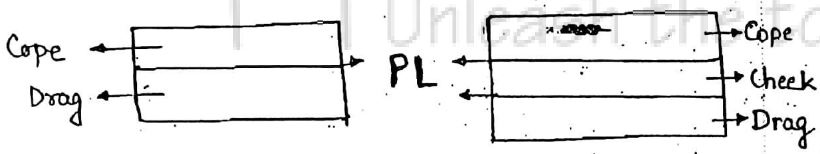
It is a process in which molten metal liquid will be allowed to solidify in a pre defined mould cavity. After this solidification, by breaking the mould, required shape of the object can be produced.

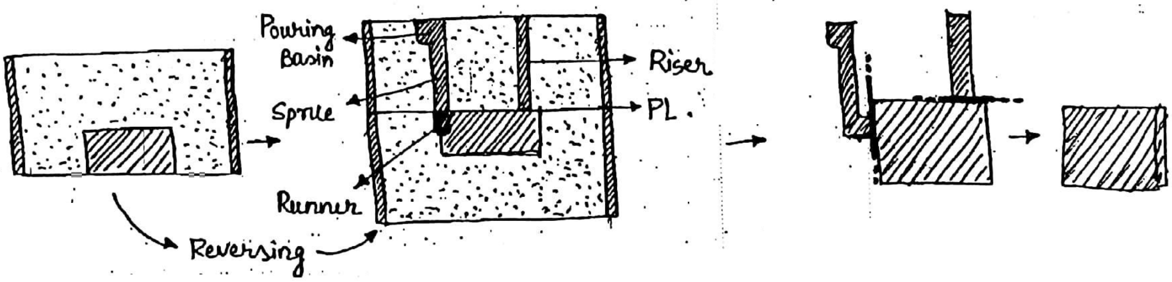
1) Pattern. 2) Moulding Sand. 3) Tools.

1) **PATTERN** :-

Mould box

① Two box :- ② Three box :-

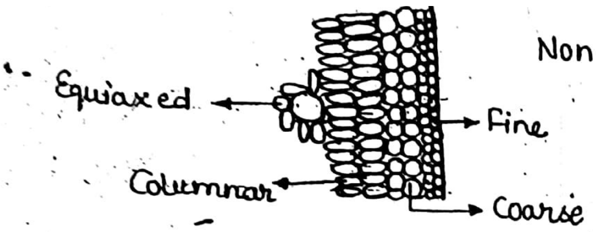




- **ADVANTAGES** :-

1) Complex shape of the object can be produced.
2) It is a less expensive process.
3) Ductile & Brittle materials can be produced
4) Large sized objects can be produced by casting only

• DISADVANTAGES :-



Non-uniform Grain structure

$T_p = T_m + \Delta t$
↳ Degree of superheat (100° – 250°C)

1) Casting objects are not having smooth surface finish.
2) It is a taborious & time-consuming process.
> There is a possiblity of gas defects in casting ($2H_2O \rightarrow 2H_2 + O_2$).
> Casting objects are not having uniform mechanical properties due to non-uniform cooling.

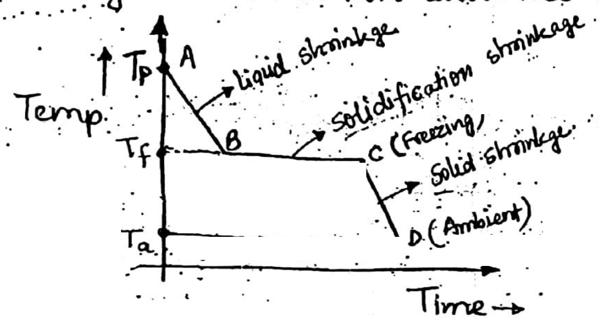
- **SELECTION OF THE MANUFACTURING PROCESS.**

It will depends upon :
1) the shape & size of the objects.
2) properties required by the objects.
3) accuracy & surface finish required.
4) Cost of the object.

- **PATTERN** :- It is the replica of final casting to be produced with some allowances.

Types of Allowances :-
i) Shrinkage or Contraction.
ii) Draft or Taper.
iii) Machining or Finish.
iv) Shake or Rapping.
v) Distortion or Camber.

i) Shrinkage or Contraction allowance :-



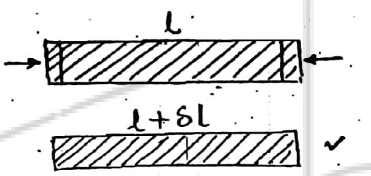
When the liquid metal is allowed to solidify in the cavity, there is a possiblity of shrinkage or contraction of the material.

When the liquid metal is ~~cooling~~ cooled from pouring to freezing temp, shrinkage is liquid shrinkage.

During the phase transformation, shrinkage of the material is solidification shrinkage.

When the solid casting is cooled from freezing to ambient temprature, the shrinkage is solid shrinkage.

