

Metal Casting (Principles of M.C By Loffer & Russen that)

①

Casting is a process in which the liquid molten metal is poured into the casting cavity whose shape is same as that of the casting to be produced, allow it to solidify and after solidification the casting can be taken out by breaking the mould.

ABITH FRANCIS

F.I.M.E

8121940250

usually mould single usage only

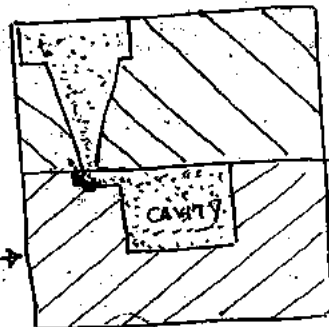
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COPE →

DRAG BOX →



Steps

1. Pattern making
2. Mould and core making
3. Pouring and solidification
4. Fettling
5. Inspection

① Riser Design

② special casting process

③ Defects

PATTERN MAKING

Pattern is a replica of the casting to be produced.

Replica - shape of the pattern remains same as that of the shape of the casting to be produced, but size of pattern is diff from the size of the casting to be produced

$$\text{Pattern size} = \text{Casting size} + \text{Allowances}$$

Allowances

1. Shrinkage Allowance
2. Machining Allowance
3. Draft Allowance
4. Shake Allowance
5. Distortion Allowance

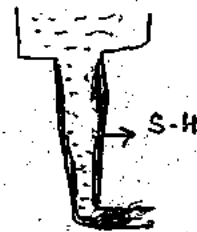
Shrinkage Allowance

P.T (Pouring Temp) $\rightarrow$ Temp at which molten metal is poured into the casting cavity.

usually molten metal is poured at a Temp above ~~molten~~ melting point Temp to avoid the solidification of molten metal in the casting case

$$P.T = M.P + (150 \text{ to } 200^\circ\text{C})$$

$\downarrow$
degree of Super Heat

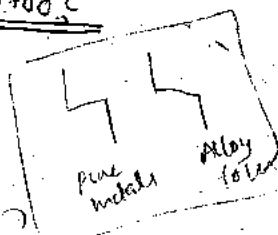


ex: Iron

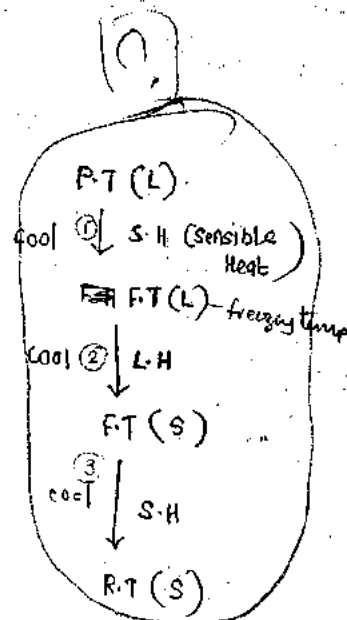
$$P.T = M.P + (150 \text{ to } 200)$$

1539 to 150 to 200

$\approx 1700^\circ\text{C}$



- In pure metals no Temp change will occur during phase change
- In alloys Temp change occurs

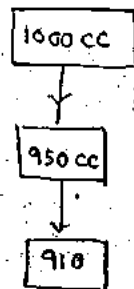


During casting process the substance is getting shrinking in all the 3 stages. whatever the shrinkage taking place in first 2 stages is called liquid shrinkage, whatever the shrinkage

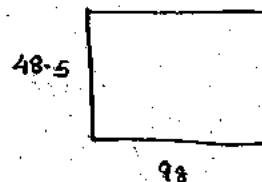
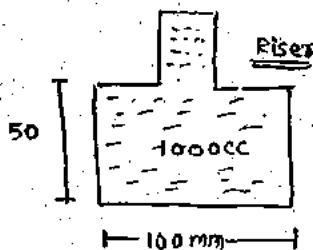
taking place in 3rd stage is called solid shrinkage

shrinkage (change in dimensions, volume)

The liquid shrinkages are always specified as percentage over volume, whereas solid shrinkages are specified as percentage over dimensions.



Liquid shrinkage can be compensated by providing Riser in the casting process and solid shrinkages can be compensated by providing shrinkage Allowance on the pattern



After solidification

SHRINKAGE ALLOWANCE

It is the allowance provided on the pattern to compensate the solid shrinkages taking place during the cooling of the material from Freezing Temp to Room Temp as a solid.

To avoid this originally we can increase the cavity size or increase in size of pattern.

~~As largest~~ out of All the metals used in casting process Al will be shrinking largest i.e. about 6%. so during casting as Al ~~the~~ size of Riser reqd is largest.

$$\delta L = L \times \Delta T$$

$$= L \times (T_f - T_r)$$

change in dimension

$$= \delta A$$

L = dimension of component

α = coeff of thermal expansion

T_f = final temp

T_r = room temp

S.A. $\propto \alpha$

$$K_{BRASS} = 23 \mu m/m^{\circ}C$$

$$K_{STEEL} = 21 \mu m/m^{\circ}C$$

$$\text{Admiralty metal} \left\{ \alpha = 23.5 \mu m/m^{\circ}C \right.$$

[LATEST DEVELOPED]

[Slight modification to Brass]

$$\alpha \approx 0 \quad (0.0000096 \mu m/m^{\circ}C)$$

Invar

$$\text{Platinum-Iridium alloy} \quad \alpha \approx 0$$

⑤ -ve shrinkage

expansion during cooling

GREY C.I

Contraction during Heating

ie the dimensions of the pattern must be made less than the casting

the total shrinkage ie liquid ~~shrinkage~~ as solid shrinkage both together will be highest in case of steels.

Eg: casting of size (200x100x70mm)

the size of Riser reqd is largest for

- (a) ~~Al~~ (b) steel (c) Brass (d) C.I

the size of pattern is Largest for

- (a) Al (b) steel (c) ~~Brass~~ (d) C.I

Grey CI
width % shrinkage 1/3

what is Ratio of vol of Patt
vol of cavity

- ③ 0.97 ⑥ 0.99 ⑦ 1.01 ⑧ 1.03

Solid shrinkage

(% over dimension)

for grey CI
Vol is Reduced

$$\frac{(0.99 \times 500) \times (0.99 \times 200) \times (100 \times 0.99)}{500 \times 200 \times 100}$$

Machining Allowance

The extra material provided on the pattern and it can be removed by machining from casting after the casting process is completed.

i) It is provided Because of as it the casting component will have poor surface finish, but most of the engg application requires good or excellent surface finish. To get this good surface finish machining must be done on casting.

ii) To accommodate the variation in shrinkages taking place due to variation in Room temp during solidification

$$S.A = L \alpha (T_f - T_h) =$$

$$M.A = x \text{ mm / side}$$

The amount of x depends on ^{complexity} criticality of components.
During casting of critical components large amount of machining allowance will be provided.

→ shrinkage and machining Allowances are the major allowances which will be affecting the dimensions of the pattern

a) cylindrical casting 400mm length and 200 mm dia

$$S.A = 2\% \text{ and } M.A = 2 \text{ mm / side}$$

Pattern size with provision for S.A

$$D = 200 + \frac{2 \times 200}{100} = 204$$

$$L = 400 + \frac{2 \times 400}{100} = \underline{408}$$

Pattern size with provision for M.A + S.A

$$D = 204 + (2+2) = \underline{208} + \frac{2 \times 4}{100} = \underline{208.08}$$

$$L = 408 + (2+2) = \underline{412} + \frac{2 \times 4}{100} = \underline{412.08}$$



Pattern with Prov M.A

$$D = 200 + 2 + 2 = 204$$

$$L = 400 + 2 + 2 = 404$$

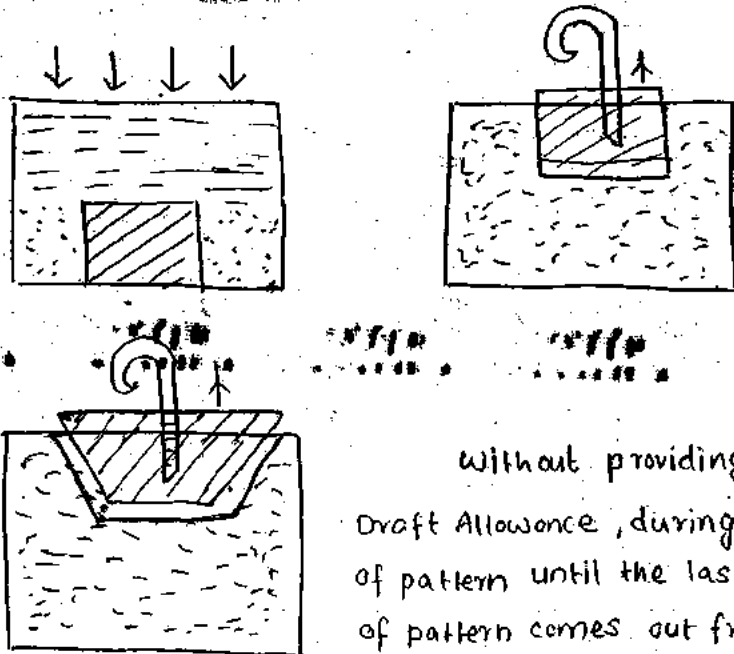
P.S. with Provision M.A.T.S.A

$$D = 200 + \frac{2 \times 204}{100} = 208.8$$

$$L = 200 + 408 +$$

Draft Allowance

~~Making~~ Making the vertical surface of pattern into inclined is called Draft Allowance. It is provided for ~~easy removal~~ of pattern from mould.



without providing the Draft Allowance, during removal of pattern until the last point of pattern comes out from mould,

- there is a contact existing b/w the pattern and the mould. Any vibrations taking place to the human hand during removal of pattern may cause damage to the mould part. To avoid this if the vertical surface of the pattern is made into inclined, as soon as the pattern is lifted by some amount immediately the gap is forming b/w the pattern and mould all round. Hence the pattern can be ~~removed~~ ~~without any~~ ~~damage~~.

