Casting Welding

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Casting & Welding

Book ① Manufacturing science Gosh & Mallik

② Manufacturing Engg. & Technology
Kalpak Jain

Manufactaring processes:- It is a processes of converting raw material into a finished product.

- It is a processes of value addition to the raw material

Classification

① casting → Basic / primary

② Forming

③ Pebrication process

④ Material removal process.

② – ④ } ⇒ Secondary

⇒ ① zero process

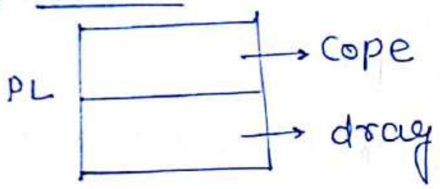
② Additive

③ subtracting

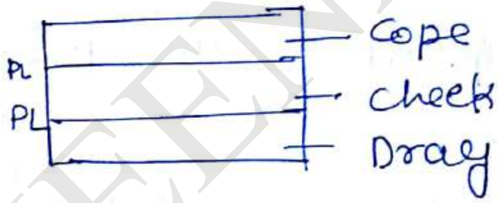
Casting :- It is a process in which motton liquid will be allow to solidify in a predefine mould carity. after the solidification by braking the mould require shape of the object can be produced.

mould box :-

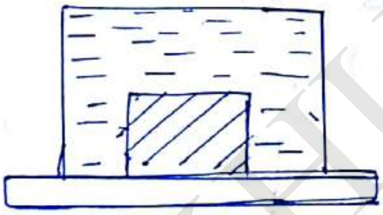
① Two box

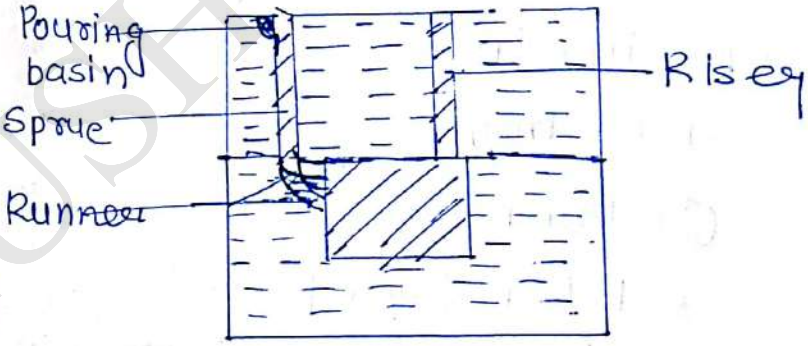


② Three box

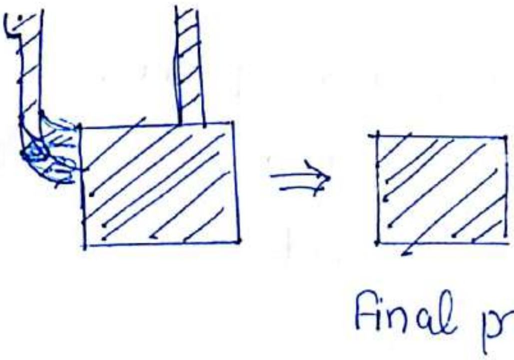


Process — ① pattern
② moulding sand
③ Tools





we can produce following part / Application
① m/c tool bleds
② Road Roller
③ Engine blocks
④ Gear box



Final product

Advantages:-

① Complex shape of the object can be produced.

② It is simple and less expansive process.

③ Ductile and brittle material Can be produced.

④ large size object can be produced by Casting only

limitations :—

① Casting object are not having smooth surface finish

② It is laboures and time consuming process.

③ There is a posibility of gas deffect can be expected in Casting

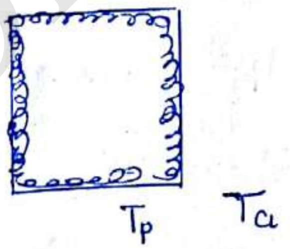
④ Mechanical properties of casting not having uniform properties due to non-uniform Cooling

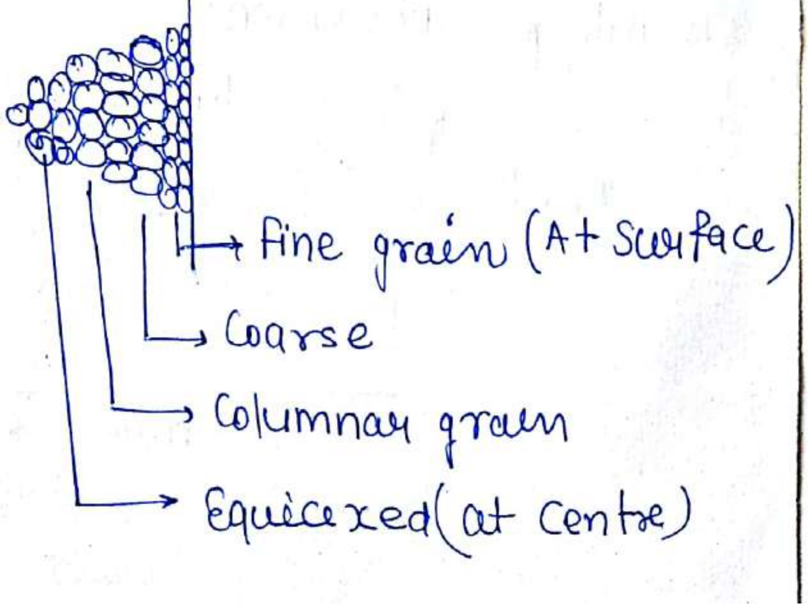
$$T_p = T_m + \Delta t$$

Pouring temp

mellting teemp

Degree of superheat (100-250°C)





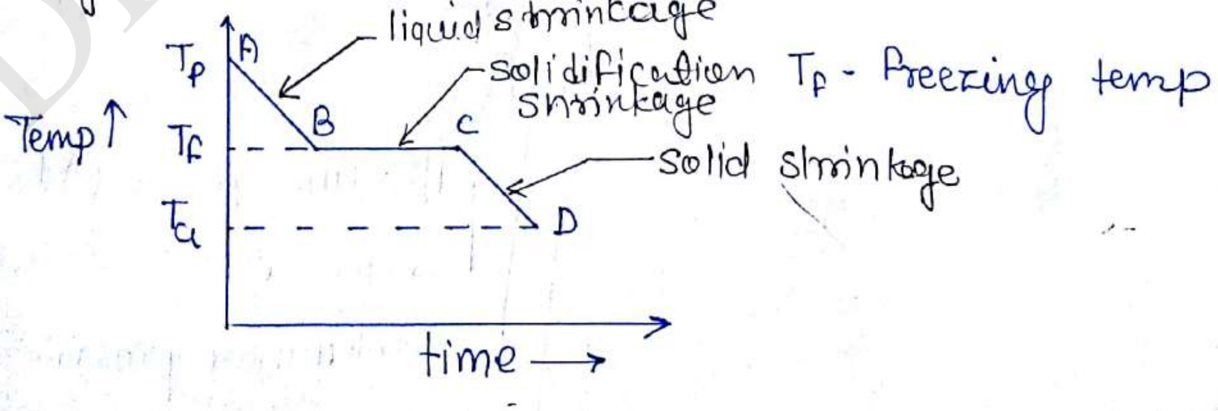
Selection of manufacturing Processes will depands on :—

① shape and size of object to produced.
② Properties required by the object.
③ Accuracy and surface finish required by the object.
④ No. of Component to be produced.
⑤ Cost of object.

Pattern :- It is replica of final casting to be produced with some modification. modification are in form of allowances.

Allowance
① shrinkage (or) contraction
② Draft (or) taper
③ Machining (or) finish
④ Shake (or) Rapping
⑤ Distortion (or) camber

Shrinkage Allowance :-



when the liquid metal is allow to solidify there is a possibility of contraction of material during Solidification process. due to this size of casting decrease.

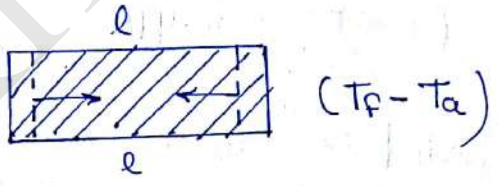
(i) When liquid metal is Cooled from pouring temp to freezing temp The shrinkage is liquid shrinkage

(ii) During phase transformation process the shrinkage is solidification shirkage. When solid

(iii) casting is cooled from freezing to ambient temp. shinkage is solid shrinkage

✱ Liquid & solidification shrinkage can be componseted by providing riser there value are expsess in term of percentage of shirnkage Volume.

Solid shrinkage can be componseted by increasing the dimesion of pattern provideng shrinkage allowance These value are express in terms of linear dimension (mm/m).



Solid shrinkage value

① Bismuth → Negligible
② white metal → 5 mm/m
③ cast irom → 10 mm/m
④ Aluminium → 13 mm/m
⑤ Copper → 17 mm/m
⑥ steels → 20 mm/m
⑦ Brass → 23 mm/m

- * liquid and solidification shrinkage is maximum for 'Al' which require more Volume of Raiser.

- * Solid shrinkage is maximum of brass which require large size pattern
- * Total shrinkage is maximum for steel

Problem :- A Cubical casting of 50 mm size undergoes volumetric solidification shrinkage of 4 % and volumetric ~~solidification~~ solid contraction is 6 %. There is no Raiser is used and pattern making allownece is not considerd what is the final size of casting.

Sol

Sol^n Initial Volume = $(50)^3$ mm^3

Volume after ~~to~~ solidification shrinkage 4 %

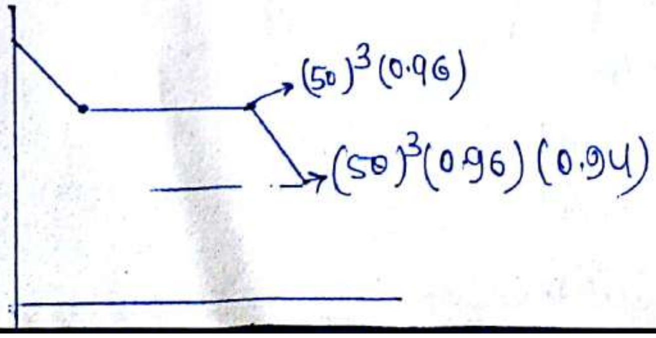
$= (50)^3 \times 0.96$

Volume after solid contraction 6 %

$= [(50)^3 \times 0.96]\, 0.94$

Final Volume $V = a^2 = 112800$ mm^3

$a = 48.317$ mm



Composition (2·5-4% carbon) & iron
(1-3% silicon)

Gray Cast iron:— In case of Gray Cast iron their is possibility of expansion of material in liquid & solidification state. Due to this no. riser is require this is due to conversion of free form of the carbon in to graphite flex (BCC to HCP)

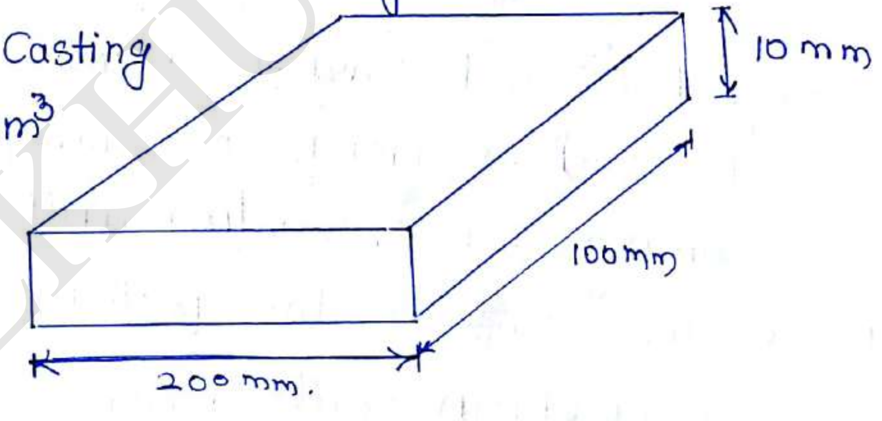
In solid state there is a posibility of contraction of material.

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

% of carbon >2.8% expansion
<2.8% contraction

Problem:- A Gray cast iron block of dimension $(200 \times 100 \times 10)\ mm^3$ is produced by sand moulding process pattern making allowance is 1% what is the ratio of volume of pattern to the casting.

Soln Volume of Casting
$= (200 \times 100 \times 10)\ mm^3$

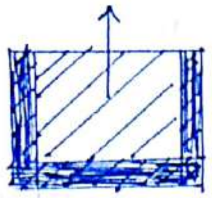


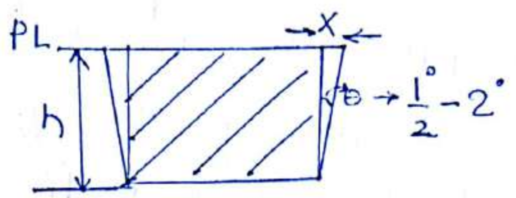
Volume of pattern $= (200+2) \times (100+1) \times (10+0.1)\ mm^3$

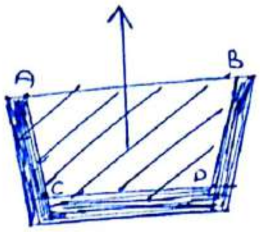
$$\frac{\text{volume of pattern}}{\text{Volume of casting}} = \frac{(200+2)(100+1)(100+0.1)}{200 \times 100 \times 10} = 1.03$$

If % of carbon not given assume contraction

Draft (or) Taper Allowance :-





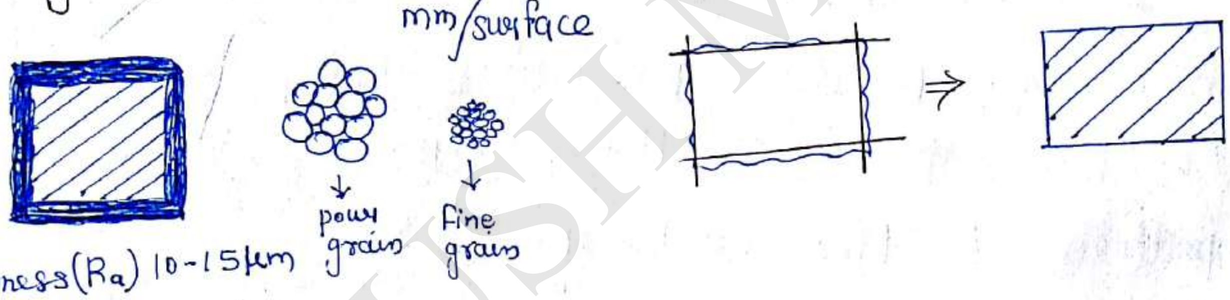


$x = h\tan\theta$

$\tan\theta = x/h$

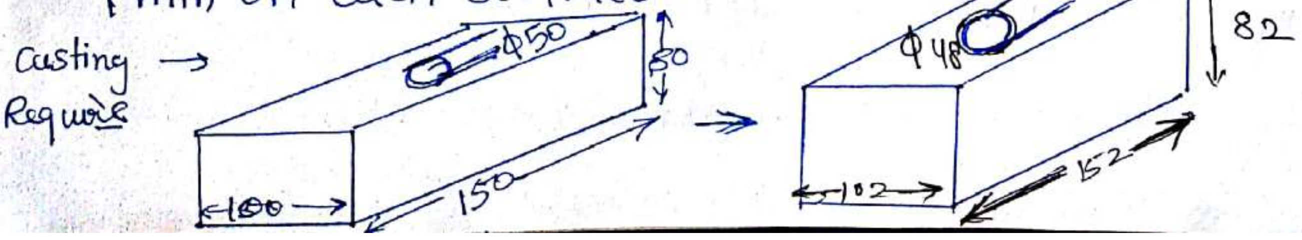
For easy removal of pattern from the mould for the verticle surface of pattern to minimise continues contact with pattern and mould surface, draft or taper allowance is provided.

Maching (or) finish allowance :-

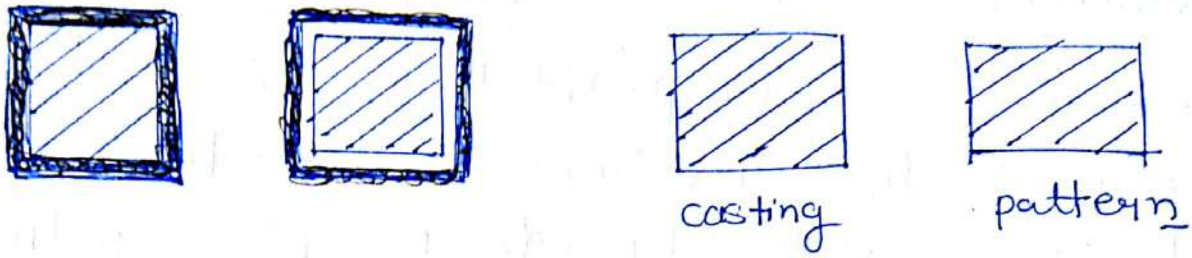


Casting object are not having smooth surface finish To get smooth surface finish machining is require. Due to machining size of casting will decrease To overcome thes size of the pattern can be increase by providing machining allowance

Problem Calculate the dimension of pattern for the casting shown below by condidering Maching allowance 1 mm on each surface

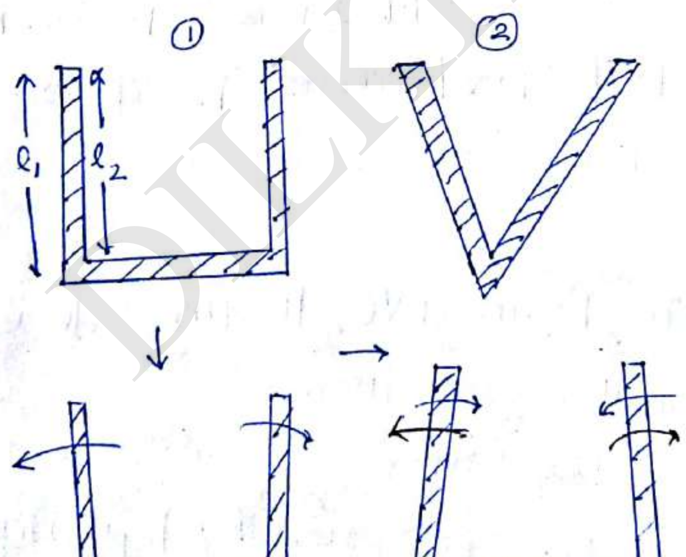


Shake (or) Rapping Allowance:-



Moulding sand will be stick to the surfale of pattern due to adhesive property . for easy removal of the pattern from mould some clearance is require between pattern and mould surface this can be produced by shaking of pattern. Due to shaking of pattern size of cavity slightly increase To overcome this size of pattern can reduced by providing ~~by~~ shake allowance. It is -ve allowance provided on the pattern

Distortion (or) cambee Allowance:-



* Distortion will takes place out side due more stress outside ($l_1 > l_2$)

it dep

* it is a zero allowance because we are only changing to shape of pattern.

* Due to differance in linear dimension there is possibility distortion of casting. To overcome this distortion allowance provided on the pattern opposite to the direction of distortion. This values will depands on $\left(\frac{l}{t}\right)$ ratio.

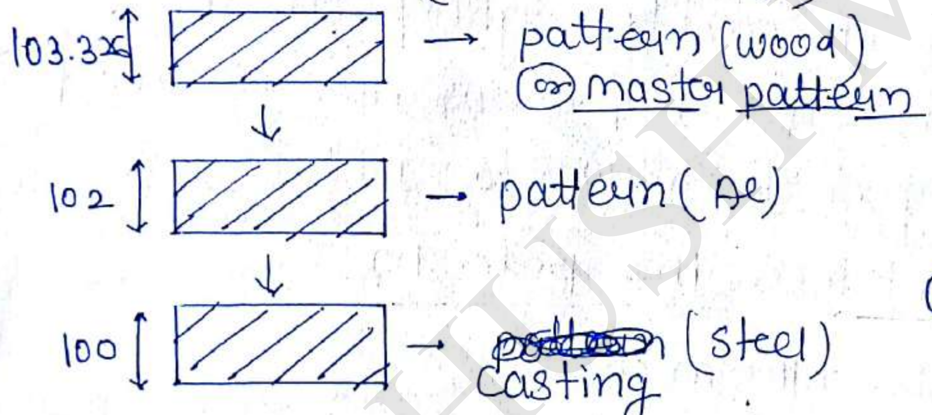
Pattern Materials :-

① Wood - low cost, easy to manufacture, easily available,

② Metals & Alloys - Al, brass, CI, steel etc.

Ex

(Double shrinkage)



① steel (20mm/m) :-

1000mm → 20mm

100mm → 2mm

② Al (13 mm/m)

1000 mm → 13 mm

102 mm → 1.326 mm

Ex

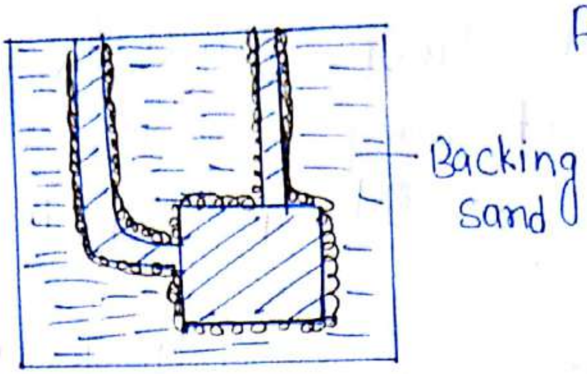
To produce casting of steel first ~~we~~ need ~~to~~ wood pattern and then Al

③ Plastic :- Polystyrene, Foam, PVC, thermocole etc.

- These pattern can only use one time
- Expendable or disposable pattern.

- Wax - Investment Casting (prepared by Injection moulding)

* Hg - mercast process
(-39°C)
Freezing temp.

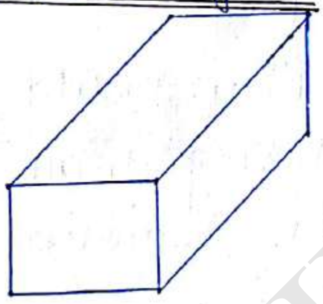


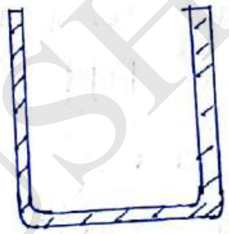
Full Moulding / EPC
cavity less

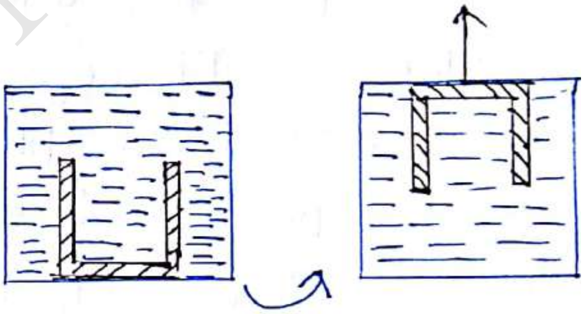
* Draft & shake allowane are not require in plastic pattern because it is in gaseous form.

Types of pattern:-

① Solid (or) Single:-

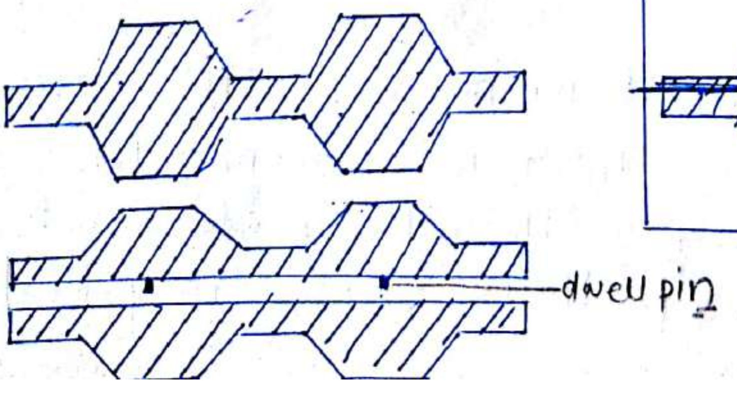


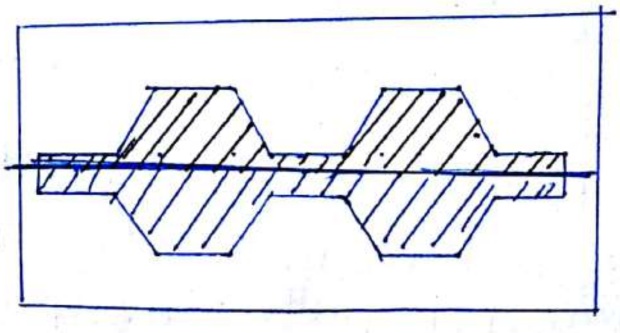




If the object to be produced is simple in shape and size Solid or Single piece pattern can be used one of the surface of pattern must be flat it is simple and less expansive

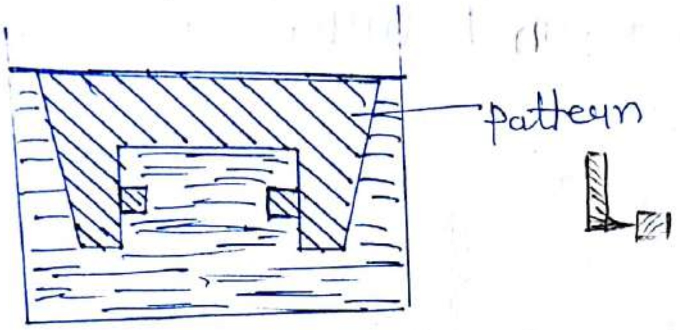
② Split piece pattern:-





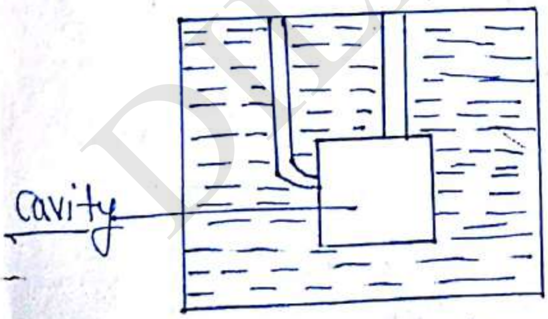
If the Complexity of object ~~is~~ will be ~~mo~~ more pattern can be split along parting line they can be removed from mould sprately to get required cavity.

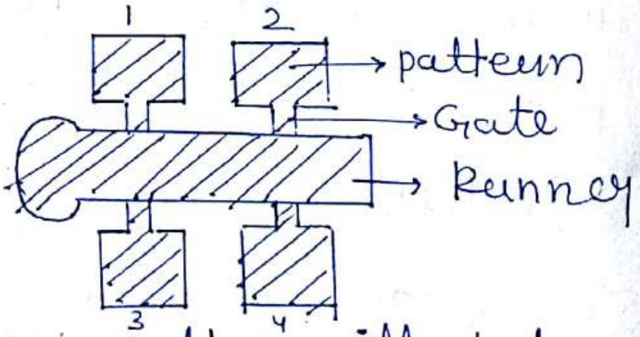
③ loose piece pattern:- Used in projections & Undercuts



If the patterns are having some projections and undercuts It can be removed from mould by assuming loose piece. After removing main part of the pattern loose piece can be removed from mould to get required cavity.

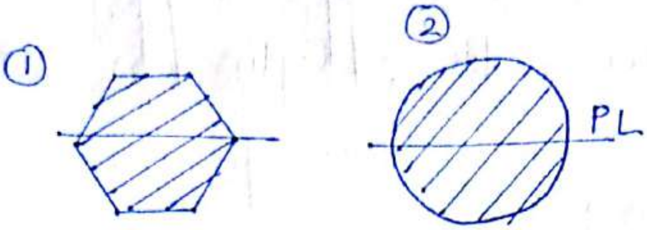
④ Grated pattern:-

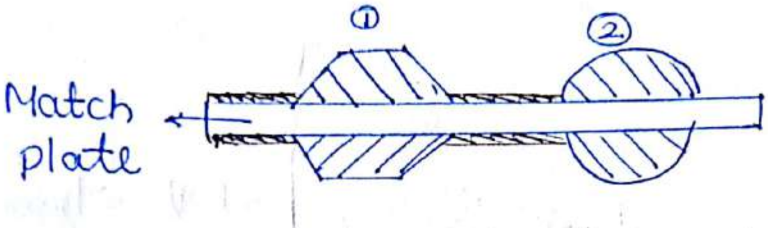


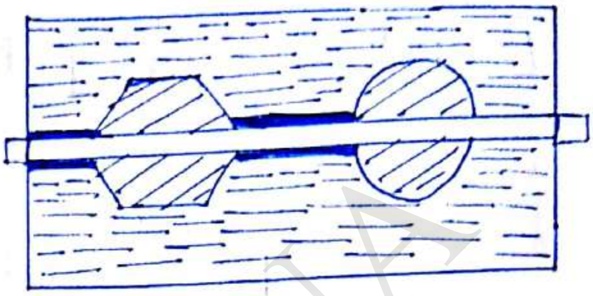


To produce gating element manually will take more time in mass production To overcome this number of pattern along with getting element will produce a single pattern know as gated pattern.

⑤ Match plate pattern:-

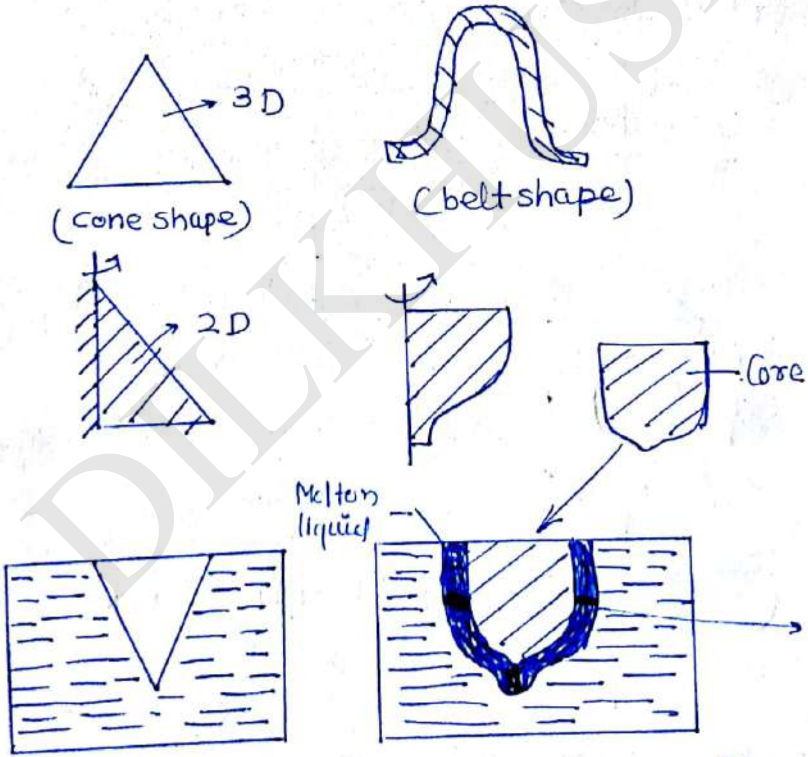


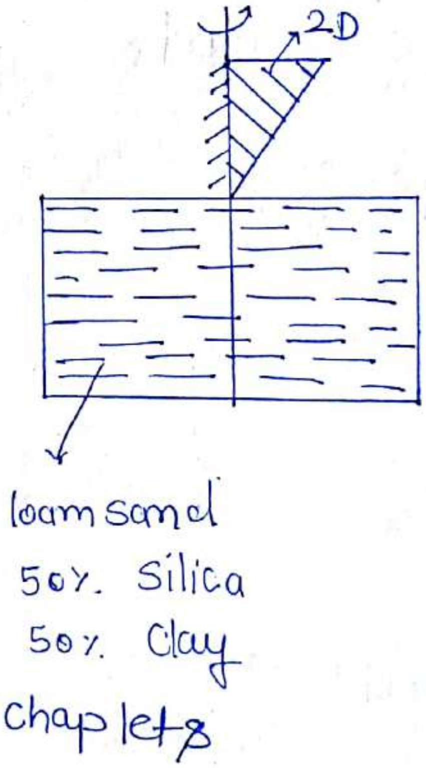




To produce complex shape of the object in mass production Number of patterns can be ~~spe~~ split along particle line and they will be added on both side of match plate along with gating element.

⑥ Sweep Pattern:-

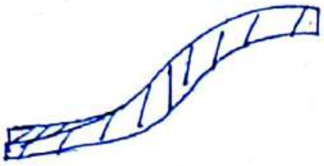


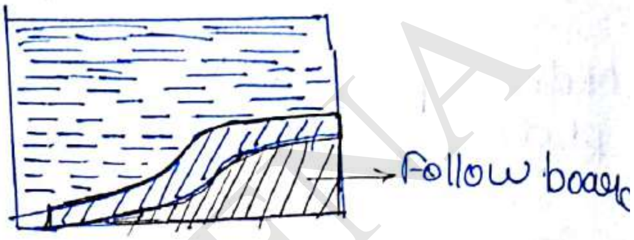


To produce 3-D complex shape of mould cavity 2-D plane pattern will be rotated on the surface of mould to get required shape of cavity.

it is not the true shape of pattern it used for axis symmetric object only
Ex:- Core, large size belt. or Cylinderical object etc

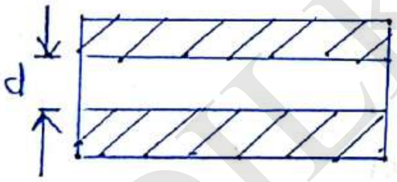
⑦ Follow board pattern:-



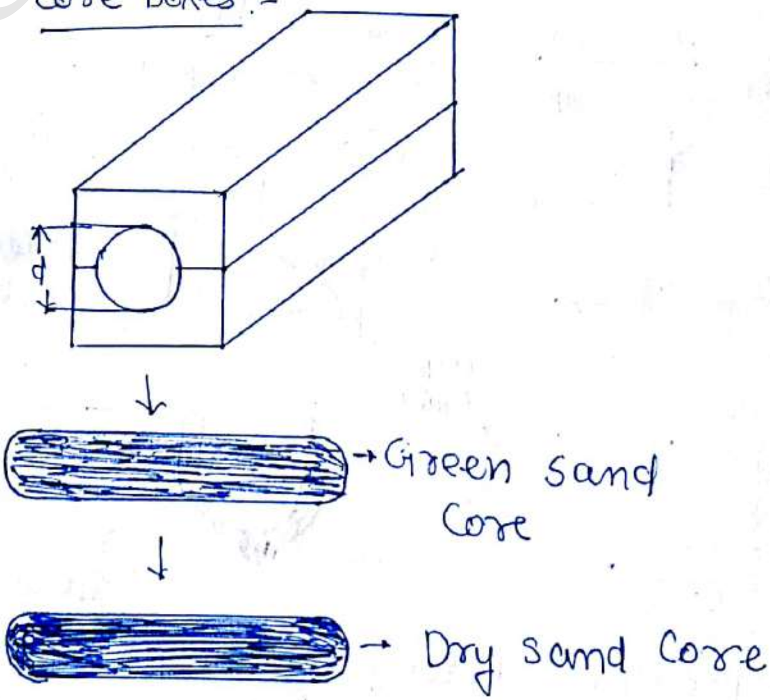


If the pattern are not having sufficient strength due to ramming force there is a possibility of breaking of pattern to overcome this pattern are supported by proviending follow board.

Core Design:-



Core boxes:-



Core sand:-

moulding Sand
+
organic binders
(linsed oil, Molasses etc)

Net Buyoncy force (P) $= \left(\begin{array}{c}\text{Wt. of liquid}\\ \text{Metal displace}\end{array}\right) - \left(\begin{array}{c}\text{Wt. of}\\ \text{core}\end{array}\right)$

$P = Vg\rho_m - Vg\rho_c$

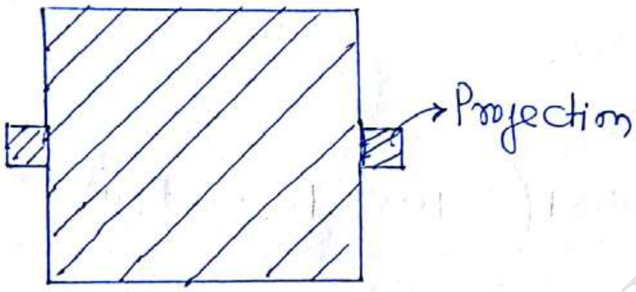
$\boxed{P = Vg(\rho_m - \rho_c)}$

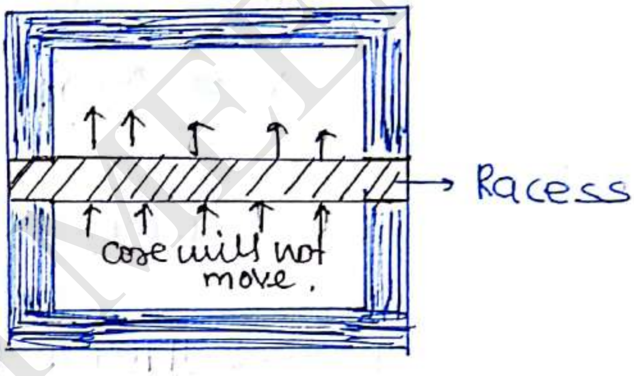
$P \leq 3.5 A_c \rightarrow cm^2$

ρ_m - density of Molten Metal
ρ_c - density of Core
V - volume of core
A_c - X-S/c Area of Core

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

Core prints:

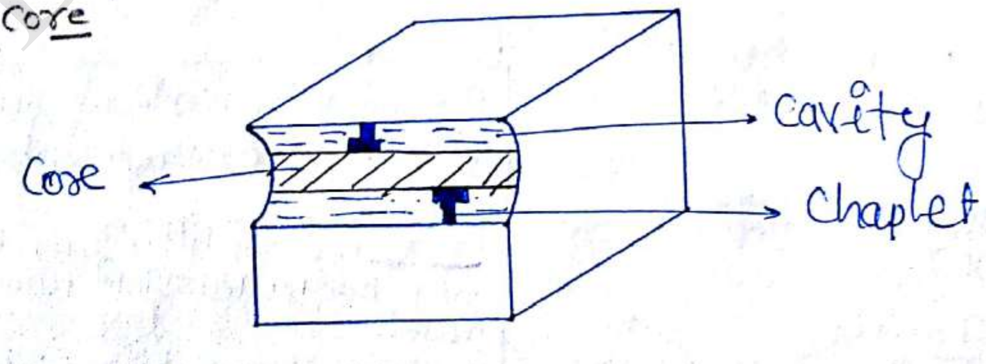




⇒ These are the projections on pattern and produce Recess inside the cavity to position the core properly.

Chaplet:- These are the mettalic object used to support the core inside the cavity they are made up of same material as Castieng.

To provide support to ~~core~~ core



Problem:- A hollow casting is produce a cylindrical Core with ~~height~~ h = d = 100 mm. Density of molten metal $\rho_m = 2700\ kg/m^3$ & density of core ~~matel~~ material is $\rho_c = 1600\ kg/m^3$ What is net buoyancy Force (P) = ?

Sol

$$H = D = 100 mm$$

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

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

$$V = \frac{\pi}{4} D^2 \cdot H$$

$$P = \frac{\pi}{4}(100)^2 \cdot 100 \times 9.81 (2700 - 1600) \times 10^{-6}$$

P = ~~8.470935~~ N

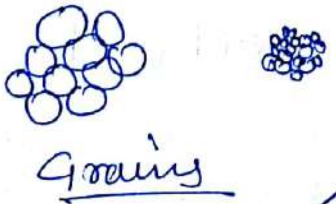
P = 8.475231581

Moulding Sand and their property:-

Moulding Sand Consist of

Silica → 70 - 85%.
Clay → 10 - 20%.
water → 2 - 8%.
Additive → 1 - 6%.

Clay - Bentonite
- Kalonile
both are in
In power form



Fission & Fusion are nuclear rxn that produce energy

Fission = splitting of a heavy unstable nucleus into two lighter nuclei

Fusion: where two light nuclei combine together release vast amount of energy

Properties of Moulding sand

① **Refractoriness**: Ability of moulding sand to witdhstand high temp. of liquid Metal without fusion called refractoriness.

② **Permeability** :- Ability of moulding sand to allow the ~~gasesoa~~ gases escape is known as permeability.