Liquid and solidification shrinkage can be compensated by providing the RISER. These values are expressed as "% of shrinkage volume of the material." Solid shrinkage can be compensated by providing shrinkage allowance on the PATTERN. These values are expressed in terms of "linear dimensions".



$-\delta l = l \alpha \Delta T$ (α → thermal expansion coeff.)

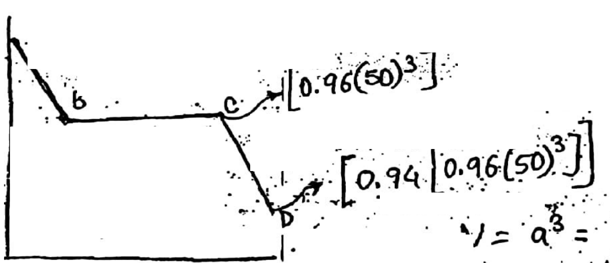
SHRINKAGE VALUES FOR DIFFERENT MATERIALS :- (Solid Shrinkage) :-

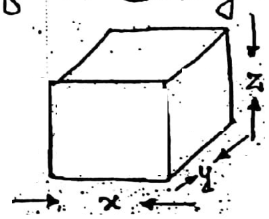
1) Bismuth → Negligible
2) White Metal → 5 mm/m
3) Cast Iron → 10 mm/m
4) Aluminium → 13 mm/m
5) Copper → 17 mm/m
6) Steel → 20 mm/m
7) Brass → 23 mm/m
8) Zinc → 24 mm/m

→ Liquid and solidification shrinkage is maximum for Aluminium which requires large sized riser.

→ Total shrinkage is maximum in steel.

Q. Cubical casting of 50 mm size undergoes volumetric solidification of 4% and volumetric solid contraction of 6%. There is no riser provided. What is the final size of the casting?





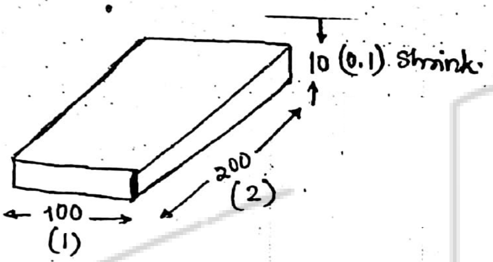
$V = a^3 = 112800 \text{ mm}^3$

$a = $ ~~48.317 mm~~.

⇒ In case of **grey cast iron** due to conversion of carbon into graphite flakes, there is a possiblity of expansion of the material. There is **no need of riser**. In solid state there is a possiblity of contraction of material. To overcome this, size of the pattern can be increased by providing shrinkage allowance.

Q. A grey cast iron block of dimensions 200 × 100 × 10 mm³ is produced by sand moulding. Pattern making allowance (solid shrinkage) is 1%. What is the ratio of volume of pattern to the casting.

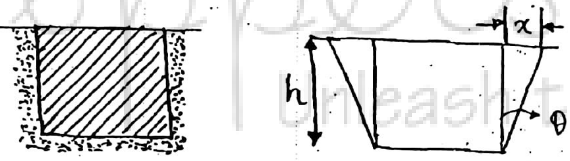
Soln :-



$$\frac{\text{Volume of pattern}}{\text{Volume of casting}} = \frac{(200+2)(100+1)(10+0.1)}{200\times 100\times 10}$$

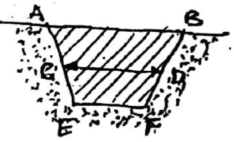
$$= 1.03$$

- DRAFT OR, TAPER :- [OPTIONAL]

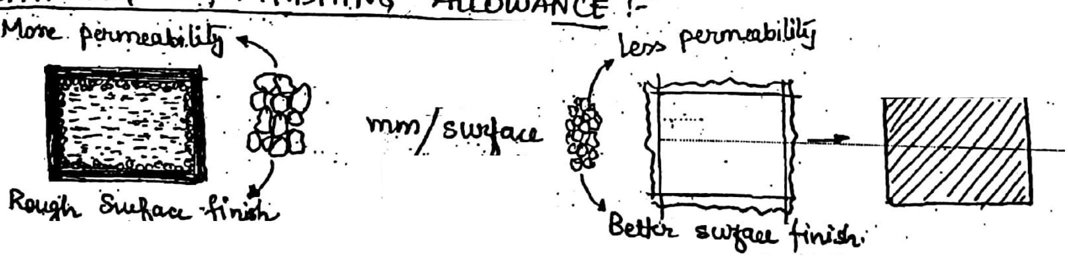


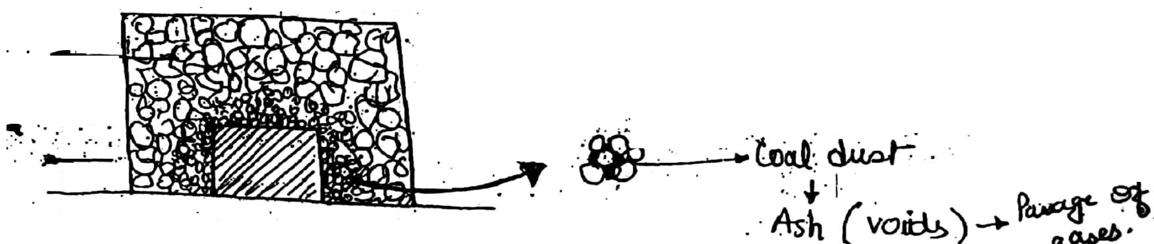
$x = h \tan\theta$

For easy removal of the pattern from the mould to minimize the continuous contact b/w pattern & mould surface for the vertical surface of the ~~papp~~ pattern, draft or taper allowance is provided.