Because of ~~the~~ property of moulding sand during moulding

as -ve allowance

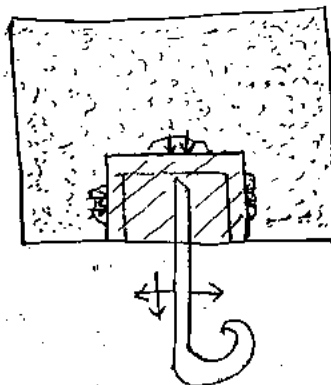
of pattern so taken

- It Reduces the dimension

mould making person

- purely depends on

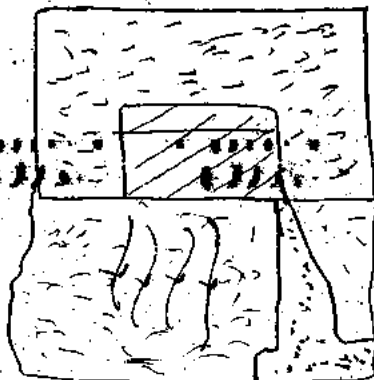
Shake Allowance:



material for producing ~~large size casting~~ such as

Polyethylene used as casting

Polyethylene



-39°C
-89°C
mercury
freezer

[Freezing Temp of Mercury] -89°C

gas or vapour, Hence draft allowance is not reqd.

Liquid whereas polyethylene will be removed in form of

Wax and mercury will be removed in the form of a

material, No draft material need not be provided

materials like wax, mercury, polyethylene as pattern

In casting process if the pattern is made by using



During casting of V or U shape castings because of existence of diff. in shrinkages at diff locations, the shrinkage forces are acting on the legs of V or U. ^{so that} The legs will bend outwards producing inclined legs at casting. This is called as distortion problem in casting process. To avoid this the legs of the pattern will be bend inwards by an amount equal to distortion allowance so that during solidification due to shrinkage force legs are bending outwards producing vertical legs.

Amount of distortion allowance will be $\frac{L}{E}$ Ratio; If $\frac{L}{E}$ increases, distortion allowance also increases.

Pattern Materials

Properties

1. should not absorb the moisture
when moisture is absorbed it ~~will~~ pattern will expand. so cavity increases.
2. Low density
3. Good surface finish
4. Easiness in fabrication
5. cheap.

Types of Material

1. wood

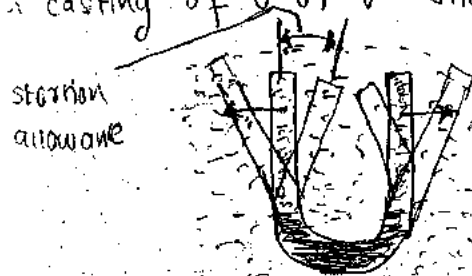
wood patterns have all the good properties except that it ~~are~~ absorb the moisture.

the moulding sand will get adhered to the pattern. So during removal of pattern the adhered moulded sand will try to come along with the pattern and it damages the mould wall. To avoid this the pattern is shaken before removal so that adhered moulding sand is separated from the pattern and the pattern will be removed without damaging the mould box. But during shaking process the size of the cavity will be increasing and casting size increases. ~~decreases~~ To maintain the casting size the original ~~cast~~ ~~size~~ ~~new~~ pattern size must be reduced by an amount called as shake allowance. The amount of shake allowance depends on the mould making person. All the above mentioned allowances are increasing the size of the pattern but shake allowance decreases the size of the pattern so it is taken as a negative allowance.

If the pattern is made by using the materials like wax, mercury, polystyrene as pattern material, no shake allowance need to be provided.

★ Distortion Allowances (Bending Allowances)

Doesn't read on all the castings. But it is mainly read on casting of 'U' or 'V' shaped castings.



Comp stress >
Tensile stress
so doesn't Bend
inward.

① Wood: out of the available woods, ~~teak~~ and ~~cherry~~ are

$\rho = 0.4 - 0.8 \text{ g/cc}$ the one which has lowest moisture absorbing capacity so they are used as pattern materials.

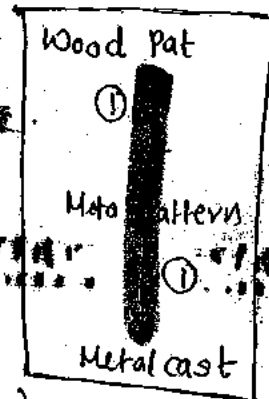
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2 * Metals:-

Metal patterns are having higher density and difficult to fabricate i.e. for manufacturing of metal patterns using casting process again the wooden patterns must be used so that on the wooden patterns

~~allowance~~ allowance must be provided.

out of the diff metals the low density metals are ~~aluminum~~



~~metals~~ - (much costly $\approx$ Gold cost.)

Most commonly used metal patterns are made by using ~~aluminum~~ Metal patterns are preferred when the castings are to be produced continuously.

3 * Plastics

They possess all good properties which are read for a pattern material. Hence plastic patterns are the most commonly used materials ~~today~~ today.

ex: ~~epoxy~~ (thermosetting) ~~resin~~

* 4) Wax :-

If wax can be used as a pattern material because ab

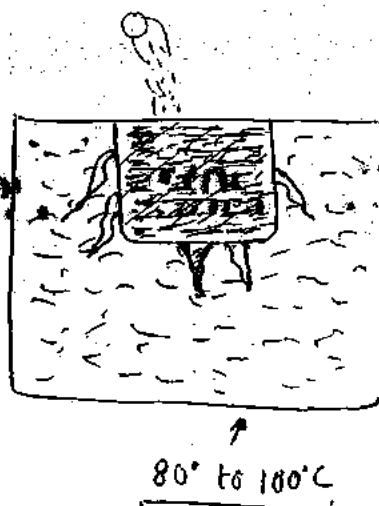
Adv

- ① ~~Due to high softness~~ of wax, the complex shapes of patterns can be produced very easily. Also because of wax
- ② Patterns is removed in the form of liquid so complex shape of pattern can be easily removed. Surface
- ③ Finish produced in wax pattern is excellent. Hence excellent surface finish can be produced in Casting also.

Dis-Advantage :-

Because of very High softness max size of

- ① pattern used is ~~very small only~~



(Bending)

Why?
Due to evaporation of moisture at 80°-100°C

If wax pattern is used along with ~~some~~ mould



- ② Then ~~some~~ tails are formed.

ex of components produced by wax patterns are

~~the blades,~~
~~the system,~~
~~the system,~~

5) Mercury (frozen mercury)

Mercury will be first cooled to a temp of -70 to -80°C and make the pattern, by using this pattern make the mould and this mould will be left in atmospheric conditions so that the temp of the mercury will be increasing $\Rightarrow$ becomes liquid.

- Now by inverting the mould liquid mercury can be taken out.

When the mercury is used as pattern material it has very high density, diff to make the pattern, costly and highly poisonous. Hence it is not a generally preferable pattern material. But it is used in case of manufacturing of very small castings with excellent surface finish without machining.

~~Water~~ Moulding sand will be used for manufacturing of the mould. It consists of 3 basic elements

1) Silica sand particles

used for producing reqd

2) clay

used for producing

3) water or sodium silicate

used for

to blow the

Types of sand

- Silica sand + clay + water $\rightarrow$ Green sand
- Silica sand + clay + sodium silicate $\rightarrow$ Dry sand
- Green/dry sand with
— % clay $\geq 50\%$ = loam sand

- * Generally used for producing large casting,
- * Mainly used for producing good surface finishing

(upto ) (cohesivity & collapsibility prop.)
to increase the properties of moulding sand like

* 1. Sawdust or wood powder

They are added to increase the  property
of moulding sand and  of moulding sand.

* 2. Coal powder

used for increasing the  of the
moulding sand.

* 3. Starch or dextrin

used for increasing or  deformation
of moulding sand.

* Properties of Moulding Sand:-

1. Porosity property - the ability of escaping the air or gases

through the moulding sand is called porosity property.

porosity property of moulding sand is required for escaping
air or gases present in casting cavity during filling of

If not installed into the cavity and avoiding the defects like blow holes. If air or gases are present in cavity it will affect the strength of casted object as blow holes will be formed.

Permeability test is used for determining the porosity property of moulding sand.

American foundry standard
AFS or ASTM standard

$D = H = 5.08 \text{ cm} \rightarrow$ Circular

$V = 2000 \text{ cc}$

$P =$ gauge pressure (g/cm^2)
 $= 10 \text{ g/cm}^2$

$t =$ time taken to bring

the volume V from pressure

P to atm pressure

★ Permeability Test:

Permeability
Number
(PN)

$$PN = \frac{V \cdot H}{P \cdot A \cdot T}$$

$$PN = \frac{501.28}{P \cdot A \cdot T}$$

A/c. Area $= \pi/4 D^2$

$T =$ in m + s

Pressure P can be taken as either standard value or non standard value.