- It is expressed by permeability number

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

V – Volume of air passing through Speciman ($V = 2000\ cm^3$)

H = Height of cylinderical speciman = 2" = 5.08 cm

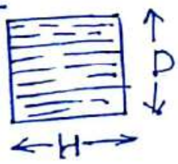
p = difference of pressure of air (g/cm^2)

A = X-S/c Area of Speciman ($A = \frac{\pi}{4} D^2\ cm^2$)

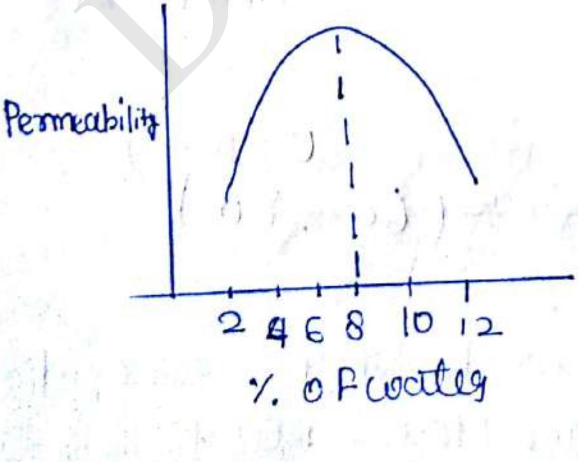
T = Time taken by air to allow to escape (min)

$P_n \propto \frac{1}{T}$ $\boxed{P_n \to 8\text{-}120}$

A.F.S



$H = D = 2''$
$= 2 \times 2.54$
$H = D = 5.08\ cm$
$V = 2000\ cm^3$



* Higher clay (>20%) – Permeability (↓)

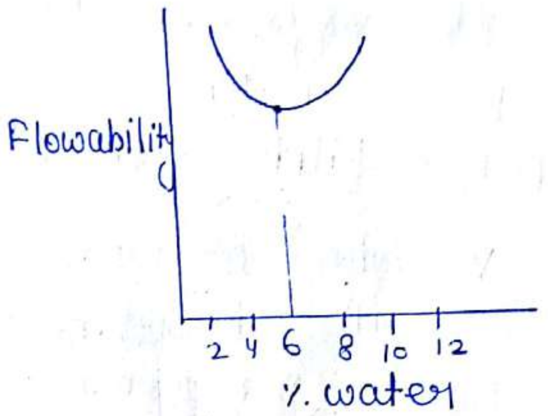
$$P = \frac{501.2754}{PT} \quad P - g/cm^2 \quad T - min$$

$\xrightarrow{}$ cm^2

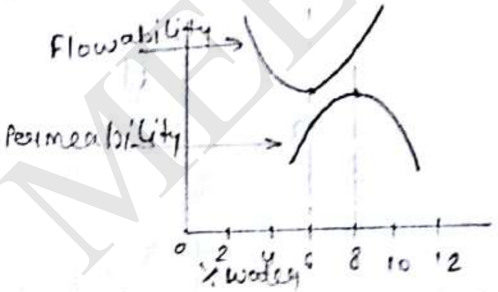
$$P = \frac{3007.552}{T} \quad T - sec \quad g = 10\ g/cm^2$$

③ Flowability :- Ability of Moulding sand to enter In to all the corner of ~~box~~ mould box due to ramming force this know as Flowability :-

% of water Vs Flowability



Small grain
- Flowability (↑)

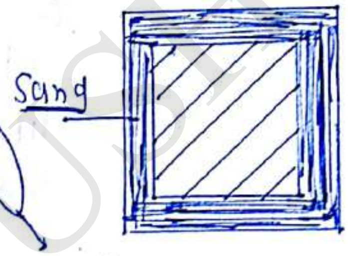


Retain
strength → Shape

Hardness → Reduce erosion

④ Strength :-

At start — Green Sand
As we pour metal in cavity — Dry Sand
— Hot Sand
After Moisture evoperation



by ↑ temp.

To retain the shape of the cavity and to widthstand Forces applied by liquid metal on the mould surface mould must have sufficient strength.

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

* Avg :- (60 - 80)

hardness is a surface property.
To minimise erosion and to widthstand Forces applied by liquid metal on mould surface Mould must be having sufficient hardness.

- If the hardness is < 60 dimensional stability of the casting will be decrease
- If the hardness is > 80 permeability of Mould will be decrease.

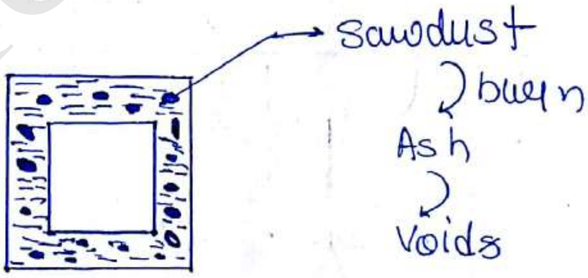
⑤ Adhessive property:
Cohessive property:

⑥ Adhessive property:- bond formation between two different Material

⑦ Cohessive property - bond formation between two similar Material.

* Moulding sand also require sufficient thermal conductivity (k) & low Coefficient of linear expansion(α)

⑧ Collapsibility



As temp ↑ → sawdust burn & Ash produce → Voids occur
then → permeability (↑)
→ Collapsibility (↑)

Ability of the moulding Sand due to which mould surface will not provide any resistance due to Solid Contraction of the casting is know as collapsibility. ⇒ High Collapsibility
↳ low strength & hardness

Additive used in Moulding Sand

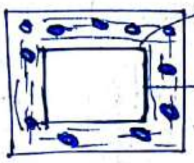
① Sawdust (or) wood flour } Collapsibility & permeability

② linseed oils, Molasses, dextrin } Hardness & strength

③ Coal dust } surface finish

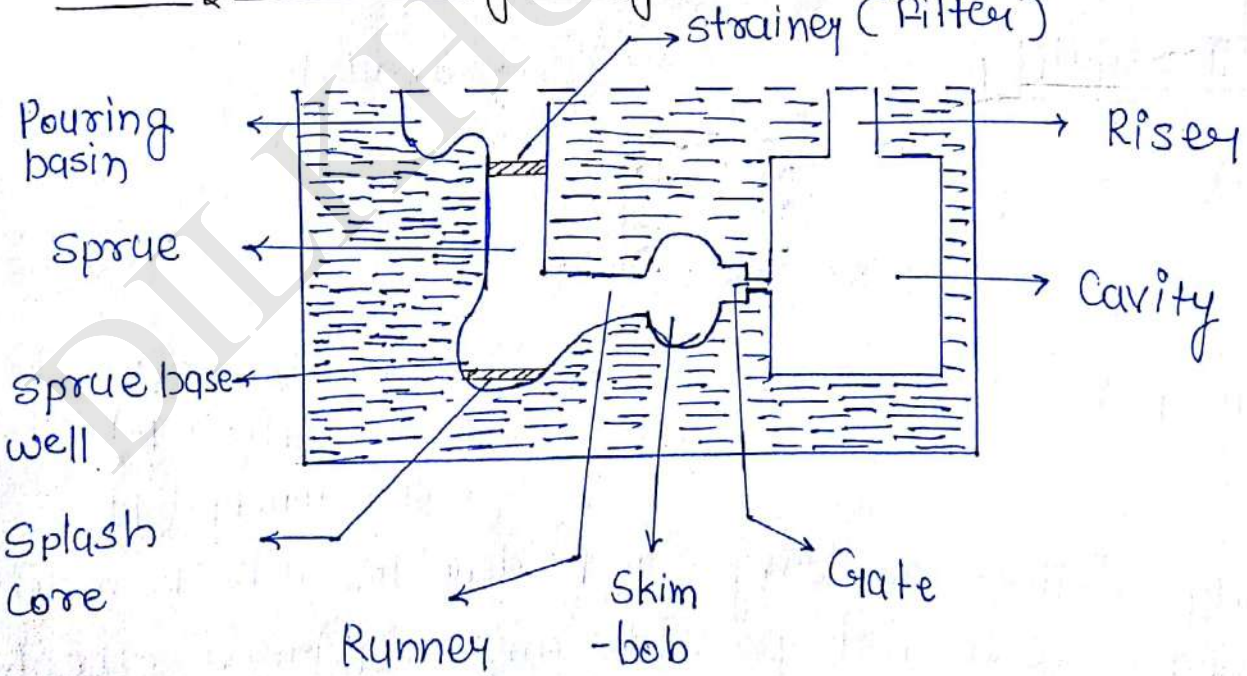
mould wash

(having carbon to increase surface finish)



→ Ash (it goes to surface of molten metal & give surface finish.

Element of Gating Design



* strainer & splash core made of ceramics (withstand high temp)

Objective of gating design

(i) Design the gating element such that liquid metal can be enter into the cavity Within a given time with optimum Velocity without Causing turbalance, splashing of the liquid Metal and Mould erosion.

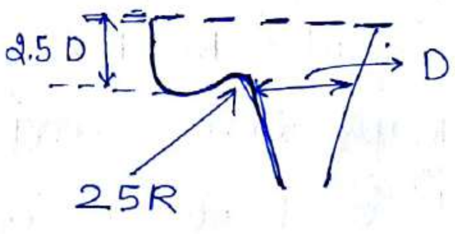
(II) Produce the Gating element such that pure liquid metal can be enter into cavety without Airaspiration effect

(III) Design the Gating to produce maximum casting yield.

$$\text{casting Yield} = \frac{\text{Vol. of Cavety}}{\text{Vol. of Cavity + Volume of gating element}}$$

$$\boxed{\text{casting Yield} = \frac{V_c}{V_c + V_g}}$$

Pouring basin :-

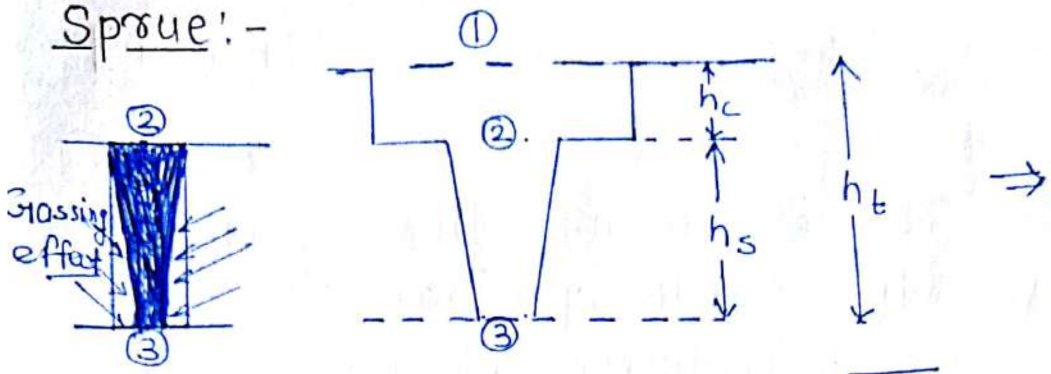


* Pouring basin is design to reduce to velocety of liquid metal which is enter into the sprue.

D - diameter of sprue at top

$R = D/2$

Sprue :-



$u_3 >> u_2$

$\because v = \sqrt{2gh}$

$u_2 = \sqrt{2gh_c}$

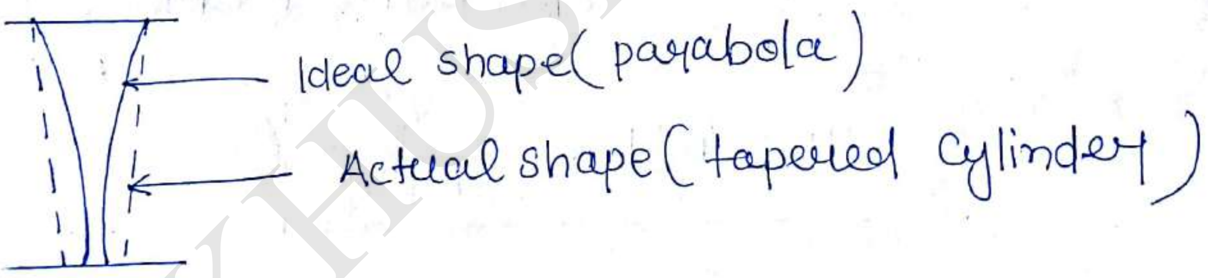
$Q = A_2u_2 = A_3u_3$

$u_3 = \sqrt{2gh_t}$

$A_3 << A_2$

$$\Rightarrow \frac{A_2}{A_3} = \frac{u_3}{u_2} = \frac{\sqrt{2gh_t}}{\sqrt{2gh_c}} = \sqrt{\frac{h_t}{h_c}}$$

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



Air aspiration effect :- Atmospheric gasses can be absorbe in geting element will mixup with liquid Metal and Form gas defect this effect is know as air aspriation effect

→ To overcome this effect the ideal shape of sprue is parabola. To reduce the manufacturing dificulties shape of sprue considered as tapered cylinder.

Problem!- In a gating design height of sprue is 200 mm. X-S/c Area of sprue at begaining is 650 mm². Discharge rate of liquid Metal is $6.5 \times 10^5 mm^3/s$ What is the X-S/c Area of sprue at bottom.

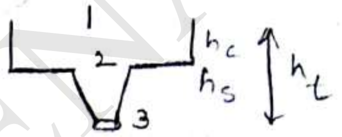
Soln

$h_s = 200 mm$

$A_2 = 650 mm^3$

$Q = 6.5 \times 10^5 mm^3/s$

$A_3 = ?$



$Q = A_2 u_2$

$\cancel{6.5} \times 10^5 = 650 \times u_2 \Rightarrow$
$\cancel{10}$

$\Rightarrow u_2 = 10^3 m/s$

~~$u_3 = \sqrt{2gh_s} = \sqrt{2 \times 10 \times 20}$~~

~~$u_3 = 62.64 m/s$~~

So ~~$A_3 =$ [illegible]~~ u_3

$u_2 = \sqrt{2gh_c} = \sqrt{2 \times 9810 \times h_c} = 1000$

$h_c = 50.96 mm$

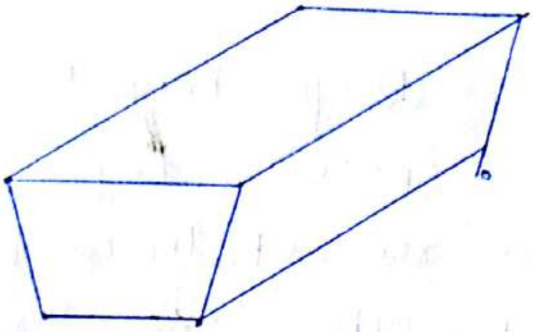
$h_t = 200 + 50.96 = 250.96 mm$

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

$A_3 = 292.92 mm^2$

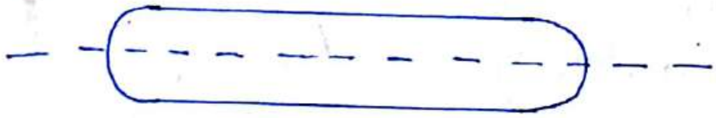
Runner :-

(i)



Heat transfer losses more
(High surface Area)

(ii)



⇒ To minimise ~~heat~~ turbulant and discharge losses of Metal shape of runner is considered as teepizoidal but it is having more surface Area

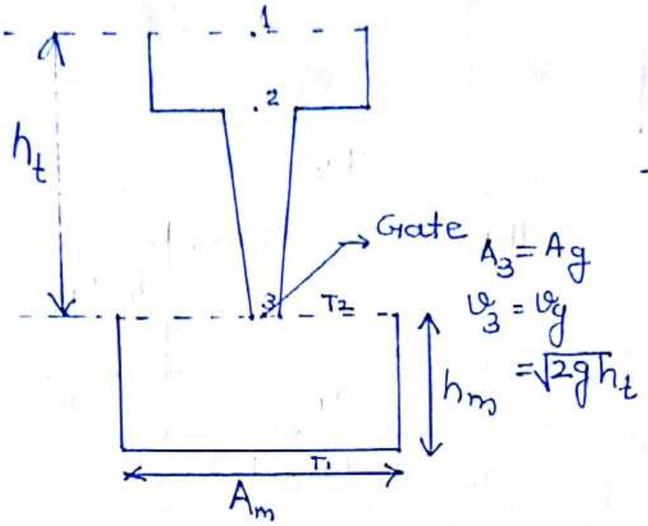
⇒ To minimize heat transfer losses of liquid Metal shape of the runner is Considered as cylindrical.

28 July 2016

Gate (Ingate)

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

Top Gate :-



Prefferred for
- Ferrous Material
- Min. depth of cavity
- low thickness
- High surface Area.
- $\frac{\Delta T}{h}$ temp Gradient low
- ~~loses less heat~~
- $(T_1 - T_2)$ less
- Low heat loss

- Liquid Metal is directly enter into the cavity from the bottom of sprue at atmospheric pressure.
- Velocity of liquid metal which enter in the cavity is very high. There is possibility of turbulance & splashing of liquid Metal. It is not used for casting non-ferrous material it can be use for ferrous Material with min. depth of Cavity.
- There is favorable temp. Gradient of liquid Metal in the cavity.

Gate $A_3 = A_g$: $v_3 = v_g$ velocity at Gate

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

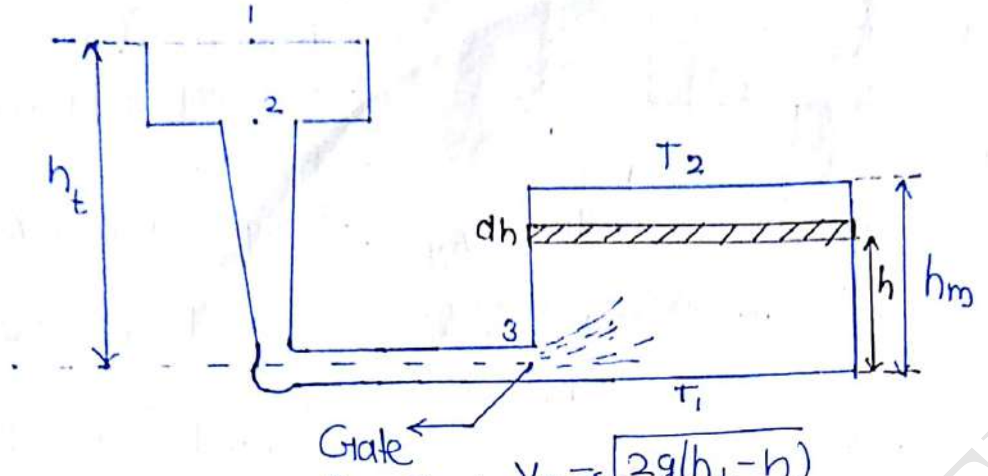
$$t_f \cdot A_g v_g = A_m \cdot h_m$$

Time taken to fill Cavity or Filling time

$$\boxed{t_f = \frac{A_m \cdot h_m}{A_g v_g} = \frac{V_m}{A_g v_g}}$$

V_m - Volume of Cavity

Bottom Gate:-



$\frac{\Delta T}{h}$ High

$(T_1 - T_2)\uparrow$

$A_3 = A_g$: $V_g = \sqrt{2g(h_t - h)}$

→ Gate is provided at the bottom of the cavity. liquid Metal is enter into the cavity from bottom to top. Velocity of the liquid Metal in cavity is negligible there is no turbulent & splashing. It can be use for casting of non-ferrous Material. There is unfavorable temp. Gradient of Liquid Metal in cavity (ΔT high होने के कारण ferrous material जल्दी में oxide बन जायेगा.

→ velocity of gate change w.r.t. h

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

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

$t = 0, \quad h = 0$

$t = t_f, \quad h = h_m$

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

Time taken to Fill the Cavity.

$$\boxed{t_f = \frac{2A_m}{A_g\sqrt{2g}} \left[\sqrt{h_t} - \sqrt{h_t - h_m}\right]}$$

if $\underline{h_t = h_m}$

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

$\because h_t = h_m$

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

$$\boxed{t_{f_b} = 2.\ t_{f_T}}$$

* Time require to fill the cavity by bottom gate is 2 times of fill by top gate when $\underline{h_t = h_m}$

* if $h_m > h_t$ → ~~te~~ then it can only fill $(P_1) > P_{atm}$ -pressure

Problem:- In a Gating design dimension of cavity is given by $(50\times25\times10)\ cm^3$ it is filled by top gating with pouring height of 15 cm and area of gate is 5 cm^2 Time taken to fill the cavity is?

Sn A $V_m = (50\times25\times10)\ cm^3$

$A_g = 5\ cm^3$ $\qquad h_t = 15\ cm$

$V_g = \sqrt{2gh_t} =$

$$t_f = \frac{V_m}{A_g V_g} = \frac{50\times25\times10}{5\times\sqrt{2\times981\times15}}$$

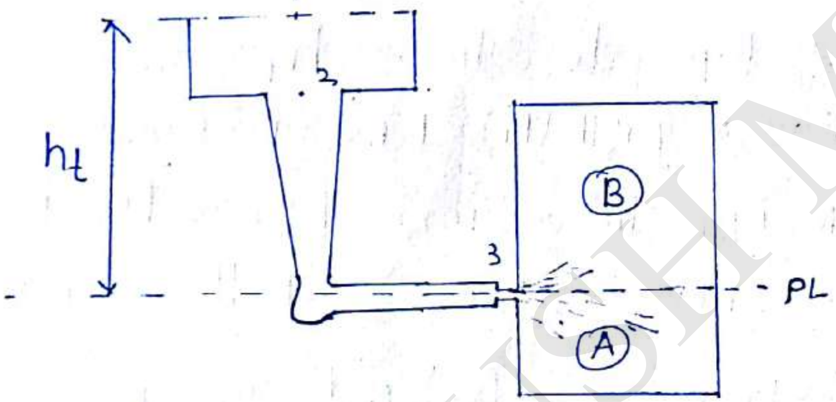
$t_f = 14.57$ Sec.

by bottom gate $h_m = 10$ cm

$$t_{fb} = \frac{2 \cdot (50 \times 25)}{5 \times \sqrt{2 \times 981}} \left(\sqrt{15} - \sqrt{(15-10)} \right)$$

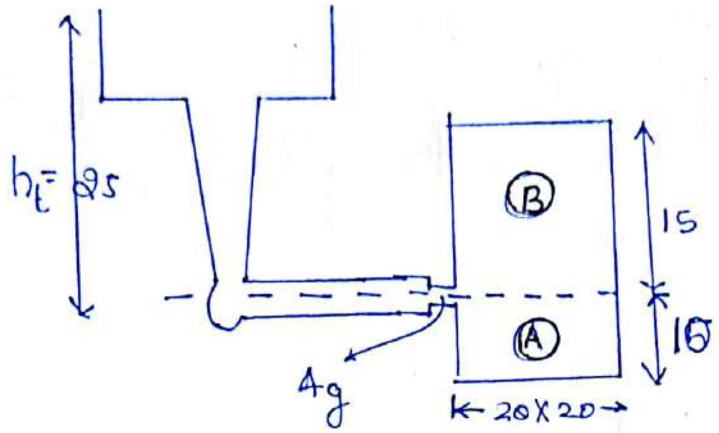
$$t_{fb} = 18.47 \text{ sec.}$$

Parting Line Gate:-



To get the advantage of both top & bottom Gate, gate is provided along the parting line such that liquid metal can be filled into the cavity below the parting line by assuming top gate and above the parting line it can be filled by assuming bottom gate it is the most commonly used type of gate

Problem



All dimesion are in Cm

Calculate the dimesions of gate liquid metal Can be completly fill into the cavity with mein 10 sec.

$$t_f = t_{f_t} + t_{f_b}$$

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

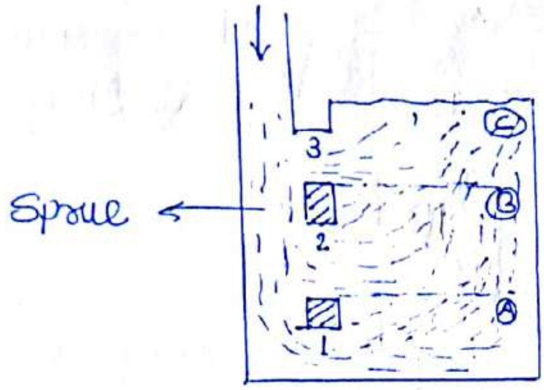
$$10 = \frac{20 \times 20 \times 10}{A_g \sqrt{2 \times 981 \times 25}} + \frac{2 \cdot (20 \times 20)}{A_g \sqrt{2 \times 981}} \left(\sqrt{25} - \sqrt{10} \right)$$

$$10 = \frac{18.06}{A_g} + \frac{33.19}{A_g}$$

$$A_g = \frac{51.25}{10}$$

$$A_g = 5.125 \text{ Cm}^2$$

Step Gate:-

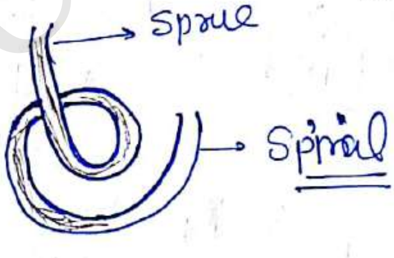


To fill the molton liquid into very large size of cavity no. of gates are provided in to form of step such that liquid metal filled into cavity within giving time without causing turbulance and splashing of liquid Metal.

Fluidity of Liquid Metal:-

AFS - American foundary society

Spiral test:-



Ability of the liquid metal to fill into the cavity is know as fluidity it is the property of a liquid metal it can be determinant by Conducting spiral test. Distance covered by liquid Metal in a Strandard Spiral before solidification will gives the value of fluidity.

Property		Fluidity
① Pouring temp	↑	↑
② Viscosity	↑	↓
③ Density	↑	↓
④ %.of water in sand	↑	↓
⑤ Surface finish of Cavity	↑	↑

* If %. water increase it require more heat to evorate so fludity decrease

* Density increase mass will increase So fludity ↓

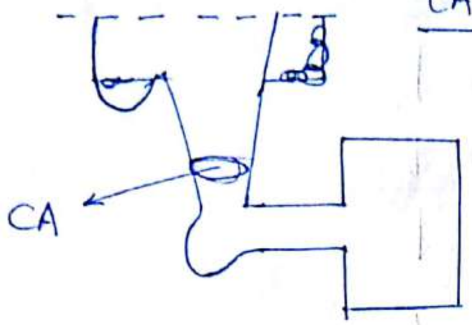
Choke Area :-

$$\boxed{C_A = \frac{m}{\rho t_f C_d \sqrt{2 g h_t}}}$$

It is the minimum x-s/c area in all the gateing element. It will Control the flow of metal which enter in cavity. It is the First parameter to be calculated in all the gateing element

m = mass of casting
ρ = density of material
C_d = coefficient of discharg
t_f = filling time

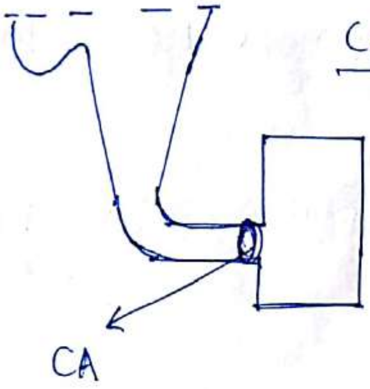
Un-pressurised Gating



CA = A_s

- low casting Yield
- used for non-ferrous.

Pressurised Gating



CA=A_g

- high casting Yield
- used for ferrous
- V↑, back pressure develope
back flow also occure.

Un-pressurised Gating

Chock Area is at the bottom of sprue. Velocity of liquid metal which is enter in ~~sprue~~ Cavity will be less. The is no possibility of turbulance & splashing it can be used for casting of non-ferrouse material. casting yield will be less. There is a posibility of air aspiration effect.

Pressurised Gating

Chock area is at the gate velocity of liquid Metal which is enter in cavity. ~~the~~ will be high. There is possibility of turbulance & splashing. It can be used for casting of ferrouse material. Casting Yield will be high. There is no posibility of air aspiration effect

Gating Ratio

$A_s : A_r : A_g$

A_s - Area of sprue
A_r - Area of runner
A_g - Area of Gate.

1 : 2 : 1 - pressurised gating (can back flow occurs) P↑

1 : 1 : 1 - Un-pressurised gating

U.P.G.	P.G.
1 : 2 : 3	3 : 2 : 1
1 : 2 : 2	2 : 2 : 1
0.5 : 1.5 : 1	2 : 3 : 0.5

Problem: In a gating design gating ratio is 1:2:4 is used to produce casting of mass m = 2 kg & t_f = 11.2 sec. density of material is $\rho = 2700\ kg/m^3$ height of liquid metal above the gate is h_t = 250 mm assuming coefficient of discharge $C_d = 0.98$ calculate the dimension of gate

Soln G.R. ⇒ 1 : 2 : 4 = $A_s : A_r : A_g$

$m = 20\ kg$, $t_f = 11.2$ sec., $\rho = 2700\ kg/m^3$, $h_L = 250mm$

$C_d = 0.98$

Choke Area $A_s = CA = \dfrac{20}{2700 \times 11.2 \times 0.98 \times \sqrt{2 \times 9.81 \times 0.250}}$

$CA = 3.047 \times 10^{-4}\ m^2$

Choke area CA = $3.04\ cm^2$

it is un-pressurised gating so $\underline{A_S = CA}$

$GR = A_s : A_r : A_g = 1:2:4$

$CA = A_s = 3.04\ cm^2$

$A_g = 4A_s = 4 \times 3.04$

$A_g = 12.18\ cm^2$

$A_g = \frac{\pi}{4} d_g^2 = 12.18 \Rightarrow \underline{d_g = 3.9\ cm}$

$A_r = 2A_g = 2 \times 3.04$

$A_r = 6.08\ cm^2$

$A_r = \frac{\pi}{4} d_r^2 = 6.08 \Rightarrow \underline{d_r = 2.78\ cm}$

If the Gating ratio chage $G.R \Rightarrow 4:3:1$

then $CA = A_g$

$A_s = 4A_g$

$A_r = 3A_r$

$G.R\ 4:3:1 = A_s : A_r : A_g =$

Solidification Time :-

Chvorinov's principle

Always

$(t_s)_r > (t_s)_c$

↓ ~~casting~~ riser

↓ Casting

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

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

k → solidification Factor (s/m^2)

$t_s \propto \frac{1}{k}$ → thermal Conductivity

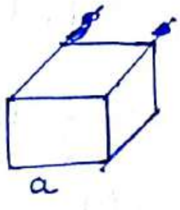
$t_s \propto \frac{1}{\alpha}$ → thermal diffusivity

$t_s \propto c$ → Heat capacity

High thermal Conductivity, higher the heat transfer rate so time taken in Solidify is less.

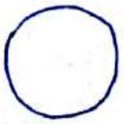
$\left(\frac{V}{A}\right)$ Calculation $\left(\frac{\text{Volume}}{\text{Surface Area}}\right)$

① Cube :-



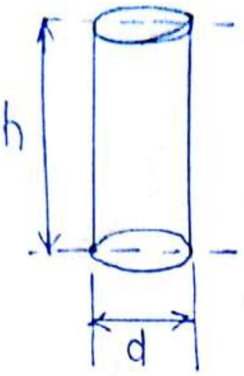
$$\frac{V}{A} = \frac{a^3}{6a^2} = a/6$$

② Sphere :-



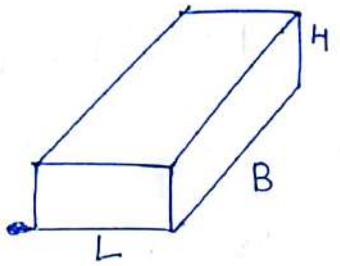
$$\frac{V}{A} = \frac{4/3\pi R^3}{4\pi R^2} = \frac{R}{3}$$

③ Cylinder:-



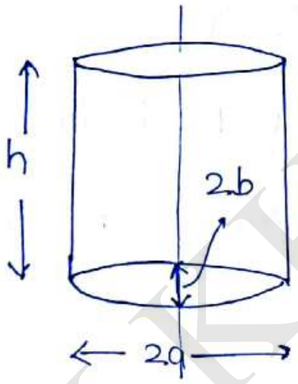
$$\frac{V}{A} = \frac{\frac{\pi}{4} d^2 \cdot h}{2 \cdot \frac{\pi}{4} d^2 + \pi d h}$$

④ Slab:-



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

⑤ Eiliptical Cylinder :-



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

Problem:- A molton drop of metal in spherical shape with 2mm radius will solidy in 10 sec. what is Solidification time of same molton drop with double radius.

Sol^n $t_{s_1} = 10$ sec. $r_1 = 2$ mm , $t_{s_2} = ?$, $r_2 = 4$mm

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

$$t_s \propto \left(\frac{r}{3}\right)^2 \Rightarrow \frac{t_{s_1}}{t_{s_2}} = \left(\frac{r_1}{r_2}\right)^2 \Rightarrow t_{s_2} = 10 \times \left(\frac{4}{2}\right)^2$$

$$t_{s_2} = 40 \text{ sec.}$$

Q.17
Pg.72
workbu

$k = 0.97 \times 10^6 \; s/m^2$

$t_s = ?$ sphere $D = 200$ mm

$$t_s = k\left(V/A\right)^2 = k\left(\frac{R}{3}\right)^2 = k\left(\frac{D}{6}\right)^2$$

$$t_s = 0.97 \times 10^6 \left(\frac{0.2}{6}\right)^2$$

$$t_s = 1077.78 \text{ sec.}$$

Q.15

$$(t_s)_{cube} / (t_s)_{sphare}$$

$$= \left(\frac{V}{A}\right)^2_{cube} / \left(\frac{V}{A}\right)^2_{sphare}$$

Volume same
$V_c = V_s$

$$\frac{(t_s)_{cube}}{(t)_{spha}} = \frac{(V/A)_c}{(V/A)_s} = \frac{(4\pi r^2)^2}{(6l^2)^2} = \left(\frac{4\pi}{6}\right)^2 \left(\frac{r}{l}\right)^4$$

$V_c = V_s$

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

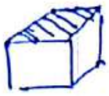
$$\frac{(t_s)_c}{(t_s)_s} = \left(\frac{4\pi}{6}\right)^2 \left(\frac{3}{4\pi}\right)^{4/3} = 0.649$$

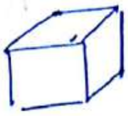
Q26

$$(t_s) \propto \left(V/A\right)^2$$

⊕ $V_1 = a^3$ $\qquad V_2 = a^3$

$A_1 = 5a^2$ $\qquad A_2 = 6a^2$





$$\frac{(t_s)_1}{(t_s)_2} = \frac{\left(V/A\right)_1^2}{\left(V/A\right)_2^2} = \frac{\left(a/5\right)^2}{\left(a/6\right)^2} = \frac{36}{25}$$

Q.28 $\quad r = h = 6$~~0~~cm

For ractangular plate $(7 \times 10 \times 2)\ \text{cm}^3$

$t_s = 1.36$ sec.

$$t_s = k\left(V/A\right)^2$$

$$1.36 = k\left(\frac{7 \times 10 \times 2}{2(70+20+14)}\right)^2$$

$$k = 3\ \text{min}/\text{cm}^2 = [illegible]$$

$$\frac{(t_s)_c}{(t_s)_R} = \frac{\left(V/A\right)_c}{\left(V/A\right)_R} = \frac{\left(\frac{7 \times 10 \times 2}{2(70+20+14)}\right)^2}{\left(\frac{\frac{\pi}{4}(6)^2 \cdot 6}{2 \cdot \frac{\pi}{4} \cdot 6^2 + \pi(6)(6)}\right)^2} = 0.45$$

$$(t_s)_R = \frac{1.36}{0.45} = 3.022\ \text{min}.$$

(29)

$a = 2h$, $h = r$

$$\frac{(t_s)_{cy}}{(t_s)_c} = \frac{\left(\frac{\pi r^2 h}{2\pi r^2 + 2\pi r h}\right)^2}{\left(a/6\right)^2} = \frac{\left(\frac{r^3}{4r^2}\right)^2}{\left(a/6\right)^2}$$

$$\frac{(t_s)_{cy}}{(t_s)_c} = \left(\frac{h}{4}\right)^2 \cdot \left(\frac{6}{2h}\right)^2 = 0.5625$$

(31)

$$\frac{(t_s)_c}{(t_s)_s} = \frac{(V/A)_c^2}{(V/A)_s}$$

$V_c = V_s$

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

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

$$\frac{4}{(t_s)_s} = \frac{(A)_s^2}{(A)_{cu}^2} = \left(\frac{6a^2}{4\pi r^2}\right)^2$$

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

$(t_s)_s =$ ~~21.76~~ Secs

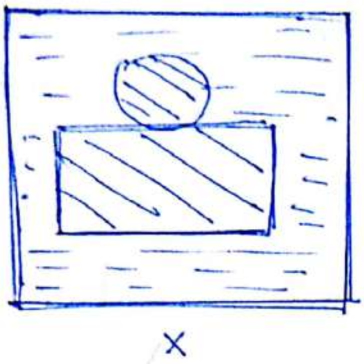
$(t_s) = 6.15$ sec.

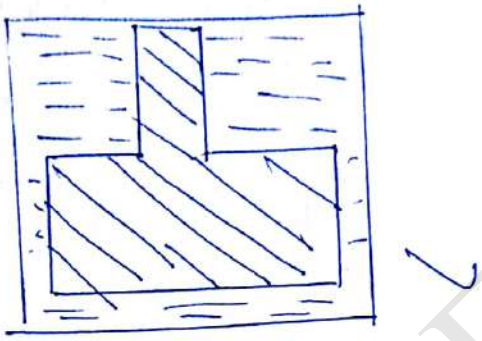
$$\frac{(t_s)_c}{(t_s)_s} = \left(\frac{A_s}{A_c}\right)^2 = \left(\frac{4\pi r^2}{6a^2}\right)^2 = \left(\frac{4\pi}{6}\right)^2 \left(\frac{r}{a}\right)^4 = \left(\frac{4\pi}{6}\right)^2 \left(\frac{3}{4\pi}\right)^{4/3}$$

$t_s = 6.15$ sec

Riser:-

✓ $\left(\frac{A}{V}\right) \rightarrow$ Cooling Characterstics

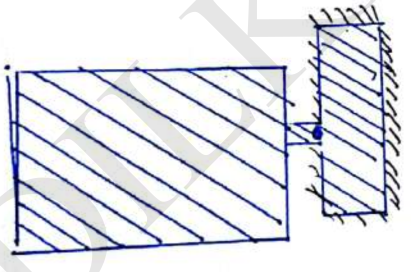




For a given Volume of riser sphere is having min (A/V) ratio but it is not Considered as the shape of riser this is due to availibity of liquid metal in the spherical riser is at center. Cylinder will be considerd as the shape of riser.

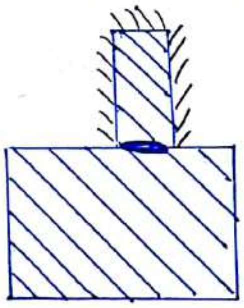
Types of Riser:-

① Side Riser



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

② Top Riser



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

Top Riser is effective as compare to Side riser because it's is having less surface Area.

optimum Condition

① side riser

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

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

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

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

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

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

$$\boxed{h = d}$$

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

$$\left(\frac{A}{V}\right) = \frac{2\cdot\frac{\pi}{4}d^2 + \pi d^2}{\frac{\pi}{4}d^3} = \frac{\frac{3\pi}{2}}{\frac{\pi}{4}d} = \frac{6}{d}$$

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

② **Top Riser**

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

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

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

$$\frac{dA}{d(d)} = 0 \Rightarrow \frac{\pi}{2} d - \frac{4V}{d^2} \Rightarrow V = \frac{\pi}{8} d^3 = \frac{\pi}{4} d^2 \cdot h$$

$$\left(h = d/2\right)$$

$$A/V = \frac{\frac{\pi}{4} d^2 + \pi d h}{\frac{\pi}{4} d^2 \cdot h} \Rightarrow \boxed{h = d/2}$$

$$A/V = \frac{\frac{\pi}{4} d^2 + \frac{\pi d^2}{2}}{\frac{\pi}{8} d^3} = 6/d$$

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

☆

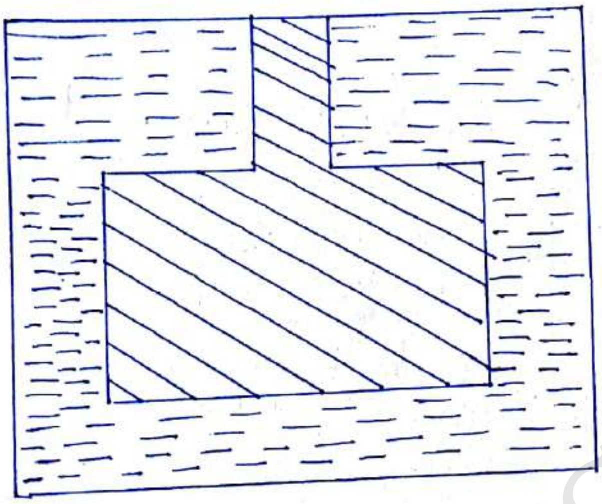
Side Riser	$h = d$	$(A/V) = 6/d$
Top Riser	$h = d/2$	$(A/V) = 6/d$

Riser Design:-

Method-I

① ⓐ Vol. of Riser = 3 x % Shrinkage Vol. Of Casting

ⓑ $\left(\frac{A}{V}\right)_C \geq \left(\frac{A}{V}\right)_R$



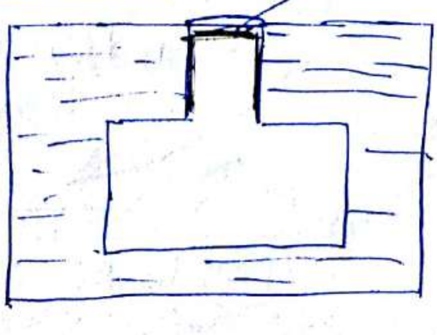
* By using this Method dimension of riser can be calculated if % of shrinkage of the material will be given.

Method to increase the performance of riser!

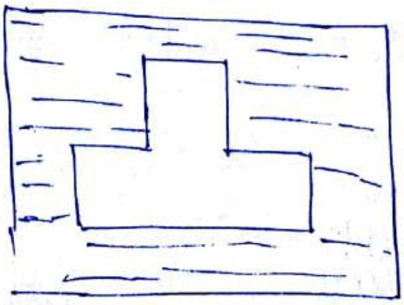
① provide insulating material
② Exothermic Material
③ use optimum conition $(h = d/2, h = d)$
④ Provide Blind riser

insulating Material put here

Open riser



Blind riser



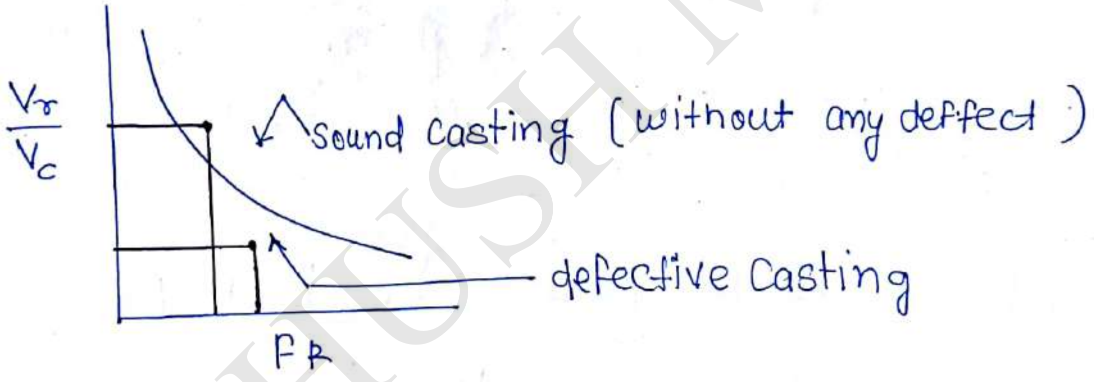
Method-II

② Caine's Method :-

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

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

$X = FR$, $Y = \frac{V_r}{V_c}$, a, b, c are constant.