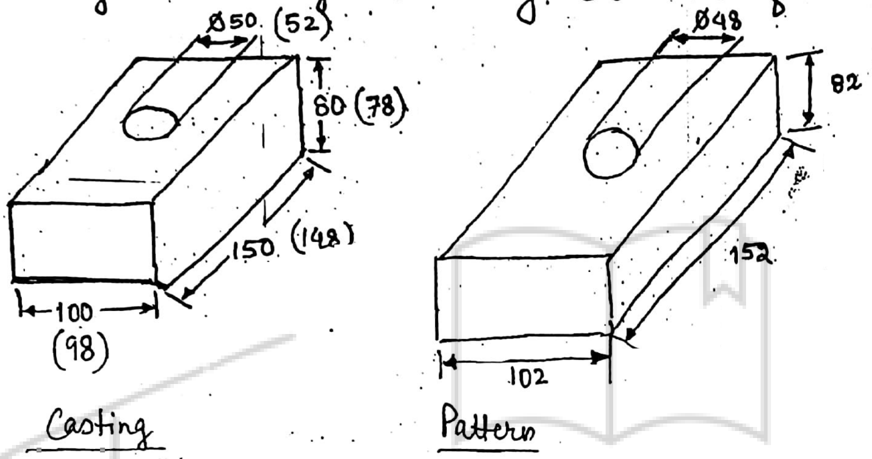
- MACHINING OR, FINISHING ALLOWANCE :-



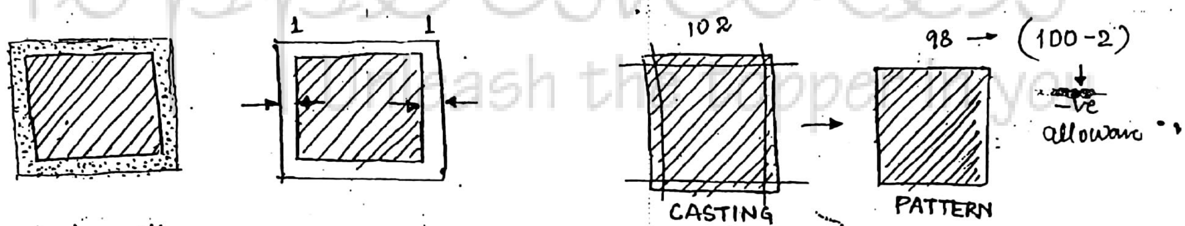


Casting objects are not having smooth surface & finish. To get better surface finish, machining is required. Due to machining, size of the casting will be decreased. To overcome this, size of the pattern can be increased by providing machining allowance.

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

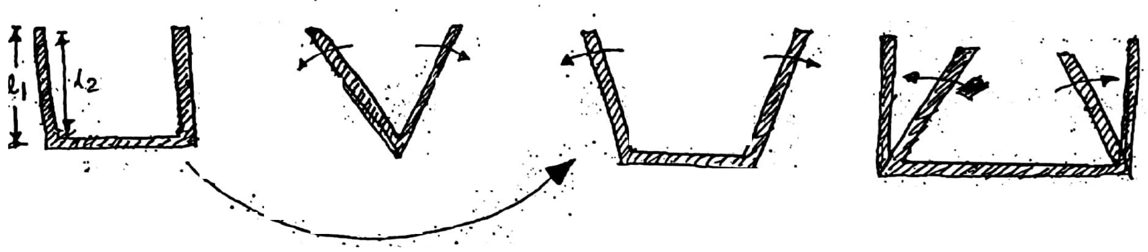


- SHAPING OR RAPPING :- [COMPUSARY]



Moulding sand will stick to the pattern's surface during ramming. For easy removal of the pattern, some clearance is required b/w pattern & mould surface. This can be produced by shaking of the pattern. Due to shaking, size of the cavity will be increased. To overcome this, size of the pattern can be reduced by providing shake allowance. It is a -ve allowance provided on the pattern.