$P = 10 \text{ g/cm}^2$ - stand value

$$PN = \frac{501.28}{T}$$

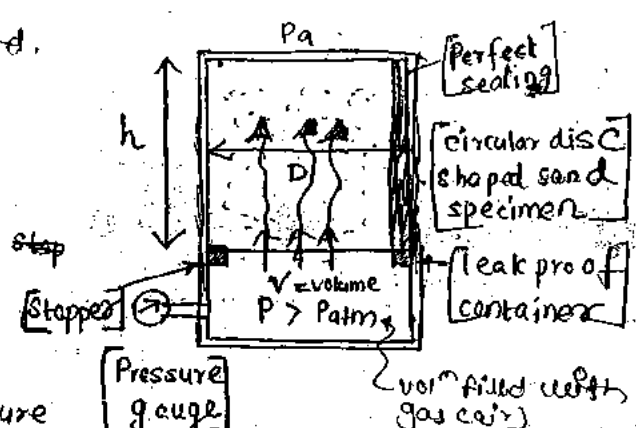
Here permeability Number indicates, higher the porosity property of a moulding sand

Factors affecting porosity property of a moulding sand

1. Grain size of silica sand particle

(Higher the grain size higher the porosity)

{ Grain size $\uparrow$
Gaps b/w particles
become larger }



higher the % of clay the porosity will be less. It

reduces the porosity of moulding sand.

{ clay will fill gaps existing b/w the sand particles, hence porosity decreases }

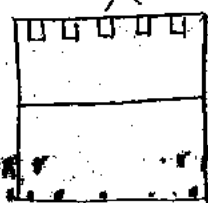
3. Ramming force / compressive force applied during mould preparation.

Higher compressive force, lower the porosity property.

4. Adding saw dust and wood powder the porosity property can be improved.

5. Venting or vent Holes $\rightarrow$ Porosity can be increased.

vent Holes



II

Strength:

Tensile

Compressive

Shear

UTM can be

used for determining strength.

UTM - universal Testing Machine

III

Cohesiveness property

Ability to form ~~same material particles~~ is

called as cohesiveness property or shear strength.

It is determined by UTM and the name of the test is

ILSS - Inter laminar shear strength Test



IV

Adhesiveness: Ability of ~~material formations~~ b/w ab

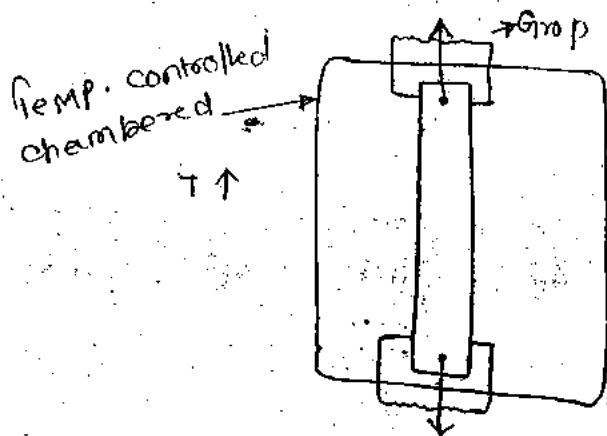
~~material particles with other materials~~

testing is done using UTM



V Refractoriness: Ability of ~~the sand~~ Higher Temperature ~~resistance~~ ~~resistance~~

Testing using CIM - with temp control chamber



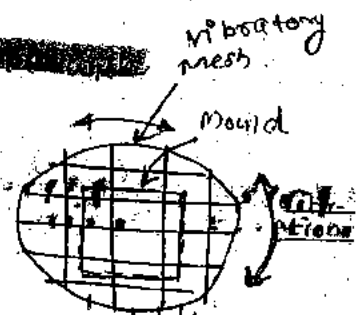
{ Temp is increased slowly and ~~at~~ at what temp sand specimen fails is noted }

NOTE:

Load is maintained constant

VI collapsibility:- Ability of ~~the sand~~ ~~resistance~~ force application

Measured using ~~the sand~~



By leaving ~~sand~~ specimen over vibrator mesh and vibration is applied. By slowly increasing the vibration of mesh it is possible to determine, at

[Additive used be added to mould's sand.]

what vibration mould can be Broken. Based on this vibration, the force at which ~~the~~ mould is Breaking can be determined. As the force reqd for Breaking mould is reducing collapsibility property of mould is increasing

VII

Flowability:- Ability of ~~the sand~~ into each and every corner of the mould is called flowability. It can be measured using orificemeter.

(Fluidity $\rightarrow$ only for fluid.) - It is not the prop. of moulding sand.

Methods of Mould Making

1) Hand Molding:- If force reqd for Ramming or Compressing of molding sand is obtained by human hand, it is called as Hand Molding

2) Advantages:-

- It is a cheaper methodology

- Because human being knows where the projections and extensions are present on the pattern hence he can apply lesser amount of force to avoid damage taking to the pattern

Limitations:- This Method is used whenever less no. of casting is to be produced

- Non uniform strength and Hardness of Mold can be obtained

- Time taken for making one mold will be Higher. $\therefore$

production rate is low.

- Ramming force can not be applied uniformly

2) Machine molding.

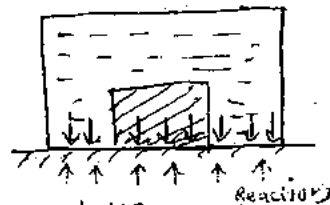
If machine is used for producing Req'd Ramming or Compressive force, it is called Machine Molding.

a) Jolting

b) squeezing

c) Jolt & squeezing

d) sand sinking



A. Jolting: Sand filled mould is Raised to certain

amount of Height so that it is possessing P.E. when

it is leaving freely on to the ground the P.E of the

mould is converted into impact energy and impact load which is acting on the ground. the equal and opposite

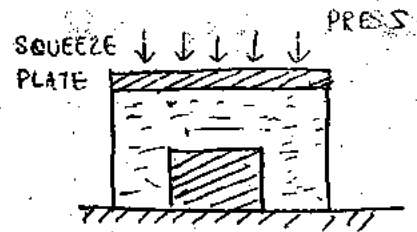
reaction force offered by ground is acting on the mould

for Ramming of mould sand is (for ramming of molding sand.)

1. The Reaction force produced by ground cannot be transferred up to the top of mold. Hence top of mold is having lower strength only. Jolting may not be sufficient for making the mold (^{Not giving} uniform strength.)

B. Squeezing:- Force is applied using mechanical or hydraulic press on to the plate. The plate is squeezing or transferring force to the molding sand for Ramming or Compressing of molding sand.

Because force may not be transmitted up to the bottom of the mold there is variation in strength of mold. The top of mold is attaining higher strength whereas bottom of mold is having lower strength.

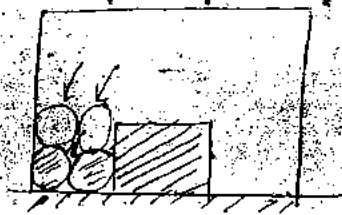


Gr. Joint & Squeezing

By combining joint and squeezing operation it is possible to get higher strength and hardness of top and bottom of mold. Uniform strength and hardness can be obtained if the height of mold is < 200 mm. If the height of mold is greater than 200 mm both top and bottom are getting higher strength. To get the uniform strength throughout the height of mold with whatever may be the height of mold the best process is sand sinking op.

d) SAND SINKING:- ^{Small quantity} Small (Qty) of molding ^{sand} will be thrown into the mold with certain amount of force using a machine so that ~~the sand will sink~~ will be taking place

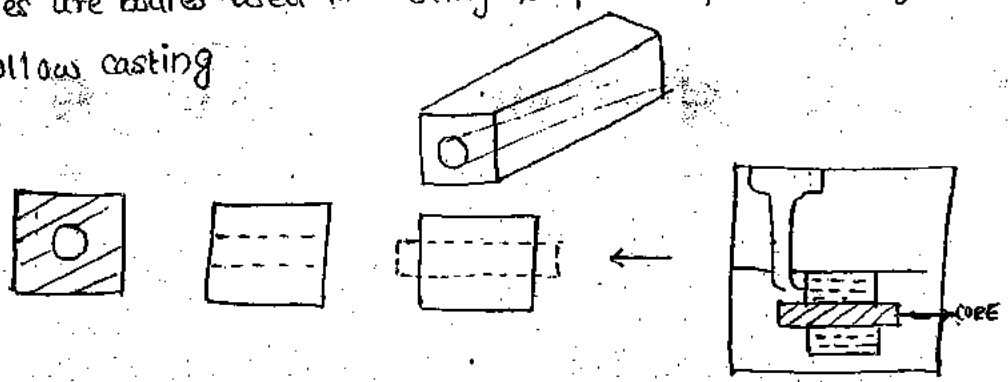
~~in the mold~~ in the mold. ① sand sinking is ~~the process~~ and ② it ~~is the process~~ and