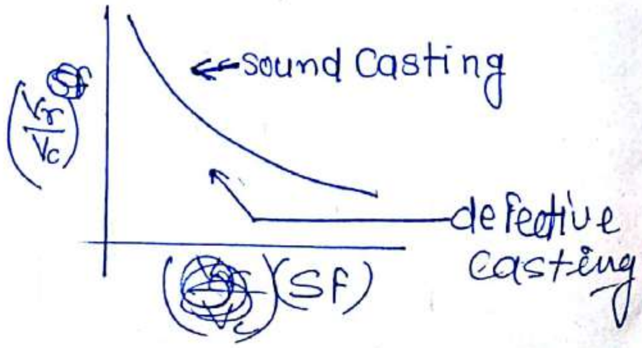


Using this method dimensions of the riser Can be Calculated For a simple shape of casting

Method-III

③ Modified caine's Method :-
(Noval research laborator Method)

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



L - length.
W - width.
T - thickness.

Geometory	Safe factor(SF)
i> Cube	$\frac{a+a}{a} = 2$
ii> Sphere	$\frac{D+D}{D} = 2$
iii> Cylinder	$\frac{H+D}{D}$
iv> slab	$\frac{L+B}{H}$

Method - IV

④ modulus Method :-

$$\boxed{\text{modulus} = \left(\frac{V}{A}\right)} = \frac{\text{Volume}}{\text{surface area}}$$

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

Q. 7.1
Pg. 74

$$V_c = (25 \times 12.5 \times 5)\ cm^3$$

$$V_r = 3 \times 3\%\ V_c$$

$$V_r = \frac{3 \times 3 \times (25 \times 12.5 \times 5)}{100} = 140.625\ cm^3$$

$$V_r = \frac{\pi}{4} d^2 \cdot h \qquad \text{Side riser } h = d$$

$$140.625 = \frac{\pi}{4} d^3 \quad \Rightarrow d = \underline{5.636258259}\ cm$$

shrinkage along is mention
so this is Answer.
if nothing mention go further.

$$\left(\frac{A}{V}\right)_c = \frac{2\left[25\times12.5+12.5\times5+5\times25\right]}{25\times12.5\times5} = 0.64$$

$$\left(\frac{A}{V}\right)_r = \left(\frac{6}{d}\right) = \frac{6}{5.636} = 1.064$$

$\left(\frac{A}{V}\right)_c < \left(\frac{A}{V}\right)_r$ Condition is failed

So Need Redesign Riser

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

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

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

Q.32

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

$$X = \frac{0.10}{Y-0.03} + 1$$

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

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

$$\left(\frac{A}{V}\right)_c = \frac{2\left[250\times250+(250\times50)2\right]}{250\times250\times50}$$

$$\left(\frac{A}{V}\right)_c = 0.056$$

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

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

$X = FR = \frac{0.056}{6/d}$; $Y = \frac{V_r}{V_c} = \frac{\frac{\pi}{4}d^3}{(250\times250\times50)}$

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

$\left(\cancel{\frac{0.056d}{6}} - 1\right)\left(\cancel{\frac{\frac{\pi}{4}d^3}{250\times250\times50}}\right) = \cancel{0.1}$

$\left(\frac{0.056}{6}d - 1\right)\left(\frac{\frac{\pi}{4}d^3}{3125000} - 0.03\right) = 0.1$

$d = 128.4$ mm

Q. 30

$V_c = 25\times15\times5 \text{ cm}^3$

$SF = \frac{25+15}{5} = 8$ So

$\Rightarrow \frac{V_r}{V_c} = 0.50$

$\frac{\frac{\pi}{4}d^3}{(25\times15\times5)} = 0.50 \Rightarrow d = 10.60784$ cm

Q A cylindrical riser h = d is positioned on top surface of a Cylinderical casting with d = 200mm & h = 100 m using Modular Method calculate the dimension of riser.

$$M_R = 1.2 M_C$$

$$\left(\frac{V}{A}\right)_R = 1.2\left(\frac{V}{A}\right)_C$$

$$M_R = 1.2\left(\frac{\frac{\pi}{4} d^2 . h}{2\frac{\pi}{4} d^2 + \pi d h}\right) = \frac{dh}{4\left(\frac{d}{2}+h\right)}$$

$$M_R = 1.2\left(\frac{\frac{\pi}{4} \times (200)^2 . 100}{2 . \frac{\pi}{4}(200)^2 + 200 \times 100 \times \pi}\right)$$

$$M_R = 1.2 \times 25$$

$$M_R = 30$$

$$M_r = \frac{\frac{\pi}{4} d^2 . h}{\frac{\pi}{4} d^2 + \pi d h} \qquad h = d$$

$$M_r = \frac{d}{5}$$

$$d/5 = 30 \Rightarrow d = 150 \text{ cm}$$

Ⓣ2

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

$$\left(\frac{V}{A}\right)_1 = \left(\frac{\pi \frac{D^2}{4} h}{2\cdot\frac{\pi}{4}D^2 + \pi D h}\right) = \frac{D^2 h}{2D^2 + 4DH}$$

$$\left(\frac{V}{A}\right)_1 = \frac{dh}{2d + 4H} = \frac{d^2}{2d+4d}$$

$$\left(\frac{V}{A}\right)_1 = \frac{d}{6}$$

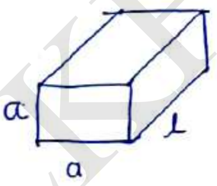
$$V = \frac{\pi d^2}{4}\cdot h$$

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

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

$$\boxed{h = d}$$

Square parallelopiped



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

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

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

$$\frac{(t_s)_{cy}}{(t_s)_{sp}} = \frac{(V/A)^2_{cy}}{(V/A)^2_{sp}} = \frac{(A)^2_{sp}}{(A_{cy})^2}$$

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

$$= \left(\frac{4}{\pi}\right)^2\cdot\left(\frac{\pi}{4}\right)^{4/3} = 1.174$$

$$\frac{\partial A}{\partial v} = 0$$

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

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

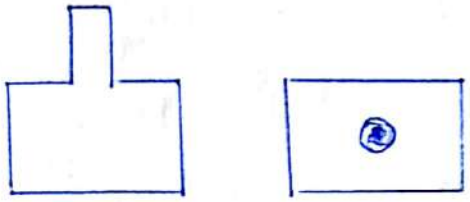
$$a = l$$

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

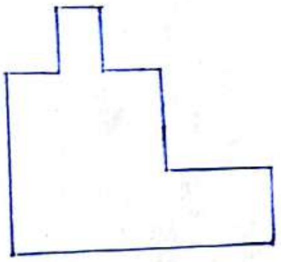
$$\frac{\pi}{4}d^3 = a^3 \Rightarrow \frac{a}{4} = \left(\frac{\pi}{4}\right)^{1/3}$$

Position of Riser:-

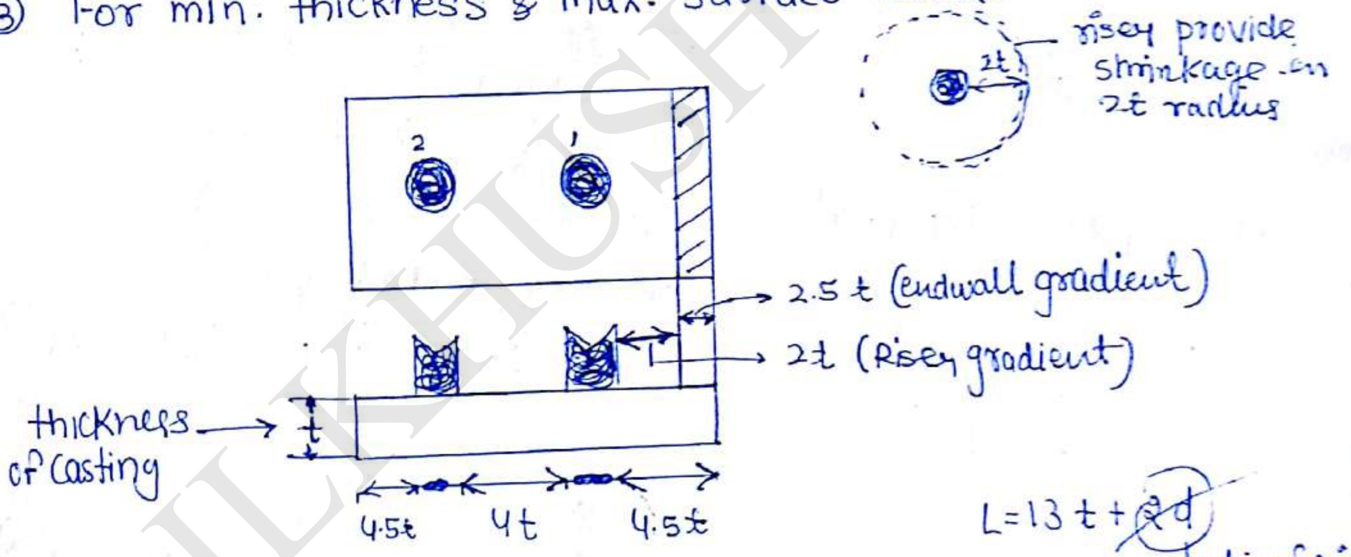
① For uniform thickness



② for non-uniform thickness



③ For min. thickness & max. surface Area.



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

↳ dia of riser but Neglate it

~~typ~~

(i) with endwall effect

L = 13 t (Two riser)

L = 9 t (one riser)

(ii) without endwall effect

L = 8t (Two riser)

L = 4t (one riser)

L - Max. length of Casting

t - thickness of casting

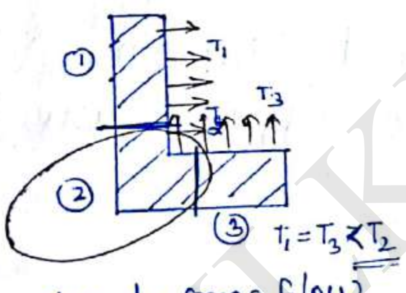
- for uniform thickness and simple shape of casting on riser is sufficient to componset to shrinkage & it is position at the top surface of casting at the center.

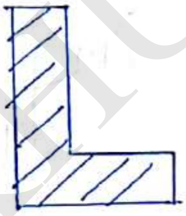
- for non-uniform thickness of casting riser is provided higher thickness of casting. ~~for in~~

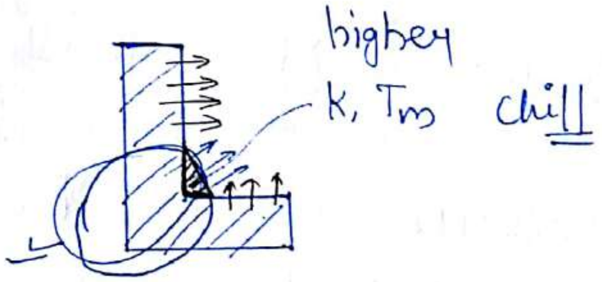
- for min. thickness & max. surface area of casting due to fast rate of shrinkage of material more no. of riser provided to componset the shrinkage of casting

- In calculation of length of casting diameter of riser can be neglated if given consider.

Chills & Padding :-







- due to cross flow ΔT is low in this x-s/c So less Heat transfer takes place So there is non-uniform shrinkage &

$$q = -KA\frac{dT}{dx}$$

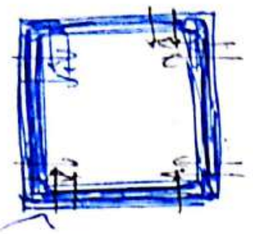
- Due to non uniform heat transfer hot tears/crack will occurs

- In x-s/c ① & ③ Material solidify faster.

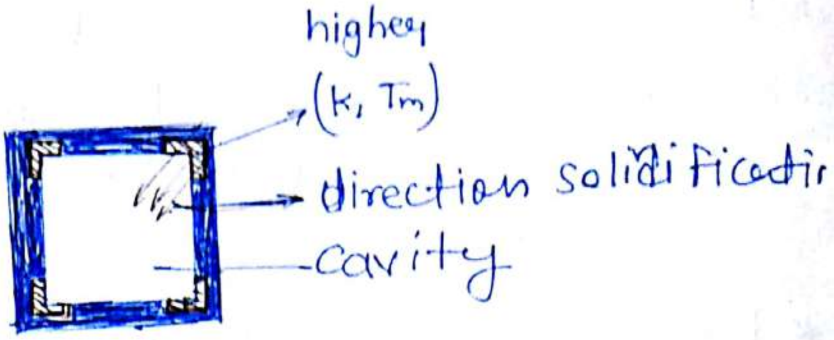
- Higher thermal conductivity (K) & higher melting point (T_m) material chills are providing for uniform heat transfer

- in that perticular x-S/c

Padding :-



Chanse of erosion at critical x-s/c



After casting remove padding & chills by filing

Chills :- At a min x-s/c in the mould cavity to maximise the heat transfer rate and to provide uniform & direction solidification mettalic objects are provided these are known as Chills.

Padding :- At critical x-s/c to mini erosion and to provide uniform cooling and uniform solidification metallic object of higher k, Tm are provided these are know as padding

☆ By providing chill & padding uniform solidification and directional solidification can be possible

Classification of Casing Technique :-

① Expendable Moulding:
(Sand Moulds)
- Sand moulding
- shell moulding
- Investment
- Full moulding
- CO_2 moulding

- time Consuming
- laborious process
- non uniform Cooling & solidification
- less accuracy.
- Complex shape and can produce

② Permanent Moulds:-
(Metallic Moulds)
- Centrifugat
- Die casting
- Slush casting
- squeeze Casting

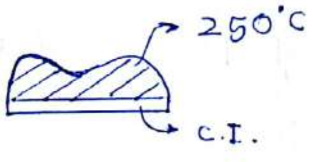
- Can use more time & mass production
- surface finish
- Fast rate of Heat transfer So fine grain develope so high Strength

③ Continuous casting:- large length bloom bittel produce for high production

→ Gas deffect occurs
- Metal to metal contact possible So solid lubricant require
- low T_m should produce

Shell Moulding:-

Pattern :

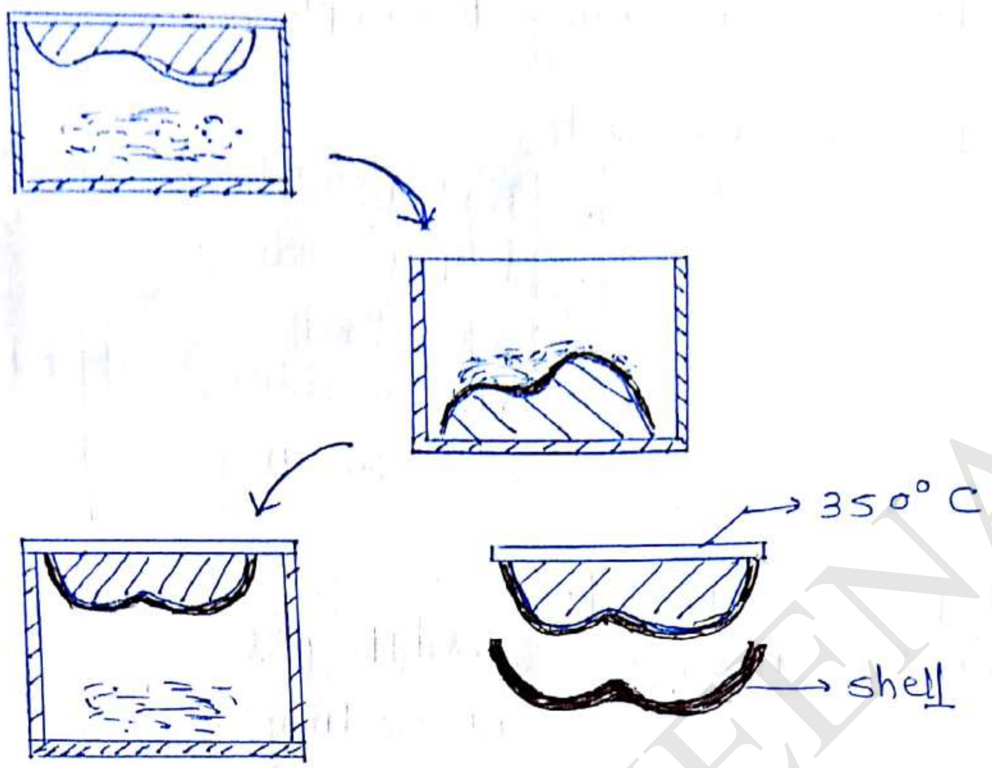


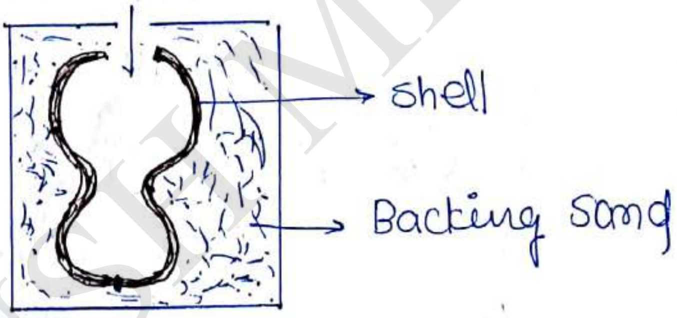
Moulding material : - Fine grain silica
- Phenolic resine
  - Phenol formaldehyde
  - Urea formaldehyde
- Alcohol

→ Synthetic polymers (Plastic)
(made by Rxn of phenol with formaldehyde)

thermosetting → use only once

thermoplasteing ⇒ can re use.





* only shell is wasted

* Backing sand can reuse.

Appications

1) Cylinder blocks of Air cooled I.C. engine

2) Rocker arms

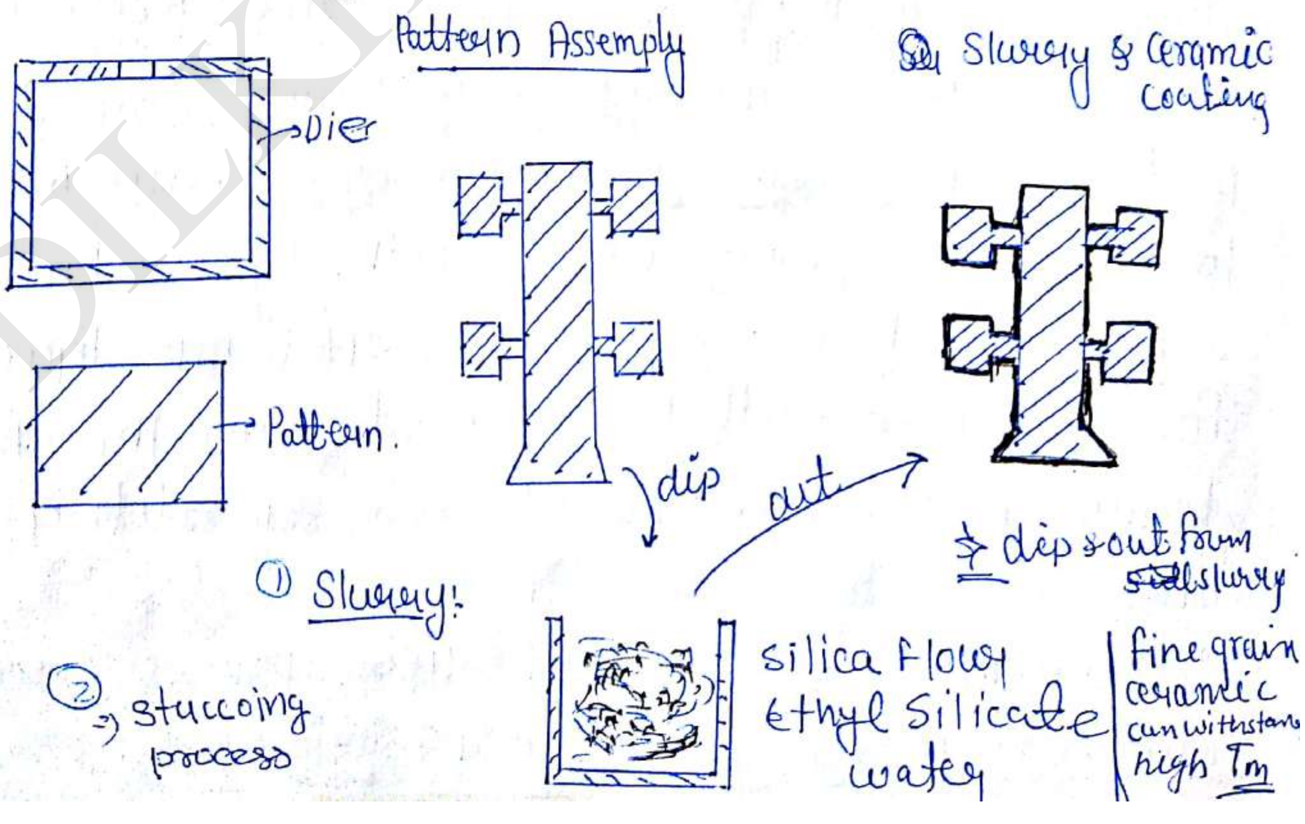
3) Valve plates of Refrigerator

⇒ To produce batter surface finish of casting when compare to sand moulding this technique can be used. Pattern is produce by metal and it will be heated upto 250°c

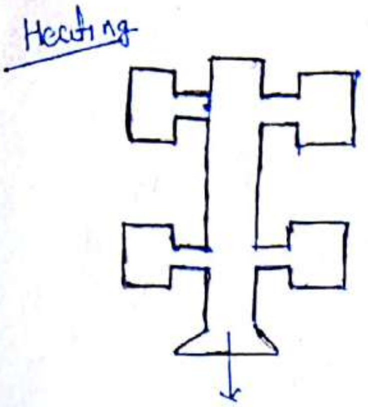
- Moulding materials is contact with heated metallic pattern Due to heat from the pattern phenollic resins will activate the bonding property and moulding Sand will be stick to the surface of pattern in the shape of shell. Thickness of shell will depand ~~by~~ on Contact time between pattern & Moulding material is know as dwell time.

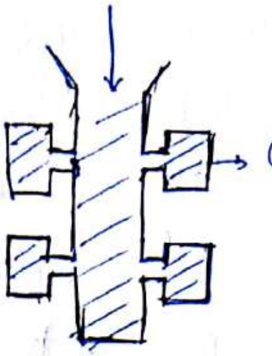
Pattern & shell will be seprated from mould and ~~they will seprated from~~ and they will be heated upto 350°. To increase the strength of the shell. Shell will be seprate from pattern by providing no. of shell they will be addeded to get the required cavity. It will be seprated by brakeing sand. liquid material will be allow to solidify inside the shell cavity.

Investment casting:-



Dewexing





Ceramic shell

- pattern use only once
- prefferecd for high T_m
- Batter surface
- complex shape
- Mass production
- possibility of gas defect so done under vaccum
- costly,

Application:- Gas turbine blades, Jet engine part, Medical implants, dentures (आर्टिफिशल equipment) Gold ornament etc

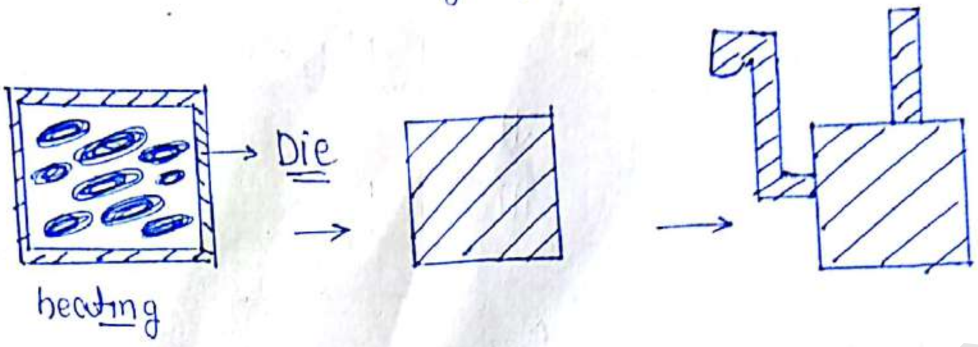
⇒ Pattern use only onke so it called
- Expandable pattern & expandable mould
- lost wax process

Pattern is produced by wax material. it can be produced by Die. No. of patterns will be added along with gating element to produce pattern assembly. By providing slurry coating around the pattern fine grain ceramic particle will be added to produce required ceramic shell. By heating ceramic shell wax can be converted into liquid form and it will be removed from the shell. Liquid metal will be allow to ~~set~~ solidify in the shell.

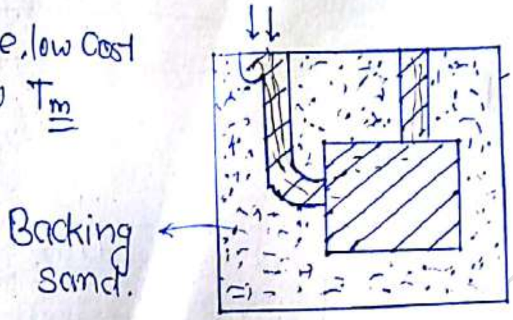
To minimise gas defect this process carried out under vaccum. Accuracy & surface finish of object are high

Full Moulding :- or (Evoprate pattern casting) (EPC) or or (Cavity less moulding) or (lost foam process)

Pattern:- plastic :. Polystyrene, Foam, PVC, Thermocole.



- Complex shape, low Cost
- Used for low T_m



* pattern evaporated in the form gasses.
* After solidify all gasses escape.
* prefferd for low T_m

Application: Motor casing, lock component, Filling etc.

Pattern is produced by plastic and by adding the slurry coating on the pattern silica sand will be added to produce the require shell by providing inside the mould box backing sand will supported liquid metal will be directley filled on the pattern. Due to high temp of liquid metal pattern will start evaporation and a evopareted gasses can be allowe to escape from the mould to produce cavity into which liquid metal will be allow to solidify. After solidification by bracking the mould object can be removed. ~~from casting~~ Cost of processes is less.

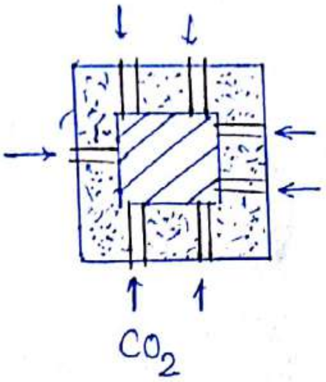
CO_2 Moulding :-

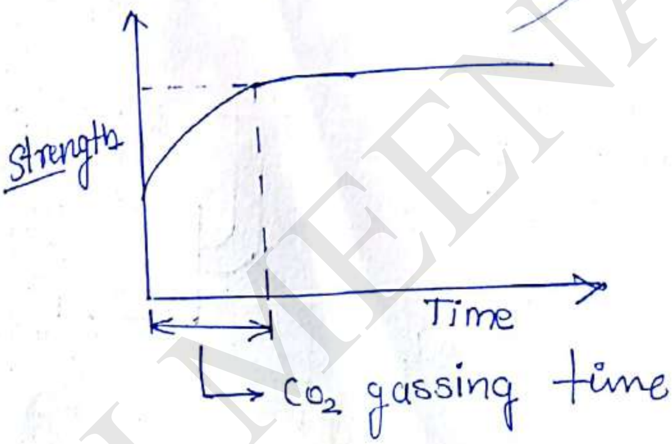
$Na_2Sio_3 \rightarrow$ 2-6 % (Sodium silicate)

$$Na_2Sio_3 + Co_2 \longrightarrow Sio_2 + Na_2Co_3$$

$$\Downarrow$$

Silicagel



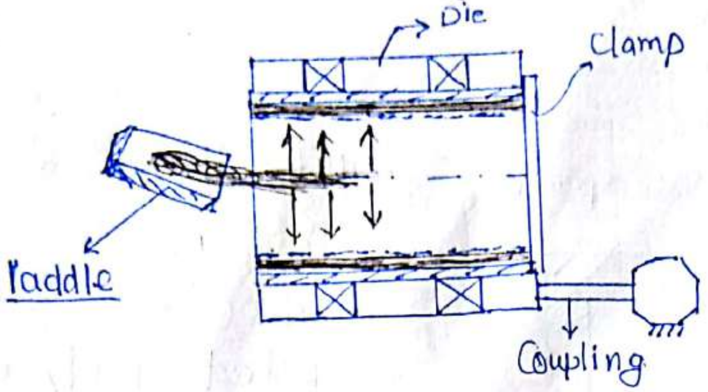


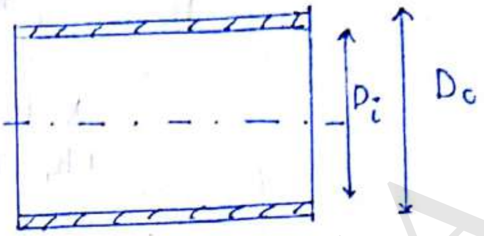
To increase the strength and hardness of large size of mould and core this technique can be used Mould is prepared by adding Na_2Sio_2 binder. Co_2 gas is supplied to mould for sufficient time it will react with Na_2Sio_2 and produce silicagel which is having batter bonding property due to this strength and hardness of mould can be increase strength of mould will depand on time of supplying Co_2 gas to the mould known as Co_2 gassing time.

Application :- Preparing of large size Mould like machine tool beds, turbine houshing, Engine block etc.

Centrifugal casting:-

① True centrifugal:- (only centrifugal force)





Application:- Hollow cylindrical pipes, Gun barrels & large size bushes, propelle shaft etc.

→ voids remove (due to high centrifugal force so density increase & fine grains

- less density impurity comes towards center.
- No gating element, No riser, $\boxed{\text{Casting Yield } 100\%}$, No core
- batter surface, mass production.
- Inside surface may have roughness due to impurities.
- Energy require to rotate more.

How much rotation needed?

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

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

R_m - mean radius of mould

a - acc^n of mould

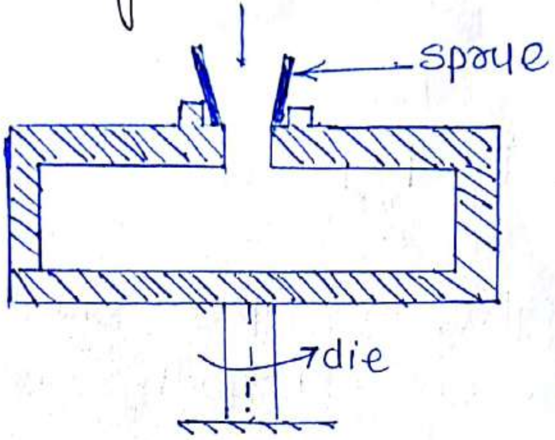
60-70% ~~of~~ times of g

To produce hollow objects without using the core this technique can be used. liquid metal enter into mould which is under rotation due to centrifugal force high density pure metal can be forced away from center and less density impurity collected towards to center. Due to centrifugal force without any gas defect high dense structure with fine grains can be produce.

accuracy and ~~better~~ surface finish is very high.
it can be used For mass production.

- It can be used for axis symmetrical cylindrical objects only.

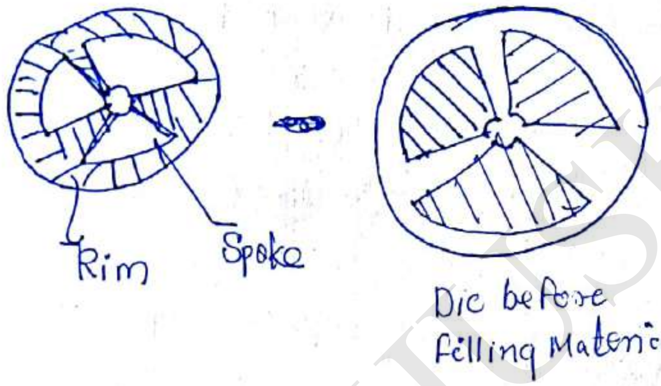
② semi - centrifugal :-



Applications :-

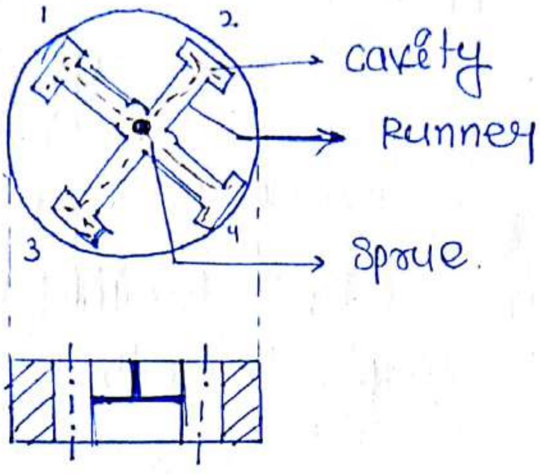
- Pulleys
- wheels
- spoked wheels etc.

- Axis symmetrical objects.
- More material require outside



To produce symmetrical shape of objects which require more material and strength at the outside when compare to inside this technique can be used. Liquid metal is enter in center of sprue by means of gravity force and it is forced away from the centre by mean of centrifugal force. Liquid metal is solidified First at the outside and it is progressing towards the centre

© centrifuging :-



(object mass)
if $m_1 > m_2$
then we increase size of gating.

To produce unsymmetrical object in mass production this technique can be used. No. of cavity are produced on the die along with gating element. Liquid metal is enter into the centre of the die by mean of gravity force and it is force into the cavities with non a uniform centrifugal force know as centrifuging axis of ~~sg~~ rotation of mould no coinside with axis, of object.

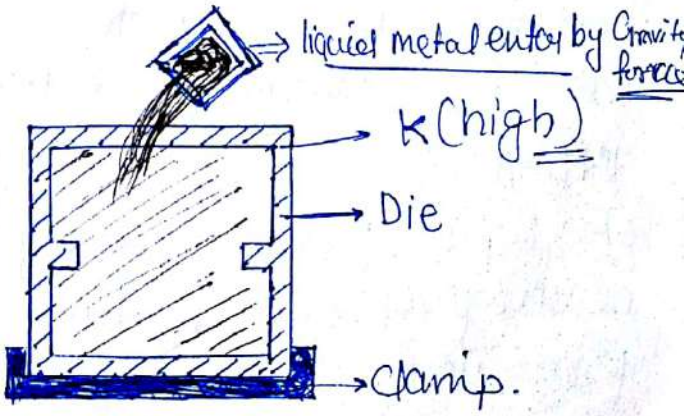
Application :- Pattern used in investment casting made up of wax material

Die Casting

Die casting
- Gravity
- Pressure

* Gravity Die Casting :→

- Simple object.
- mass prodn
- better surface, fine grain
- High strength
- cooling rate higher (higher k)



Liquid metal is enter into cavity by means of gravity force only. It is used to produced simple shape of object only.
Surface finish and accuracy of objects are very high. it can be used for mass production.

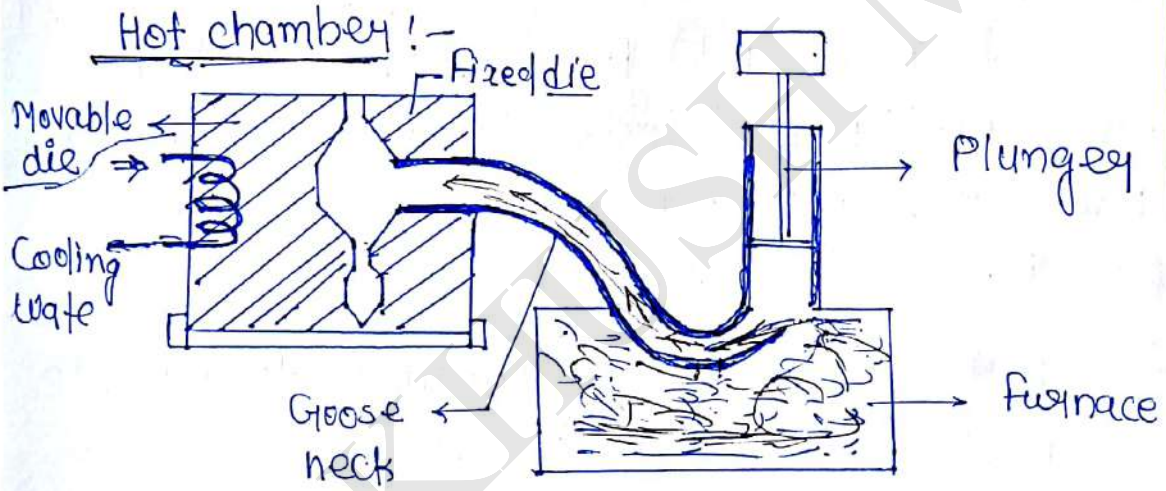
Applications :- Piston used in automible made up of Al, & it alloys. And other simple shape of the objects.

Pressure Die Casting :-

- Hot chamber
- Cold chamber

Pressure required 100 -200 MPa

Hot chamber :-



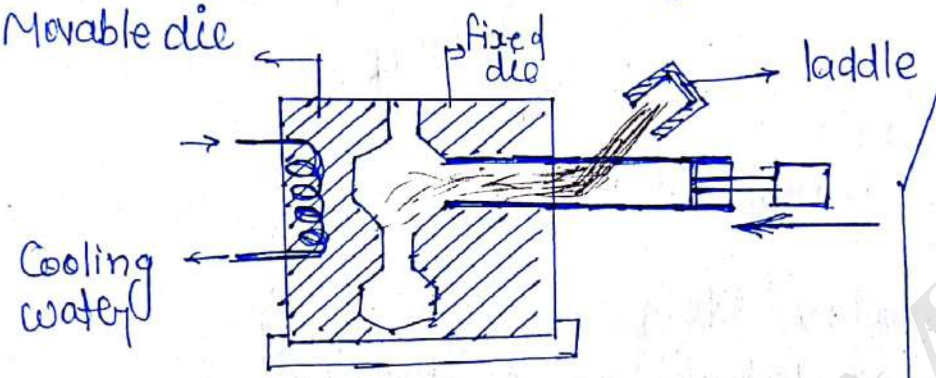
- mass production
- preffer for low Tm
eg led, Tin, Zn
- due to sticking property of Al it not used in it

Liquid Metal is forced in the cavity under external plunger force. It can be used to produce complex shape of the object which are made up of low ~~mot~~ melting material like Led, Tin & Zinc.
P Furnace is integrated with die. Heat transfer loses of liquid Metal are ~~g~~ negligible. Production rate is very high. Liquid metal is gating solidified under pressure.

mechanical properties of the object are superiour
Thin section of Casting can be produced.

* Due to sticking tendency of Al, life of Goose nack will be reduce it is not used in this technique.

Cold chamber Die Casting



- Fast rate
- Complex Shape
- Less contact time with champer
- low Tm material
- ☆ Al, Cu, Brass etc. (Non-ferrous)
- ☆ Not used for ferrous Material
- Small size object (< 20kg) casting.

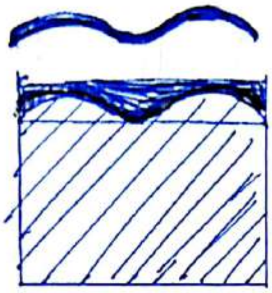
Furnace is seprated from the die. It is used to produced object made of Al, Cu, Brass etc. it is not used for ferrous material. Due to rapid cooling better mechanical properties can be possible. Contact time of liquid metal at the inside surface of chamber is less it life is not getting affected size of casting are limited to 20 kg only. High production rate is possible.

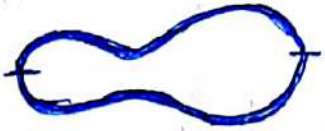
Application:- carburator, Valve bodies, Crack cases, Fuel injection pump part, toilet fixtures

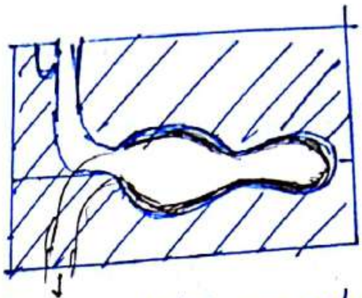
Question: Compare die casting and investment casting w.r.t. following.

	Die	Investment
① production rate →	High >	low
② complexity of object →	low	high
③ Melting point temp. of Material :→	low	high

Slush Casting :-







after req. thickness rotate die

- low T_m material
-

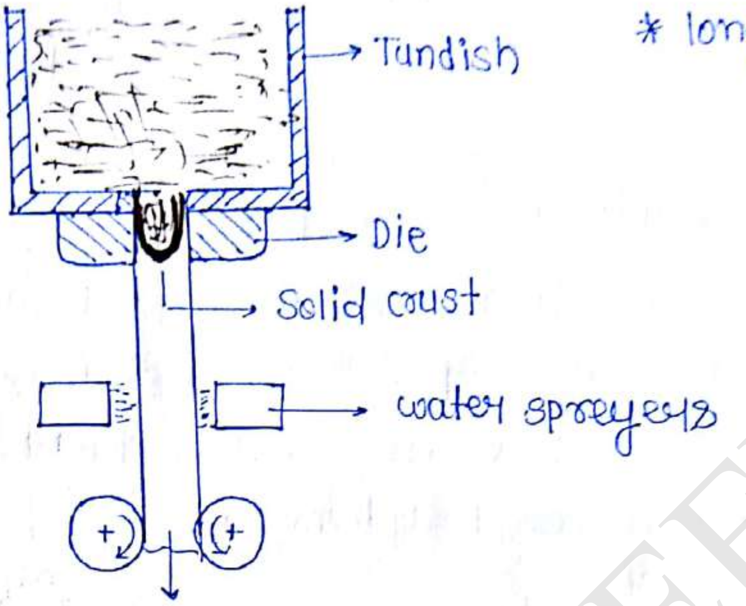
Application :- - Thin casting,
- Hollow thing casting
- Toys
- Decorative items
- Hollow statues
- lamp shades
- Thin ornaments etc. ✗✗

$$t_s \propto (V/A)^2 \Rightarrow t_s \propto (t)^2 \Rightarrow \boxed{t = C_1\sqrt{t_s} + C_2}$$

where t thickness of Casting ✓
t_s solidification time
C_1, C_2 Constant depends on properties of liquid metal & die material

To produce thin castings and hollow thin castings without using the core this technique can be used Liquid metal will be allow to solidify on the die after getting required thickness of the casting by rotating the die unsolidify metal can be seprated from solidified metal this is know as partial solidification. It is generally used for low melting point, non ferrous material only.