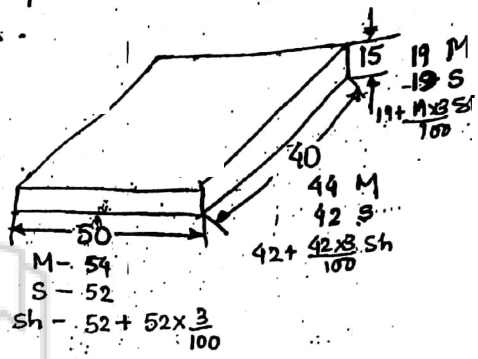
- DISTORTION OR CAMBER ALLOWANCE :-



Depending on the shape & size of the casting, due to difference in the casting linear dimensions, there is a possiblity of distortion in the casting during shrinkage. To overcome this distortion allowance is provided opposite to the direction of distortion. It is a zero allowance.

Q. Calculate the dimensions of the pattern for the casting shown below by considering following allowances.

i) Machining → 2 mm/surface
ii) Shrinkage → 3%
iii) Shakes → 1 mm/surface



∴ Finished :- 53.56 × 43.26 × 19.57

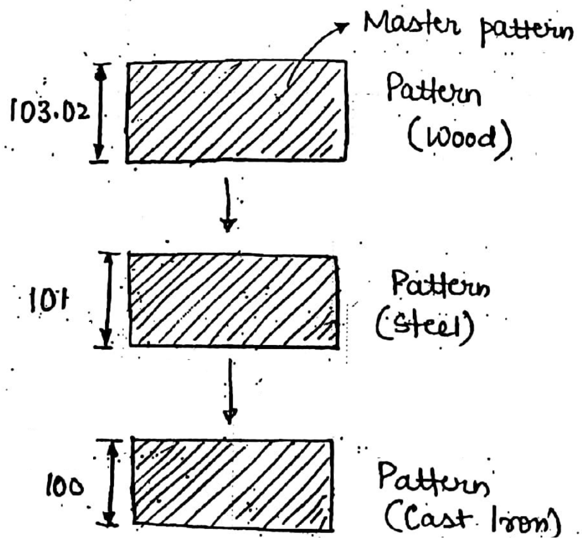
Ratio :- $\frac{\text{Vol}^m \text{ of pattern}}{\text{Vol}^m \text{ of casting}} = \frac{53.56 \times 43.26 \times 19.57}{50 \times 40 \times 15} = 1.51$

- **PATTERN MATERIALS :-**

1) Wood :-

2) Metals & Alloys :- Al, C.I., Steels, Brass etc.

3) Plastics :- Polysterene, Foam, PVC, Thermocole etc.

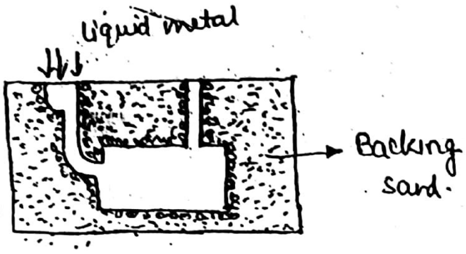


100
+ 1
+ 2.02
103.02

Double Shrinkage Allowance

① Cast iron (10 mm/m) :-
1000 mm → 10 mm
100 mm → 1 mm

② Steel (20 mm/m) :-
1000 mm → 20 mm
101 mm → 2.02 mm



"Expandable pattern"

" Disposal Pattern".

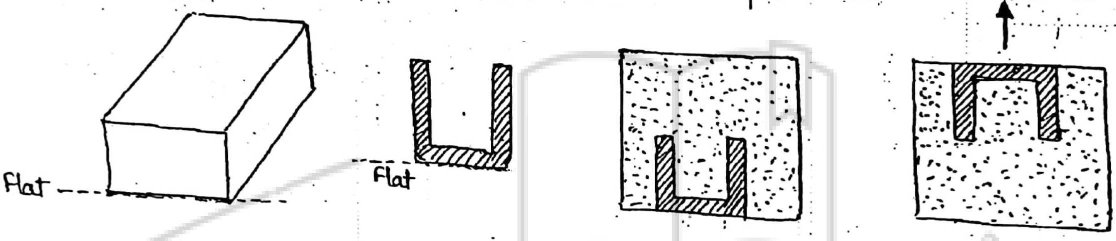
Called Full moulding / cavityless moulding

Using Wax → Investment casting

Using Hg → Mercast casting.

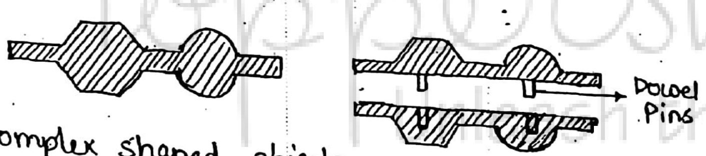
- **TYPES OF PATTERNS :-**

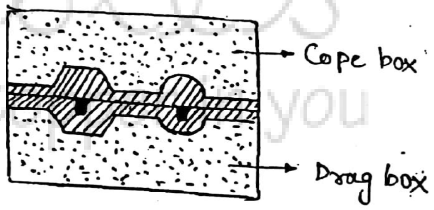
1) **Solid or, Single Piece :-** If object to be produced is simple in shape & size



One of the surface of the pattern is flat.