SAND SINKING

CORE MAKING:-

cores are bodies used in casting for process for producing hollow casting



* Properties which must be possessed by core material e/s:-

1. ~~Moisture~~ { No Bond formation takes place and can be easily removed }

2. ~~Moisture~~

3. ~~Moisture~~ should have High strength

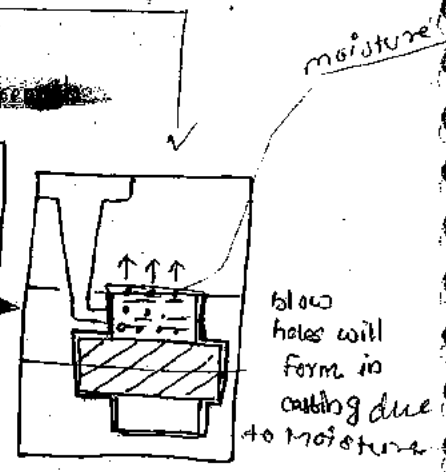
due to density diff there will be upward or downward buoyancy force, the core material should withstand it

4. ~~Moisture~~ absorbability

↑
antiractory
property

If moisture is present it will evaporate

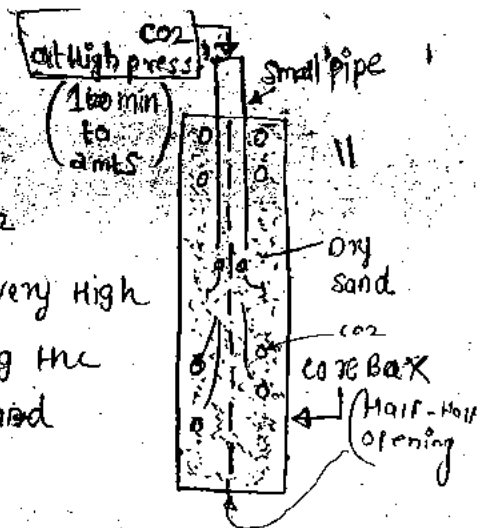
with little amount of force we should break the core and take it out



to satisfy the above four properties of core material, the commonly used material for manufacturing of core is ~~Moisture~~

METHOD

When CO_2 is supplied into dry sand at High pressure it is chemically reacting with sodium silicate and produces silica gel. on drying the silica gel for 1 to 2 mins it gives very High strength to the core. Now by opening the core Box, the core can be taken out and used in casting process.

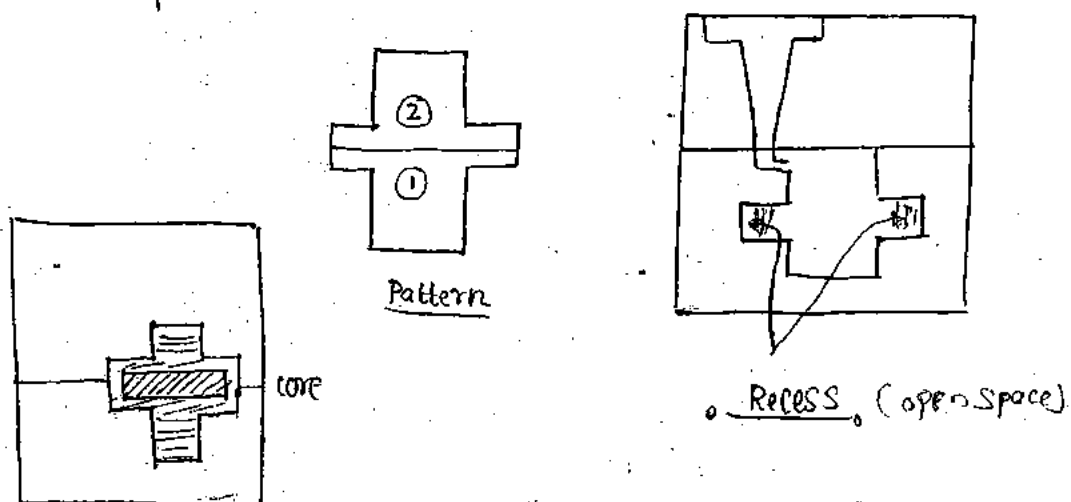


Whenever High strength of core obtained due to formation of silica gel and drying will not be lasting for longer period. After 2 to 3 hrs of manufacturing of core; the strength of core starts Reducing and after 5 hrs it is found that the core become like a loose sand which can be removed very easily.

~~Recess~~ provided in the material for ~~casting~~

and ~~extension~~ of cores is called Core print

Core prints can be produced by providing extension on the pattern.



When extensions are provided on the pattern, Removal of pattern from the molds will become difficult and

- for this pattern divided into two portions, one part of pattern will be kept inside the ~~box~~ and another part of pattern will be kept in ~~box~~

Box and make the molds so that it is to remove pattern as well as placing of core into mold ~~and~~ is also easier

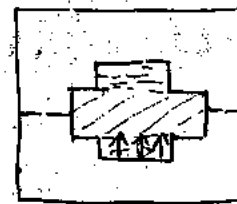
ρ = density of molten metal } Generally ~~more~~ than $7g/cc$
 $\rho > d$ (in general)

d = ~~1.5~~ to $5.5g/cc$ of core

V = vol of core

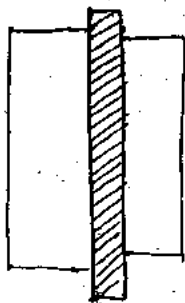
Net Bouyancy Force

= wt of liquid displaced - wt of core



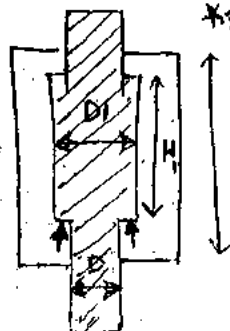
$$\text{Net B.f} = V \times \rho \times g - V \times d \times g$$

If A is Molten metal then $d = \rho$



Net Bouyancy force is zero

{ for uniform cylindrical vertical }
core



Net Bouyancy force

= wt of liquid displaced due to projected portion - Total wt of core

$$F_b = \left[\frac{\pi}{4} (D_1^2 - D_2^2) \times H \times \rho \times g \right] - \left[\frac{\pi D_1^2 H}{4} + \frac{\pi}{4} (D_1^2 - D_2^2) H \right] d \times g$$

* Load: (N)

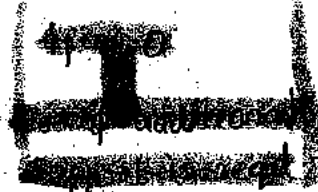
Load which is supported by core print

$$= 350 A \text{ Newtons}$$

Surface Area of core print in m^2

unsupported Loads

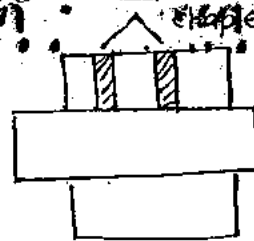
$$= \text{Net buoyancy force} - 350 A$$



Additional Support

Additional support reqd in casting process which is obtained by using chaplets in casting process.

Chaplets are used in casting process because it is becoming an integral part of casting and chaplets are used in casting process.



the chaplets must be properly cleaned

before placing them into the casting cavity, to avoid the weak joint formation b/w solidified metal and chaplets.

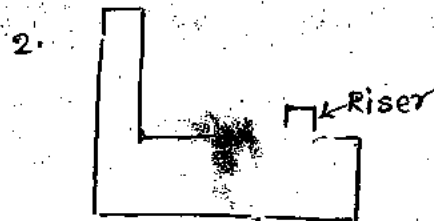
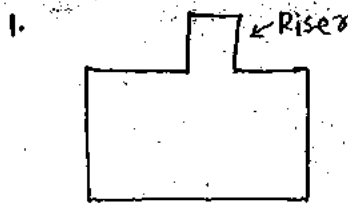
size of chaplet to be provided.

cross sectional area chaplet must be provided - even though chaplets are basically provided as an additional support in casting process, but the chaplet also provides the additional support.

In casting process

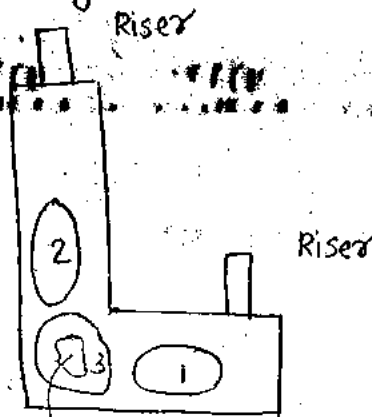
1. During casting of a uniform cross section of casting the Riser is provided at top most point of casting cavity

2. During casting of non uniform c/s castings the Riser is provided near to the thickest portion than the thinnest portion



L shaped uniform vertical casting

even though 2 risers are provided here it is not able to compensate liquid shrinkage produced



--- In the corner portion of cavity, during solidification, void (shrinkage cavity) vol^m of molten metal present in the corner portion is higher than vol^m of molten metal other than other portion.

Zone 3 solidifies after the zone 1 and zone 2 solidified

∴ shrinkage produced can't be compensated. Because amount of metal in corner is larger and heat transfer is longer

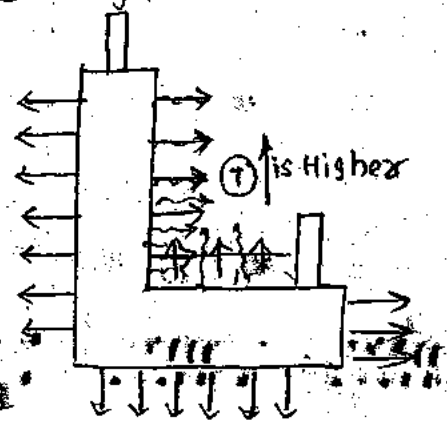
4. From the above figure the molten metal in zone 1 and zone 2 is solidifying before the zone 3 because the qty of molten metal present in zone 3 is

Cross higher than zone 1 and zone 2. Hence large amount (time) of heat is to be removed and time taken for solidification is higher. 13

- (ii) ~~at corner~~ portion of cavity heat transfer is taking place in ~~2~~ directions $\therefore$ mold present at corner of cavity attain higher temp $\therefore$ easily temp b/w molten metal and mold is lower and hence the ~~time taken~~ heat transfer is ~~low~~ $\Rightarrow$ time taken for solidification of molten metal in zone 3 is higher.