Continuous casting :-



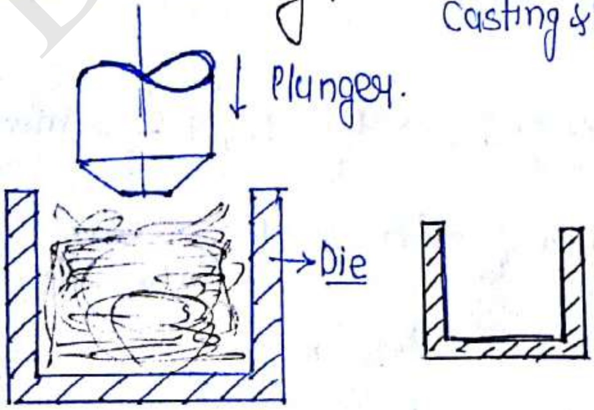
Application

* long length blooms

Liquid Metal will be stored in a tundish it will be allowed through the die opening. The output of die a solid crust on which a water will be sprayed to cool the material at a faster rate depanding on the properties requried by the object. different cooling rates are provided on the object. Production rate is very high continuously long length metallic object can be produced by using this technique

Squeeze Casting :-

Combination of Casting & <u>Forging</u>



* better mech. properties

* No gasses effect.

* Shape depand of shape & size of plunger.

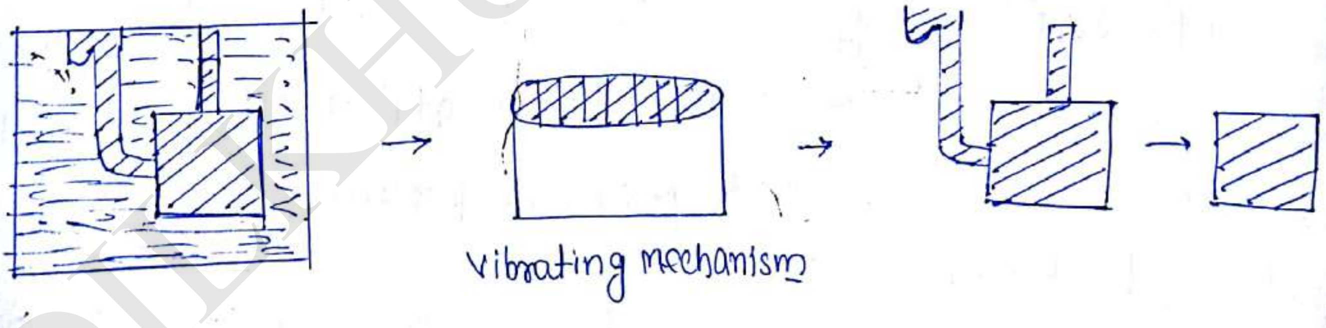
\+ better surface finish.

It is a combination of casting and forging liquid metal is allow to solidify in the die by appyeng the plunger force liquid metal can be enter ento the gap between die and plunger. Liquid metal is getting solidify under pressure from the plunger due to which, high dence better mechanical properties of the object can produced.
Shape and size of casting will depand on shape and size of die and plunger.

Application :- Al brakes shoes,
Busheesmade up from brass & bronze.

Cleaning of casting.

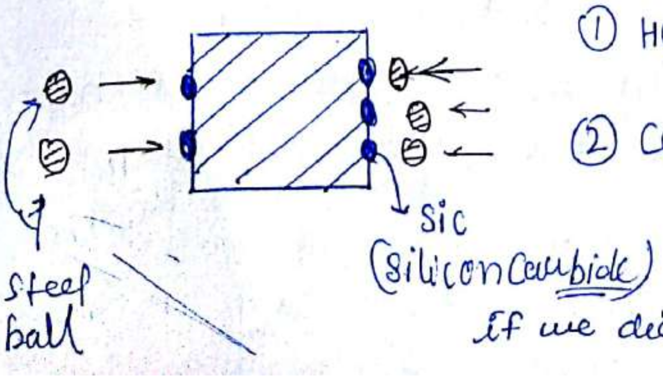
① Fettling :-



② shot/sand blasting :- (when silica particle fused on surface on casting

① Hardened steel balls ϕ 2-3 mm.

② Coarse grain sand



if we did direct machen

Fettling

It is a processes of breaking the mould by providing vibrating mechanism and seprating the gating element from the casting is know as fettling

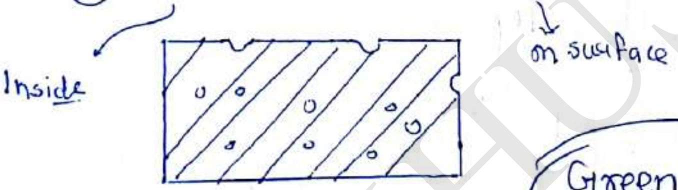
Shot/sand blasting:

To seprate the silica sand particle which are fused on the surface of casting steel ball will be forced on the surface of casting along with air pressure is know as shot blasting. If the cores grain sand will be used for clearning of casting then it is called sand blasting.

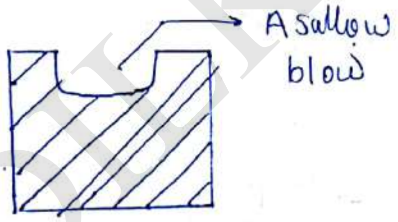
Casting Defects :-

① Gas Defects :-

ⓐ Blow holes & open blows :-

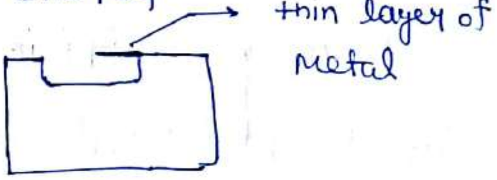


ⓑ Scar :-

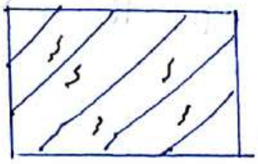


Green Sand
H_2O
$2H_2O \rightarrow 2H_2 + O_2$

ⓒ Blister



ⓓ Pinhole porosity



ⓐ Gas defect which are formed inside the casting or blow hole and which are fromed on the surface of casting are open blow.

ⓑ A shallow blow which is Form on the surface of casting is scar.

ⓒ It is a scar covered by thin layer of Metal. & is called blister

Ⓓ Small size gas holes which are formed due to Hydrogen gas is know as pin hole porosity.

Remedies :-

① Heat the liquid metal in Furnace upto pouring temp

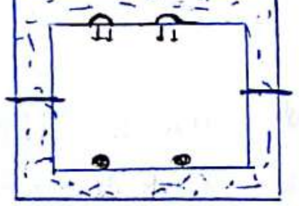
② Convert green sand mould in Dry sand Mould before Filling of Metal in cavity.

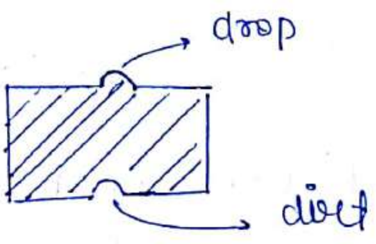
③ Select the moulding sand such that it is having sufficient permeability

④ Provide vent holes.

② Moulding material & method

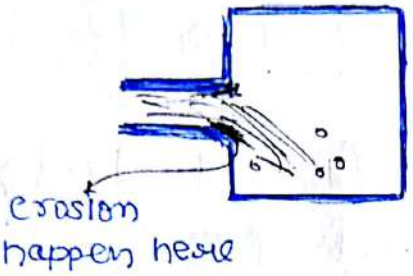
ⓐ Drop & Dirt :-

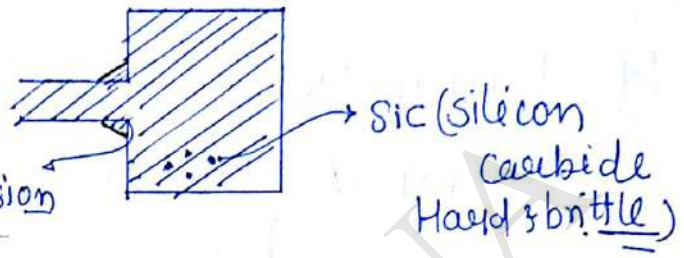




Due to improper remming moulding sand sand will droped from cope box to drag box. will Form a projection on the surface of casting know as drop and a cavity on the bottom surface of Casting know as dirt

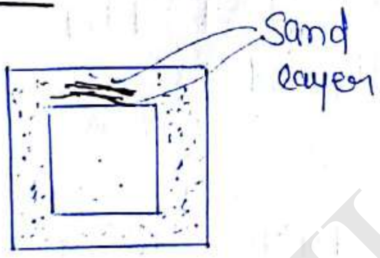
ⓑ <u>cuts and washes</u>:-





At min. X-S_C due to lack of hardness and high velocity of the liquid Metal moulding sand will be eroded will produce cuts and washes.

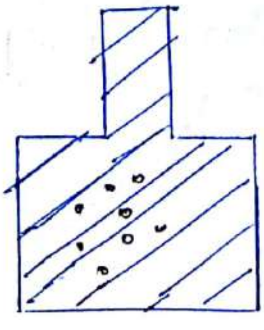
ⓒ <u>scab</u>:-



Due to Improper ramming ie if the liquid metal can be penetrated into loose sand layer will form a project on the surface of casting know as scab

③ Gating Design:-

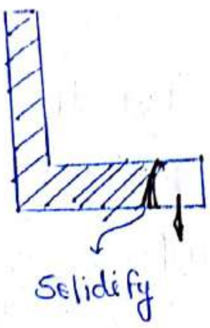
ⓐ shrinkage cavities



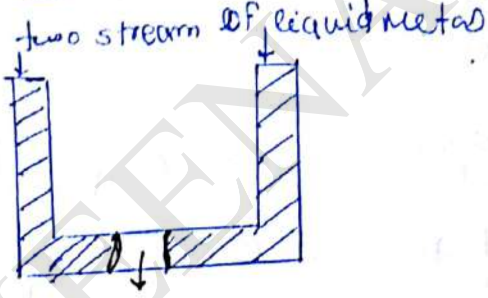
Due to improper riser design cavity form due to shinkage of metal is know as shrinkage cavity.

④ Pouring Metal:-

(a) Misrun



ⓑ Cold shuts



ⓐ Due to lack of fluidity and pouring temp. before reaching the cavity of the liquid metal is solidify will form misrun.

ⓑ Two stream of liquid metal which are not fushed properly will ~~form~~ form a discountinity in casting

Remedies

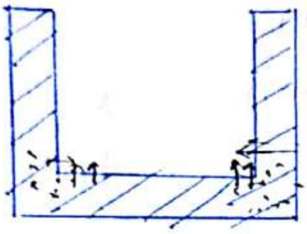
① Heat the liquid metal in the furnace upto pourting temp.

② Increasing the surface finish of caveity.

③ Desing the gating element properly

⑤ Metallurgical Defects :

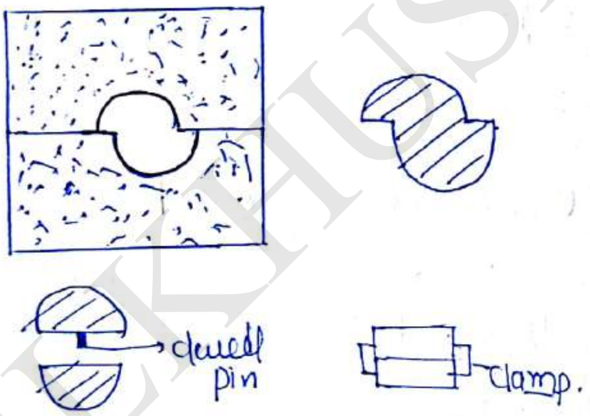
Hot tears/ cracks :-



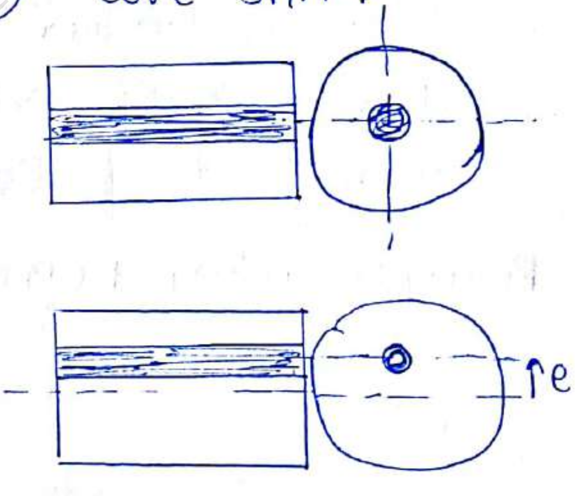
Due to non-uniform Cooling internal stress can be develope in casting if the stess can be more then the strength of the material cracks can be formed to overcome this chills and padding is provided

⑥ other defects:-

ⓐ Mould shift



ⓑ Core shift



ⓐ Due to improper positioning of Cope box on the drag box will produce the miss match along the parting line in the casting this cane be overcome by proviceding dwell pins & clamps

ⓑ shifting of the core from its origional position due to bouncy force this can be overcome by providing core points & chaplets.

Types of furnace (only ESE) (Prefer Note)

Crucible furnace! - Non-ferrous

charge ORE + Flux + Coke

Cupola furnace! - input → Pig iron — operating temp 1650°

output → Cast iron

ORE - pig iron
↓
Flux = $CaCO_3$
↓
coke -

if furnace have pre heating called Hot blast cupola → high temp (temp. higher than ~~co~~ cupola.)
~~operating~~

* operating temp in hot blast cupola is higher then conventional cupola.

Electric arc furnace! — Non Consumable electrode strikes arc.

Induction furnace - Heat generation due to eddy current (Mutual induction)

- ✓ small & large quantity possible
- ✓ Can Use Ferrous & Non Ferrous, ∟ operating temp (1700°C)
- – High Cost, Fast process.

Reverberatory furnace:- (Coal + gas fuel) burn in burner then heat transfer through burner to heat metal.

- ✓ low Cost
- ✓ low polution
- ✓ Heat transfer looses max.
- ✓ Ferrous & Non ferrous both Can melted
- ✓ operating temp (1700°C)
- ✓ High space require

Cupola :-

Charge (Fe_2O_3 & Fe_3O_4)

↓

Blast Furnace

↓

Pig iron

↓

Cupola

↓

Cast iron

- * Blast furnace output is pig iron
- * Pig iron is output of blast furnace
- * cast iron is output of Cupola.

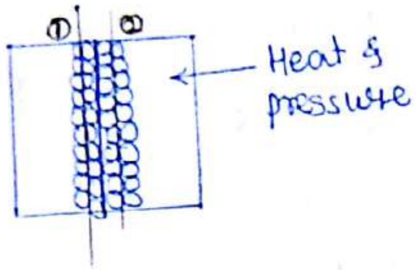
Melting Ratio / charge Ratio :-

It is a ratio of metal to the fuel.

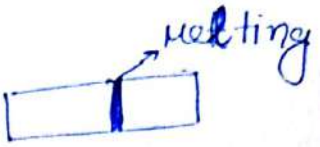
Metal : Fuel ⇒ 4:1 → 12 : 1

- * it represent the efficiency of furnace
- * In cupola furnace ⇒ 10 : 1 (Metal : Fuel)

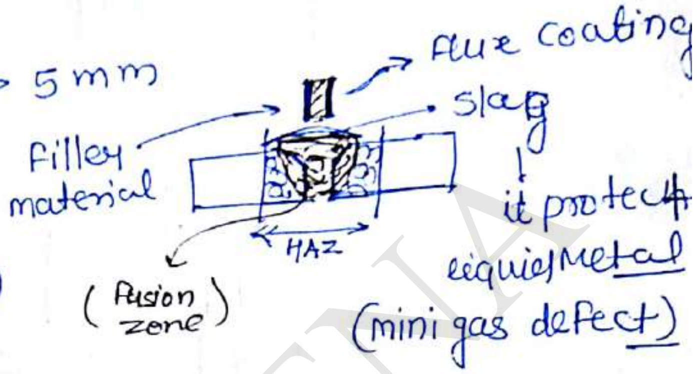
Welding:- Joining process (Permanent joints)



① t < 5mm



② t > 5mm



(Non uniform properties)

Welding :- it is a process in which localized permanent joint can be produced with or without application of heat, with or without application of pressure or pressure alone and with or without application of filler material for joining of similar or dissimilar material.

Advantages:-

1) Welding is a permanent joint, strength of joint will be equal to or more than the strength of base materia

2) leak proof joint can be possible

3) It can use for similar of dissimilar material.

4) Welding can be done in any position

limitation :-

① skilled operator is require

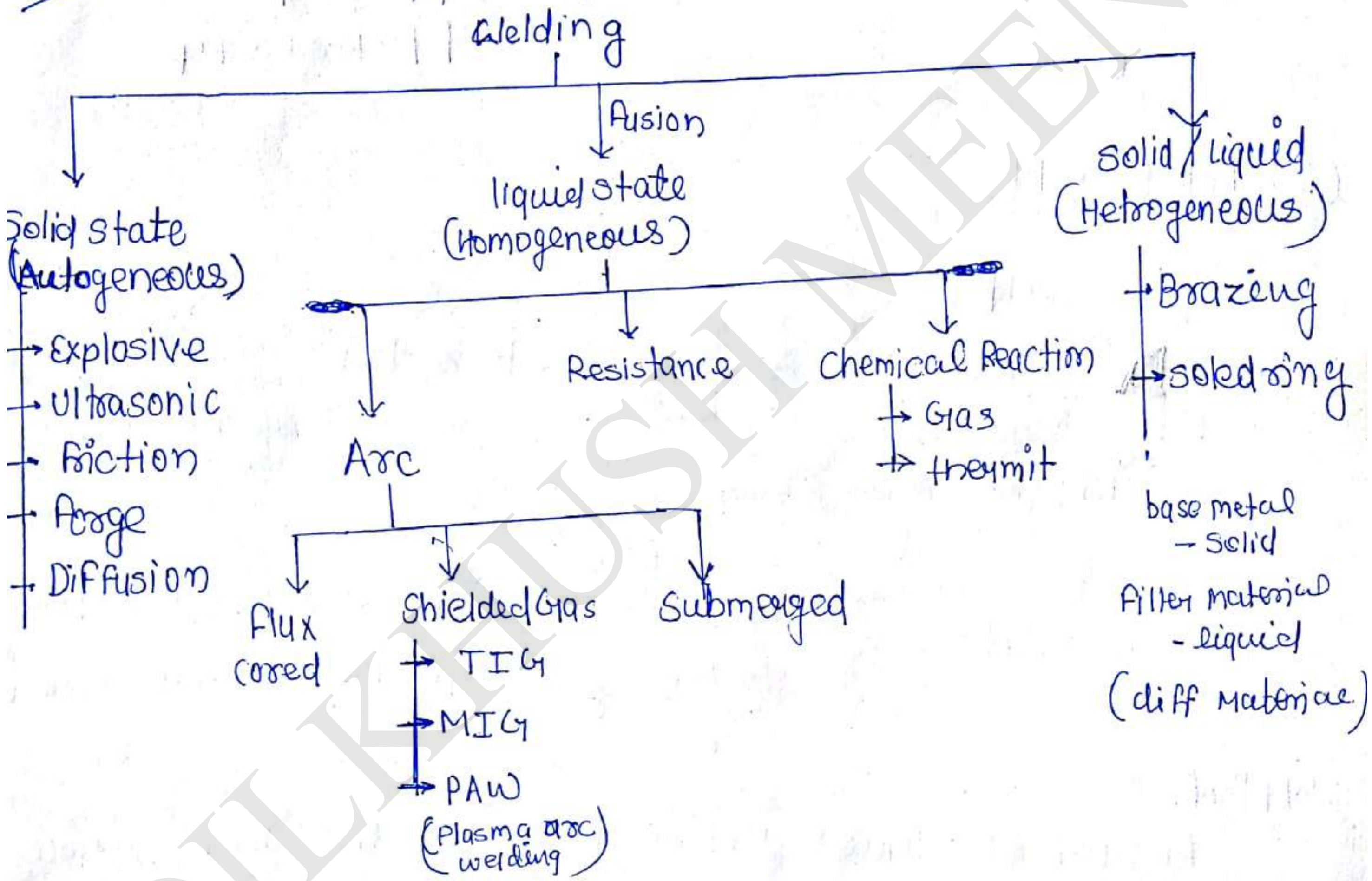
② setup Cost is More.

③ Internal stress can be develope in the joint due to this crack will be formed and weld distortion will be takes place.

④ There is a possibility of Heat affected zone (HAZ)

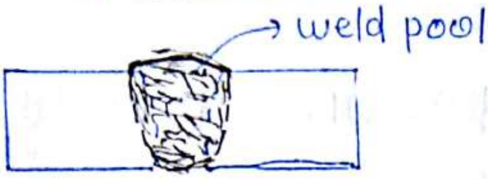
Imp

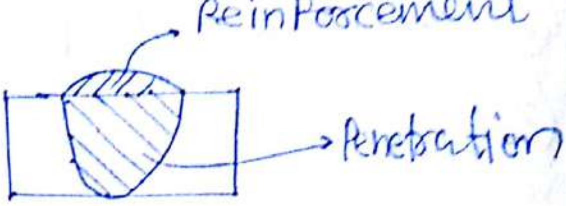
Classification of welding

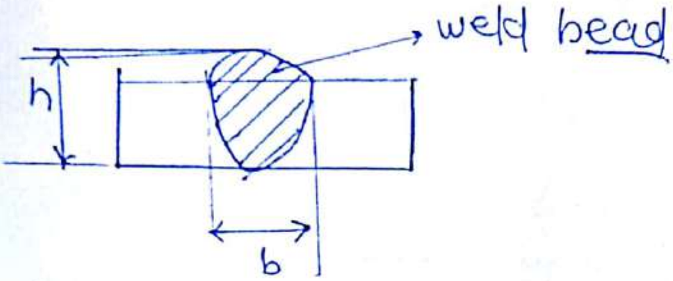


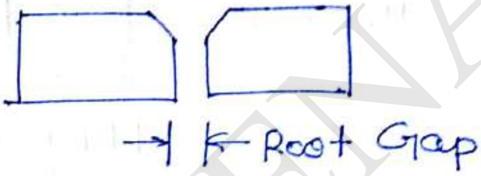
Terminology :-

① Butt Joint :-

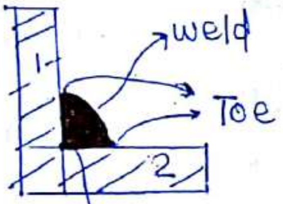


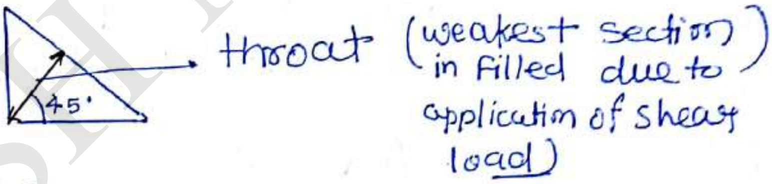






② Fillet weld :-





$$\% \text{ Dilution} = \frac{A_P}{A_P + A_R}$$

A_P - Area of penetration

A_R - Area of reinforcement

Weld Pool :- Amount of liquid Metal between the two surfaces before solidification.

Weld bead Amount of material which is added into the work piece in a single pass

Reinforcement :- Amount of material which is projected from the base material.

Penetration:- It is a depth upto which weld Metal can be penetrated in base material.

Root gap:- shortest distance between two workpieces before joining.

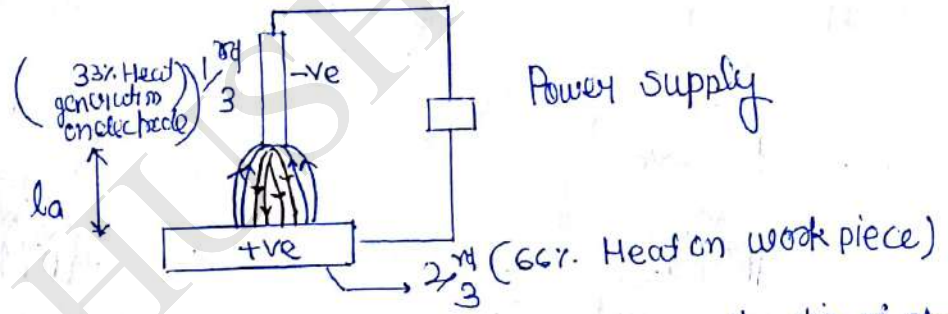
Toe:- It is a junction ~~the~~ between weld face and workpiece.

Root:- Point of deepest penetration in a fillet.

Throat:- shortest distance between weld face and root.

Arc Welding:-

Principle:-

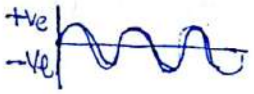


d → dia. of electrode

l_a - Arc length (0.5 - 1.5)d

work piece

- * +ve side more heat generation due more k.e. high velo. of e^-
- * Due to Collision b/w e^- & +ve ions spark will generated
- * In a cycle uniform heat & heat generation

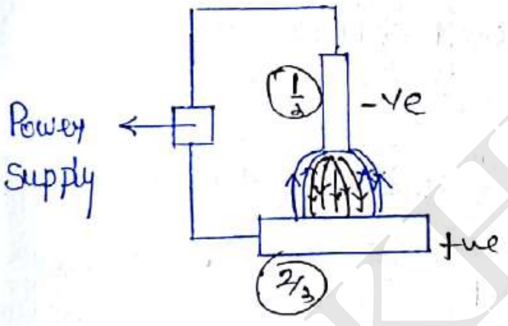


When the electrode is in contact with workpiece due to short circuit arc will be generated. In order to Continue the arc some gap is maintained between electrode and workpiece know as arc length.

- When the e^- are moving From -ve to +ve, $\frac{2}{3}$rd of heat will be generated on anode and due to moment of +ve ions From +ve to -ve, $\frac{1}{3}$rd of heat will be generated on cathode (-ve) side.
- Due to continuously changing the polarity uniform heat will be generated on the electrode and workpiece in AC arc welding
- In order concentrate more heat on the electrode and workpiece DC arc welding can be used.

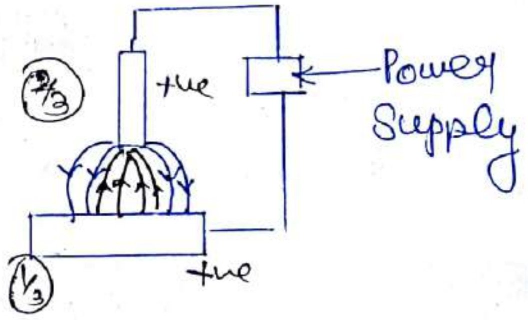
DC Arc welding :-

① straight polarity (DCSP, DCEN)



- Direct current straight polarity (DCSP)
- e^- -ve → +ve

② Reverse polarity (DCRP, DCEP)



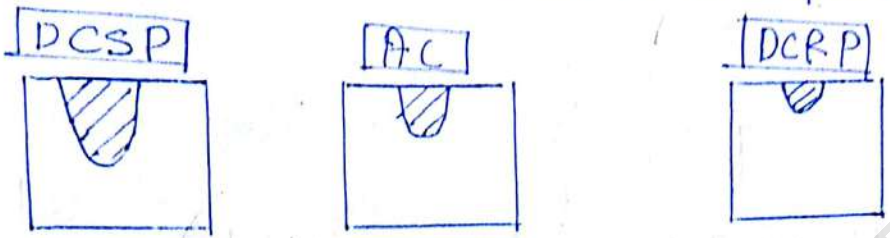
~~Reverse~~
- Direct current reverse polarity (DCRP)
- e^- +ve → -ve

Straight Polarity :- ① electrode is -ve, workpiece is +ve more heat will be on the workpiece when compare to electrode.
② used for welding of high thickness and high melting point materials.
③ depth of penetration is more, weld deposition rate less.

Reverse polarity :- ① Electrode is +ve, workpiece will be -ve.

② More heat will be on the electrode when compare to workpiece.

③ Depth of penetration less, weld deposition rate is more



weld d penetration.

Welding Techniques :- $P = VI \Rightarrow V_a = A + B l_a$

if V↑, I↓, Heat↓.

There are two ~~mo~~movement for electrode

1. linear movement of electrode wrt workpiece know as linear welding speed.
2. Downward movement of electrode to maintain constant arc length.

* If two movememt of electrode are controlled manually then it is called manual arc welding technique.

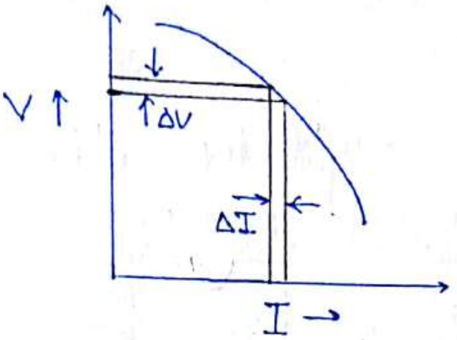
* If two movement are controlled by automatic machines then it is called automatic welding technique.

* If ~~of the~~ one of the movement is manually & one is automatic, then it is called semi automatic welding technique

Type of welding machines:-

① constant current Type:- (Droop)

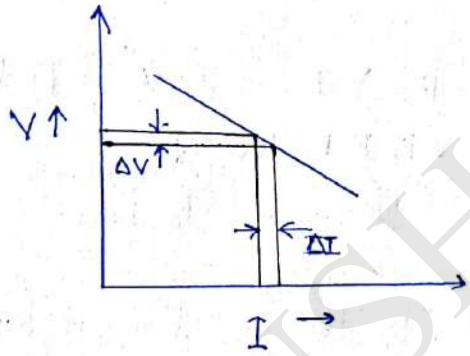
(used in manully)



* small change in ΔV
small change in ΔI

② constant Voltage Type:- (linear/Flat)

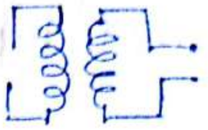
(used in Automatic)



① for a small change in arc voltage the corresponding change in current will be very small these are used in manual arc welding technique.

② For a small change in arc voltage the correspondin change in current is large. These are used in automatic welding technique.

① Open circuit Voltage: (V_o)



It is the max. rated Voltage that can be measure b/w two open terminal under no loading conditions

② Short circuit current: (I_s)
It is the max. rated current which is require to generate the arc.

③ Duty cycle:- It is the % of time during which ~~ae~~ arc will be on without over heating element in a welding machine

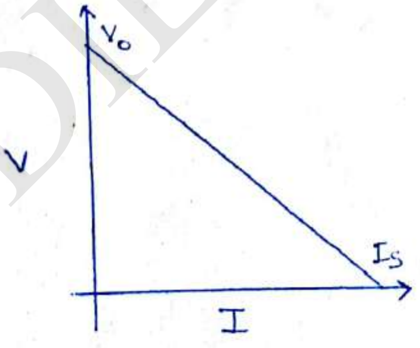
I^2D = Constant
D - duty cycle
I = current

$$\boxed{\text{Duty Cycle} = \frac{\text{Arc time}}{\text{Arc time} + \text{idle time}}}$$

AWS → 10 min (American welding society)

BIS → 5 min (Buro (ब्यूरो) of indian standard) eg. $\frac{3}{3+2} = 60\%$

⇒



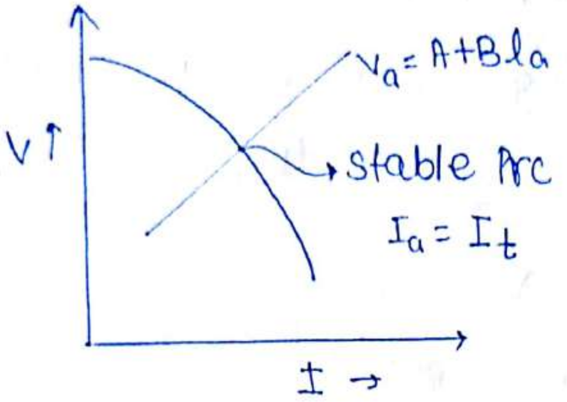
$$\frac{x}{a} + \frac{y}{b} = 1$$

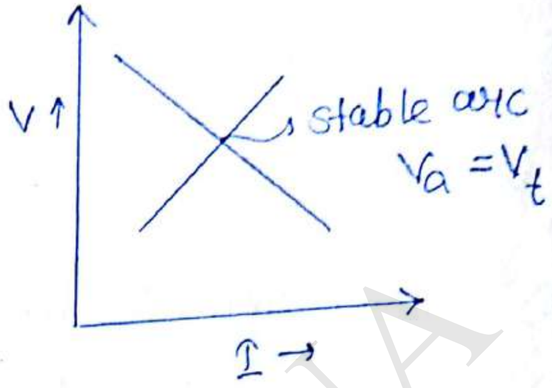
$$\boxed{\frac{I_t}{I_s} + \frac{V_t}{V_o} = 1} \quad -①$$

$$\boxed{V_a = A + B\,l_a} \quad -②$$

Stable Arc. Generation Condition

☆ Constant Current type ☆ Constant Voltage type





Problem:- Arc length voltage characteristic are given by $V_a = 24 + 4 l_a$, V-I characteristic assumed as state line with open circuit voltage $V_0 = 80$ V & short circuit current $I_s = 600$A determine opt^m are length for max^n power.

Sol^n

$$V_a = 24 + 4 l_a$$

$$V_0 = 80 V, \quad I_s = 600 V$$

$$P = f(l_a) \Rightarrow \frac{\partial P}{\partial l_a} = 0 \Rightarrow (l_a)_{opt.}$$

$$\frac{I_t}{600} + \frac{V_t}{80} = 1$$

$$V_t = 80 - \left(\frac{I_t}{600}\right)80$$

For stable arc $V_a = V_t$

So

$$24 + 4 l_a = 80 - \left(\frac{I_t}{600}\right) 80$$

$$I_t = (4 l_a + 24 - 80)\,\frac{\overset{15}{\cancel{600}}}{\underset{2}{\cancel{80}}}$$

$$I_t = 420 - 3 l_a$$

$$P = VI$$

$$P = (24 + 4 l_a)(420 - 30 l_a)$$

$$\frac{\partial P}{\partial l_a} = 0 \Rightarrow \{ 24 + 4 l_a)(0 - 30) + (420 - 30 l_a)(4) = 0$$

$$4 \times 30 (l_a + 6) + (30 l_a - 420) 4 = 0$$

$$120 l_a + 720 + 120 l_a - 1680$$

$$240 l_a = 960$$

$$l_a = 4 \text{mm}$$

$$P_{max} = (24 + 4 \times 4)(420 - 30 \times 4)$$

$$P_{max} = 12 \text{ kw}.$$

Problem:. V-I charactertic of power source given by $I_t^2 = -600(V-60)$ arc charactoristic given by $I_a = 20(V-16)$, determine power of stable arc.

Soln

$$I_t^2 = -600(V-60)$$

$$I_a = 20(V-16)$$

for stable arc $I_a = I_t$

$$-600(V-60) = \{20(V-16)\}^2$$

$$2V^2 - 61V + 332 = 0$$

$$V = 7.09\text{ V}, \quad 23.4\text{ V}$$

$$\times \qquad\qquad \checkmark$$

$$I_a = 20(V-16) \quad ; \quad V > 16$$

$$I_a = 20(23.4-16)$$

$$I_a = 148 \text{ Amp}$$

$$\text{Power} = VI$$

$$= 23.4 \times 148$$

$$P = 3.436 \text{ kW}$$

Problem:- Arc length Voltage characteristic is given by $V_a = 20 + 4 l_a$ Arc length in welding process change from 4 mm to 6 mm and current changes from 450 Amp to 550 Amp Assuming a linear power source charateristic determine V_0 & I_s

★ Low length high current
★ High length low current

Sol^n

$$V_a = 20 + 4 l_a$$

$$l_{a_1} = 4\,mm \rightarrow I_{t_1} = 550\ A$$

$$l_{a_2} = 6\,mm \rightarrow I_{t_2} = 450\ A$$

$$= V_{a_1} = 20 + 4 \times 4 = 36 \text{ volt}$$

$$V_{a_2} = 20 + 4 \times 6 = 44 \text{ Volt}.$$

$$\boxed{V_a = V_t}$$

$$V_t = V_0 - \left(\frac{I_t}{I_s}\right) V_0$$

$$V_{t_1} = V_0 - \left(\frac{550}{I_s}\right) V_0 = 36 \quad \text{—①}$$

$$V_{t_2} = V_0 - \left(\frac{450}{I_s}\right) V_0 = 44 \quad \text{—②}$$

$$V_0 = 80 \text{ Volt}$$

$$I_s = 1000 \text{ Amp.}$$

Problem:. A DC Welding machine with linear power source characteristic provide V_0 = 80 Volt ~~& I_s =~~ and I_s = 800 Amp. During welding arc length changes from 5 mm to 7 mm and current changes from 500 to 460 Amp what is the linear voltage characteristic of welding arc.

Sol

$$V_0 = 80 \text{ Volt} \quad I_s = 800 \text{ Amp} \qquad V_a = a + b l_a$$

$$l_{a_1} = 5 \text{ mm} \qquad I_{a_1} = 500 \text{ Amp}$$

$$l_{a_2} = 7 \text{ mm} \qquad I_{a_2} = 460 \text{ Amp}$$

$$\frac{V_t}{V_0} + \frac{I_t}{I_0} = 1$$

$$\frac{V}{80} + \frac{I}{800} = 1$$

$$V_t = 80 - \frac{I_t}{10}$$

$$V_t = V_a = a + b l_a \qquad I_t = I_a$$

$$a + b l_a = 80 - \frac{I_a}{10}$$

$$a + 5b = 80\cancel{0} - \frac{500}{10} \Rightarrow a + 5b = 30 \quad ①$$

$$a + 7b = 80\cancel{0} - \frac{460}{10} \Rightarrow a + 7b = 34 \quad ②$$

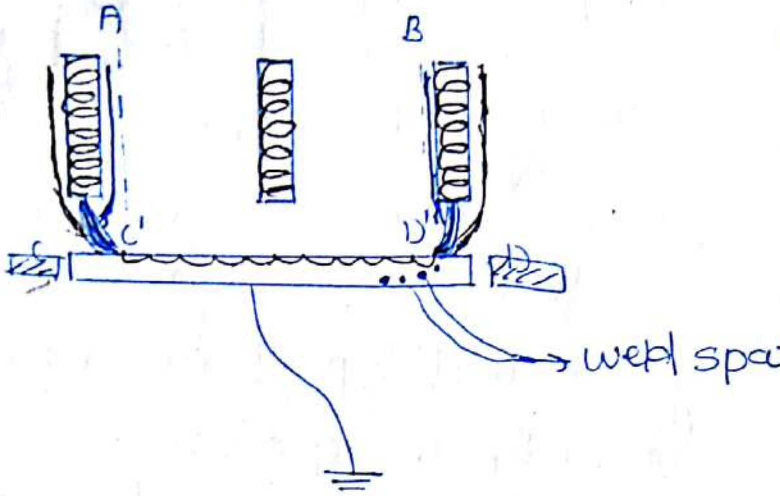
from eq ① & ②

$$2b = 4 \Rightarrow b = 2$$

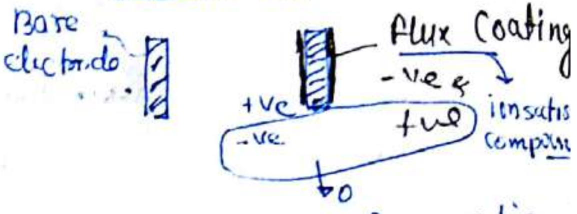
$$a = 30 - 5 \times 2 \Rightarrow a = 20$$

$$\boxed{V = 20 + 2L}$$

Arc Blow:-



* without Flux Coating electrode called Bare electrode



Effect of magnetic flux is zero by providing flux coating.

Defleration of electric arc towards the workpiece at the begaining and end to workpiece due to deflection of magnetic flux lines is know as ~~ae~~ arc blow or magnetic arc blow.
Due to arc blow heat consantraetion on workpiece at the begaining and end will be reduce and weld spatter will be formed

Remedies:- ① Provide some extra material at the begaining and end of workpiece known as Tab in & Tab out

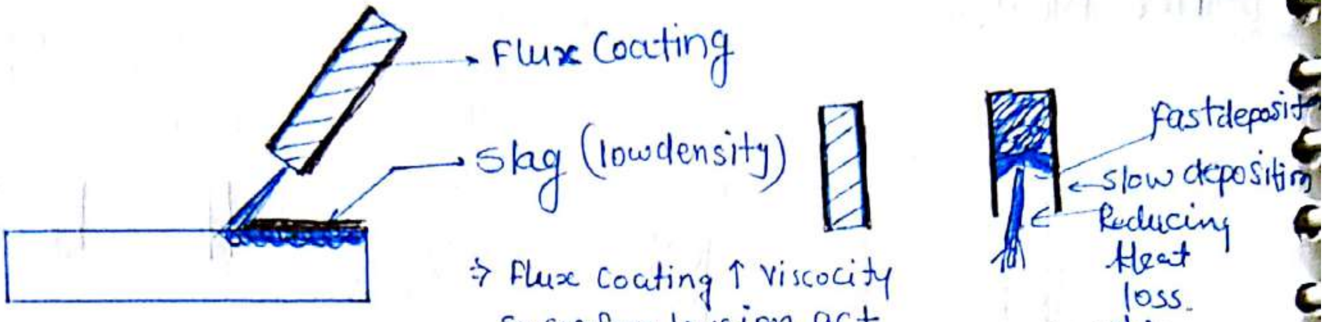
② Reduce the intensity of curreneet.