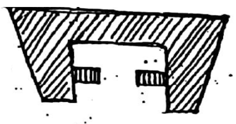
2) **Split Piece Pattern :-**





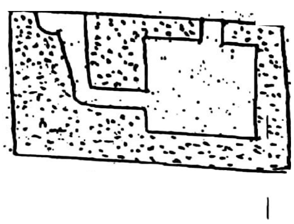
For complex shaped objects, pattern can be split into no. of split pieces along the parting line such that they can be removed from cope and drag boxes seperately.

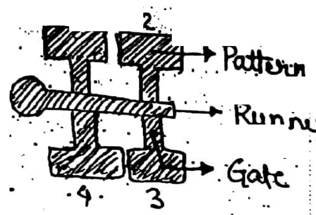
3) **Loose Piece Pattern :-**



If the objects are having internal projections or undercut, loose piece patterns can be used. After removing the main part of the pattern loose peice can be removed from the mould to get the required cavity.

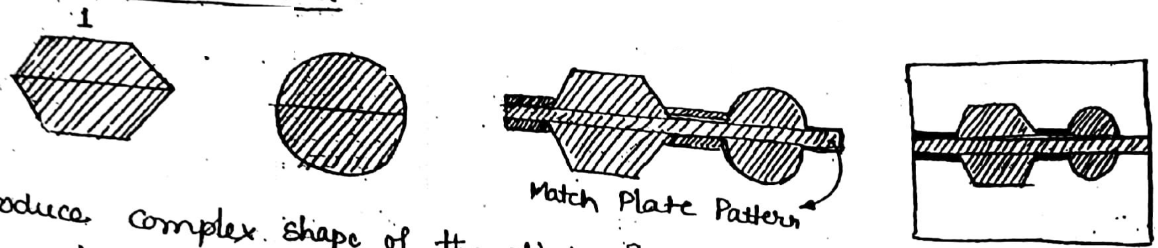
4) **Gated Pattern :-**





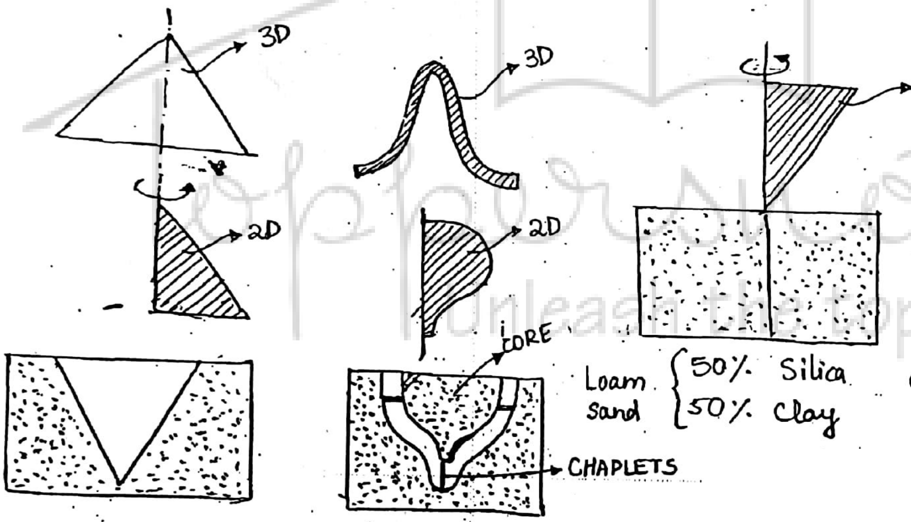
To produce no. of cavities in mass production producing of the gating elements manual will take more time. To overcome this, no. of patterns along with gating elements will produce a single pattern, known as gated pattern.

5.) <u>Match Plate Pattern</u> :-



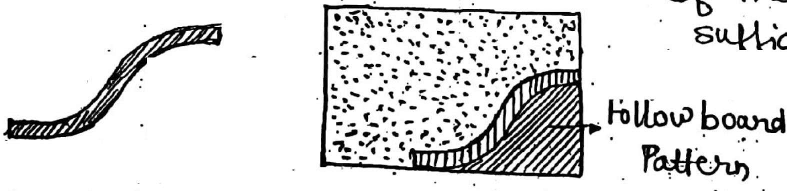
To produce complex shape of the object in mass production, no. of patterns can be split along the parting line and they will be added on both sides of matchplate along with gating elements to produce is single pattern known as match plate pattern.

6.) <u>Sweep Pattern</u> :-



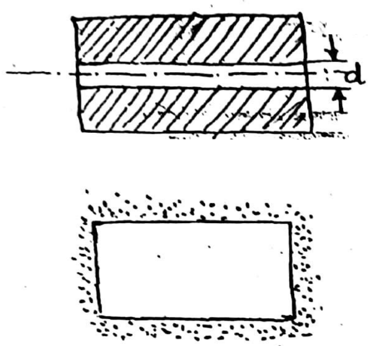
To produce 3-D complex shape of the mould cavities, 2-D plane patterns can be rotated in the mould. This is generally used for axis symmetric objects only.