Because zone 3 metal is solidifying at the last even though the risers are provided it is not possible to compensate

the liquid shrinkage taking place in zone 3, hence



$$Q \propto dT \times$$

$$\propto A \rightarrow \text{can't be done } \times$$

$$\propto k \checkmark$$

$$\propto \frac{1}{dx}$$

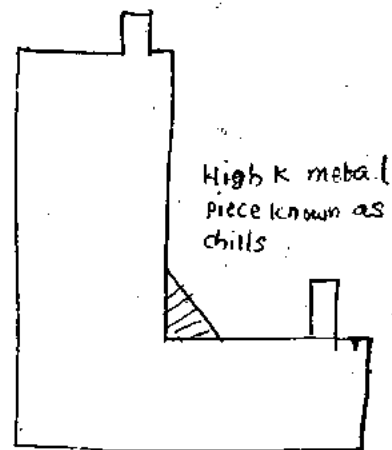
To avoid formation of voids or

shrinkage cavity

~~by solidifying molten metal~~

for this

it is not possible to reduce the volume of molten metal in zone 3 and it is not possible to reduce

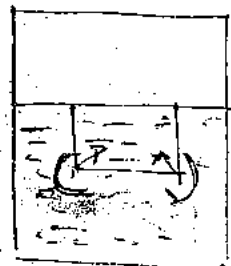
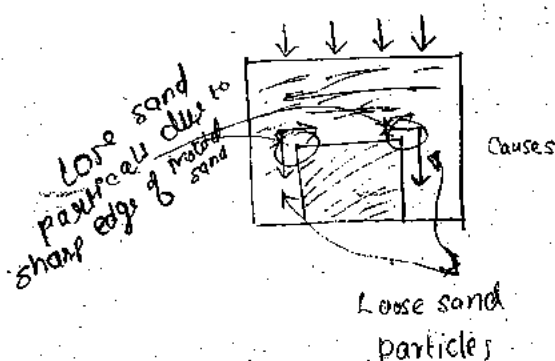


It is possible by increasing the thermal conductivity of corner of cavity. It is done by increasing the thermal conductivity of mold at corner of cavity. To increase the thermal conductivity ~~on high thermal conductivity~~ metallic piece is placed at corner of cavity in the mold during molding itself. So because of the metallic piece placed at the corner it is possible to ~~keep the heat transfer in specified direction~~ so that solidification of molten metal in cavity will take place according to reqd methodology called as directional solidification. The metallic piece provided in the casting process is called as chill.

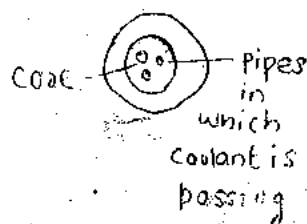
- ① Chill material must have ~~high thermal conductivity~~ high thermal conductivity.
- ② ~~Thermal conductivity of chill material must be greater than~~ Thermal conductivity of casting metal.

During casting process chill will ~~be attached~~ be attached to the casting, if it is not ~~at~~ obstructing functionality of casting, leave it as it is, otherwise ~~remove the chill by welding~~.

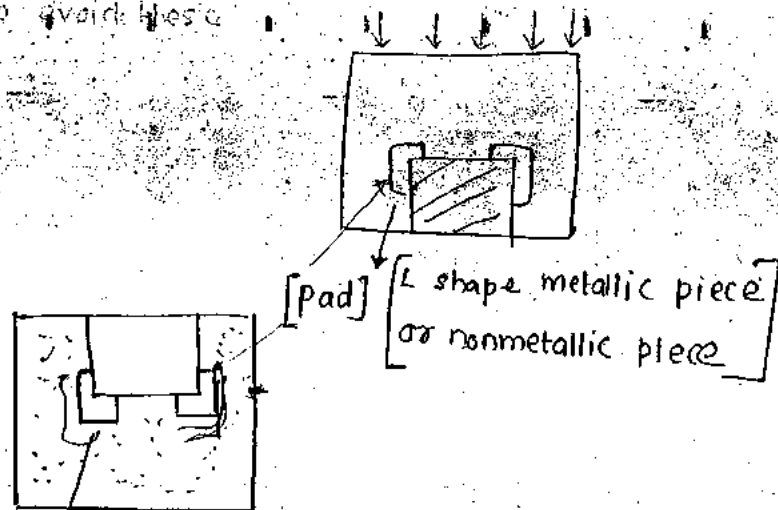
Pads or Padding.



used for producing Gun Barrels.



To avoid this



14

[Loose Sand will not be eroded due pad]

~~During~~ The pattern used will also have sharp edges at corner. During the molding

operation when ramming force is applied, sand particles present at the corner ~~gets~~ of pattern will get slipped away and produces loose sand particles at corners. when molten metal is poured into cavity

~~this loose particles at the corners gets eroded and enters into the cavity producing~~

~~eroding~~ To avoid this L-shaped metallic or non metallic pieces will be placed at corner of the pattern during molding itself. This L-shaped pieces will not allow the molten metal to directly come in contact with the loose sand particles. Hence it will ~~not be eroded~~. The L-shaped pieces are called ~~called~~ as pads or padding. Because

* ~~it is used for padding of mold of molding~~

* ~~the pads also prevent sand from solidification~~ as an additional function.

★ Pouring

The molten metal is always poured into the casting cavity using a system called gating system. It consists of 4 basic elements

① Pouring Basin

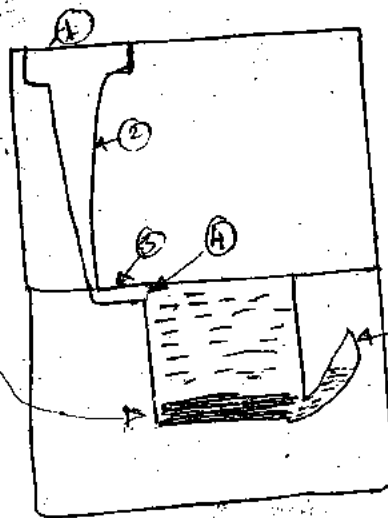
2. sprue

3. Runner

4. Ingate

★ characteristic of gating system:-

The Gating system must be designed such that the time taken for pouring or filling of molten metal into the cavity is as small as possible. This is due to, no part of casting cavity should start to solidify before complete filling of casting cavity.



$$P.T = \frac{\text{Vol}}{\text{Area} \times \text{vel}}$$

pouring
Time

① Large resistance since time become long and it will cause defects

② Large vel also not possible. velocity of molten metal of gating system as max as possible within the

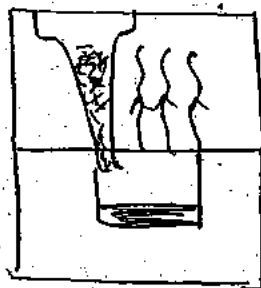
Limits of Laminar flow If flow becomes Turbulent, then Sand erosion takes place due to impinging of molten metal into the walls.



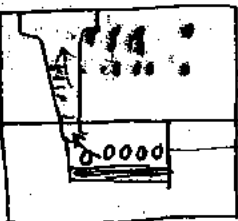
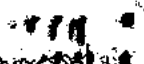
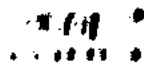
Turbulent

- ③ During filling the molten metal into the cavity, the gating system should ensure ~~full~~ flow of ~~molten metal~~ ~~partial flow~~ ~~attained~~

easiest
Passage
of
Compressed
air inside
cavity



High fluid pushes
Back low fluid so
air is pushed back so
again small air particles
get produced in cavity.



usually occurs
at beginning of
flow

compressed air
flows back

PARTIAL
FLOW

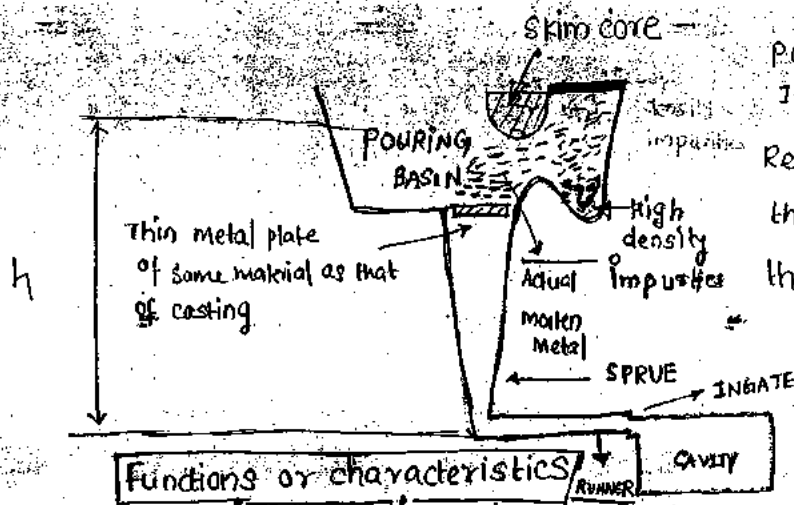
small
air
particles

- ④ The Gating system should be designed such that any impurities present in molten metal can be separated without entering into casting cavity.