③ Use small arc length at the begaining and end of workpiece.

④ Provide flux coating on the electrode.

Bare electrode में Arc Blow ज्यादा होता है।

Functions of Flux Coating:-



⇒ Flux Coating ↑ Viscocity so surface tension act opposite to Gravity in case of overhead welding

① Flux coating material will act as deoxidizers.

② By forming the slag it will protect the liquid Metat from the atmospheric gasses.

③ slag will control the heat transfer rate of liquid metal in the weld pool

④ it will increase the strength of joint.

⑤ it will control the viscosity of liquid metal by

⑥ By reducing the heat transfer looses from arc heat consentration on the workpiece will be increase.

Flux coating Materials:-

① De-oxidizing Elements:-

Graphite, Alumina, Ferrosilicon, Ferro magnis

② Slag formation Compound:

Iron oxide, Silicon di-oxide, titanium oxide, silica Flor and Calcium floride (CaF_2)

③ Arc stabilizer:-

sidium oxide, calcium oxide, potasium silicate.

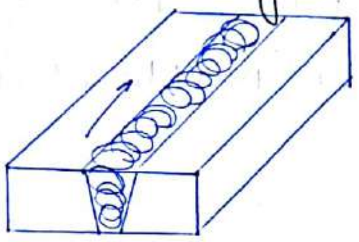
④ Alloying element:- Cr, Ni, Co, Vd (Venedium)

⑤ Gas forming Materials:-

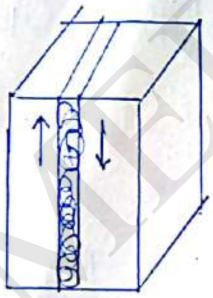
~~Sol~~ Cellulose & $CaCO_3$ (calcium carbonate)

Welding Techniques based on Position:-

① Flat welding:- (F)

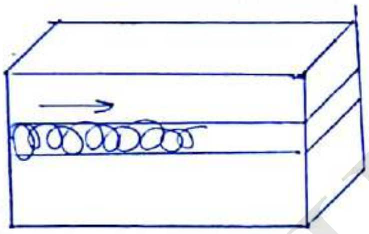


③ Vertical (V) (V.D)

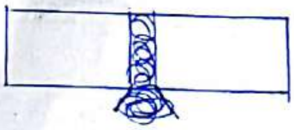


Gravity ↓
Surface tension ↑
weld pool reduce
✱ Most preferred

② Horizontal welding:- (H)



④ overhead (O)



Electrode specification: (Designation)

As per BIS standard

T.S. Y.S. %

E	1	2	1	322	P
I	II	III	IV	V	VI

I - Type of electrode manufacturing (E = Extrusion)

II - type of flux Coating (1 - high cellulose, 2 - TiO_2 or Rutile Coating)

III - position of electrode (0 - F, H, V, D, O
1 - F, H, V, D
2 - F, H

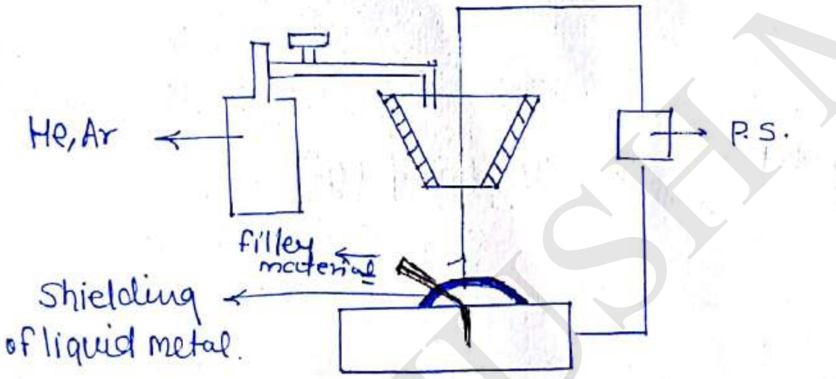
IV - Polarity (1 - D^+ direct current electrode +ve Reverse polarity
2 - D^+V90 direct current electrode +ve with $V_0 = 90$ Volt

V - strength of electrode (a) tensile strength (3 = 300 series
(b) Yield strength (2 = 200 series
(c) % of elongation (2 ⇒ 2%)

VI (P) → specific information regarding electrode
P - deep penetration

Shielded Gas arc welding :-

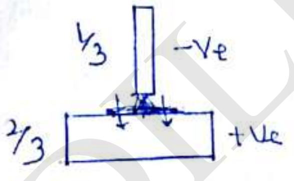
① Tungsten Inert Gas (TIG) :- (TIG, GTAW)
Non-Consumable electrode



① t < 5 mm

② t > 5 mm

① DCSP

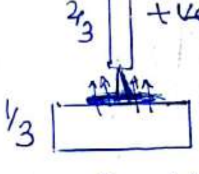


① possibility of oxide formation so we can't do Al, Mg, Alloy welding

③ First half of cycle e⁻ -ve to +ve 2nd half of cycle e⁻ +ve to -ve so Metal Oxide Clean we can use AC. for welding of Al, Mg. Alloys.

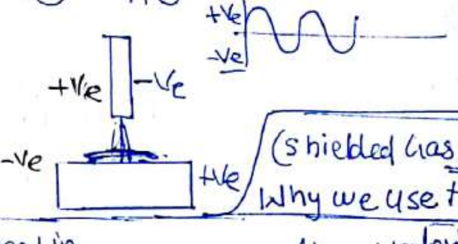
② DCRP

x - we not use it due to high heat generation in electrode



② Initial oxide layer present but due to e⁻ movement from -ve to +ve so Oxide layer also move with e⁻ oxide layer can be remove by providing inert gas ~~this~~ process called cathodic cleaning

③ AC



(Shielded Gas) Why we use this?

defect in flux coating

Flux Coating Material rxn with Moisture $(H_2O) \to 2H_2 + O_2$

* In Flux Coated we can not do welding ~~[illegible]~~ Al, Mg Alloy because it form Al_2O_3 it will not allow metal to go inside.

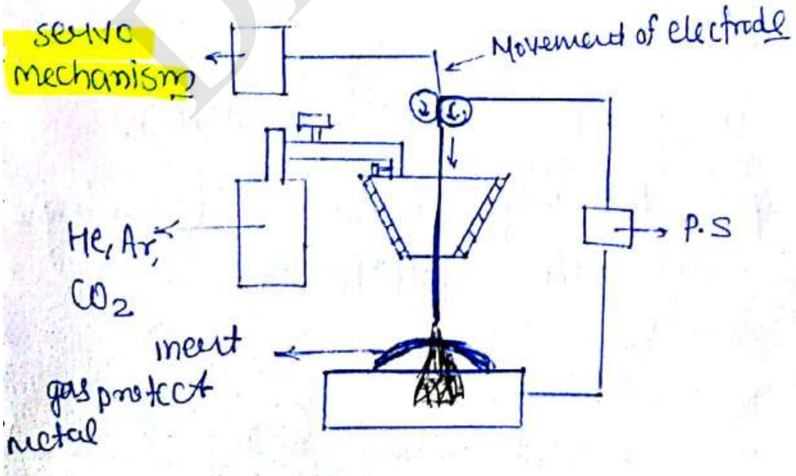
Arc is generated between a non-consumable tungsten electrode and workpiece. For welding of less then 5mm thickness of workpiece material without using filler material joint can be produced. For more then 5mm thickness of workpiece material filler material is supplied externally. and the movement is controlled manually.

Liquid Metal in the weld pool can be protected by providing inert atmosphere.

For welding of Al, Mg Alloys AC power supply can be used in which 1st half of cycle due to straight polarity more heat will be on workpiece and oxcide layer can be formed. In the reverse polarity movement of e^- from workpiece to electrode oxide layers cleaned from work surface this is know as cathodic cleaning.

Application:- ① welding of Al, Mg & its alloyes in automobile, aerospace and chemical industries.

② Metal inert Gas:- (MIG, GMAW)

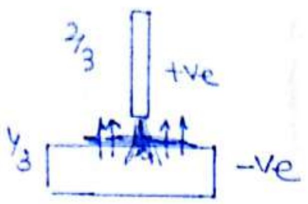


preferred for

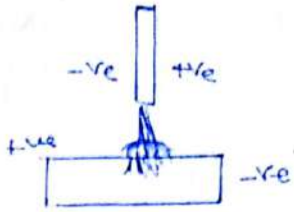
t > 5mm

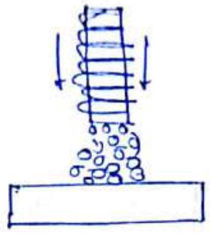
I → 150-350A

① DCRP !-



② AC





① Droplet transfer → due to Gravity

② Globular transfer

③ spray transfer → due to electromag. force.

Arc is generated between a consumble electrode and workpiece electrode is in the form of wire and it will be supply to the workpiece through the movement of roller. Roller movement can be controlled by ~~se~~ providing servo Mechanism.

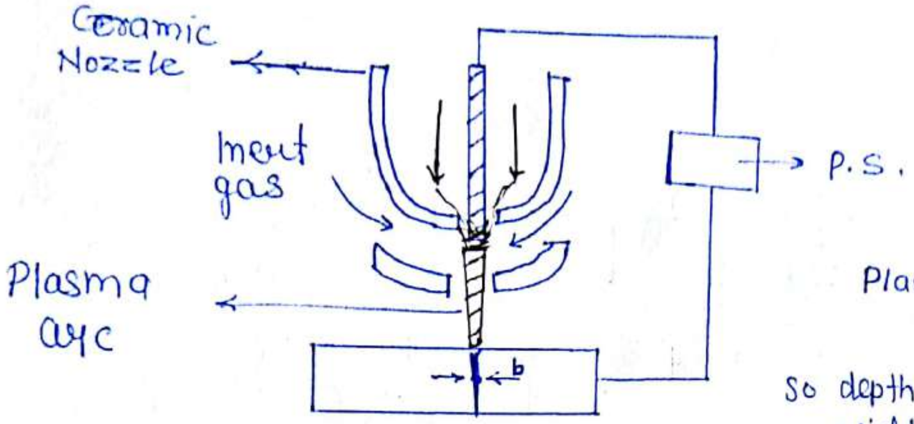
⇒ For welding of Al, Mg alloys and all other material DCRP or AC power supply can be used with high rate of current. Metal can be transferd from electrode to workpiece in the form of spray transfer due to this depth of penetration is maximum.

⇒ It will be used for welding of more then 5mm thickness of workpiece material.

⇒ Weld deposition rate & welding speed will be more

Application :- ① used for welding of Al, Mg, Cu and its alloys in aerospace and automobile industries

③ Plasma arc Welding (PAW)



I ⇒ 100-150 A

max. possible temp.

11,000 °C

Plasma high v → high K.E.

$Q = \underset{\downarrow}{A} V \uparrow$

so depth of penetration high
width of weld beed low
low HAZ, use for high T_m, t

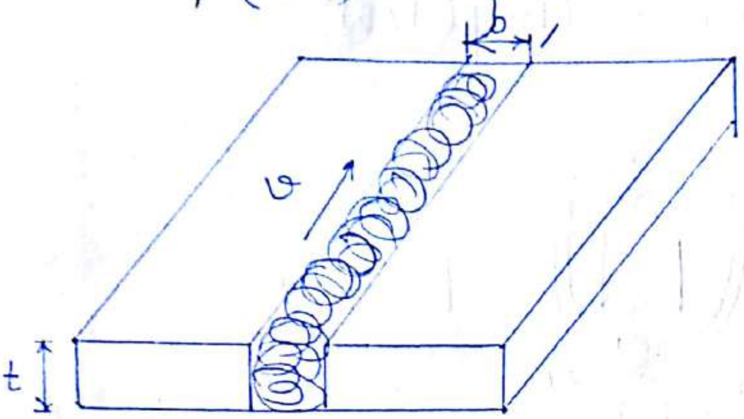
Arc is generated between a non-consumble tungston electrode and workpiece.

High pressure plasma will be supplied through the ceramic nozzle and it will produce plasma arc. Which is having high K.E. and it will be focus on work piece at a given point due to this heat concentration on the workpiece so is very high high thickness and high melting ~~mote~~ temp. material can be welded.

- → Weld beed width and HAZ less.
- → Depth of penetration and welding speed high.
- → Operating and maintance cost will be more.

Application: - ① Welding of Ti, Co, Mb and it alloy in aerospace, jet engine and turbine blades.

Melting efficiency (η_m)



$$A_b = b \times t$$

$v \rightarrow mm/s$

$P = VI \rightarrow \underline{\underline{W}}$ $\quad \frac{J/s}{m^2 \cdot m/s} = \frac{J}{\underline{\underline{m^3}}}$

$\eta_h \rightarrow$ Arc heat transfer efficiency

$H_m \rightarrow$ Heat required to melt (J/mm^3)

$H_s \rightarrow$ Heat supplied (J/mm^3)

$\boxed{H_s = \frac{VI}{A_b v}} \; J/mm^3$ $\qquad \boxed{H_m = mC\Delta T + mL}$

Actual amount of heat transfer on work piece

$\boxed{H_s = \frac{VI}{A_b v}\eta_h} \; J/mm^3$ {per unit Volume}

$\boxed{H_s = \frac{VI}{v}} \; J/mm$ per Unit length

$$\boxed{\eta_m = \frac{H_m}{H_s} = \frac{H_m}{\frac{VI}{A_b v}\eta_h}}$$

Q.13

$V = 25V$

$I = 300V$ $\qquad \vartheta = 8\ mm/sec.$

$\eta_h = 0.85$

$$H_s = \frac{VI}{A_b \vartheta} \eta_h \quad J/mm^3$$

per unit length (J/mm) $= \frac{VI}{\vartheta} \eta_b$

$$H_s = \frac{25 \times 300}{8} \times 0.85$$

$$H_s = 796.87\ J/mm$$

Q.15

$\eta_m = 0.5$ $\qquad H_m = 10\ J/mm^3$

$\eta_h = 0.7$ $\qquad P = 2\ kW$

$A_b = 5\ mm^2$

$$H_s = \frac{VI}{A_b \vartheta} \eta_h$$

$$\eta_m = \frac{H_m}{H_s} = \frac{10}{\frac{2 \times 1000 \times}{5 \times \vartheta} \times 0.7} = 0.5$$

$$\Rightarrow \frac{1\cancel{0}\cancel{0}}{\cancel{5}} = \frac{2 \times 1\cancel{0}\cancel{0}\cancel{0} \times 0.7}{\cancel{5} \times \vartheta \times 1\cancel{0}}$$

$$\vartheta = 14\ mm/s$$

Q.28 $\quad H_s = 1200\ J/mm \qquad \eta_m = 45\%. \qquad \vartheta = 6\ mm/sec.$

$H_m = 15\ J/mm^3$

$$\eta_m = \frac{H_m}{H_s}$$

$$H_s = \frac{VI}{\vartheta_b} \eta_h = 1200\ J/\underline{\underline{mm}}$$

$$3\,\cancel{15} = \frac{\overset{9}{0.45}}{1\cancel{00}} \times \frac{\overset{3}{12\cancel{00}}}{A_b}$$

$$A_b = 36\ mm^2$$

Q.38

$I = 50\text{ A} \quad V = 60\text{ V}$

$v_1 = 150\text{ mm/min} = \frac{5}{2}\text{ mm/s}$

$v_2 = 120\text{ mm/min} = 2\text{ mm/s}$

$(H_s)_1 = (H_s)_2 \qquad V_1 = V_2$

$$\left(\frac{VI}{A_b v}\right)_1 = \left(\frac{VI}{A_b v}\right)_2 \Rightarrow \frac{50\times\cancel{60}}{\cancel{5}/2} = \frac{I\times\cancel{60}}{2}$$

$\Rightarrow \quad I = \underline{40\text{ A}}$

Q.41

$v = 300\text{ mm/min} = 5\text{ mm/s}$

$I = 150\text{ A} \quad V = 20\text{ V}$

$L = 900\text{ mm} \quad \eta_h = 0.80 \quad R = 36\text{ k}\Omega$

$$H_s = \frac{\overset{30}{\cancel{150}}\times 2\cancel{0}}{\cancel{5}} \times \frac{0.8\cancel{0}}{1\cancel{00}}$$

$H_s = 30\times 16$

$H_s = \underline{480\text{ J/mm}}$

(43)

$\boxed{I^2 D = \text{Constant}}$

$I_1^2 D_1 = I_2^2 D_2$

$(100)^2 (0.60) = (160)^2 D_2$

$$D_2 = \frac{100\times 100\times 0.60}{160\times 160} \Rightarrow D_2 = 0.234$$

$$\%\text{ Chang} = \left(\frac{0.60 - 0.234}{0.60}\right)\times 100$$

$\%\text{ Change} = 60.937\ \%$

Q.46 $I = 200 V$

$V = 25 V$

$\vartheta = 18 \text{ cm/min} = \frac{180}{60} = 3 \text{ mm/sec}$

wire $d = 1.2$ mm

$f = 4$ m/min $\quad \eta_h = 65\%$

$$H_s = \frac{V I}{\vartheta} \eta_h$$

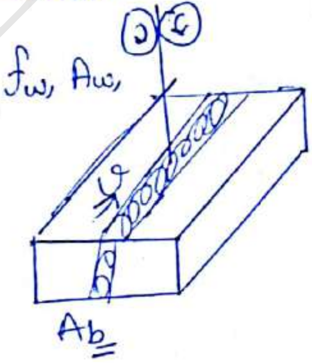
① $H_s = \frac{25 \times 200}{3} \times 0.65 \Rightarrow H_s = 1.08 \text{ KJ/mm}$

[illegible] × [illegible]

~~$f = v A d$~~

~~$\frac{4 \times 1000}{60} = 3 \times A \times 1.2 \rightarrow A = 18.51 \text{ mm}^2$~~

MIG



② $A_w \times f_w = A_b \times \vartheta$

$\frac{\pi}{4} (1.2)^2 \times 4 \times 100 = A_b \times 18$

$A_b = 25.13 \text{ mm}^2$

Q.30 $V_0 = 80 V \quad I_s = 600 A$

$$V_t = V_0 - \left(\frac{I_t}{I_s}\right) V_0$$

$$V_t = 80 - \left(\frac{I_t}{600}\right) 80$$

$$P = I_t \left(80 - \left(\frac{I_t}{600}\right) 80 \right)$$

$\frac{dP}{dI_t} = 0 \Rightarrow 80 - \frac{I_t}{300} \times 80 = 0 \Rightarrow I_t = 300 A$

$V_t = 40 V$

$P = V_t I_t = 300 \times 40$

$P = 12 KW$

☆ Max. Power Condition.

$$\boxed{V_t = \frac{V_0}{2}} \; ; \; \boxed{I_t = \frac{I_s}{2}}$$

Q.44 $V_0 = 80$ $I_s = 300\text{ A}$

$I_t = \frac{I_0}{2}$ For max. power

$I_t = \frac{300}{2} = 150\text{ A}$

Quest Steel blades are welded by arc welding using linear power source characteristic with $V_0 = 60V$ & $I_s = 300$ Amp. Arc length is $l_a = 4$ mm, welding speed $\vartheta = 2.5$ mm/s, Heat transfer efficiency $\eta_h = 0.85$ arc length Voltage is given $V_a = 20 + 2.5\, l_a$ Heat input per unit length of workpiece is $H_s = ?$

Soln $V_0 = 60\,V$

$I_s = 300\,A$

$l_a = 4\,mm$

$\vartheta = 2.5$ mm/s

$\eta_h = 0.85$

$V_a = 20 + 2.5\, l_a$

$H_s = ?$

$$V_t = V_0 - \left(\frac{I_t}{I_0}\right) V_0$$

$$V_t = V_a = 20 + 2.5 \times 4$$

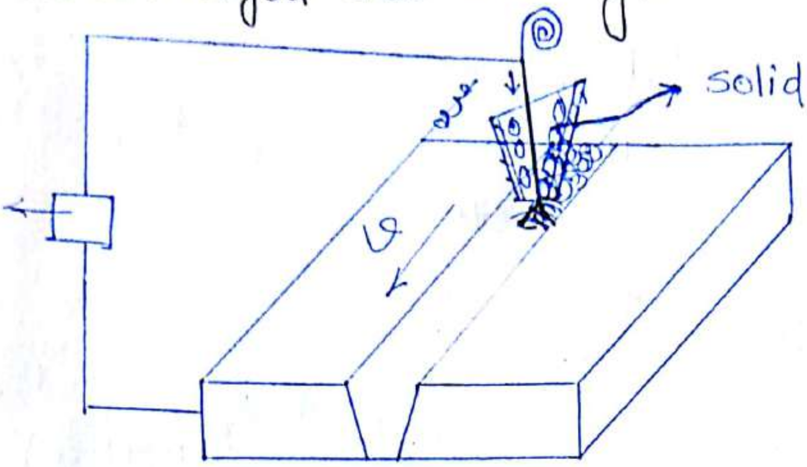
$$V_a = 30\,V$$

$$\Rightarrow 30 = 60 - \left(\frac{I_t}{\cancel{300}_{5}}\right) \times \cancel{60}$$

$$\underline{\underline{I_t = 150\,A}}$$

$$H_s = \frac{150 \times 30}{2.5} \times 0.85 \Rightarrow H_s = 1.53\,kJ/mm$$

Submerged arc welding:-



$t = 15 - 50$ MM

$I = 200 - 2000$ A

deposition Rate

$\div 20$ kg/hr

$\vartheta = 5$ m/min

- Automatic welding technique.
- Granulator flux

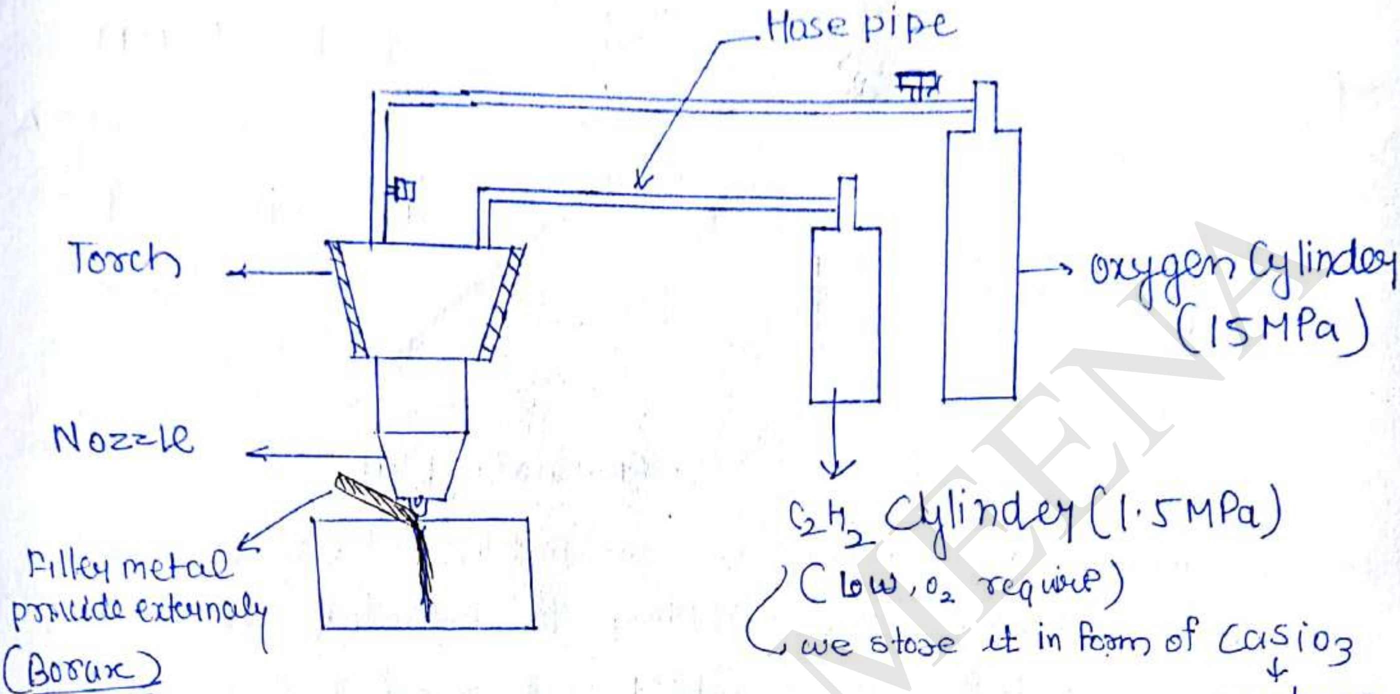
Arc is generated between a consumble electrode and workpiece. Through the welding torch solid form of the flux contineously supplied. it will be covering on the surface of arc such that arc will be submerged under the flux due to this heat transfer loses from the arc will be reduce, Heat concentration on workpiece is increase and depth of penetration is more.

- Splashing ~~the~~ of the liquid metal is less and weld spatter and slag inclusion will be minimum welding speed and weld deposition rate is very high.
- Used for welding of high thickness materials.
- It is used in Flat position only.
- Heat affected zone is more!

Applications:- ① Febrication of pressure vassels, & LPG Cylinder, ② joining of high thick plates in ship building

Chemical Reation Welding:

① Gas welding: (oxy - acetylene)



(Low, O_2 require)
we store it in form of $CaSiO_3$ + acetone

Primary Reaction:

$$C_2H_2 + O_2 \longrightarrow 2CO + H_2 + \Delta h_1$$

secondary Reaction

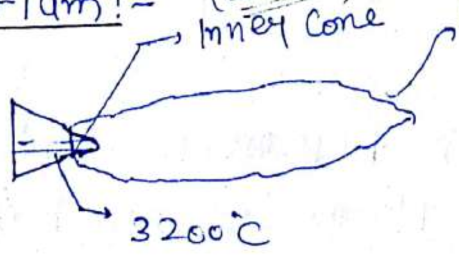
$$2CO + H_2 + \frac{3}{2}O_2 \longrightarrow 2CO_2 + H_2O + \Delta h_2 \quad (\Delta h_2 > \Delta h_1$$

$$\checkmark \quad C_2H_2 + \frac{5}{2}O_2 \longrightarrow 2CO_2 + H_2O + \Delta h$$

Types of Gas Flames:-

① Neutral Flam:-

Hissing Sound

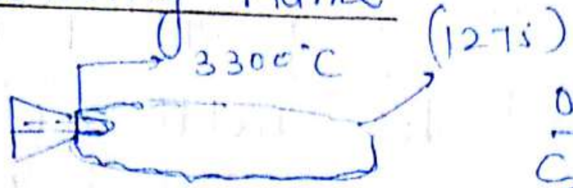


it cover more area so more heat loss

$$\frac{O_2}{C_2H_2} = 1:1$$

② Oxidizing Flame

Roaring Sound



$$\frac{O_2}{C_2H_2} = 1.15 - 1.5$$

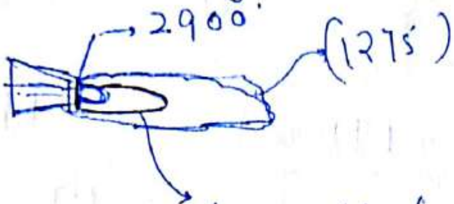
possibility of oxide formation

(High amount of O_2)

Eg. Cu, Zn can welded

③ Carburizing Flame

No Sound



$$\frac{O_2}{C_2H_2} = 0.85 - 0.92$$

Intermidiate Flam

(unburnt carbon in C_2H_2 is represented by this)

(less amount of O_2)

exo - outside

endo - inside

Eg. Ni, High C steel

→ By Burning the C_2H_2 (Acetylene) in the presence of oxyzen (O_2) due to exothermic reaction Heat will be produced and this will be used for melting of base material to produce a fusion joint.

→ For complete combustion of 1 mole of C_2H_2, 2.5 moles of O_2 is require in which 1 mole is consumed from oxygen cylinder and 1.5 mole are consumed from atmosphere.

→ By controlling the volume flow rate of O_2 & C_2H_2 different Flame can be produced they will be used for different application.

Application :-

Application of Flames

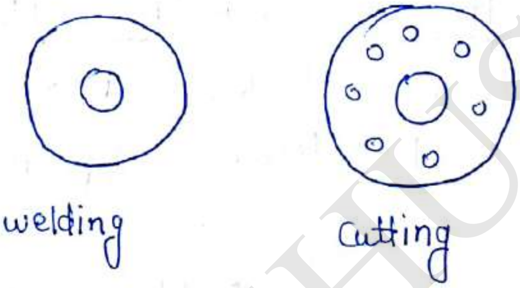
① **Netutral Flame** :- it is general purpose flame used for welding of Mild steel, low carbon steel, medium carbon steel, Al, Cast iron etc.

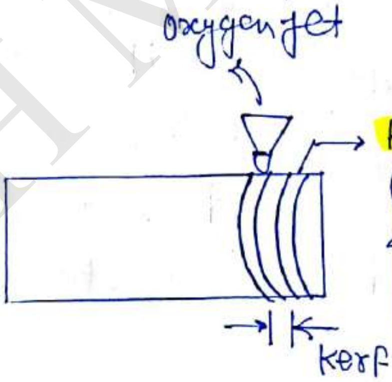
② **oxidizing Flame** - Welding of Cu, Zn, Brass

③ **Carburizing Flame (Reducing Flame)** - welding of high carbon steel and Ni bassed alloy.

Gas Cutting :-

Nozzle tip

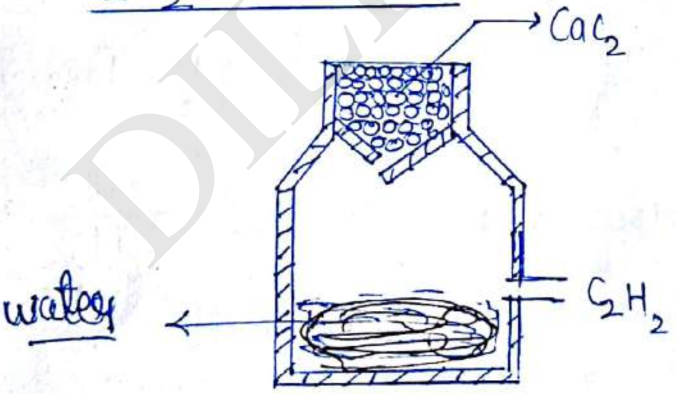




kindling temp
{mini temp at which material ready to get oxidizing}

*Al oxide have more density

C_2H_2 Generator



*using this we can easly produce C_2H_2 gas

$$CaC_2 + 2H_2O \rightarrow C_2H_2 + Ca(OH)_2$$

Same setup which is used for welding can be used for gas cutting except in the form of nozzle tip

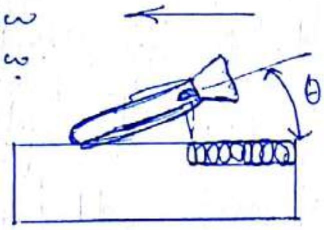
In ~~g~~ Gas cutting through the circumferancle hole initially neutral flame is coming it will be used for preheating the base material upto kindling temp. It is a mini. temp at which material is readly to get oxedize.

After this by using high pressure oxyzen jet more amount of ~~meta~~ material is oxedise and remaining material blown in the form of droplet

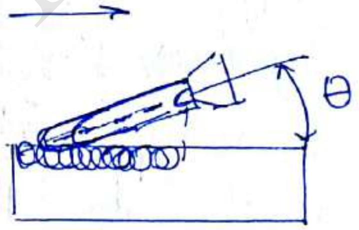
Gas welding technique :-

① Forehand ② Backhand

eg 1w' - 24w
9w' - 24w
preheat
reduce temp diff.



$\boxed{\theta \propto 't'}$

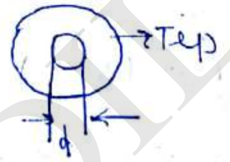


outer flame - preheating the material

- slow rate of cooling
- ~~poor~~ Grain Ductile property
Coarse

Outer Flame - Reheating the material
- stress remove due to reheating
- crack formation reduce.

Nozzle



$\theta \propto t$
$d \propto 't'$

Fore hand :- In this technique inner cone is melting the base material and outer flame is preheating the base material before welding. Due to this by reducing the diff. of temp. slow rate of cooling take place and coarse grain found which is having sufficient ductility.

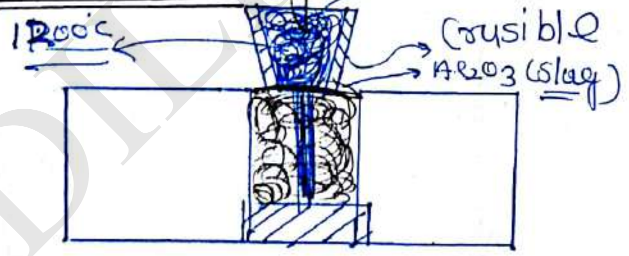
During the contraction process because of ductility by reducing internal stress crack formation can be minimize.

② Backhand:- In this technique inner Cone is melting the material and outer flame is reheating the already welded material due to stress develope in the process can be relived (Annealing)

Cast Iron

In case of cast iron if the diff. of temp is very high due to fast rate of cooling Bee form of the carbon will be converted into carbides They are very brittle and hard due to thes crack will be Formed. To overcome this cast iron can be best welded by Gas welding with preheating.

Thermit welding :-



thermit mixture

Fe_3O_4 : Al (3 : 1) By mass

CuO_2 : Al

Cr_2O_3 : Al

at 1200°C Reaction

$$3Fe_3O_4 + 8Al \longrightarrow 9Fe + 4Al_2O_3 + \Delta h$$

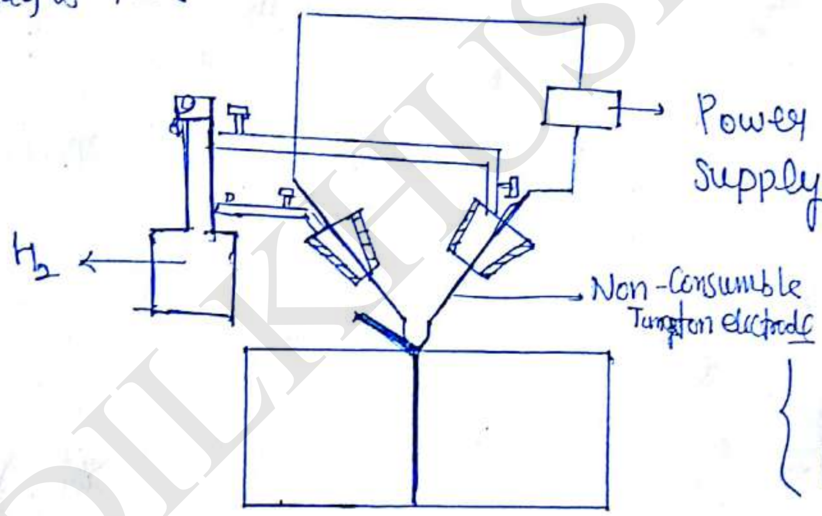
Thermit mixture can be heated in a crusible upto 1200°c by using 'Mg' rods. At this temp due to thermit reaction heat will be produced by using the heat iron will melted and it will be enter in workpiece. By allowing the liquid metal to solidify Joint can be produce, Al_2O_3 will be acting as a slag.

Applications:- Repair works of Railway rails, Joining of broken casting & high thickness plate.

Atomic hydrogen welding:-

Now a day TIG & MIG used instead of this

Heat Generate at 4000°c (No possibility of getting water at high temp)



Die steel
Tool steel
Can welded

AC power supply

$$\left\{\begin{array}{l} H_2 \rightarrow H + H - \Delta h_1 \\ H + H \rightarrow H_2 + \Delta h_2 \end{array}\right.$$

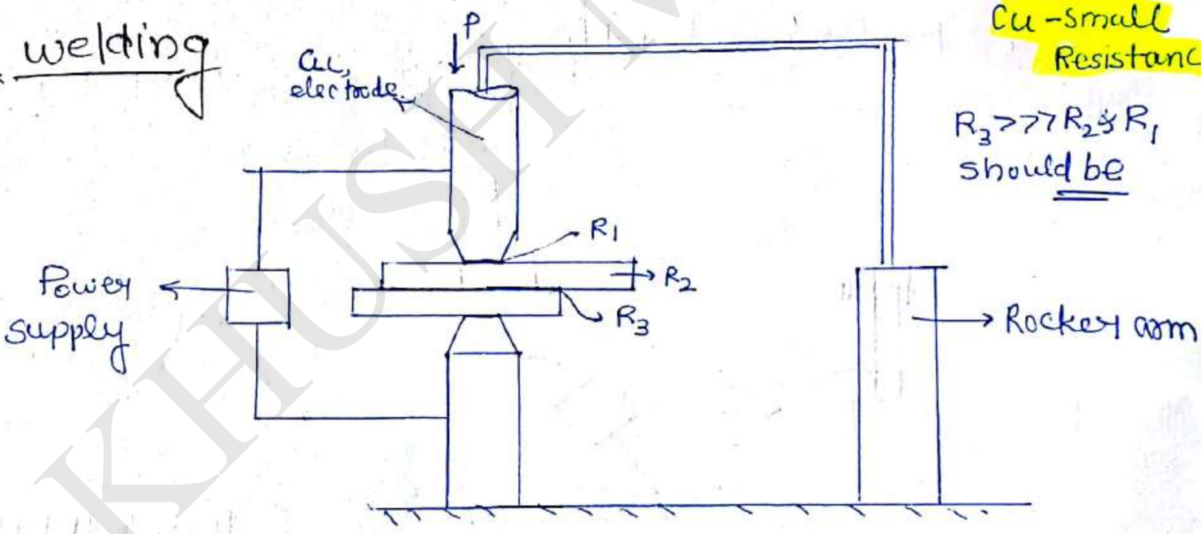
Arc is generated between 2 Non Consumble tungston electrode. By supplying Hydrogen gas to the arc due to ~~arc~~ heat from arc Hydrogen molicules will be dissociated into hydrogen atoms by Consuming heat from the arc. When they will be in contact with cold surface of workpiece due to unstability they will recombine as Hydrogen molicules during the process more heat will produced it will be supply to workpiece for melting of workpiece. Hydrogen gas will be acting as a heating agent and it will also act as shielding gas to protect the liquid metal from atmospheric gases.

- → AC power supply can be used.
- → Joining of toop steel & Die steel,
- → Repair works of cutting tools & Dies

03 Aug 2016

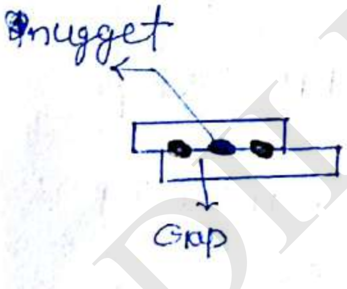
Resistance welding :-

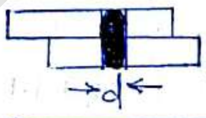
① Spot welding



Cu - small Resistance

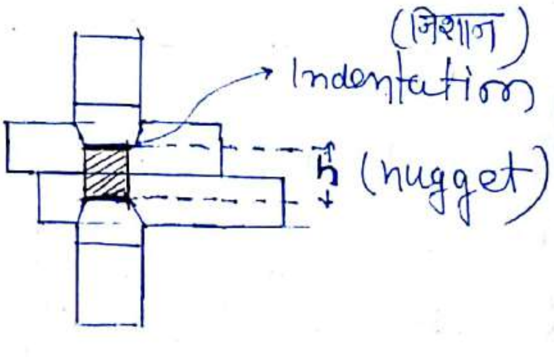
$R_3 >>> R_2$ & R_1 should be

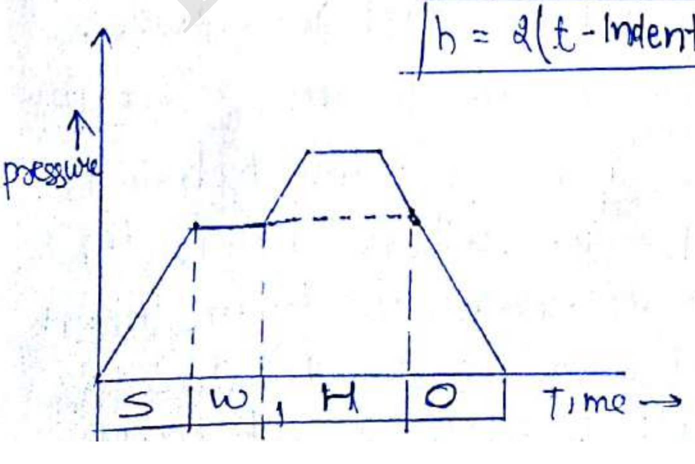




$\boxed{d = 6\sqrt{t}}$

$\boxed{h = 2(t - \text{Indentation})}$





s - squeeze time
w - weld time
H - Hold time
o - off time

} cycle time

Thickness → 1 - 2 mm (sheet)

$I \rightarrow 10{,}000 - 50{,}000$ A

$t \rightarrow 0.01 - 0.5$ sec.