7.) <u>Followboard Pattern</u> :-

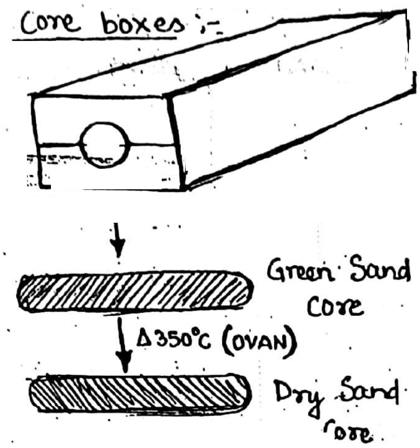


If the patterns are not having sufficient strength, due to ramming force, there is a possibility of breaking of the pattern. To overcome this, patterns are supported by providing followboard. That cavity is made mould later and after solidification, the mould is broken to get the product.

CORE DESIGN :-



Core boxes :-



core sand :-

moulding sand
+
organic binder
[linseed oil,
molasses etc.

Net buyoncy force = Wt. of liquid metal displaced − Wt. of the core

$$\Rightarrow P = Vg\rho_m - Vg\rho_c \Rightarrow P = Vg[\rho_m - \rho_c]$$

V → Volume of the core
ρ_c → Density of core material
ρ_m → Density of the molten liquid metal

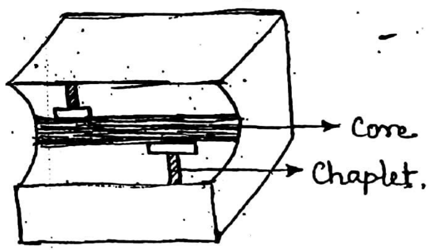
Core Prints :-

$P \le 3.5 A_c$ (A_c → core print Area, cm^2.)

Core prints are the projections on the pattern used to produce a recess in the cavity to position the core properly.

Chaplets :- These are the metallic objects used to support the core in the cavity. These are made up of same material as casting.

Q. A hollow casting is to be produced using a cylindrical core of 200 mm height and 150 mm dia; is positioned horizontally. Density of molten metal is 7800 kg/m³ and density of core material is 1600 kg/m³. Calculate net buoyancy force on the core ?



$$P = \frac{\pi}{4}(150)^2(200)\times10^{-9}\times9.81\,(7800-1600) = 214.96\ N.$$

MOULDING SAND :-

Silica → 70-85%
Clay → 10-20%
Water → 2-8%
Additives → 1-6%

[Refractoriness Temp.]

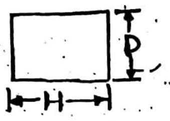
Silica → 1710°c
Zirconium → 2600°c
Ceramic → 3500°c
Graphite → 4200°c

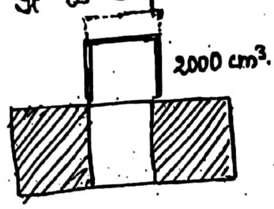
PROPERTIES :-

1. **Refractoriness** :- Ability of the moulding sand to withstand high temp. of the liquid metal without fusion.

2. **Permeability** :- Ability of the moulding sand to allow the gases to escape is known as permeability. It is expressed by permeability number.

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





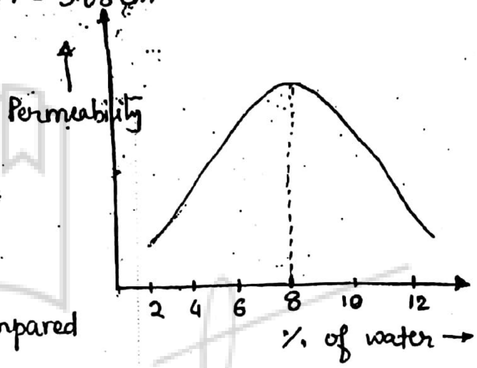
V = Vol^m of air passing through specimen (2000 cm³) H = D = 2" = 2×2.54 = 5.08 cm

H = Height of standard cylindrical specimen.

P = Difference of pressure of air passing through the specimen (gm/cm²)

A = Cross-sectional Area of the specimen $[\frac{\pi}{4}D^2]$

T = Time taken by air to escape [min]



Uniform Grains have more permeability when compared to non-uniform grains.

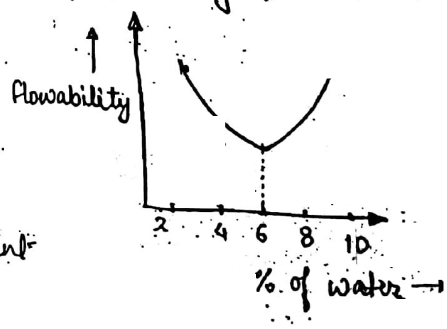
Q. Determine the permeability of the moulding sand if 2000 cm³ is allowed to escape through a standard cylindrical specimen for 1 min 20 sec at a pressure of 5 gm/cm²

Sol^n.- We know that,

$$P_H = \frac{VH}{PAT} = \frac{4\times2000\times5.08}{5\times\pi\times(5.08)^2\times1.33} = 75.17$$

3. **Flowability** :- Ability of the moulding sand to flow into all the corners of the mould box due to ramming force.