- ⑤ The Gating system should be designed such that no sand erosion can take place in gating system.
(Respiration - Air goes in)

- ⑥ ~~Partial flow~~ will take place during filling of molten metal into the casting cavity.

A POURING BASIN



pouring Basin,
It is acting as a
Reservoir for supplying
the molten metal to
the casting cavity.

Functions or characteristics

1. The ~~pouring basin~~ separates the impurities (Lighter and heavier impurities present in the molten metal).
2. A thin plate placed at end of pouring Basin will absorb the excess heat available in the molten metal and the total plate will get melted at a time so that molten metal produced by plate and molten metal collected over the plate will try to flow through the gating system simultaneously which ensures the full flow of molten metal thru the gating system.
3. The size and shape of Pouring Basin will not have much effect on the flow rate or pouring time of molten metal in the gating system.

B SPRUE

It is ~~always vertical with~~ It is
always vertical with ~~smooth~~

characteristics / Functions :-

Basically velocity of molten metal in gating system

$\left[h = \text{height of sprue} \right]$

* 1. The height of sprue is mainly responsible for producing velocity of molten metal in gating system. The height of the sprue is selected such that vel. of molten metal in gating system must always be greater than flow.

* 2. Straight tapered sprue is selected to avoid the aspiration effect in the gating system. (Air in-out) or air bubble

$A_s = c/s$ Area of Bottom of Sprue

C] RUNNER

It is a connecting passage b/w pouring basin and down gate.

It is always horizontal with uniform cross-section.

① → Rectangular cross-section is the standard one for runner.

$$Q_{act} = C_d \times A_{th}$$

C_d = coeff of discharge.

② → Trapezoidal c/s has highest value of C_d . so it is selected, ③ Runner is also used to separate the impurity from molten metal.

* Why trapezoidal is not selected for sprue?

diff to manufacture. cylindrical can serve the same fn. whenever flow is taking place.

C_d is irrespective of the cross section used. i.e.

so whichever c/s is easy in manufacturing the corresponding c/s will be taken as sprue c/s. for the case of runner, care of selection of C_d is easy to manufacture.

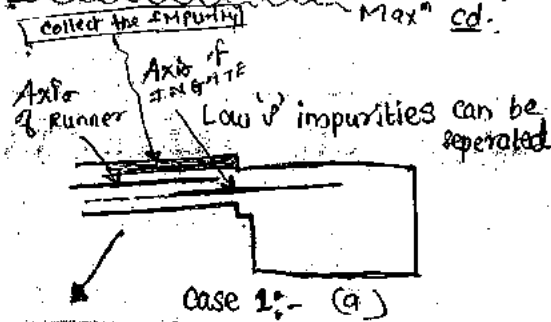
$A_R =$ cross sectional Area of Runner

D. INGATE

(a) (b) It is the last part of gating system from where the molten metal is entering into the Casting Cavity. It is also Horizontal and Uniform Trapezoidal c/s for having Max^u cd.

* FUNCTIONS:-

there is an offset b/w Runner axis and ingate axis



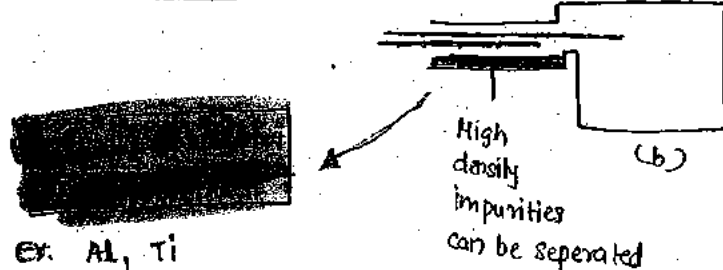
AXIS OF RUNNER ABOVE INGATE AXIS

ex: STEELS, COPPER

Runner axis can be below ingate axis also.

IE RUNNER IN COPE BOX
INGATE IN DRAG BOX

Ingate:-
(Aggregates are also used ingating syst.)
P.T.O.



ex: Al, Ti

AXIS OF RUNNER BELOW THE INGATE AXIS

SO RUNNER IS PLACED IN DRAG BOX
INGATE IN COPE BOX

$A_g =$ c/s Area of INGATE

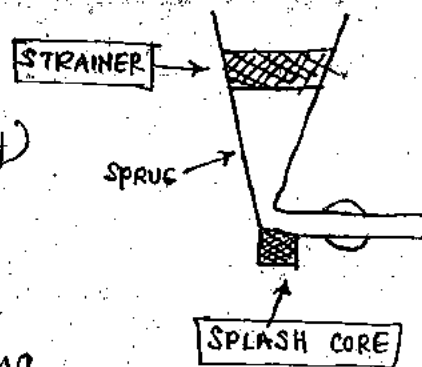
→ In order to increase the efficiency of pouring of molten metal into casting cavity some additional accessories are also used in Gating System

1★

ALWAYS KEPT IN SPRUE ONLY

→ used for separating / the impurities present in molten metal

→ Made By using ~~ceramic~~ ~~material~~ (TO STRAIN THE IMPURITY)

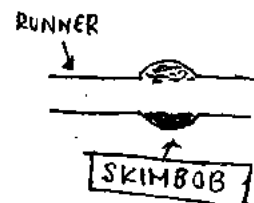


2★

used for ~~removing~~ from Bottom of sprue. Also made by using ~~material~~

3★

It is a semicircular cut given in Runner.
It is used for ~~removing~~ present in molten metal.



★ AS FAR AS POSSIBLE IMPURITIES SHOULD BE SEPERATED FROM MOLTEN METAL

★ CLASSIFICATION OF GATING SYSTEM

- Based on Pressure above molten metal in Pouring Basin
 - A. Nonpressurised Gating system
 - B. Pressurised Gating system

2) Based on position of Ingate

A. TOP GATING SYSTEM

B. BOTTOM GATING SYSTEM

C. PARTING GATING SYSTEM

D. STEP GATING SYSTEM

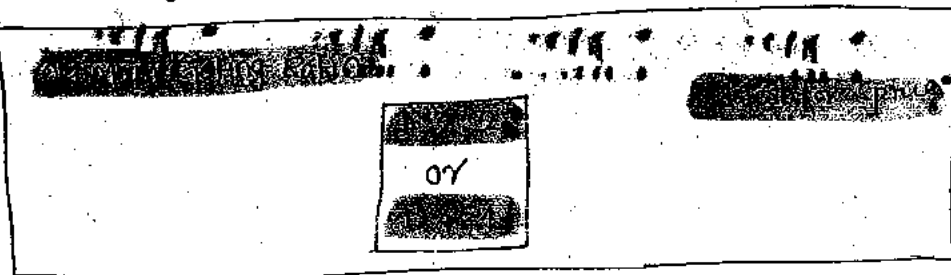
★ NON PRESSURISED GATING SYSTEM (in pouring basin)

If pressure above molten metal in gating system is equal to atmospheric pressure, it is called as non pressurised



Gating system.

It is very easy to maintain by just opening the Pouring Basin to atmosphere. But it is not suitable for casting of highly reactive metals like Aluminum.



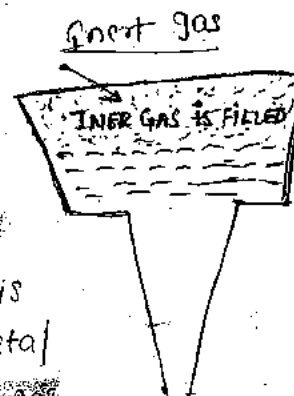
★ PRESSURISED GATING SYSTEM

If pressure above molten metal in Pouring Basin is greater than atmospheric pressure, it is called pressurised gating system

ie Pressurised Basin

REASONS

- ① During casting of reactive metals, the top of pouring Basin is simply closed and space above molten metal in pouring Basin is filled with inert gas.



2. BACK PRESSURE GATING SYSTEM

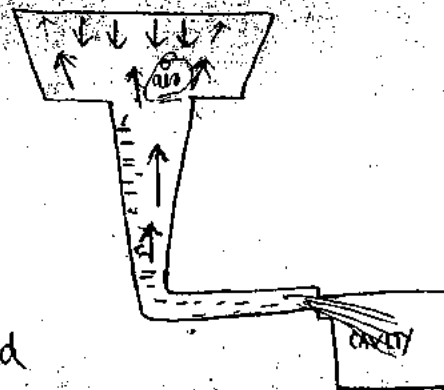
Reason

Sometimes during filling of molten metal in casting cavity due to some reasons if the flow of molten metal is delayed in gating system. The air which is

being compressed in casting cavity.

is pushed back in the direction and collected on the top of molten metal

in Pouring Basin which has the same shape. This is called Back Pressure Gating system.



Velocity of Molten Metal absolutely depends on $v = \sqrt{2gh}$ at P_{atm}



Max Height of Sprue $\leq$ Height of Cope Box

How to increase v beyond h_{max}

By increasing pressure

$$v = \sqrt{2gh + 2\frac{(P - P_a)}{\rho}}$$

P = Pressure above molten metal

Whenever the velocity of molten metal in gating system is to be increased within the limits of laminar flow, without increasing the height of the sprue, the only possibility is

by increasing the pressure above the molten metal in pouring basin.