- Cu is highly Conductive and low resistive So we use Cu, electrode.
- Due to lifting of electrode again again, leak there is a small gap b/w nuggets So leak proof joint not possibles

mass of nugget $\boxed{m = V\rho}$

Heat require to melt $\boxed{H_m = mc\Delta T + mL}$

Heat supplied $\boxed{H_s = I^2RT}$ J

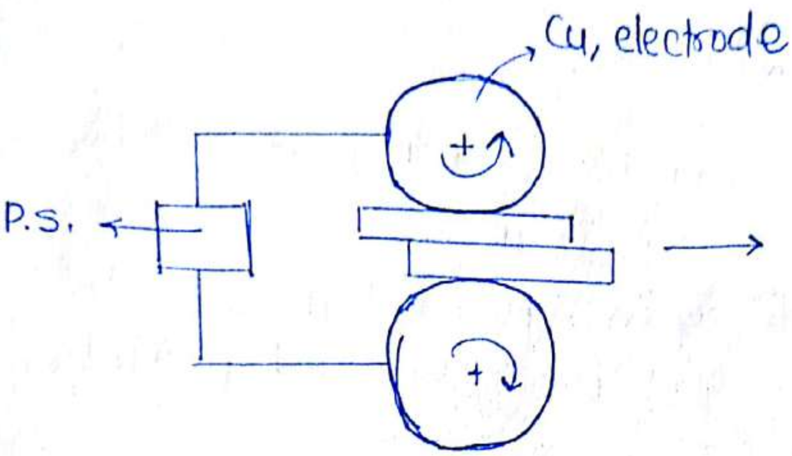
Melting efficiency $\eta_m = \frac{H_m}{H_s}$

* If nothing is mention about H_m than $H_m = H_s$

For joining of sheet material in mass production this technique can be use. Two sheets are provided between two Cu, electrodes. By supplying high rate of current for small fraction of time Heat will be generated at contact to two surfaces. After getting sufficient amount of heat by applying pressure joint can be formed between two surfaces below the electrode. leak proof joint not possible there is a possibility of indentation b/w electrode and workpiece.

Application:- Lap joining of sheet metals in automobile and refrigerator bodies

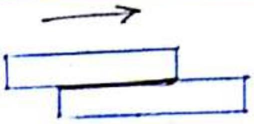
② Seam Welding :-



High welding speed

$v \rightarrow 5\ m/min$

$$\boxed{v = \frac{\pi D N}{60}}$$



* contineous spot welding, leak proof joint possible

Two sheet are provided between two electrodes which are in the form of rollers. By supplying high rate of current through rollers heat generation takes place at the contact of workpieces.

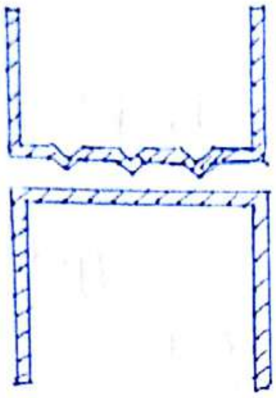
By rotating the rollers rolling pressure can be applied To produce the joint between two surfaces welding speed is more. leak proof joint can be possible.

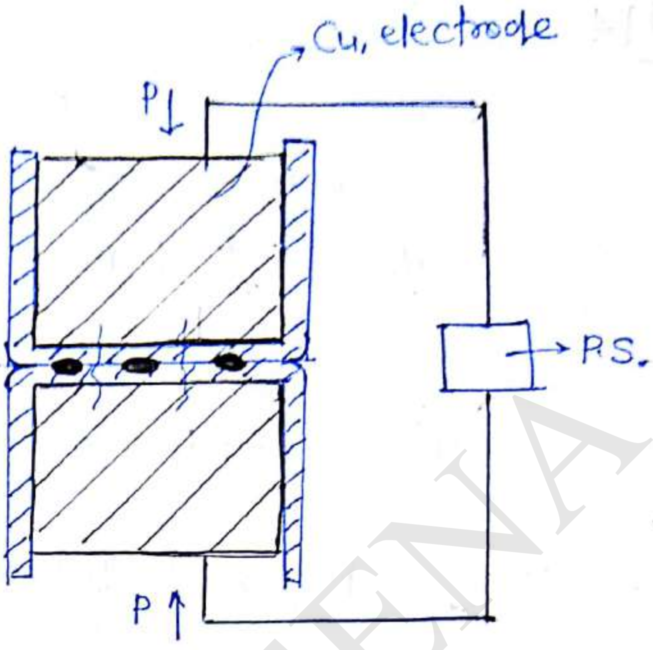
There is a possibility of indentation between electrode and workpiece material.

Application - - febrication of fuel tanks and radiator bodies

- Mufflers used in exhaust ~~s~~ pipe

③ Projection welding :-





* projection are produce by embossing processes

~~One~~ One of the sheet to be welded produce projection by using embossing technique.

By providing two sheets between large size Cu, electrode High rate of Current Can be supply. At the contact of projections due to Contact resistance heat will be generated. After getting sufficient amount of heat by switch of power supply external pressure can be applied through the electrode such that nugget can be pForms at projection. More no. of nugget Can be produce in a Single cycle. It can be use in mass production.

There is no possibility of indentation b/w electrode & workpiece leak proof joint is not possible

Application : - Joining of threted screw & nuts to the sheet material
- febrication wire mess & ~~gro~~ grills.

Q.14

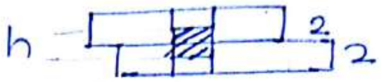
$t = 2\,mm$

$R = 75$ micro ohms.

$I = 6000\,A$

$t = 0.15$ sec.

$H_m = 2.9\ J/mm^3$



$d = 5\,mm \quad h_{nugget} = 2.5\,mm$

Volume of nugget

$H_s = I^2 R t$

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

$H_s = (6000)^2 \times (75 \times 10^{-6}) \times (0.15)$

$V = \frac{\pi}{4} (5)^2 (2.5)^2$

$H_s = 405\ J$

$V = 49.08\ mm^3$

$H_m = 2.9 \times 49.08 \ (J/mm^3 \times mm^3)$

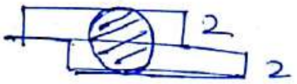
$H_m = 142.35\ J$

$\eta_m = \frac{H_m}{H_s} = \frac{142.35}{405} = 35\%$

⑯

$t = 2\,mm$

$R = 500\ k\Omega$



$I = 10^4\ A$.

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

time = 10 Mili second

$m = \rho V$

$V = \frac{4}{3}\pi(2)^3 = 33.51\,mm^3$

$H_s = I^2 R t$

$H_m = \rho V (C\Delta T + L)$

$H_s = (10^4)^2 \times (500 \times 10^{-6})(10 \times 10^{-3})$

$H_s = 500\ J$

$H_m = 33.51 \times 10^{-9} \times 700 (800 \times 1520 + 300 \times 10^3)$

$H_m = 351.85\ J$

$\eta_m = \frac{351.85}{500}$

$\eta_m = 70.8\%$

Q.31

Thickness = 1.5 mm

$I = 10000$ A

$t = 0.2$ sec.

$R = 100\ \mu\Omega$

$d = 5$ mm

$\rho = 8000 kg/m^3$

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

$$V = \frac{\pi}{4}(5)^2(3)$$

$$V = 58.90 mm^3$$

$$m = \rho V$$

$$m = 8000 \times 10^{-9} \times 58.9$$

$$m = 4.71 \times 10^{-4}$$

$$H_m = \cancel{mc}\ \Delta T + mL$$

$$H_m = mL$$

$$H_m = 4.71 \times 10^{-4} \times 1200 \times 10^3$$

$$H_m = 565.48 \text{ J}$$

$$H_s = I^2 R t$$

$$H_s = (1000)^2 \times (100 \times 10^{-6}) \times 0.2$$

$$H_s = 2000 \text{ J}$$

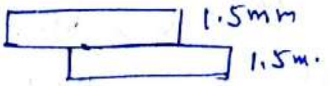
Heat require to melt $\eta_m = \frac{H_m}{H_s}$

So Heat supplied to sourrounding $= (1 - \eta_m) \times 100$

Heat supplied to Sourrounding $= \left(1 - \frac{565.48}{2000}\right) \times 100$

$= 71.726$ %

Q.42



$I = 10000$ Amp.

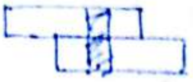
$R = 150\ \mu\Omega$

$t = 0.4$ sec.

$$H_s = I^2 R t = (10000)^2 \times 150 \times 10^{-6} \times 0.4$$

$$H_s = 6000 \text{ J}$$

Q.32



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

$V = \frac{\pi}{4} (6)^2 . 4$

$V = 113.09 \text{ mm}^3$

$H_m = H_s$

$V \times H_m/V = (25,000)^2 \times R \times 0.005$

$113.09 \times 10 = 3125000 \ R$

$R = 3.619 \times 10^{-4} \ \Omega$

$R = 362 \ \mu\Omega$

Q.45

$\rho = 2700 \text{ kg/m}^3$

$c = 896 \text{ J/kg}$

$T_m = 933 \text{ K}$

$T_a = 303 \text{ K}$

$L = 398 \text{ kJ/kg}$

$H_s = 0.5 \text{ J}$

$A = 0.05 \text{ mm}^2$

$V = Ah \Rightarrow m = \rho V \Rightarrow m = A h \rho$

$H_m = H_s$

$\rho V (C \Delta T + L) = H_s$

$0.05 \times h \times 10^{-9} \times 2700 \left(896 \times 630 + 398 \times 10^3\right) = 0.5$

$h = \underline{\underline{3.84 \text{ mm}}}$

<u>Problem</u> For a spot welding of two sheets of 3 mm thickness with welding current 10,000 A for 0.2 s Heat disipeated to base metal is 1000 J, Assuming Heat requires for melting is $H_m = 20 \text{ J/mm}^3$, Contact resistance $R = 200 \ \mu\Omega$ what is the volume of weld nugget.

Sol^n

$I = 10{,}000\ A$

$t = 0.2\ s$

$H_l = 1000\ J$ → Heat loss

$H_m = 20\ J/mm^3$

$R = 200\ k\Omega$

$$H_s = I^2Rt = (10^4)^2 \times 200 \times 10^{-6} \times 0.2$$

$$H_s = 4000\ J$$

$$H_d = H_s - H_m$$

$$1000 = 4000 - V \times 200$$

$$V = 150\ mm^3$$

Heat require to melt

$H_m = H_s - H_d$

$H_m = 4000 - 1000$

$H_m = 3000\ J$

$$\eta_m = \frac{3000}{4000} \times 100 = 75\%$$

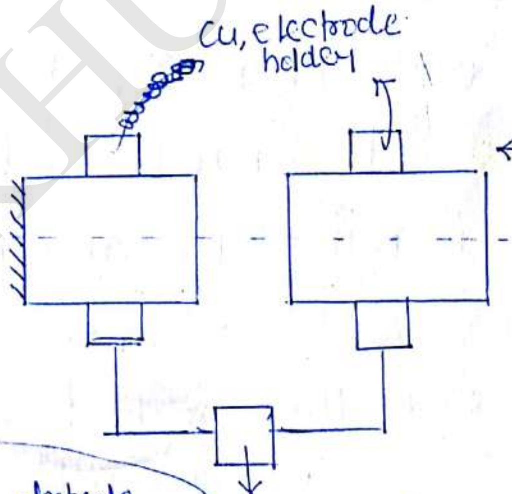
Flash Butt welding:-

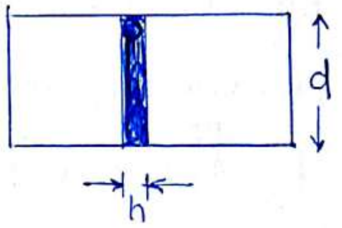
h - width of weld beed

h - amount of material which is melted from the both ends of object.

* Heat produce due to contact Resistance.

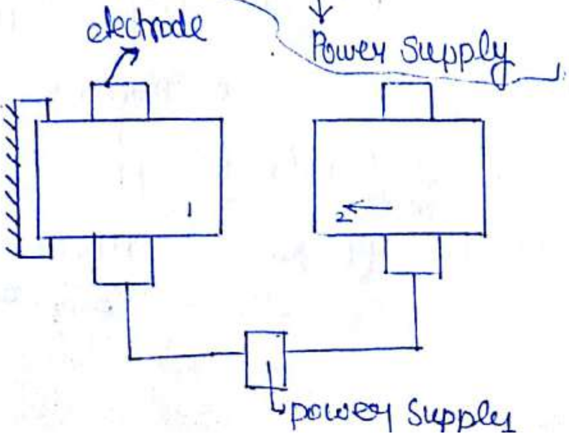
*Preffered of object dia ϕ → 0.2 - 25 mm

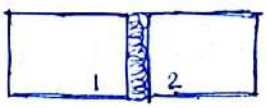




$$V = \frac{\pi}{4} d^2 \cdot h$$

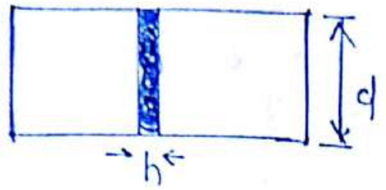
Flash welding:-





Flash Butt welding (Heat generation less)

$$V = \frac{\pi}{4} d^2 \cdot h \Rightarrow m = \rho \times V$$



$$H_m = mC\Delta T + mL$$

$$H_s = I^2 R T$$

$$\eta_m = \frac{H_m}{H_s}$$

h- amount of material which is melt from the both ends of object.

Flash welding (Heat Generation High)

* Heat generation due electric arc. So it is not resistance welding it is arc welding.

Flash Butt welding

For joining of the object end to end to produce a butt joint between the two surface this technique can be use. Two objects which are to be welded one will be fixed and other is having linear movement. By making the contact of two workpieces end to end flash will be produce. By increasing the contact between the two surface heat will be generated due to ~~resis~~ resistance between two surface. After getting sufficient amount of heat by switch of the power supply external pressure can by applied a fusion joint

Flash welding

By providing two workpiece between two Cu, electrode holder initially contact is made between the two surface due to short circuit arc will be produced inorder to continaoue the arc further some gap is maintain b/w two workpiece. Due to electric arc b/w two surfaces Heat will be generated. After getting sufficient amount of heat by switchoff the power supply external pressure can be apply to produce the joint

Application! – Joining of objects end to end which are madeup of low carbon steels, high carbon steel, Al alloys ($\phi = \underline{0.2 - 25\ mm}$)

Problem!.– Two hollow of 110 mm outside diameter and 100 mm inside diameter are joint by flash butt welding using 30V power supply at interface 1 mm material melt from each pipe which a Internal resistance $R = 42.4\,\Omega$ heat require for melting of metal is $H_m = 64.4\ MJ/m^3$ time taken for welding is,

Sol^n

$$V = \frac{\pi}{4}\left(110^2 - 100^2\right)(2)$$

$$Vol = 3298.67\ mm^3$$

$$V = IR$$

$$I^2 = V^2/R^2$$

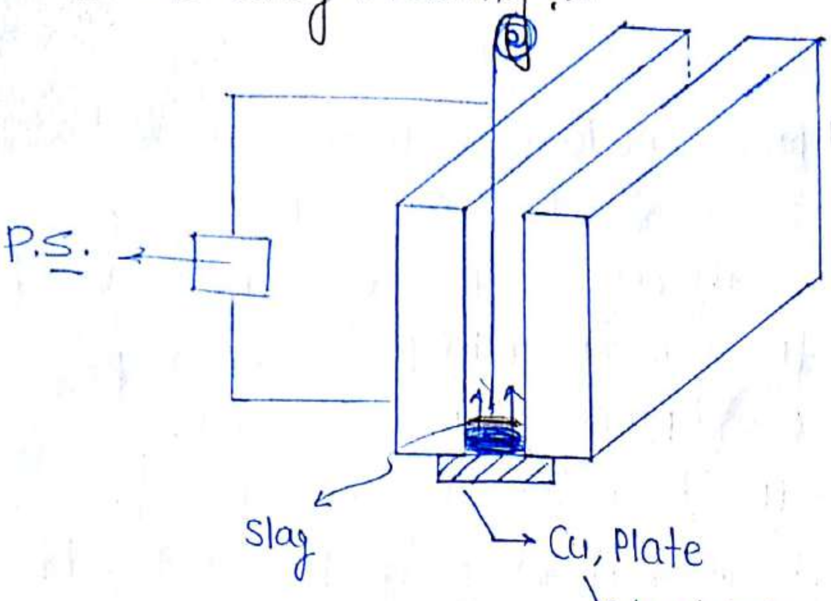
$$H_m = H_s = I^2Rt = \frac{V^2}{R^2}\cdot R\cdot t$$

$$64.4\times10^6 \times 3298.67\times10^{-9} = \left(\frac{30}{42.4}\right)^2 \times 42.4 \times t$$

~~t ≈ 9.86 sec. ≈ 10 sec.~~

t = 10 Sec.

Electroslag Welding :-



to minimise metal loos
sheat trams fay at Fast Rate

High thickness

t = 50-200 mm

I = 1000 A

DCRP

- Done only in ~~horizontal~~ verticle position
- No. of electrode increase according to width of workpiece.

For welding of High thickness objects edge to edge this technique can be used.

Arc is generated between ~~two~~ workpiece and electrode By melting the material between electrode and workpiece liquid Metal is form and by adding the flux slag will be produced.

When the height of liquid metal is increasing & it will be in contact with electrode due to short circuit arc will be extingash and further heat generation will be continude by supply high rade of current due to resistance of slag.

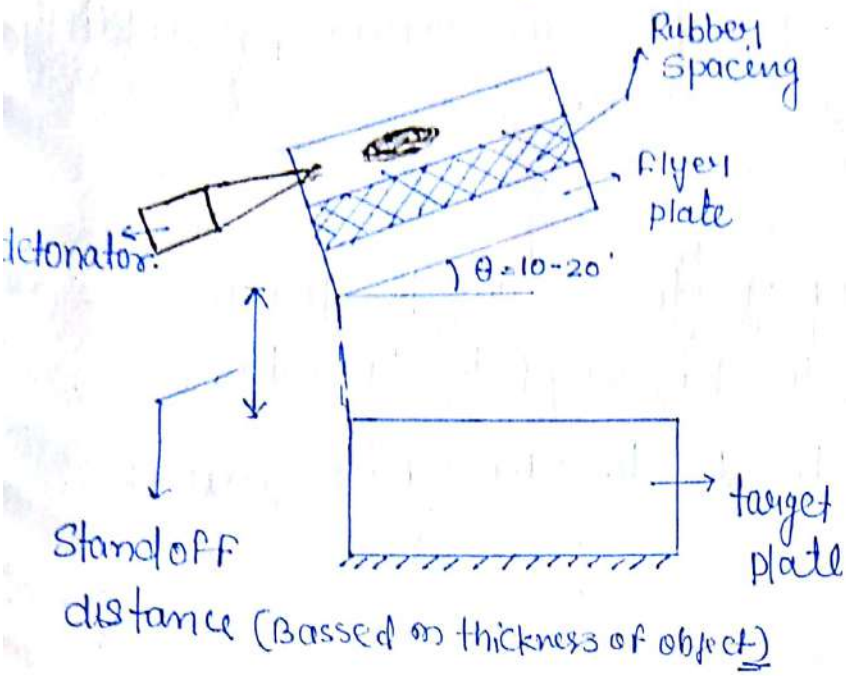
For welding of large width of workpiece more no. of power source are provided by providing More electrode welding will be done ~~in~~ only in Vertica upward direction

Application :- Ship building, febrication of press frame and rolling mill stamt.

Soled State (Autogenous)

Explosive Welding:-

(low velocity Explosive material)
- TNT
- Dynamites
- Ata Ammonium Nitrate



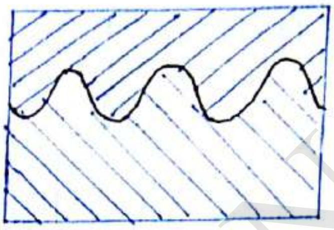


plate → should be have high thoughness (High strength)

- Not adding any filler material
- temp. is not more then T_{rr} (i.e. room temp.)

Cladding - Adding of corrosion resistance material to non corrosion resistance material ~~adding~~ in solid state called Cladding

- For ~~adding~~ welding of high thickness plate surface to surface this technique can be use.

Two workpiece which are to be welded, one will be fixed (target plane) and other is movable (flyer plate) By exploding low velocity explosive material above the flyer plate it will be forced on to the surface of ~~tag~~ target plate with more impact energy at the contact surface due to plastic deformation joint can be formed.

- Flyer plate is maintain some distance with target plate to gain the momentum.

→ Flyer plate is provided some inclination to Horizontal plane to provide direction for welding s.t.e strength of joint is very high.

Application! -① Disimilar material can be join like Al to Ti, steel to Ti etc.

② Cladding of the objects to increase Corroso resistance.

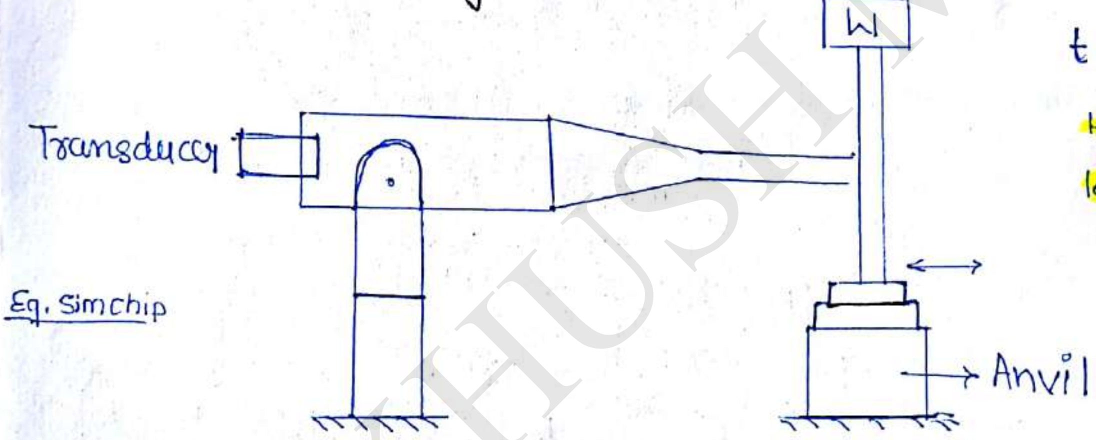
Ultrasonic Welding!-

f → 20-60 kHz

t < 1-2 mm (foils)

High Frequency

low Amplitude



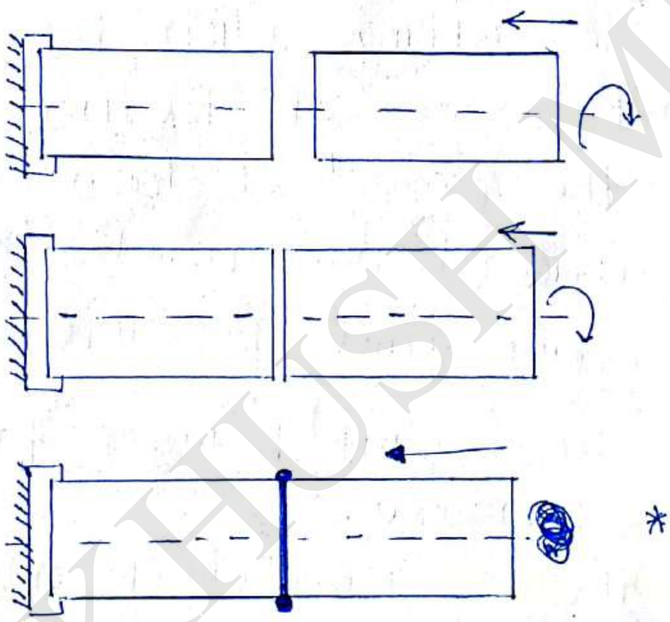
Eg. Simchip

For Joining of less thickness object like foils this technique can be use ultrasonic vibration are produce using transduce. They will be transfer to the workpiece through clamp Due to vibration at the contact of two surface due to rubbing action heat will be generated. After reaching 30-40% to melting temp. by applying external load joint can be Formed at the contact of two surfaces.

* Heat affected zone is negligible.
* Accuracy and strength of joint is more.

Application :- - Joining of armtaure binding
- Febrication of keys
- Joining of Similar and dissimilar material like Al to Glass etc.

Friction welding :-



N → 4000 - 6000 rpm

P → 40 - 400 MPa

* object must be co-axial

P < Area, strength } depends on

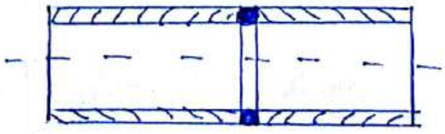
* Stop rotation by seeing Colour (Redish cherie Colour)

* Hollow object they must be having some thickness.

$F = P \times A$

$F_f = P \times A \times \mu$; $T = F_f \times r$; $P = \frac{2\pi NT}{60}$

Hollow object can also weld



☆

* pipes & Values

For joining of object which are having more strength and large size object in mass production this technequie can be used.

Two objects which are to be welded one will be fixed and other is having rotational and axial movement.

By making the contact of rotating object with fixed object at Contact surface oxide layers can be cleaned due to rubbing action. Due to continuous contact because of friction heat will be generated at the contact of two surfaces. After getting sufficient amount of heat by stoping the rotation axial pressure can be increase to produce joint between two surfaces.

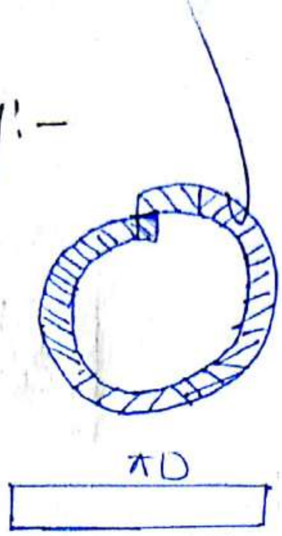
- strength of joint is more.
- It is used for the co-axial objects only

Application :- ① Joining of drill bit to shank

② Axle & hub

③ pipes and values

Forge Welding:-



It is similar to blacksmithing operation object will be heated by keeping inside the forge and hammering force will be applied to deform the object into required shape and size.

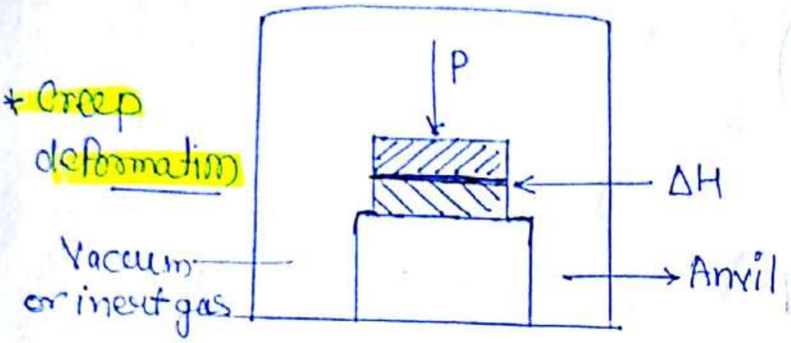
After producing the required shape by applying hammering force required shape of object can be produce by joining two ends.

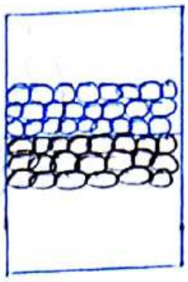
At high temp. there is a possibility of oxide form to overcome this flux material (Borax) will be used.

* Accuracy and surface finish of object will be less

Application:- Generally used for village level agriculture application

Diffusion Welding:-





* applying heat and pressure simuntaneously.
* time taking process. . Costly.
* Use vaccum & enert gas to reduce effect of oxides.

Two objects will be provided in intimate contact. By appCying heat and pressure simuntaneously w.r.t. time gradually, time depandent deformation know as creep deformation will takes place at the contact of two surface by deffusing the grain at the contact of surface uniform mechanical properties can be possible.

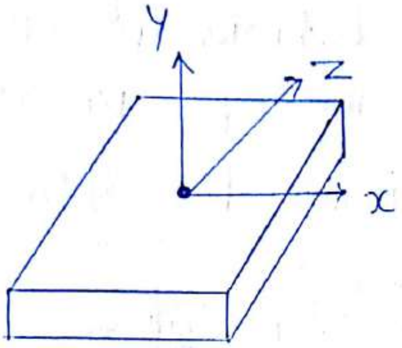
Accuracy and strength of the joint is more

Application:- ① Joining of highly refractory material like ceramic to aluminium, Graphite to ~~ate~~ Al,

② Febrication of composite leminate.

Heat Flow characteristic:-

① 3-D Flow



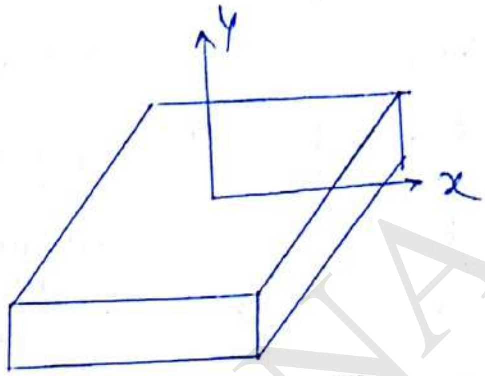
$H = f(x, y, z)$

Point source

Ex:- spot welding

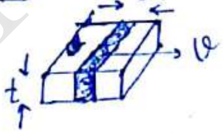
$$\boxed{Q = \frac{5}{4} \pi b k \theta_m \left[\frac{2}{5} + \frac{\vartheta b}{4\alpha} \right]}$$

② 2-D Flow



$H = f(x\, y)$

eg



line source

Ex: Butt Joint.

$$\boxed{Q = 8 k \theta_m t \left[\frac{1}{5} + \frac{\vartheta b}{4\alpha} \right]}$$

★ $\vartheta \propto \frac{1}{b} \propto$ cooling rate

★ Heat supplied depand on $k, \alpha, (t_m - t_a)$

★ If welding speed is high, cooling rate is also high. low weld width.

- amound of heat input & strength also low if velocity high.

$$\vartheta \propto \frac{1}{b} \propto \text{Cooling Rate}$$

Q = amount of heat input

b = weld beed width.

k = thermal conductivity

θ_m = diff. of melting & ambient temp.

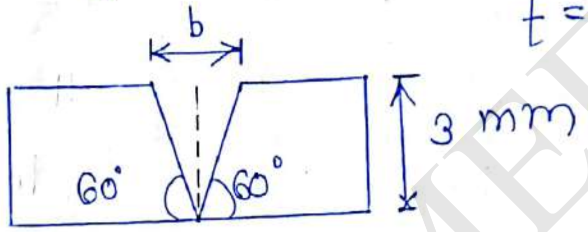
ϑ = linear welding speed

α = thermal diffusivity

t = thickness of workpiece

__Problem:-__ In a butt welding process heat input is given by $Q = 8k\theta_m t\left[\frac{1}{5} + \frac{vb}{4\alpha}\right]$. two steel plates to be welded with a power source of 2.5 kW with a heat transfer efficiency of 85%. take $k = 45\ W/m°C$, $\alpha = 1.2\times10^{-5}\ m^2/s$, $\theta_m = 1450°C$ determine maximum welding speed for the joint as shown in fig

$t = 3mm$



$t = 3$

__Sol^n__ $b = ?$ $\tan 30° = \frac{b/2}{3} \Rightarrow b = 3.464\ mm$

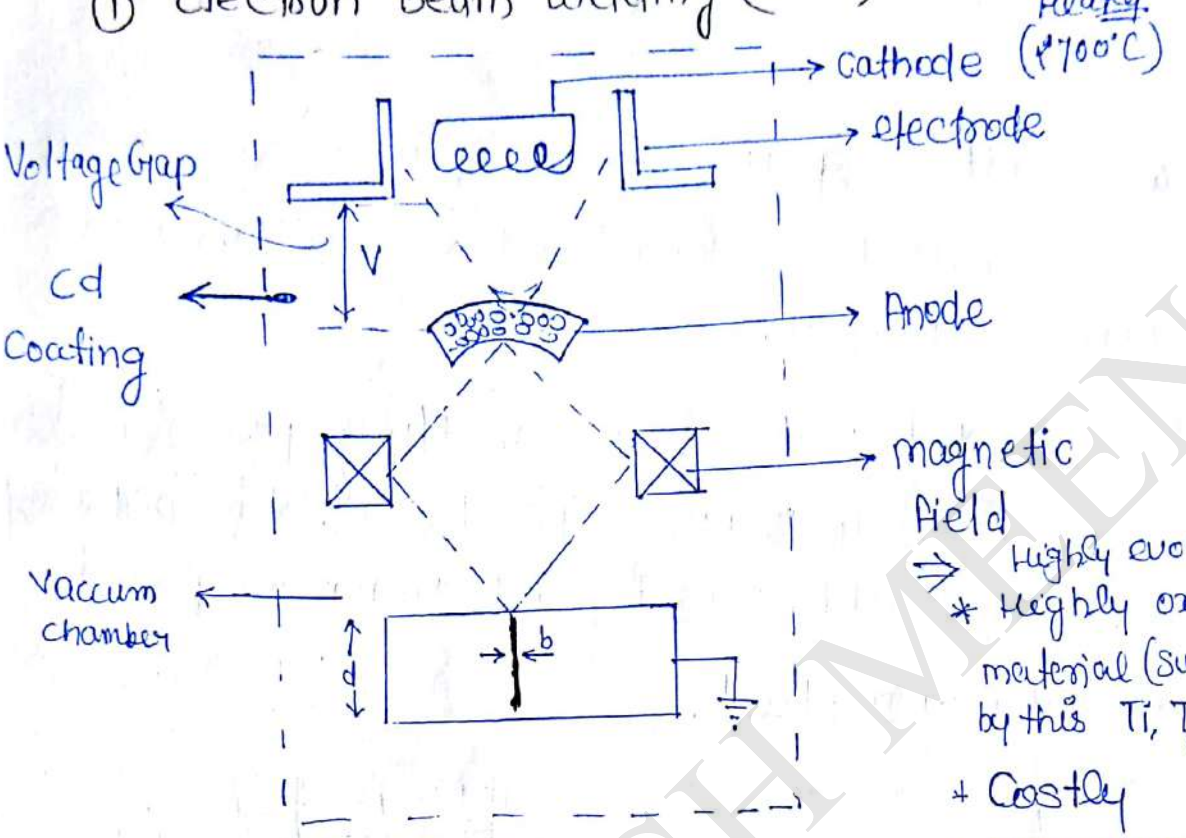
$$Q = 8k\theta_m t\left[\frac{1}{5} + \frac{vb}{4\alpha}\right]$$

$$2.5\times10^{3}\times0.85 = 8\times45\times1450\times3\times10^{-3}\left[\frac{1}{5} + \frac{v\times3.464\times10^{-3}}{4\times1.2\times10^{-5}}\right]$$

$$v = 16.03\ mm/s$$

Radient Energy technique! —

① Electron Beam welding (EBM)



⇒ Highly evorating &

* Highly oxidizing material (super alloy) welded by this Ti, Tg, Barium

+ Costly

* Vaccum chamber requir

$V \rightarrow 40 - 120$ KV

$\vartheta \rightarrow 50,000 - 2,00,000$ km/s $(2 \times 10^8 \text{ m/s})$ Velocity of e^-

$d : b$ (depth : width) $b \rightarrow$ very ~~small~~ small

$10:1 \rightarrow 30:1$ $\vartheta \rightarrow 10$ m/min (Welding speed)

Electron are emitted from cathod at high temp. They will be directed towards Anode by providing electrode. By creating more potential diff. between cathod and anode e^- will be accelarated towards anode by creating the magnetic field e^- coming from difference direction can be converge as a single ~~array~~ ray of electrone beam which is ~~havign~~ having high energy and it will be

Focus on workpiece at a given point. Due to this heat concentration on workpiece is very high

* depth of penetration & welding speed is very high

* Weld bead width and HAZ is minimum.

This process will be carried out under vaccum it is expansive process.

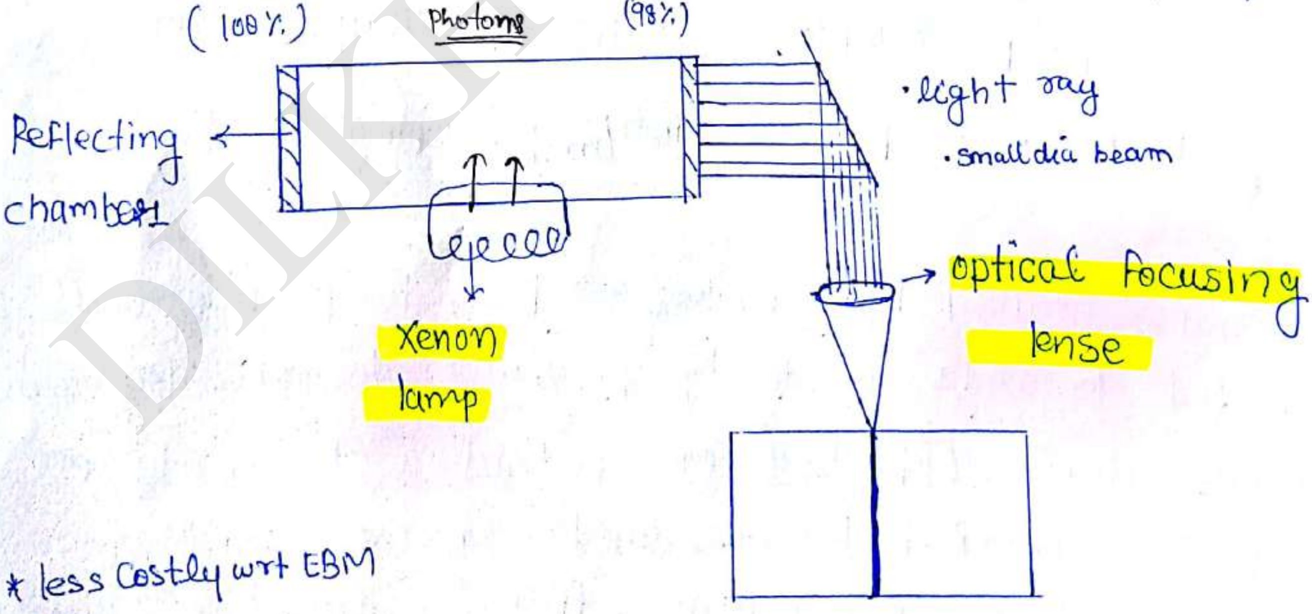
Application:- Joining of high melting point material like Ti, Barium, stainless steel (Super alloy Tungsten in aircraft, misel, ~~cast~~ gas turbine part and nuclear power plant.

04 Aug 2016

Laser Beam welding :-

1) CO_2 laser

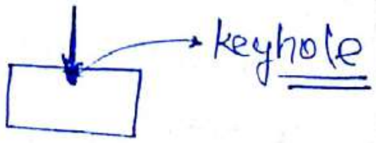
2) Nd : YAG



* less Costly wrt EBM

* d : b

4 : 1 → 10 : 1



Atoms will be pumped into high energy level by using xenon lamp. At high energy level atoms will emit the energy in the form of photons. From the reflecting chamber monochromatic and cohrent light rays will be coming and they will be directed towards the workpiece by using optical focusing lense. This laser beam will be focus on the workpiece at a given point due to this heat concentration on the workpiece will be very high. Depth of penetration and welding speed will be maximum. weld beed width and heat affected zone will be negligible.

Application :- welding of high carbon steels, Ti alloy super alloy in aerospace and electronic industries.

⇒ CO_2 laser it is gas laser mixture of CO_2, He, Ar

⇒ Nd : YAG (Solid laser)

Nd → Neodymium
Y - Yttrium
A - Al
G - Garnet.

⇒ Titanium → high T_m
⇒ Tungston → high oxidation forming tendancy

② Solid/ Liquid state welding :-

Base Metal - solid

Filler Metal - Liquid

(wetting & spreading)

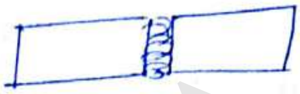
- Brazing >427° ; < M.P. base.
- Soldering < 427°

why edge prepration

✓

- easier filling of liquid
- more depth of penetraction

×



Solder ↳ (lead + Tin) Filler Material

at 427° tin start evorating

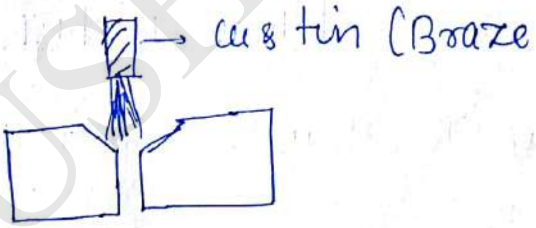
* Filler material enter due to capilory action.

Soldering solder → lead + tin (soldering) HCl + ZnCl (flux Material)

speltar → Cu & Zn, Cu & Al, Cu & Ag (Brazing

Fluxe material - Borax, (Brazing)

Braze welding

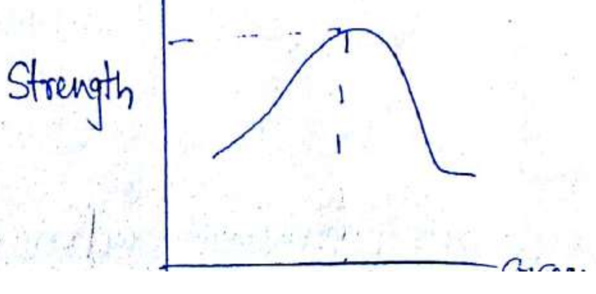


temprature

$T_{welding} > T_{brazewelding} > T_{brazing} > T_{soledering}$

Strength

$\sigma_{welding} > \sigma_{brazewelding} > \sigma_{bracing} > \sigma_{solederung}$



Soldering:- Filler material melting temp is less than 427°c ($<427°C$).

→ Filler material is an alloy of lead and Tin known as solder.

→ Filler material enter into the gap between two workpiece by means of capilary action.

→ strength of joint is less.

→ Flux material used is zinc cloride ($ZnCl$) and HCl

Application: ① Electrical & electronic circuit design
② Febrication of PCB's (Printer circuits board.

Brazing:- Filler material meting temp is greater then 427°c ($>427°c$) and less than melting temp of base material.

→ Filler matel is an alloy Cu & Zn, Cu & Al, Cu & Ag it is know as spelter

→ Filler metal is enter into workpiece by means of capilory action

→ strength of joint is more than soledring but less than weldeng

→ Flux material used is Borax.