4. **Strength** :- To retain the shape & size of the cavity and to withstand force applied by the liquid metal on the mould surface, it must be having sufficient strength.



If the moulding sand is having moisture, then it is called Green Sand. After evaporation of the moisture, green sand is converted into Dry sand. After becoming the sand dry, still liquid metal is having more heat, that will increase temp. of the sand and it will become hot, that sand is called Hot Sand.

5. Hardness :- To minimize the erossion and to withstand the forces applied by the liquid metal on the mould surface, mould must be having sufficient hardness. It is a surface property

Mould hardness NO – 0 to 100

Avg :- 60 – 80 ; If hardness is less than 60 dimensional change can take place in casting, and if it is more than 80, permeability will be decreased

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

7. Cohesive Property :- Bond formation b/w samilar materials.

→ Moulding sand will require sufficient Thermal conductivity and low coefficient of Thermal Expansion.

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

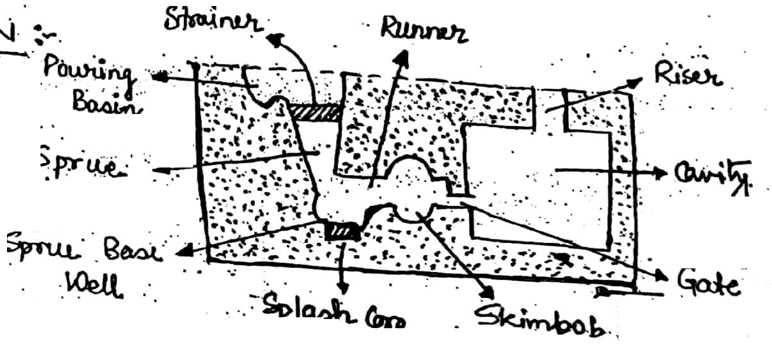
- **ADDITIVES USED IN MOULDING SAND :-**

1> Saw dust or Wood flour } Collapsibility and permeability

2> Linseed oil, Molasses and dixtrine etc. } Strength and hardness

3> Coal dust } surface finish.

- **ELEMENTS OF GATING DESIGN :-**



Objectives Of Gating Design :-

1) Design the gating elements such that liquid metal can enter into the cavity with optimum velᶜ within a given time <u>without causing turbulance, splashing and mould errosion</u>

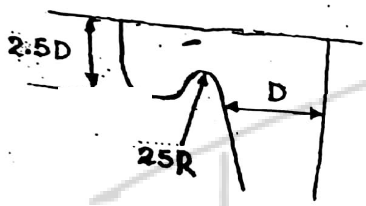
2) Design the gating elements such that pure metal can be entered into the cavity <u>without air aspiration effect</u>.

3) Produce the gating elements to get maximum yeild.

$$\boxed{\text{Casting Yeild} = \frac{V_c}{V_c + V_g}}$$

In case of ferrous materials, Oxide formation is less as compared to non-ferrous.

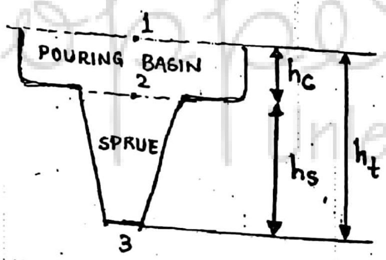
★ POURING BASIN :-



Pouring basin is designed to reduce the velᶜ of the molten metal which is entering into the sprue to minimize errosion.

★ SPRUE :-

$V_3 >> V_2$

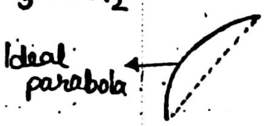


$Q = A_2V_2 = A_3V_3$

$\Rightarrow A_3 << A_2$

$$\Rightarrow \frac{A_2}{A_3} = \frac{V_3}{V_2} = \frac{\sqrt{2gh_t}}{\sqrt{2gh_c}} = \sqrt{\frac{h_t}{h_c}}$$

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



★ AIR ASPIRATION EFFECT :-

Atmospheric air (gases) can be absorbed in the gating elements in low pressure areas will mix up with the liq. metals and form gas defects known as air aspiration Effect.

To avoid air asp. effect, the ideal shape of Sprue is parabola. To reduce manufacturing difficulty, shape of sprue is considered as tapered cylinder.

Q. In a gating design, sprue is designed to avoid air aspiration effect to supply the liquid metal at 20 kg/s. ρ of metal is 7800 kg/m³. Assume height of sprue as 20 cms, and height of pouring basin as 5 cms. Calculate the dimensions of the sprue.