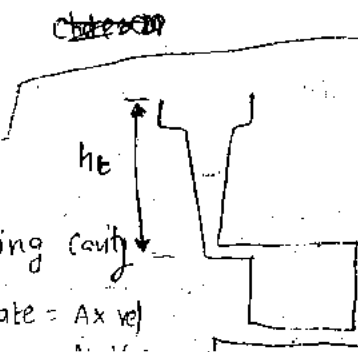


TOP GATING SYSTEM

Angle is provided at topmost point of Casting cavity

$$v_{max} = \sqrt{2gh}$$

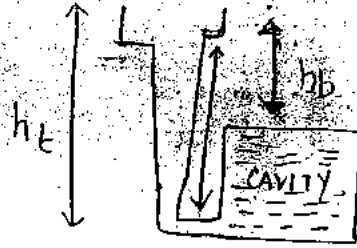
$$\text{Flow Rate} = A \times v$$



BOTTOM GATING SYSTEM



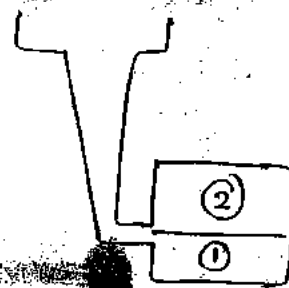
Vel goes on Reducing



PARTING GATING SYSTEM

$$P.T = T_1 + T_2$$

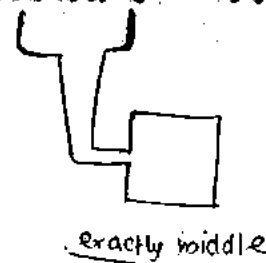
$$\frac{Vol 1}{V_{max} \times A_c} + \frac{Vol 2}{V_{avg} \times A_c}$$



MIDDLE GATING SYSTEM

TOP GATING SYSTEM CONTD.

choke Area = $\min(A_s, A_g, A_r)$
(min Area)
for increasing velocity



exactly middle

$$P.T = \frac{\text{Volume}}{\text{Flow Area}} = \frac{\text{Volume}}{A_c \times V_{max}}$$

Nonpressurised { $A_s \min$ }

* Advantages of Top Gating System

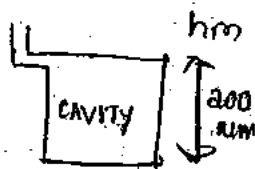
1. Uniformity of filling of casting 19
Early the velocity of molten metal in the gating system remains constant and maximum. ∴ pouring time is minimum
2. Making the top gating system is easier since it is present in cope box.

20 ~~Limit~~

* Limitations:

- ② To minimise the sand erosion the max height of cavity upto which the top gating can be used is 200 mm

- ③ It is not suitable to use for filling of cavities in horizontal



* Bottom Gating System

$$\text{Pouring Time} = \frac{\text{Volume}}{\text{Area} \times \text{Velocity}}$$

$h_i = h_m \rightarrow \text{both TOP \& Bottom}$

$$\frac{T_{\text{top}}}{T_{\text{bottom}}} = \frac{\frac{V_i}{A \times V_{\text{max}}} \times V_{\text{avg}}}{\frac{V_f}{A \times V_{\text{avg}}} \times V_{\text{avg}}} = \frac{V_i + V_f}{2 V_{\text{max}}} \Rightarrow \frac{V_i}{2 V_{\text{max}}} = 1/2$$

$$\therefore \frac{T_{\text{top}}}{T_{\text{bottom}}} = 1/2$$

$$V_{\text{avg}} = \frac{V_{\text{initial}} + V_{\text{final}}}{2}$$

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

$$V_f = \sqrt{2gh_b}$$

Advantages:

- ① $\rightarrow$ with molten metal may be filled
- ② $\rightarrow$ may be filled very easily without any sand erosion.

Disadvantages:

- ① Time Taking for filling of cavity with Bottom gating system is High
- ② Making Bottom gating system is difficult & As inco. Present

PARING GATING SYSTEM

$$P.T = T_1 + T_2$$

$$= \frac{V_{ol.1}}{A_c \times V_{max}} + \frac{V_{ol.2}}{A_c \times V_{avg}}$$

→ Pouring time with paring gate is greater than the top gating system and less than Bottom gating system.

→ The paring gate will have features of both top and bottom gating systems.

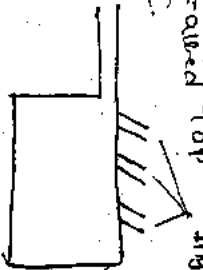
★ For Large Casting Cavity

such as:- $100 \times 100 \times 1000$

STEP GATING SYSTEM

Providing more than one ingate in a given horizontal plane for filling large casting cavity in a shorter duration is called as a step gating system. If more than one gate is provided at top, called top-gating system.

$$P.T = \frac{V_{ol}}{A_c \times V_{max}} \quad \left[\text{Top Gating} \right]$$



$$P.T = \frac{V_{ol}}{A_c \times V_{avg}} \quad \left[\text{Bottom Gating} \right]$$

$n = \text{no. of ingates}$

$$P.T = \frac{V_{ol.1}}{A_c \times V_{max}} + \frac{V_{ol.2}}{A_c \times V_{avg}} \quad \left[\text{Paring Gating system} \right]$$

25

- assumed as negligible

15
etc.

Pa.

.. 2 Pa

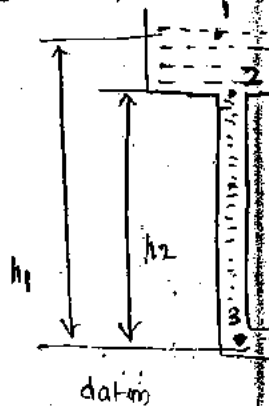
side of gating system

Hiring Effect

At 1 P 7 Patm

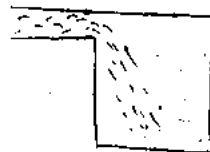
So no aspiration

At 2



Bernoulli's eqn:-

$$h_2 + \frac{v_2^2}{2g} + \frac{p_2}{\rho g} = h_3 + \frac{v_3^2}{2g} + \frac{p_3}{\rho g}$$



$$h_3 = 0$$

continuity eqn

$$A_2 v_2 = A_3 v_3$$

$$A_2 = A_3$$

$$\text{So } v_2 = v_3$$

So Bernoulli's eqn becomes

$$h_2 + \frac{P_2}{\rho g} = \frac{P_3}{\rho g}$$

$$h_2 + \frac{P_2}{\rho g} = \frac{P_3}{\rho g}$$

At Point 3

$$P_3 > P_{atm}$$

$$h_2 + \frac{P_2}{\rho g} = 0$$

$$P_2 = -\rho g h_2$$

$$< P_{atm}$$

So aspiration occurs at (2)

Pt. 3, located very near to the cavity, the P_4 0.3 is same as the other P_4 in the cavity, but P_4 in the cavity is greater than or equal atm. No aspiration effect is taking at Pt. 3.

$$P_3 = 0 \text{ gauge press}$$

$$P_3 \text{ min} = P_a = 0 \text{ gauge press}$$

The straight cylinder space will always promote the aspiration effect.

Prevention

for avoiding aspiration

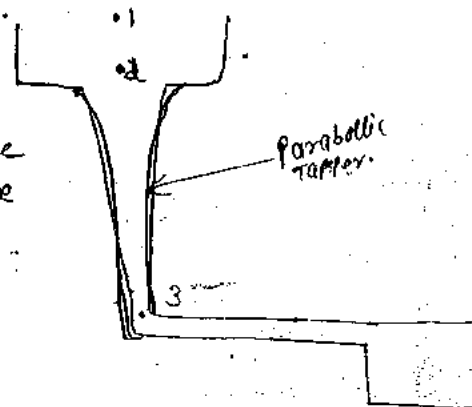
effect $P_2 = P_3 > 0$ gauge pressure

$$P_2 = P_3 = 0$$

By Bernoulli's So $v_3^2 - v_2^2 = h_2$

2g

$$v_3^2 - v_2^2 = 2g h_2$$



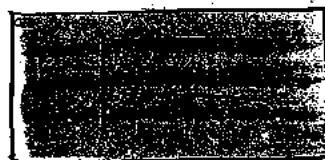
$$V_3^2 - R^2 V_3^2 = 2gh_2$$

$$V_3^2 (1 - R^2) = 2gh_2$$

$$1 - R^2 = \frac{2gh_2}{V_3^2}$$

$$R = \sqrt{1 - \frac{2gh_2}{V_3^2}}$$

$$R = \sqrt{\frac{1 - \frac{2gh_2}{V_3^2}}{2gh_2}}$$



$$\frac{A_3}{A_2} = R$$

$$A_2 V_2 = A_3 V_3$$

$$\frac{A_3}{A_2} = \frac{V_2}{V_3} = R$$

$$V_2 = R V_3$$

on the arrangement it gives Parabolic Eqn.

From the above, if

if Parabolic taper sprue is used.

If the sprue is made as a ~~parabolic~~ ~~straight~~ ~~tapered~~ ~~sprue~~ all along the length of the sprue ~~the~~ ~~zero~~ ~~gauge~~ ~~pressure~~ ~~at~~ ~~Point~~. Hence Aspiration Effect can be Eliminated.