Application: ① Joining of hydrollic circuit to minimize leakage
② Febrication of heat exchanger & radiator.

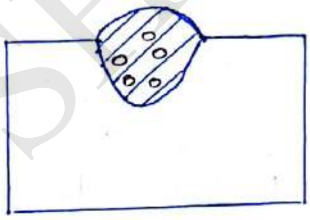
Braze welding :- Filler material melting temp is Greater than 427° (> 427°) and less then melting temp. of base material.

- → Filler metal is an alloy of Cu + Tin (Bronze)
- → Filler metal is enter into the workpiece by means of gravity force.
- → Strength of the joint is more.

Application :- ① Joining of cutting tool tips.

Welding Defects

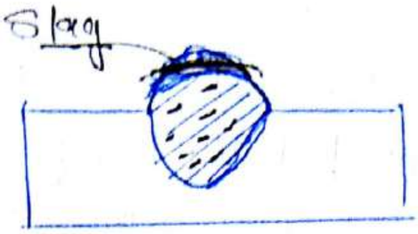
① Gas porosity :-



If the liquid metal is absorbing gasses from atmosphere and they will trapped inside the weld bead will form gas porosity.

Remedies :- ① Provide sufficient amount of flux & protect liquid metal by providing inert gas atmosphere.

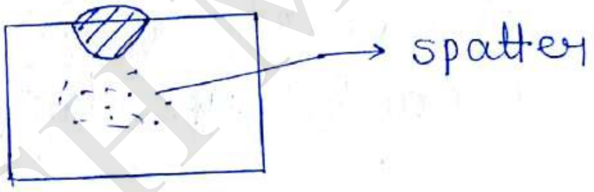
② Slag inclusion:-



Due to lack of heat input and ~~insuff~~ improper possitioning of welding torch with workpiece, if the slag is trapped inside liquid metal will form slag inclusion.

Remedies:- Provide sufficient amount of heat input and position the welding torch properly.

③ Weld spatter:-



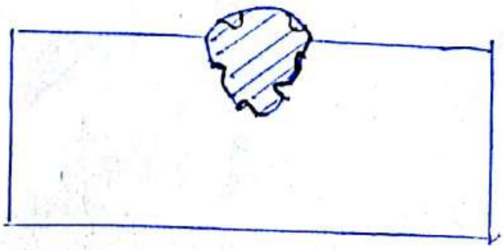
Due to excess amount of heat input liquid metal can be splash off to the base metal will form a rough surface know as weld spatter.

Remedies: ① Provide sufficient amount of heat input

② Reduce are blow.

③ select optimum welding speed.

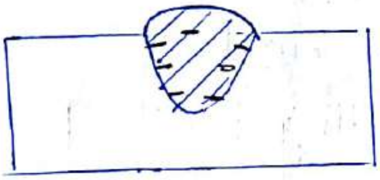
④ lack of fusion & Penetration:-



Due to ~~excess~~ leck of heat input and excess amount of welding speed filler metal is not fused properly with base metal and depth of penetration is less

Remedies!- ① Provide sufficient amount of heat input
② Select optimum welding speed.

⑤ Cracks :-



⇒ Due to non uniform cooling Internal stress will be develope inside the weld weed.

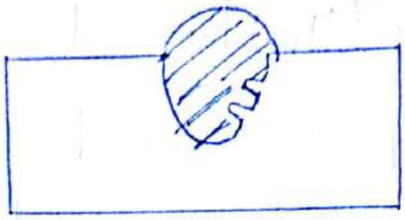
If the stess will be more than the strength of material cracks will be form.

Hydrozen embrittlement !- If atmosphere gas trapped into the weld ~~weed~~ bead and it will be penetrated into the base metal will form a crack known as hydrozen embrittlement.

Remedies!- Provide uniform cooling using preheating and post heating.
Preheat the electrode before welding

⑥ Weld Decay :-

only in case of
stainless steel.
(SS)



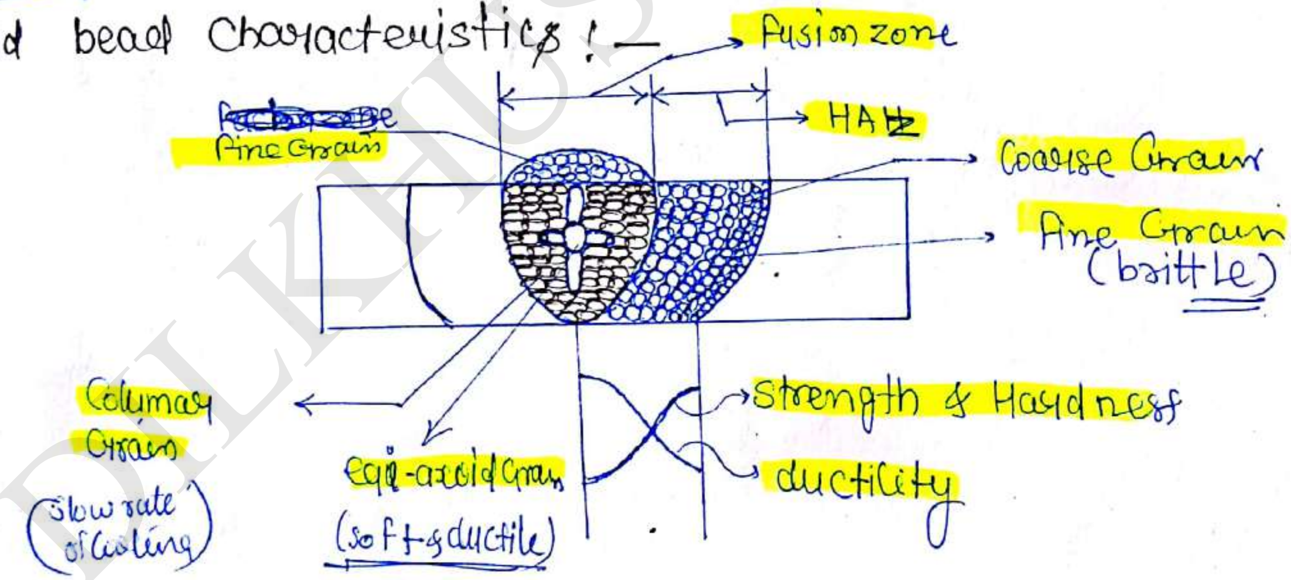
$Cr \xrightarrow{O_2} Cr_2O_3$

In stainless steel due to fast rate of Cooling Chromium will be converted in chromium carbide. Due to this in absence of Chromium there is a possibility of Corroson will takes place Due to ~~which~~ this there is possibility of cavities can be form in the weld bead is known as weld decay.

This can be overcome by providing uniform Cooling with preheating and post heating.

* V. Imp

Weld bead Characteristics :-



★ Weldability

Weldability

① Melting temp (T_m) ↑ ⇒ ↓

② thermal Conductivity (K) ↑ ⇒ ↓

③ Coeff. thermal expansion (α) ↑ ⇒ ↓

④ % of Carbon ↑ ⇒ ↓

⑤ oxide formation. tendency ↑ ⇒ ↓

eg Which is easy to weld → m.s, Al, Cu, C.I.

⇒ order m.S., CI, Cu, Al → oxide formation

FORMING

FORMING: Forming Process also known as Metal Forming is a large set of manufacturing process by which a raw material converted into a product. In this process, we apply stresses like tension, compression, shear, etc. to deformed the raw material. The example of forming processes are sheet metal manufacturing, forging, rolling, extrusion, wire drawing, thread rolling, rotary swinging, and so on.

Metal forming is a process in which the desired shape and size of a material is obtained by plastic deformation. In metal forming, stresses are induced in the material which are greater than its yield strength but lesser than its fracture strength, so that the material can be deformed into the desired shape and size. During plastic deformation, the material plastically flows and elongates in the direction of the flow of the material.

Elastic and plastic deformation: Deformation is the change in dimensions or form of a material under the action of any applied force or load. The deformation can be (i) elastic or (ii) plastic. Elastic deformation disappears completely when load is removed. Plastic deformation is a permanent deformation without failure and takes place when elastic range of the deformation has been exceeded. The plastic deformation does not disappear when load is removed.

Plastic flow of metals: Metals show a permanent and non-recoverable deformation when stressed beyond a certain minimum stress. This deformation is called plastic deformation. The plastic deformation takes place as the result of permanent displacement of atoms, molecules or group of both atoms and molecules from their original position in the lattice. The displaced atoms and molecules do not return to their original position even after the removal of stress. Now, in case stresses are increased, the metal may show a continuously increasing deformation. This phenomenon is plastic flow of metals.

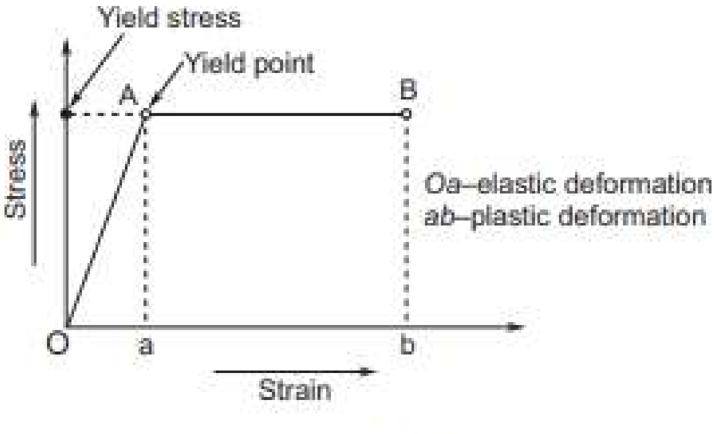


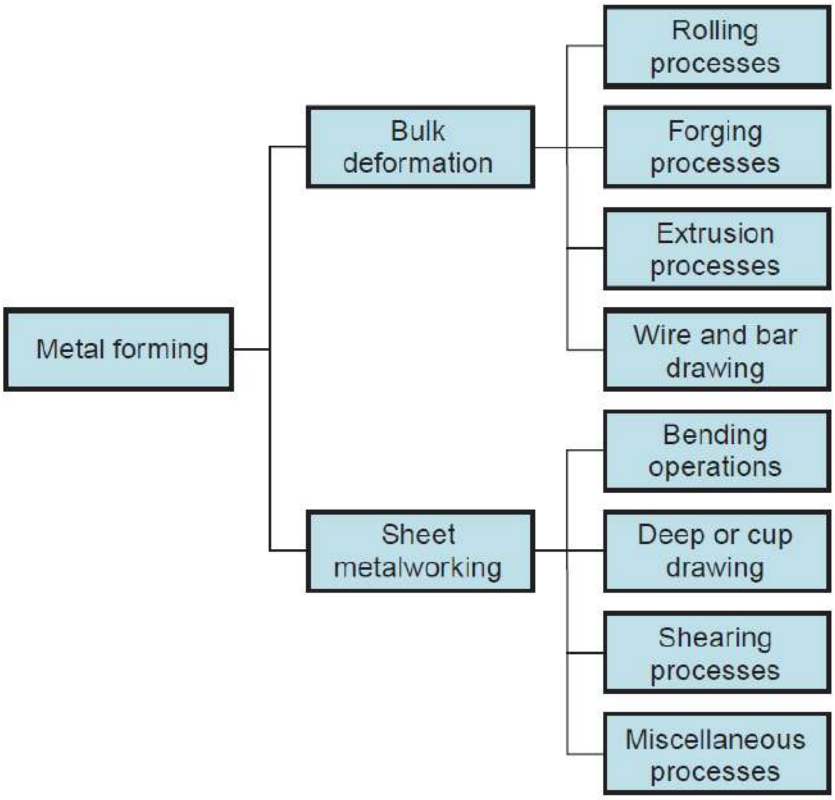
Fig. 2.1 Elastic and plastic deformation.

Factors Affecting Plastic Deformation

1. **Applied stress:** The plastic deformation depends upon the applied stress. The applied stress has to be higher than the yield strength and lower than the fracture strength. The plastic deformation increases with the applied stresses when these stresses are in between the yield strength and the fracture strength.

2. **Deformation temperature**: The metal strength decreases as the temperature is increased. Metal plasticity is greatest when deformation temperature is above the recrystallization temperature but below the melting point of the metal. Recrystallization temperature is the temperature at which the material becomes sufficient plastic for deformation due to the formation of new grains which can flow in the direction of elongation.
3. **Strain rate:** The change of deformation in a unit time is called strain rate. The plastic deformation is more at higher strain rate

Classification of Metal Forming



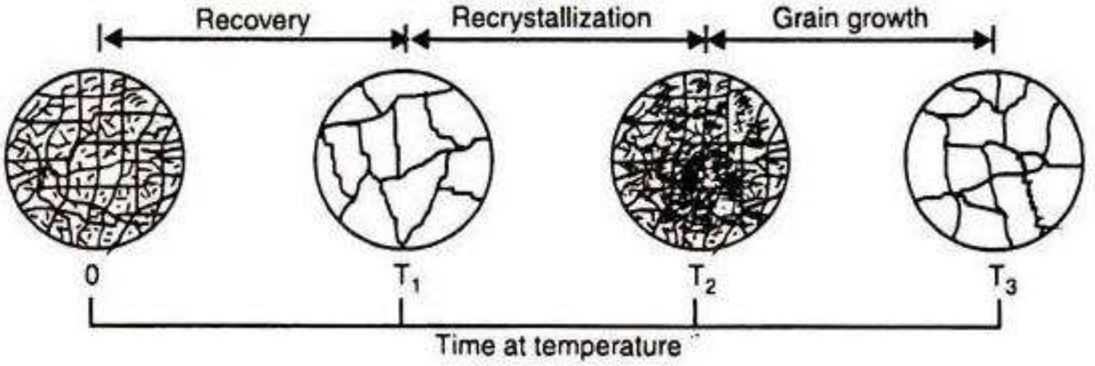
Bulk Forming:

One of the most important forming processes is the Bulk Forming process. This process can be used when the volume ratio of the metal is higher than the surface area. Along with that, the bulk-forming process works due to different types of forces. They are the shear force, the combination of tensile, and the compressive force.

Sheet Metal Forming:

Another important forming process is the Sheet Forming process. This sheet forming process works due to either the tensile force or the shear force. Usually, this force can be used in Hydraulic presses in order to produce the product from the sheets however some more steps like squeezing, bending and so on are also included in this process. In this process, no material is added or removes. Example of this type of forging is bending, deep drawing, shearing, etc.

Relationship between recovery, recrystallization and grain growth



Deformed metal, in comparison with its undeformed state, is in a non-equilibrium, thermodynamically unstable state. Therefore, spontaneous processes occur in strain-hardened metal, even at room temperature, which bring it into a more stable condition. If the temperature is raised sufficiently, the metal attempts to approach equilibrium through three processes: (a) recovery, (b) recrystallization, and (c) grain growth.

Recovery: It is a low-temperature phenomenon that results in the restoration of physical properties without noticeable change in microstructure. The recovery is critical for releasing internal stresses in forging, welded, and fabricated equipment without reducing the strength gained during and after working.

Recrystallization: It is a process in which distorted grains of cold worked metal are replaced by new strain free grains when heated above a temperature known as the recrystallization temperature. Recrystallization causes a sharp decrease in hardness and strength while increasing ductility. Recrystallization is a process by which deformed grains are replaced by a new set of defects-free grains that nucleate and grow until the original grains have been entirely consumed. Recrystallization is usually accompanied by a reduction in the strength and hardness of a material and a simultaneous increase in the ductility.

Grain growth: Grain growth is the increase in size of grains (crystallites) in a material at high temperature. This occurs when recovery and recrystallization are complete and further reduction in the internal energy can only be achieved by reducing the total area of grain boundary. The term is commonly used in metallurgy but is also used in reference to ceramics and minerals.

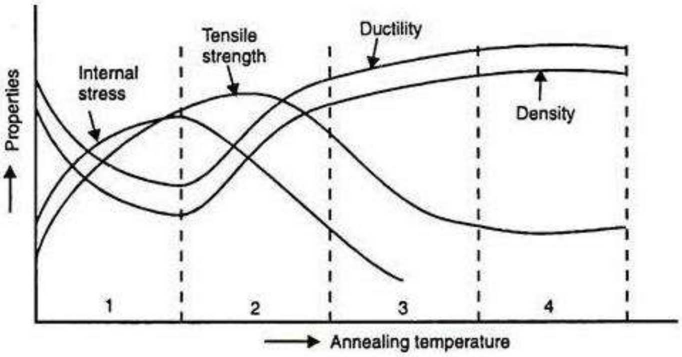
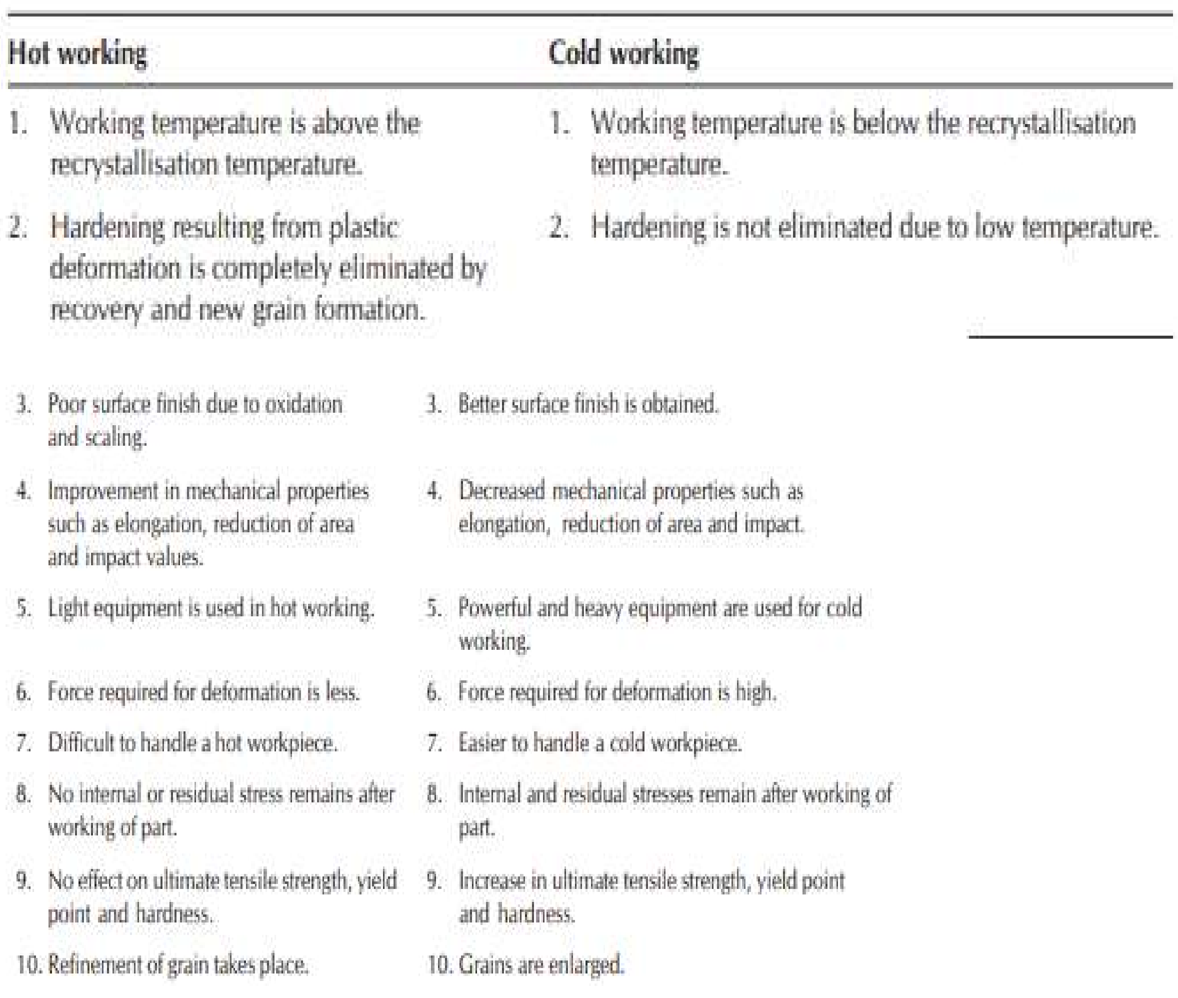


Fig. 3.21. 1. Cold worked 2. Recovery 3. Recrystallization 4. Grain growth.

Compare hot working and cold working processes.

Hot working: Hot working is defined as the process which is done above the recrystallization temperature but below the melting temperature of the metal. The recrystallization temperature for lead and tin metals is always below the room temperature. Hence, the working of these metals at room temperature is always considered hot working. The recrystallization temperature of steel is about 1000°C. Hence, working of steel below 1000°C is considered cold working. Hot rolling, hot forging and hot spinning are hot working processes.

Cold working: Cold working is defined as the process which is done below the recrystallization temperature. Generally, recrystallization temperature of metal varies between 30% to 50% of melting temperature.



Hot working	Cold working
1. Working temperature is above the recrystallisation temperature.	1. Working temperature is below the recrystallisation temperature.
2. Hardening resulting from plastic deformation is completely eliminated by recovery and new grain formation.	2. Hardening is not eliminated due to low temperature.
3. Poor surface finish due to oxidation and scaling.	3. Better surface finish is obtained.
4. Improvement in mechanical properties such as elongation, reduction of area and impact values.	4. Decreased mechanical properties such as elongation, reduction of area and impact.
5. Light equipment is used in hot working.	5. Powerful and heavy equipment are used for cold working.
6. Force required for deformation is less.	6. Force required for deformation is high.
7. Difficult to handle a hot workpiece.	7. Easier to handle a cold workpiece.
8. No internal or residual stress remains after working of part.	8. Internal and residual stresses remain after working of part.
9. No effect on ultimate tensile strength, yield point and hardness.	9. Increase in ultimate tensile strength, yield point and hardness.
10. Refinement of grain takes place.	10. Grains are enlarged.

The advantages of hot working are:

1. Homogenity of material is improved.
2. Due to grain refinement, physical properties of material are improved.
3. Material becomes soft at hot temperature, thereby change of shape can be easily achieved.
4. Energy needed for deformation is much less as compared to cold working.
5. Porosity of the material is largely eliminated.

The disadvantages of hot working are:

1. Oxidation and scaling lead to poor surface finish.
2. Dimensional accuracy is poor.
3. Equipment and its maintenance for hot working are costly.
4. Certain metals are brittle at high temperature and these metals cannot be hot worked

The advantages of cold working are:

1. Cold working increases the strength and hardness of the material due to strain hardening.
2. Good surface finish as oxidation or scaling takes place.
3. Good dimensional accuracy is possible.
4. Better mechanical properties are achieved.
5. Economical for small parts.
6. Handling of parts is easier

The disadvantages of cold working are:

1. Large parts are difficult to be worked.
2. Residual stresses can be harmful.
3. Suitable for ductile materials.
4. Tooling cost is high where high production is required.
5. High energy required for plastic deformation.

FORGING

Definition: Forging is a metal working process in which useful shape is obtained in solid state by hammering or pressing metal. It is one of the oldest metalworking arts with its origin about some thousands of years back. Some examples of shapes obtained by forging process: Crane hook, connecting rod of IC engine, spanner, and gear blanks...etc.

Classification of Forging Processes

Based on Temperature of the work piece:

1. Hot Forging
2. Cold Forging

Hot Forging: (most widely used) Forging is carried out at a temperature above the recrystallization temperature of the metal.

Advantages of Hot Working:

1. High strain rates and hence easy flow of the metal
2. Recrystallization and recovery are possible
3. Forces required are less

Di**sadvantages of Hot Working:**

1. Lubrication is difficult at high temperatures
2. Oxidation and scaling occur on the work
3. Poor surface finish
4. Dies must withstand high working temperature

Cold Forging: Forging is carried out at a temperature below the recrystallization temperature of the metal.

Advantages:

1. Less friction between die surface and work piece
2. Lubrication is easy
3. No oxidation or scaling on the work
4. Good surface finish

Disadvantages of Cold Working:

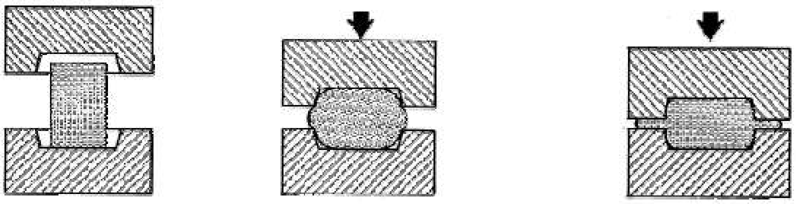
1. Low strain rates, hence less reduction per pass.
2. Recrystallization and recovery do not occur.
3. Hence, annealing is required for further deformation in subsequent cycles.
4. Forces required are high.

Different Forging Operations

1. Upsetting
2. Edging
3. Fullering
4. Drawing
5. Swaging

6. Piercing
7. Punching
8. Bending

Upsetting: The thickness of the work reduces and length increases



Steps: (i) (ii) (iii) Final

Edging: The ends of the bar are shaped to requirement using edging dies

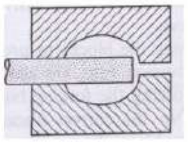


Fig 2. Edging

Fullering: The cross sectional area of the work reduces as metal flows outward, away from centre

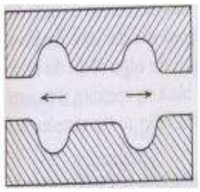


Fig 3. Fullering

Drawing: The cross sectional area of the work is reduced with corresponding increase in length using convex dies

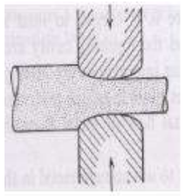


Fig 4. Drawing

Swaging: The cross sectional area of the bar is reduced using concave dies.

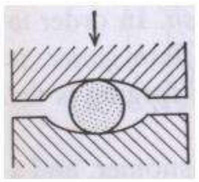


Fig 5. Swaging

Piercing: The metal flows around the die cavity as a moving die pierces the metal.

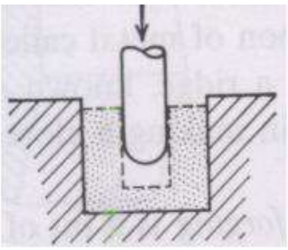


Fig 6. Piercing

Punching: It is a cutting operation in which a required hole is produced using a punching die.

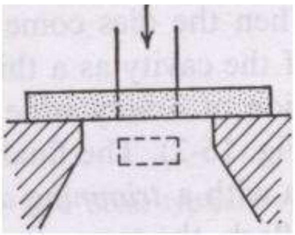
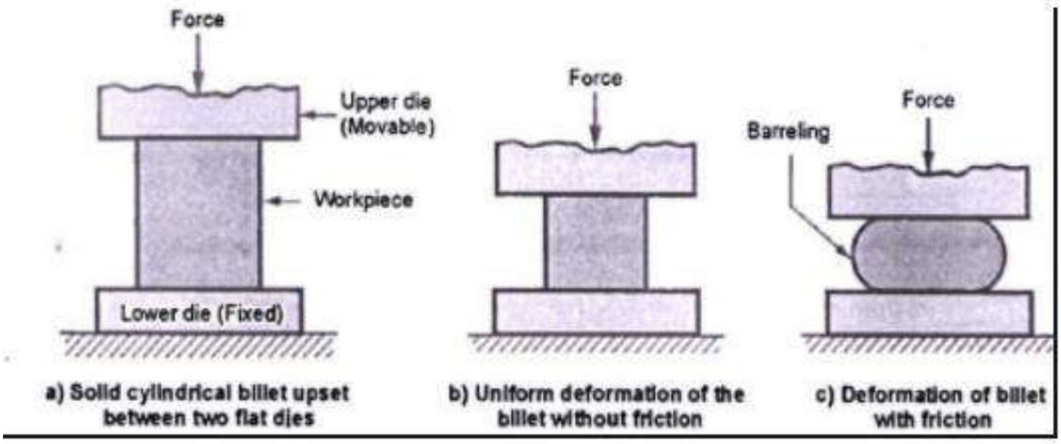


Fig 7. Punching

Bending: The metal is bent around a die/anvil.

Open forging (Smith Forging): It is the simplest forging process which is quite flexible but not suitable for large scale production. It is a slow process. The resulting size and shape of the forging are dependent on the skill of the operator. Open die forging does not confine the flow of metal; the operator obtains the desired shape of forging by manipulating the work material between blows.



a) Solid cylindrical billet upset between two flat dies

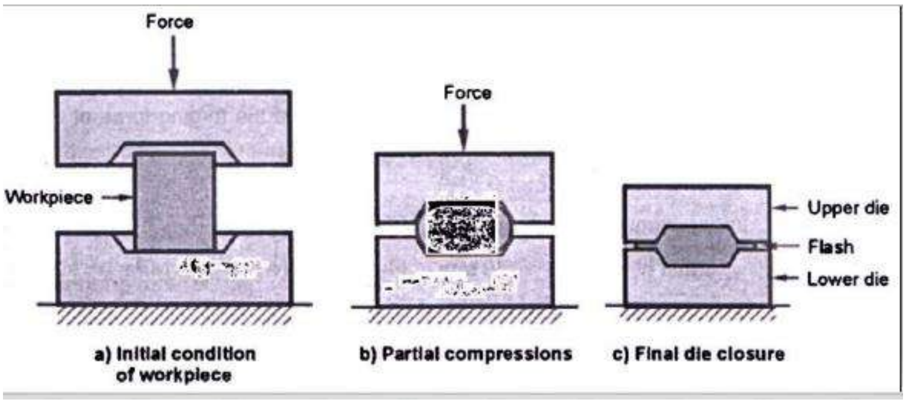
b) Uniform deformation of the billet without friction

c) Deformation of billet with friction

Open-die forging operations are applied in an open environment with several workforces. There is a ram or hydraulic press that shapes the hot bulk metal into desired shapes. The most common practice is decreasing the height of the metal billet and increasing the diameter of that billet. The obtained shape is shaped into exact shapes with additional processes. The workforce is very important in open-die forging processes. Because, the work piece must be manipulated, moved rotated, etc. via a worker or operator. The ability of the worker is very important.

1. It is the simplest and important forging process.
2. The shapes generated by this process are simple like shafts, disks, rings, etc.
3. An example of open-die forging in the steel industry is the shaping of a large square cast ingot into a round cross-section.
4. Open-die forging operations produce rough forms of work piece hence, subsequent operations are required to refine the parts to final shape.
5. Open-die forging process can be depicted by a solid work piece placed between the two flat dies (lower die is fixed and upper die is moving) and reduced in height by compressing it. This process is called as upsetting or flat-die forging.

Drop forging (Closed die Forging): The process uses shaped dies to control the flow of metal. The heated metal is positioned in the lower cavity and on it one or more blows are struck by the upper die. This hammering makes the metal to flow and fill the die cavity completely. Excess metal is squeezed out around the periphery of the cavity to form flash. On completion of forging, the flash is trimmed off with the help of a trimming die.



1. Impression-die or closed-die forging is performed with dies which contain the inverse of the required shape of the component.
2. Initially, the cast ingot is placed between the two impressed dies. As the die closes to its final position, flash is formed by the metal.
3. This flash flows beyond the die cavity and into the small gap between the die plates.
4. The formed flash must be cut away from the final component in a subsequent trimming operation but it performs an important function that, increases the resistance to the deformation of the metal
5. The initial steps in the process are used to redistribute the metal in the work part to achieve a uniform deformation and required metallurgical structure in the subsequent steps.

6. The final steps bring the component to its final geometry. Also, when drop forging is used, a number of blows of the hammer may be used for each step.
7. As flash is formed during the process, this process is used to produce more complex components by using dies

FORGING DEFECTS Though forging process give generally prior quality product compared other manufacturing processes. There are some defects that are lightly to come a proper care is not taken in forging process design. A brief description of such defects and their remedial **method is given below.**

1. **Unfilled Section:** In this some section of the die cavity are not completely filled by the flowing metal. The causes of this defect are improper design of the forging die or using forging techniques.
2. **Cold Shut:** This appears as small cracks at the corners of the forging. This is caused mainly by the improper design of die. Where in the corner and the fillet radii are small as a result of which metal does not flow properly into the corner and the ends up as a cold shut.
3. **Scale Pits:** This is seen as irregular deputations on the surface of the forging. This is primarily caused because of improper cleaning of the stock used for forging. The oxide and scale gets embedded into the finish forging surface. When the forging is cleaned by pickling, these are seen as deputations on the forging surface.
4. **Die Shift:** This is caused by the miss alignment of the die halve, making the two halve of the forging to be improper shape.
5. **Flakes:** These are basically internal ruptures caused by the improper cooling of the large forging. Rapid cooling causes the exterior to cool quickly causing internal fractures. This can be remedied by following proper cooling practices.
6. **Improper Grain Flow:** This is caused by the improper design of the die, which makes the flow of the metal not flowing the final interred direction
7. **Fins:** These are small projections on the pieces of loose Meta protruding outside the forged surface they occur mainly at parting planes of the dies possible cause is more amount of metal then required.

ROLLING

ROLLING: Deformation process in which work thickness is reduced by compressive forces exerted by two opposing rolls.

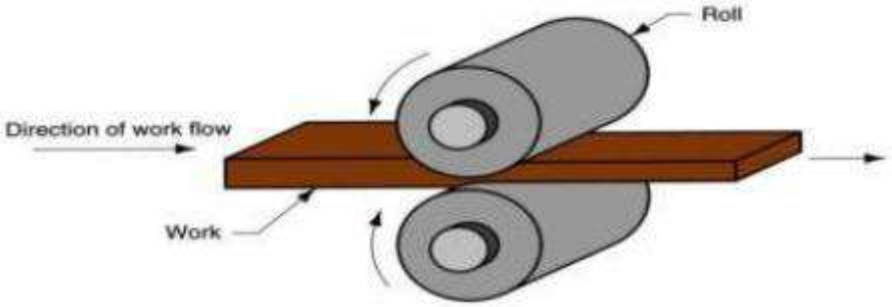


Fig: rolling process

The rotating rolls perform two main functions:

1. Pull the work into the gap between them by friction between work part and rolls
2. Simultaneously squeeze the work to reduce cross section

TYPES OF ROLLING

1. **By geometry of work:**
    - Flat rolling - used to reduce thickness of a rectangular cross-section
    - Shape rolling - a square cross-section is formed into a shape such as an I-beam
3. **By temperature of work:**
    - Hot Rolling - most common due to the large amount of deformation required
    - Cold rolling - produces finished sheet and plate stock

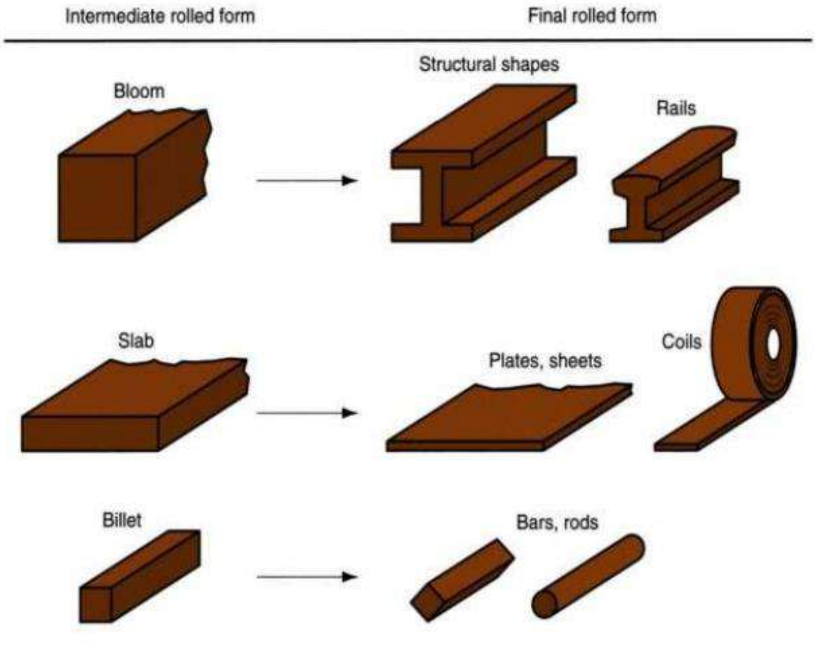


Fig 2.5 - Some of the steel products made in a rolling mill

Difference between hot rolling and cold rolling

S.No	HOT ROLLING	COLD ROLLING
1	Metal is fed to the rolls after being heated above the recrystallization temperature.	Metal is fed to the rolls when it is below the recrystallization temperature
2	In general rolled metal does not shows work hardening effect.	The metal shows the working hardening effect after being cold rolled
3	Co-efficient of friction between two rolls and the stock is higher; it may even cause shearing of the metal in contact with rolls.	Co-efficient of friction between two rolls and the stock is comparatively lower
4	Experiment measurements are difficult to make.	Experiment measurement can be carried out easily in cold rolling.
5	Heavy reduction in area of the work piece can be obtained.	Heavy reduction is not possible.
6	Mechanical properties are improved by breaking cast structure are refining grain sizes below holes and others, similar deformation in ingot (get welded) and or removed the strength and the toughness of the job should increases.	Hotness increased excessive cold working greatness crackers ductility of metal reduction. Cold rolling increased the tensile strength and yield strength of the steel
7	Rolls radius is generally larger in size	Rolls radius is smaller
8	Very thin sections are not obtained	Thin sections are obtained
9	Hot roll surface has(metal oxide) on it , this surface finish is not good	The cold rolled surface is smooth and oxide free
10	Hot rolling is used un ferrous as well as nonferrous metals such as industries for steel , aluminium, copper , brass, bronze , alloy to change ingot into slabs	Cold rolling is equally applicable to both plain and alloys steels and nonferrous metals and their alloys
11	Hot rolling is the father of the cold rolling	Cold rolling follows the hot rolling

Rolling stand arrangements or

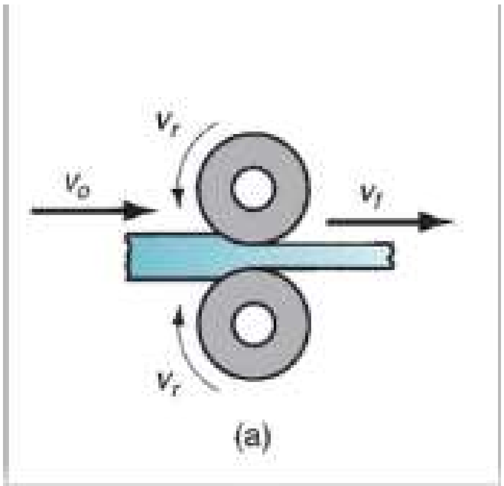
Types of Rolling mills: Rolling mills may be classified according to the number and arrangement of the rolls.

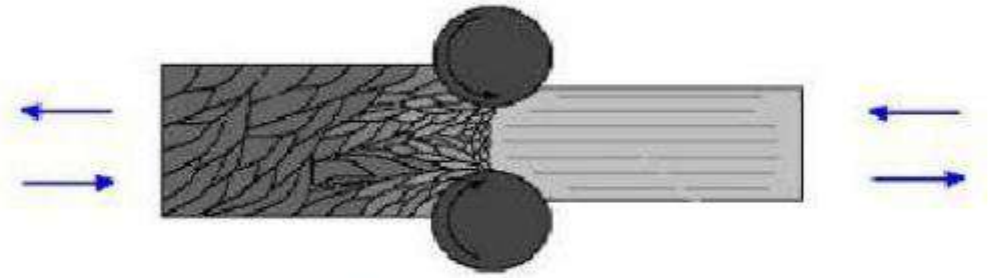
1. Two high rolling mills
2. Three high rolling mills
3. Four high rolling mills
4. Tandem rolling mills
5. Cluster rolling mills

Two high rolling mills: A two high rolling mill has two rolls only. Two high rolling mills may further classified as

1. Reversing mill
2. Non reversing mill

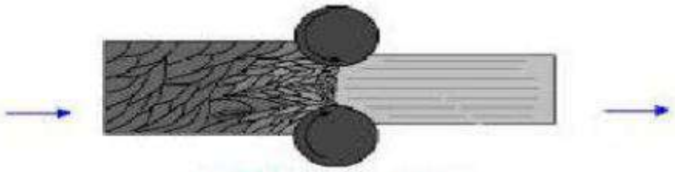
Two high reversing mill: In two high reversing rolling mills the rolls rotate is in one direction and then in the other, so that rolled metal may pass back and forth through the rolls several times. This type is used in pluming and slabing mills and for roughing work in plate, rail, structural and other mills. These are more expensive compared to the non-reversing rolling mills. Because of the reversible drive needed.





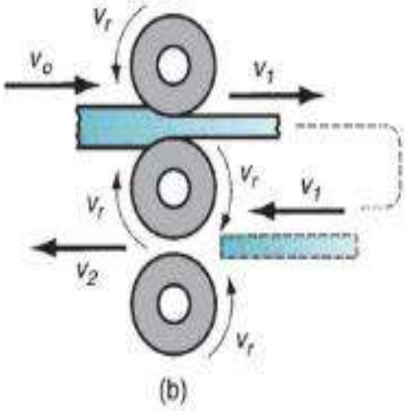
Reversing Mills

Two high non reversing mill: In two high non reversing mills as two rolls which revolve continuously in same direction therefore smaller and less costly motive power can be used. However every time material is to be carried back over the top of the mill for again passing in through the rolls. Such an arrangement is used in mills through which the bar passes once and in open train plate mill.