$m = \rho A V$

$Q = \frac{\dot{m}}{\rho} = \frac{20}{7800} = 2.564 \times 10^{-3}\ m^3/s = 2564\ cm^3/s.$

$Q = A_2 V_2 \Rightarrow A_2 = \frac{Q}{V_2} = \frac{2564}{\sqrt{2 \times 981 \times 5}} = 25.88\ cm^2.$

$A_2 = \frac{\pi}{4} d_2^2 = 25.88 \Rightarrow \boxed{d_2 = 5.74\ cm}$

$Q = A_3 V_3 \Rightarrow A_3 = \frac{Q}{V_3} = \frac{2564}{\sqrt{2 \times 981 \times 25}} = 11.57 cm^2.$

$A_3 = \frac{\pi}{4} d_3^2 = 11.57 \Rightarrow \boxed{d_3 = 3.83 cm}$

Q. In a gating design, height of the sprue is 200 mm. Velocity of metal at the begining is 0.5 m/s. What is the vel^c of the liq. metal at the bottom of the sprue?

$V_2 = 0.5$

$V_3 = ?$

$h_t = h_s + h_c$

$\Rightarrow h_t = 200 \times 10^{-3} + h_c$

$\Rightarrow h_t = 0.2 + 0.0127$

$= 0.2127 m.$

$\Rightarrow V_2 = \sqrt{2 g h_c}$

$\Rightarrow 0.5 = \sqrt{2 \times 9.81 \times h}$

$\Rightarrow h_c = 0.0127\ m.$

$\Rightarrow V_3 = \sqrt{2 \times 9.81 \times 0.2127}$

$= 2.04\ m/s.$

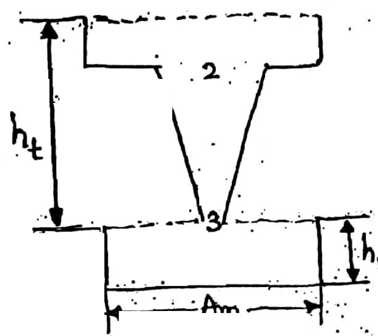
• GATE :- (INGATE)

It is the actual entry point through which liquid metal can be entered into the cavity

TYPES OF GATE :-

1) Top Gate (Verticle)
2) Bottom Gate
3) Parting Line Gate
4) Step Gate.

> TOP GATE :-



$\left(\frac{\Delta T}{h}\right)$

Liquid metal will directly entered into the cavity from bottom of the sprue at atm. pressure. Vel^c of the liquid metal which entered into the cavity is very high. There is a possiblity of turbulence & splashing. It can be used for casting of ferrious materials. There is favourable temp. gradient of the liquid metal in the cavity.

$A_3 = A_g$

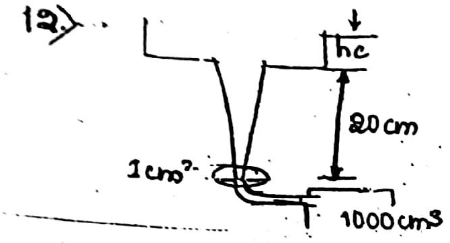
$V_3 = V_g = \sqrt{2gh_t}$

$\Rightarrow dt \cdot A_g V_g = V_m \cdot dh$

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

$$\Rightarrow \boxed{t_f = \frac{V_m}{A_g V_g} = \frac{V_m}{\sqrt{2gh_t}\, A_g}}$$

12)

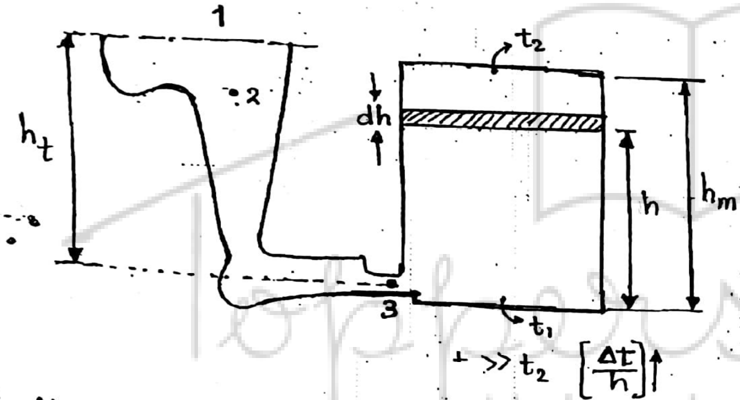


$h_t = h_s + \cancel{h_c}^{\,0}$

$\Rightarrow h_t = h_s = 20\ cm.$

$$t_f = \frac{V_m}{A_g V_g} = \frac{1000}{\sqrt{2 \times 981 \times 20} \times 1} = 5.05\ sec.$$

2) BOTTOM GATE :-



Gate is provided at the bottom of the cavity. Velocity of the liquid metal in the cavity is negligible. There will be no turbulence & splashing. It can be used for casting of non-ferrous metarials. There is unfavourable temp. gradient of liquid metal in the cavity

$A_3 = A_g$

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

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

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

When, $t = 0$; $h = 0$,

when. $t = t_f$; $h = h_m$

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

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

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