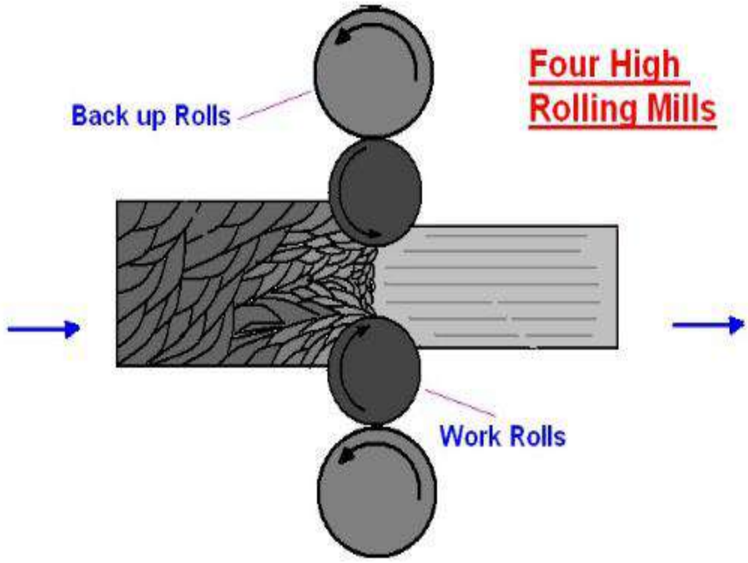


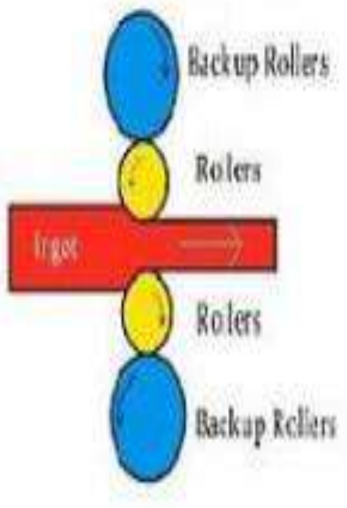
Non Reversing Mills

Three high rolling mill: It consists of a roll stand with three parallel rolls one above the other. Adjacent rolls rotate in opposite direction. So that the material may be passed between the top and the middle roll in one direction and the bottom and middle rolls in opposite one. In three high rolling mills the work piece is rolled on both the forward and return passes. First of all the work piece passes through the bottom and middle rolls and the returning between the middle and the top rolls. So that thickness is reduced at each pass. Mechanically operated lifted tables are used which move vertically or either side of the stand. So that the work piece fed automatically into the roll gap. Since the rolls run in one direction only a much less powerful motor and transmission system is required. The rolls of a three high rolling mills may be either plain or grooved to produce plate or sections respectively.

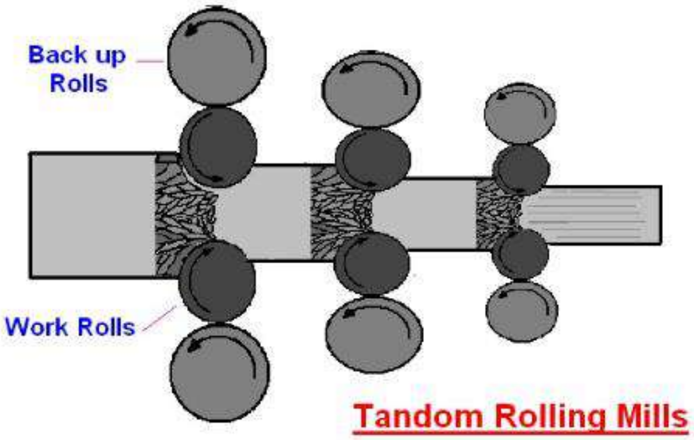


Four high rolling mill: It has a roll stand with four parallel rolls one above the other. The top and the bottom rolls rotate in opposite direction as do the two middle rolls. The two middle are smaller in size than the top and bottom rolls which are called backup rolls for providing the necessary rigidity to the smaller rolls. A four high rolling mill is used for the hot rolling of armor and other plates as well as cold rolling of plates, sheets and strips.

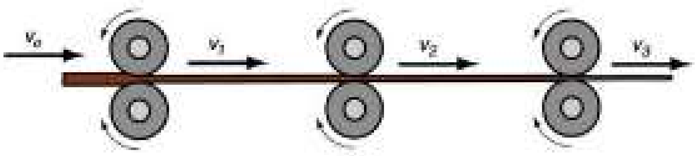




Tandem rolling mills: It is a set of two or three stands of roll set in parallel alignment. So that a continuous pass may be made through each one successively with change the direction of material.



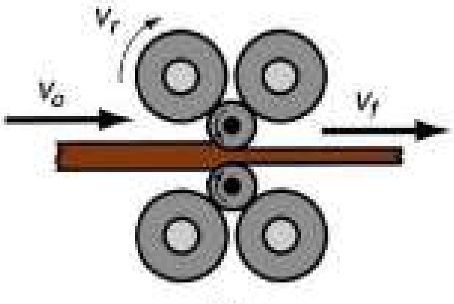
Tandom Rolling Mills



(e)

tandem rolling mill

Cluster rolling mills: It is a special type of four high rolling mill in which each of the two working rolls is backup by two or more of the larger backup rolls for rolling hard in materials. It may be necessary to employ work rolls of a very small diameter but of considerable length. In such cases adequate of the working rolls can be obtained by using a cluster mill.



(d)

cluster mill

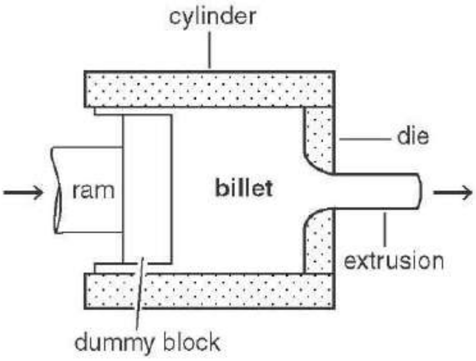
Angle-of-Bite

In rolling metals where all forces are transmitted through the rolls, the maximum angle that can be attained between the roll radius at the first contact and the line of roll centers. Operating angles less than the angle of bite are called contact or rolling angles.

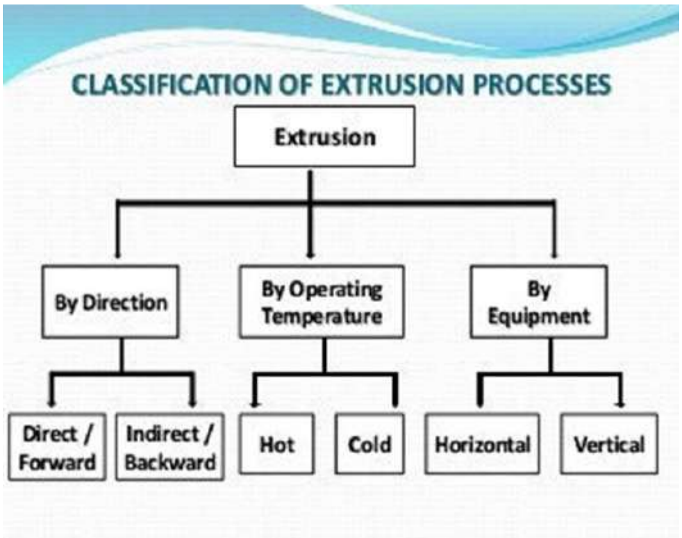
EXTRUSION

Extrusion is a **metal forming process** in which metal or work piece is forced to flow through a die to reduce its cross section or convert it into desire shape. This process is extensively used in pipes and steel rods manufacturing. The force used to extrude the work piece is compressive in nature. This process is similar to drawing process except drawing process uses tensile stress to extend the metal work piece. The compressive force allows large deformation compare to drawing in single pass. The most common material extruded are plastic and aluminium.

Extrusion is a metal working process in which cross section of metal is reduced by forcing the metal through a die orifice under high pressure. It is used to produce cylindrical bars, tubes and sections of any regular or irregular types. Forces required to extrude a metal are quite high and hence hot extrusion is most widely done as deformation resistance of metal is low at high temperature. However, cold extrusion is also performed for soft metals like Aluminium, lead etc. Difficult to form metals like stainless steels, nickel based alloys and high temperature metals can also be extruded.



CLASSIFICATION OF EXTRUSION PROCESS



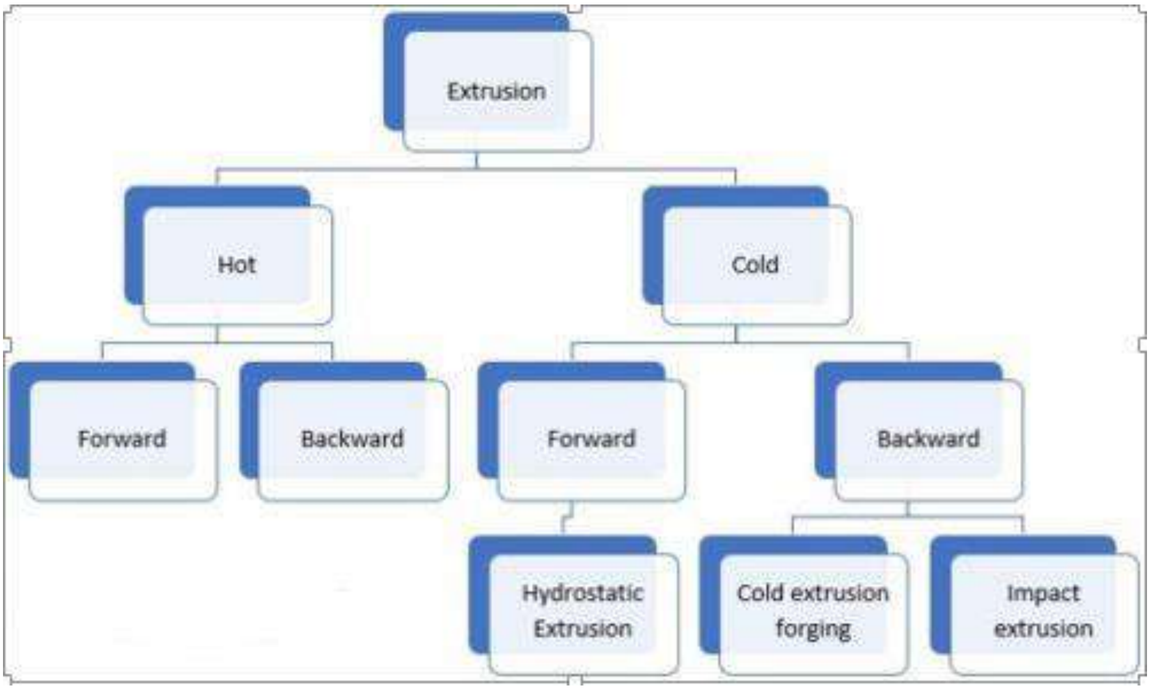


Fig: classification of Extrusion process

Working Principle: Extrusion is a simple compressive metal forming process. In this process, piston or plunger is used to apply compressive force at work piece. These process can be summarized as follow.

1. First billet or ingot (metal work piece of standard size) is produced.
2. This billet is heated in hot extrusion or remains at room temperature and placed into a extrusion press (Extrusion press is like a piston cylinder device in which metal is placed in cylinder and pushed by a piston. The upper portion of cylinder is fitted with die).
3. Now a compressive force is applied to this part by a plunger fitted into the press which pushes the billet towards die.
4. The die is small opening of required cross section. This high compressive force allow the work metal to flow through die and convert into desire shape.
5. Now the extruded part remove from press and is heat treated for better mechanical properties.

Advantages of Extrusion

1. High extrusion ratio (It is the ratio of billet cross section area to extruded part cross section area).
2. It can easily create complex cross section.
3. This working can be done with both brittle and ductile materials.
4. High mechanical properties can achieved by cold extrusion.

Disadvantages of Extrusion:

1. High initial or setup cost.
2. High compressive force required.

Application of Extrusion:

1. Extrusion is widely used in production of tubes and hollow pipes.
2. Aluminum extrusion is used in structure work in many industries.
3. This process is used to produce frames, doors, window etc. in automotive industries.
4. Extrusion is widely used to produce plastic objects.

Types of Extrusion: Extrusion can be broadly classified into two types, one is **Hot Extrusion** another one is **Cold Extrusion**. These aforementioned categories are also subdivided into categories, they are as follows

1. **Hot Extrusion**
    a. Forward Extrusion
    b. Backward Extrusion
2. **Cold Extrusion**
    1. Forward Extrusion
        a. Hydrostatic Extrusion
        b. Hooker Extrusion
    2. Backward Extrusion
        a. Impact Extrusion
        b. Cold Extrusion Forging

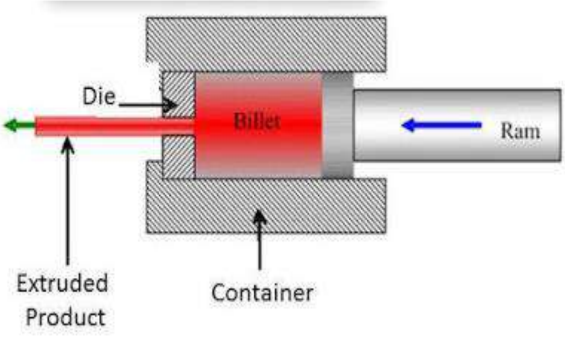
I. According to the direction of flow of metal

1. **Direct Extrusion:** In this type of extrusion process, metal is forced to flow in the direction of feed of punch. The punch moves toward die during extrusion. This process required higher force due to higher friction between billet and container**.** In this process, the metal billet is placed in a container and compressed and extruded through the die by a ram.

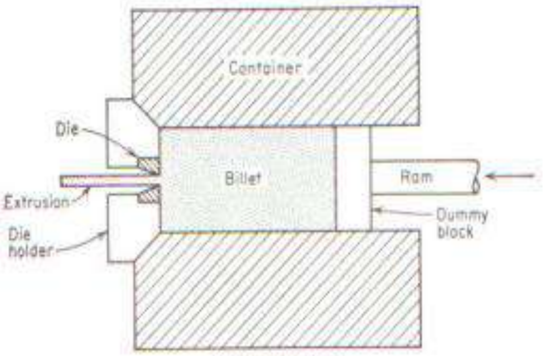
Some features of direct extrusion:

1. Both the ram and extrusion move in the same direction. A dummy block or pressure plate is in contact with the billet and ram.
2. The relative motion between billet and container wall develops high friction. Hence power required is relatively high.

3. Brittle metals like Tungsten, Titanium alloys are difficult to extrude because they fracture during the process. Fractures occur because of rapid growth of micro cracks due to tensile stresses



Direct Extrusion



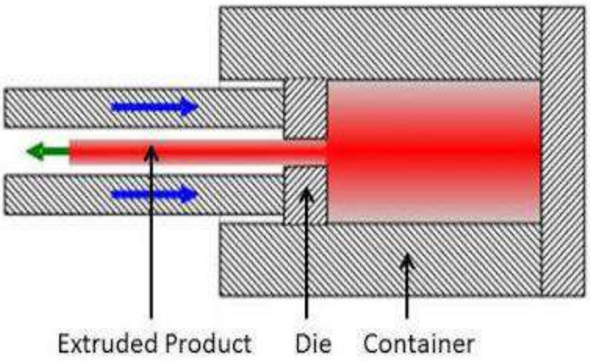
Direct extrusion

2. **Indirect Extrusion:** In this process, metal is flow toward opposite direction of plunger movement. The die is fitted at opposite side of punch movement. In this process, the metal is allowed to flow through annular space between punch and container. A hollow ram compresses metal through a die in a direction opposite to ram motion. Either the ram is moved against a stationery billet or the billet (hence container) is made to move against stationery ram.

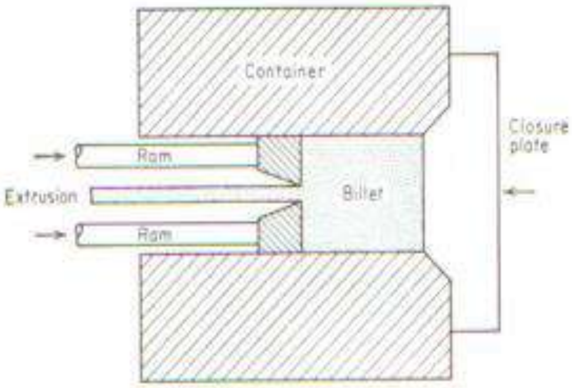
   Some features of indirect extrusion:

   a. There is no relative motion between the billet and the wall of the container.
   b. Hence friction is lower and power required is relatively less.

   Limitation; Due to hollow ram, the load that can be applied is limited and only small sections can be extruded**.**

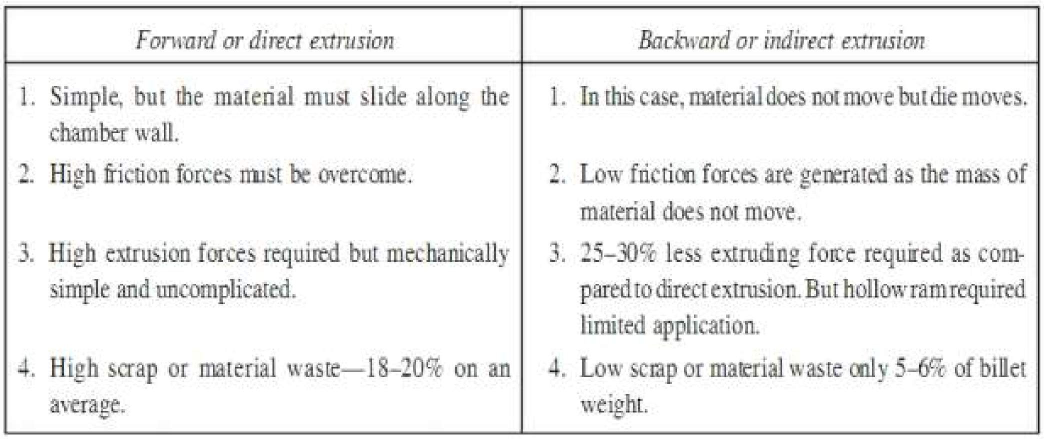


Indirect Extrusion



Indirect extrusion

Compare forward extrusion and backward extrusion



Forward or direct extrusion	*Backward or indirect extrusion*
1. Simple, but the material must slide along the chamber wall.	1. In this case, material does not move but die moves.
2. High friction forces must be overcome.	2. Low friction forces are generated as the mass of material does not move.
3. High extrusion forces required but mechanically simple and uncomplicated.	3. 25–30% less extruding force required as compared to direct extrusion. But hollow ram required limited application.
4. High scrap or material waste—18–20% on an average.	4. Low scrap or material waste only 5–6% of billet weight.

3. **Impact Extrusion:** In this process a punch moves into the die and squeezes metal around the die cavity. It may have either direct or indirect extrusion arrangement. It is useful to produce short lengths of hollow shapes like collapsible tooth paste tubes and thin walled cans.

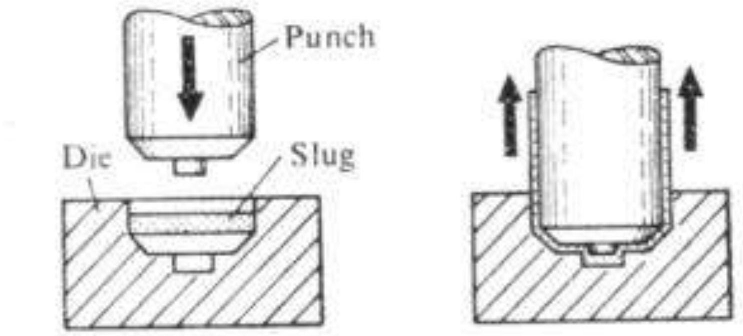


Fig. Impact Extrusion

   a. It is usually a cold working process, but the high speed of deformation develops heating. The process is limited to soft metals like lead, tin, aluminium, copper.
   b. Impact extrusion is performed at higher speeds and shorter strokes than conventional extrusion. It is used to make individual components. As the name suggests, the punch impacts the work part rather than simply applying pressure to it.
   c. Impacting can be carried out as forward extrusion, backward extrusion, or combinations of these. Some representative examples are shown in Figure.
   d. Impact extrusion is usually done cold on a variety of metals. Backward impact extrusion is most common.

e. Products made by this process include toothpaste tubes and battery cases. As indicated by these examples, very thin walls are possible on impact extruded parts.

f. The high-speed characteristics of impacting permit large reductions and high production rates, making this an important commercial process.

g. The following figures shows the different types of impact extrusions

  i. Forward impact extrusion
  ii. Backward impact extrusion
  iii. Combined forward and backward impact extrusion

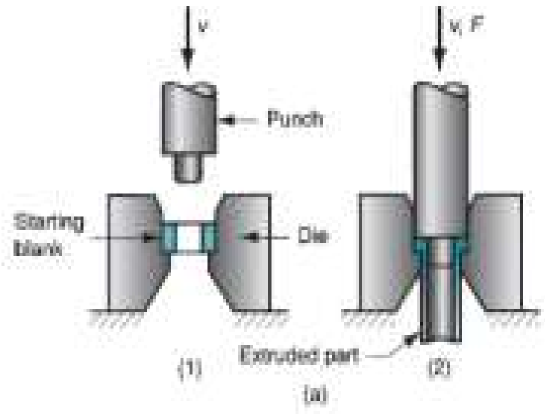


Fig: Forward Impact Extrusion

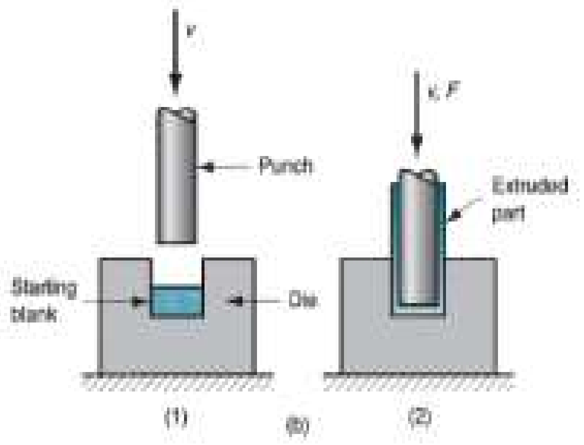


fig: Backward Impact Extrusion

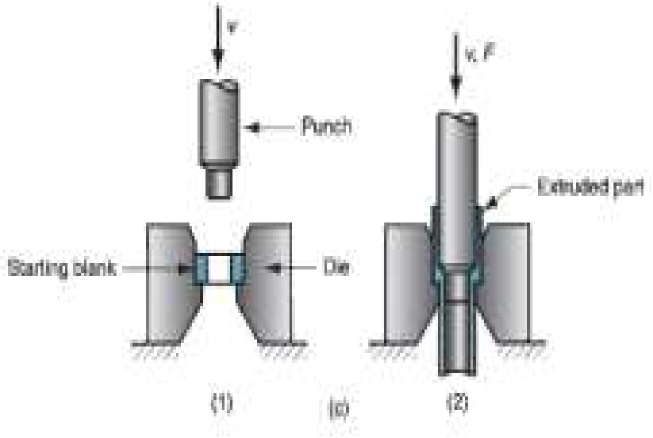
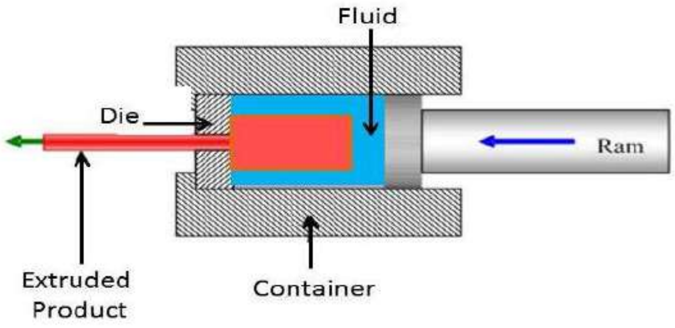


Fig: Combined Forward and Backward Impact Extrusion

4. **Hydrostatic Extrusion:** In this process the space between the ram plate and billet is filled with water. Hence billet is subjected to uniform hydrostatic pressure. Also, there is no direct contact between wall of container and work piece. Hence there is no

container-billet friction. As a result, the curve of extrusion pressure v/s ram travel is nearly flat. Therefore, large length to diameter ratios are possible.

a. One of the problems in direct extrusion is friction along the billet– container interface. This problem can be addressed by surrounding the billet with fluid inside the container and pressurizing the fluid by the forward motion of the ram, as in Figure This way, there is no friction inside the container, and friction at the die opening is reduced. Consequently, ram force is significantly lower than in direct extrusion.
b. The fluid pressure acting on all surfaces of the billet gives the process its name. It can be carried out at room temperature or at elevated temperatures. Special fluids and procedures must be used at elevated temperatures.
c. Hydrostatic extrusion is an adaptation of direct extrusion. Hydrostatic pressure on the work increases the material’s ductility. Accordingly, this process can be used on metals that would be too brittle for conventional extrusion operations



Hydrostatic Extrusion

Advantages:

1. Lubrication is very effective.
2. Extruded product has good surface finish and dimensional accuracy.
3. It is possible to use dies with very low semi cone angle (20 degrees) because friction is less.
4. This reduces extrusion pressure and improves homogeneity of deformation.
5. Redundant deformation is minimized.

Limitations:

1. Hot working is not possible.
2. Leakages of liquid are frequent due to high pressures involved (up to 1.7GPa)
3. Liquid used should not solidify at high pressure.
4. Extrusion ratios possible; 20:1 for mild steel, 200:1 for aluminium

<u>**According to the working temperature**</u>**:** Extrusion Process Can Be Classified into Two Ways

1. **Hot Extrusion:** If the extrusion process takes place above recrystallization temperature which is about 50-60% of its melting temperature, the process is known as hot extrusion.

   Advantages:

   a. Low force required compare to cold working.
   b. Easy to work in hot form.
   c. The product is free from stain hardening.

   Disadvantages:

   a. Low surface finish due to scale formation on extruded part.
   b. Increase die wear.
   c. High maintenance required.

2. **Cold Extrusion:** If the extrusion process takes place below crystallization temperature or room temperature, the process is known as cold extrusion. Aluminium cans, cylinder, collapsible tubes etc. are example of this process.

   Advantages:

   - High mechanical properties.
   - High surface finish
   - No oxidation at metal surface.

   Disadvantages:

   - High force required.
   - Product is accomplished with strain hardening.

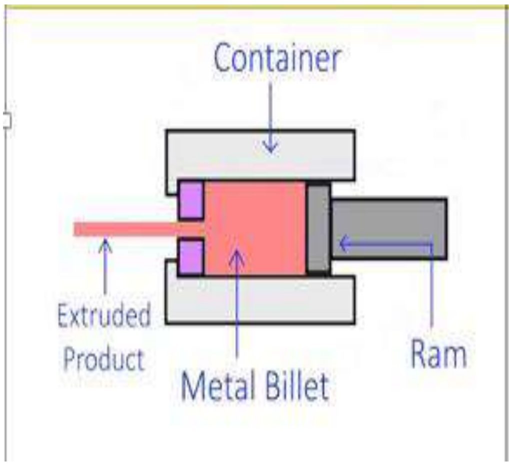


Fig: Hot Extrusion

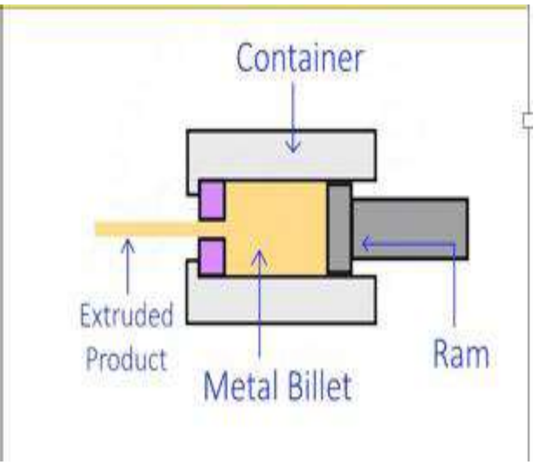
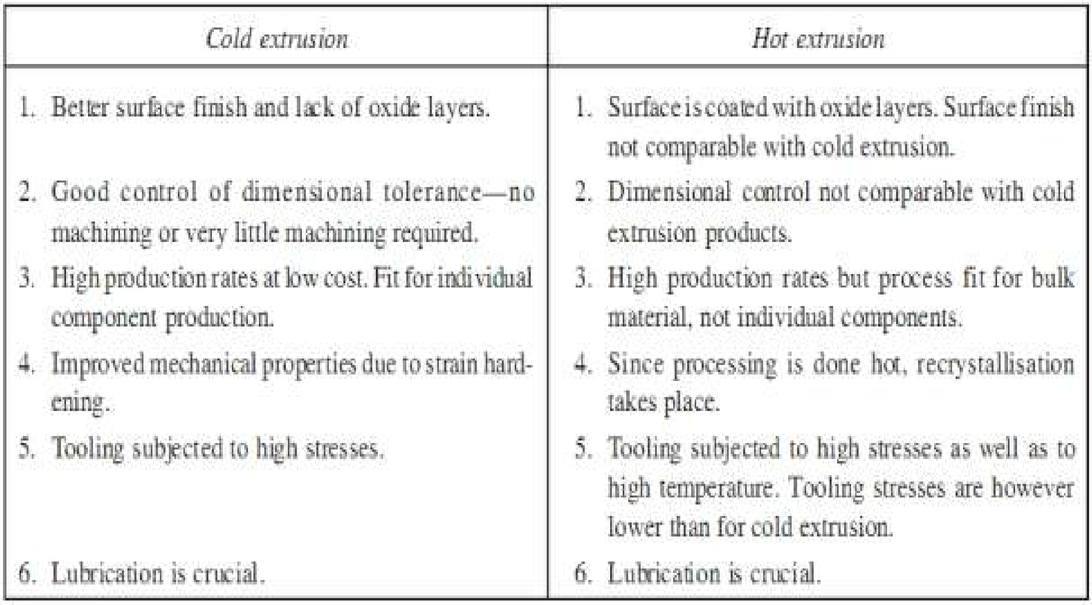


Fig: Cold Extrusion

Compare hot extrusion and cold extrusion



Cold extrusion	*Hot extrusion*
1. Better surface finish and lack of oxide layers.	1. Surface is coated with oxide layers. Surface finish not comparable with cold extrusion.
2. Good control of dimensional tolerance—no machining or very little machining required.	2. Dimensional control not comparable with cold extrusion products.
3. High production rates at low cost. Fit for individual component production.	3. High production rates but process fit for bulk material, not individual components.
4. Improved mechanical properties due to strain hardening.	4. Since processing is done hot, recrystallisation takes place.
5. Tooling subjected to high stresses.	5. Tooling subjected to high stresses as well as to high temperature. Tooling stresses are however lower than for cold extrusion.
6. Lubrication is crucial.	6. Lubrication is crucial.

DRAWING

Drawing is a metal forming process used to reduce cross section and increase length of work piece. This process associated with tensile force which distinguishes it from other metal forming processes like extrusion, forging etc. In this process a large cross section work piece is forced to pass through a die which has smaller opening comparing cross section area of work piece. This will plastically deform the work piece by decreasing its cross section area and increases its length. This process is used for making wires, rods, tubes etc.

Drawing is a metalworking process which uses tensile forces to stretch metal. It is broken up into two types: sheet metal drawing and wire, bar, and tube drawing. The specific definition for sheet metal drawing is that it involves plastic deformation over a curved axis. For wire, bar, and tube drawing the starting stock is drawn through a die to reduce its diameter and increase its length. Drawing is usually done at room temperature, thus classified a cold working process, however it may be performed at elevated temperatures to hot work large wires, rods or hollow sections in order to reduce forces

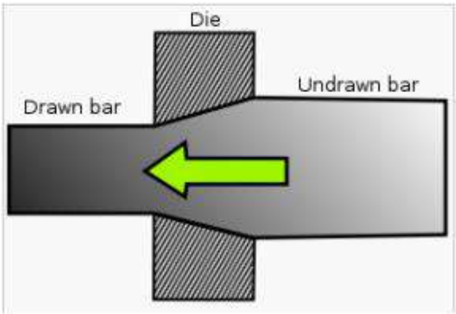


Fig. 1 Drawing

Bar, tube, and wire drawing all work upon the same principle: the starting stock drawn through a die to reduce the diameter and increase the length. Usually the die is mounted on a draw bench. The end of the work piece is reduced or pointed to get the end through the die. The end is then placed in grips and the rest of the work piece is pulled through the die. Steels, copper alloys, and aluminium alloys are common materials that are drawn.

Requirement of Drawing Process:

1. The material should have sufficient ductility so it can sustain tensile force.
2. The material should possess high tensile stress.
3. The rod or wire should be properly cleaned and dust or scale free before drawing.
4. It should be properly lubricated to reduce friction associated with operation.

Drawing Process:

Drawing process can be divided into following three types.

1. **Wire Drawing:** A wire is a circular, small diameter flexible rod. Wire drawing is an cold working process. It is an operation to produce wire of various sizes within certain specific tolerances. This process involves reducing diameter of thick wire by passing it through a series of wire drawing dies with successive die having smaller diameter than the preceding one. Mostly die are made by chilled cast iron, tungsten carbide, diamond or other tool material. The maximum reduction in area of wire is less than 45% in one pass.

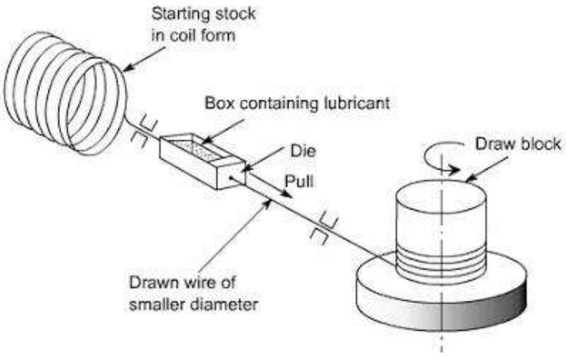
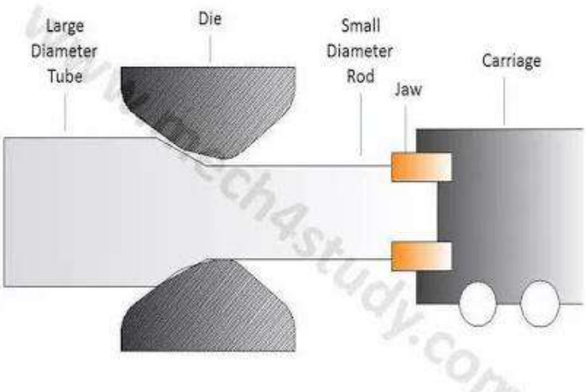


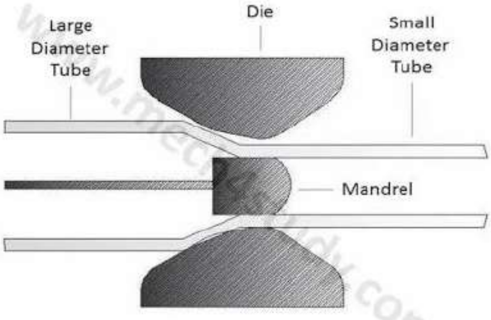
Fig: wire drawing

2. **Rod Drawing:** Rod drawing is similar process like wire drawing except it is rigid and has larger diameter compare to wire. This process need heavier equipment compare to wire drawing because the wire can be coiled but a rod should be kept straight. The work piece is first fed into die and pulled by a carriage which increase its length and decrease its cross section. Now the rod is to be cut into sections.



Rod Drawing

3. **Tube Drawing:** Tube drawing is also similar to other two processes except it uses a mandrel to reduce wall thickness and cross section diameter of a tube. This mandrel placed with die and the work piece is pulled by a carriage system as describe in rod drawing. The tube is either circular or rectangular. It also required more than one pass to complete drawing operation



Tube Drawing

Working Process of drawing:

1. First a hot rolled rod is created by other metal forming processes like forging, extruding, centrifugal casting etc.
2. Now the rod is made pointed to facilitate the entry into the die.
3. The dust or other scale particle should clean from the rod. This process is done by acid pickling.
4. Now the prepared skin is coated with lubricant. This process uses either sulling, coppering, phosphating or liming process. Sulling is a process of coating with ferrous hydroxide. In phosphating magnesium or iron phosphate is coated. Cu and Sn are used for lubricant high strength material. Oil and grease use for wire drawing and soap is used for dry drawing.

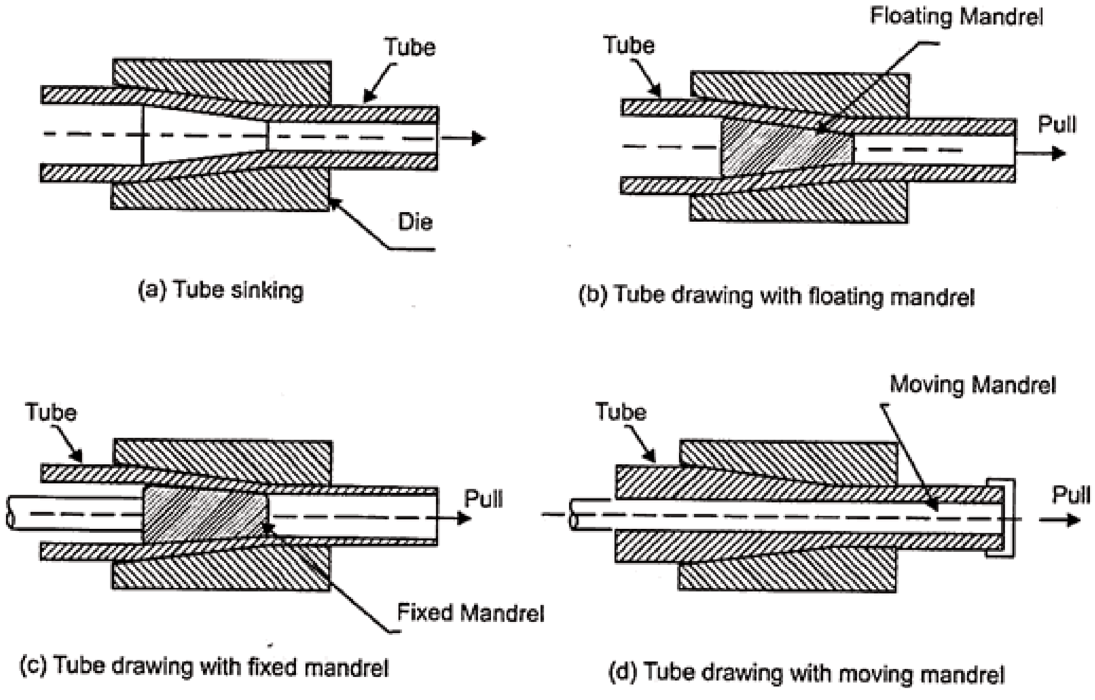
5. Now the rod is pulled through various dies to convert it into desire shape. The die is affected by several stresses so it is made by high strength alloy steel like tungsten carbide etc.

__The purpose of tube drawing can be any one of the following:__

1. To regulate the outer diameter only.
2. To regulate the outer diameter and to have good surface finish on the inner diameter. The inner diameter may not be regulated.
3. To regulate the outer as well as inner diameter.
4. To carry out a heavy reduction in thickness of the tube.

Types of tube drawing process

1. Tube sinking
2. Tube drawing with floating mandrel
3. Tube drawing fixed mandrel
4. Tube drawing with moving mandrel



(a) Tube sinking

(b) Tube drawing with floating mandrel

(c) Tube drawing with fixed mandrel

(d) Tube drawing with moving mandrel

Fig. 9.17. Tube drawing processes

1. **Tube Sinking:** In this process, tube is simply pulled through the die as shown in Fig. The outer diameter is regulated by the die diameter but there is no regulation of inner diameter or thickness of tube. The surface finish on inner diameter is also not good. During the drawing operation the thickness of tube generally changes. The thin tubes in which t/R (ratio of initial thickness to initial outer radius) is less than 0.33, the tubes get thicker on drawing. The tubes having t/R greater than 0.33 get thinner on drawing. With t/R = 0.33, there is negligible change in the thickness of tube. For threading the front end of tube through the die, many in the industry still follow the old practice of hammering the front end down thus wasting at least 200 mm length of tube. In modern practice the front end is pointed by pointing machines thus minimizing the wastage. Grippers are also designed to minimize the end wastage.
2. **Tube Drawing with Floating Mandrel:** The process of tube drawing with a floating mandrel is shown in Fig. The position of mandrel with respect to the die gets adjusted by the normal and tangential forces exerted by tube material on the mandrel**.** The frictional force tends to pull the mandrel into the die while the normal force tries to it push out. If the mandrel moves into the die the tube thickness reduces and hence the normal reaction increases, which also increases the frictional force. The mandrel takes a position where axial components of the forces are balanced**.** Since there is no external control on the position of the mandrel, it may change its position if the frictional condition changes, thus resulting in change in tube thickness. The external surface shape of the mandrel may be designed so that the mandrel adjusts its position for desired thickness of tube.
3. **Tube Drawing with Fixed Mandrel:** The process is shown in Fig. The tube is drawn through a die and a mandrel. The position of mandrel may be adjusted by the bar attached to its rear end in order to change the thickness of tube and the internal diameter. The external diameter is determined by the die diameter**.** The surface quality of both the surfaces, internal as well as external gets improved. The pull required is certainly more than that in tube sinking because of the additional deformation in the thickness of tube and also due to frictional force between the tube and the mandrel**.**
4. **Tube Drawing with Moving Mandrel:** The process is illustrated in Fig. The cylindrical mandrel and the tube are pulled together through the die. The process is generally used to reduce the thickness of tube. Since the area of cross section of tube increases towards the entry side its speed decreases while the mandrel being rigid moves with the same speed as the speed of tube at the exit. Therefore, in the deformation

zone the mandrel moves faster than the tube. The frictional force between the tube and the mandrel pulls the tube inside the die while the frictional stress between the tube and die acts in the opposite direction**.** The effects of frictional forces acting on contacting surfaces of mandrel and die tend to nullify each other. This results in net decrease of drawing stress. Therefore, the maximum possible reduction in thickness in this process is higher than that in other tube drawing processes**.**

Application:

1. This process is used for making wire of copper, aluminium etc. which are used in electrical industries.
2. Paper clip, helical spring etc. are wire drawing product.
3. Small diameter rods and tubes are drawing product.
4. It is used to produce large length of small cross section**.**