★ Limitation of Parabolic sprue:

Manufacturing is difficult so instead we take straight tapered

sprue. At any point along the length of sprue the c/s area of straight sprue $>$ than parabolic sprue

$AV = \text{const}$

$$A \propto \frac{1}{V}$$

$$P \propto \frac{1}{V}$$

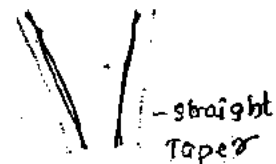
$\Rightarrow A_{\text{straight}} > A_{\text{parabolic}}$

$$V_{\text{str}} < V_{\text{parabolic}}$$

$$P_{\text{str}} > P_{\text{parabolic}}$$

$$P > P_{\text{atm}}$$

so no aspiration effect.



straight Taper

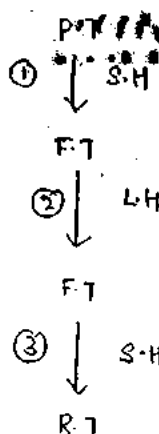
by selecting straight tapered sprue all along the length of the sprue the c/s Area is greater than parabolic sprue. $\therefore$ velocity is Reducing and Pressure is increasing. i.e. all along the length of sprue with straight tapered sprue pressure is greater than P_{atm} . Hence aspiration effect is eliminated and manufacturing also easier by using straight Tapered sprue.

Checking Aspiration.

Calculate the Area at 3.

If calculated A_3 is $<$ Given A_3 i.e. Given A_3 is more
Then no aspiration occurs. $\therefore \downarrow P \uparrow$

Solidification



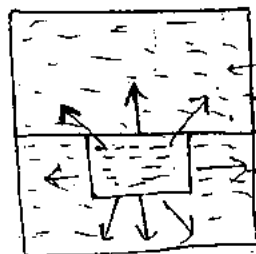
Heat to be removed for converting the liquid MM into solid

$$= m (S.H + L.H)$$

$$\text{Heat Remove } Q_{\text{R}} = \rho V (c_p (T_p - T_f) + L) \quad \text{--- (1)}$$

S = sensible Heat
 L = Latent Heat

Heat transfer from molten metal to surroundings through mold will be taking place by conduction (Temp Not const) with infinite wall thickness problem



Unsteady state conduction (Temp Not const)

$$H = \frac{A_s k \Delta T}{\sqrt{\pi \alpha T}}$$

(Heat transfer)

A_s = surface Area of Body / Casting

k = Thermal conductivity of mold

ΔT = Temp. diff in mold.

α = Thermal diffusivity,

T = Time duration

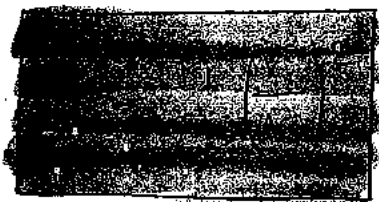
Solidification Time :-

$$= \frac{\text{Heat to be Removed}}{\text{Heat transfer}}$$

$$= \frac{\rho V [C_p(T_p - T_f) + L]}{A_s k \cdot \Delta T} \cdot \sqrt{\pi \alpha T}$$

$$\sqrt{T} = \frac{V}{A_s} \cdot \left[\frac{\rho (C_p(T_p - T_f) + L)}{k \cdot \Delta T} \right] \cdot \sqrt{\pi \alpha}$$

$$T = \left(\frac{V}{A_s} \right)^2 \left[\frac{\rho (C_p(T_p - T_f) + L)}{k \cdot \Delta T} \right]^2 \cdot \alpha \pi$$



k_1 = mold constant
= solidification factor

M = Modulus = $\frac{V}{A_s} \rightarrow \frac{\text{volume}}{\text{Area}}$
[Form Surface Area]

Casting 1

$$C_1 = 200 \times 100 \times 70 = 10 \text{ min}$$

$$C_2 = 200 \times 100 \times 10, T = ?$$

under similar conditions

[ρ, C_p ... same]

so k_1 same

[Rectangular ~~bars~~ ends]

COMPARISON
METHOD

$$\frac{T_2}{T_1} = \frac{K_1}{K_2} \left(\frac{M_2}{M_1} \right)^2$$

$$\frac{T_2}{T_1} = \left[\frac{V_2 \times A_{s1}}{A_{s2} \times V_1} \right]^2$$

$$T_2 = T_1 \left[\frac{V_2 \times A_{s1}}{A_{s2} \times V_1} \right]^2$$

$$= 10 \left[\frac{200 \times 100 \times 10}{200 \times 100 \times 70} \right] \left[\frac{2(200 \times 100 + 100 \times 70 + 70 \times 200)}{2(200 \times 100 + 100 \times 10 + 10 \times 200)} \right]^2$$

$$T = \frac{0.6 \text{ min}}{2}$$

Has to be less than T_1
Since K_1 of casting is less

~~Has to be less than~~

Page 4: 24

$$K_1 = 0.97 \times 10^6 \text{ s/m}^2$$

sphere

$$D_{sp} = 200 \text{ mm}$$

Not usually used

$$T = 2$$

$$T = K_1 \times M^2$$

$$V = \frac{4}{3} \pi (100)^3$$

$$0.97 \times 10^6 \times \left[\frac{V}{A_s} \right]^2$$

$$A_s = 4\pi R^2$$

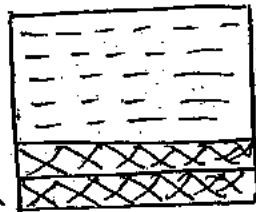
$$T = \frac{0.97 \times 10^6 \times \frac{4}{3} \pi R^3}{4\pi R^2}$$

$$T = 0.97 \times 10^6 \times \left(\frac{R}{3}\right)^2$$

$$0.97 \times 10^6 \left[\frac{D}{6}\right]^2 = 0.97 \times 10^6 \left[\frac{0.2}{6}\right]^2$$

$$= \underline{10788}$$

After 100 sec

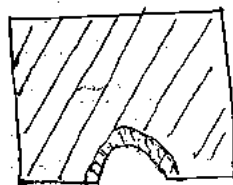
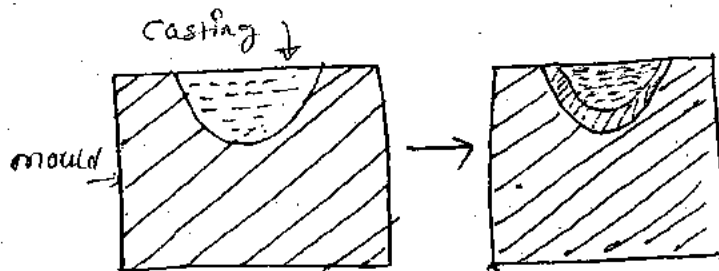


After 200 sec
What is thickness
of metal formed?

★ SLUSH CASTING PROCESS

PARTIAL CASTING [Partial Solidification is done]

→ Special casting process in which the liquid molten metal is poured into the casting cavity, allow it to solidify for some time, afterwards invert the mold so that unsolidified molten metal is falling downwards and solidified material is left over in the molding. Now By Breaking the mold the casting can be taken out.



1mm (min. requirement)
for this partial solidification req.

Producing decorative parts

lamp shades, christmas tree etc

For thin parts

$$M = \frac{V}{A s} t$$

According to solidifi

$$T \propto M^2$$

$$\text{so } T \propto t^2$$

$$t \propto \sqrt{T}$$

$$t = c_1 \sqrt{T} + c_2$$

T_1 thickness
 T_2 duration
 t_1
 t_2

c_1 and c_2 are const which depends on type of metal to be casted and shape of casting to be produced. so determined experimentally

$$t_1 = c_1 \sqrt{T_1} + c_2$$

$$t_2 = c_1 \sqrt{T_2} + c_2$$

$$c_1 = \text{—————}$$

$$c_2 = \text{—————}$$

Q2) $T_1 = 20 \text{ sec}$ and $T_2 = 50 \text{ sec}$
 $t_1 = 30 \text{ mm}$ and $t_2 = 45 \text{ mm}$

$T_3 = 100 \text{ sec}$ } $t_3 = ?$

$t_3 = ?$

$$t_1 = C_1 \sqrt{T_1} + C_2$$

$$t_2 = C_1 \sqrt{T_2} + C_2$$

$$30 = C_1 \sqrt{20} + C_2$$

$$45 = C_1 \sqrt{50} + C_2$$

$$C_1 = \underline{\hspace{2cm}}$$

$$C_2 = \underline{\hspace{2cm}}$$

$$t_3 = C_1 \sqrt{100} + C_2$$

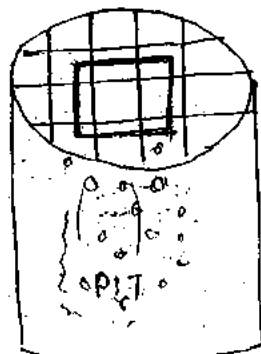
$$\sqrt{100} = 10$$

$$t_3 = \underline{6.2 \times 10 + 3}$$

★ Fettling:-

The method of and taking out casting from mold is fettling operation. vibratory mesh.

The solidified casting along with the mold is left over on the mesh so that due to the vibrational forces the mold will be and broken pieces of mold is falling into the leaving the mold box & casting over the .



the mold boxes will be sent for remolding and
casting will be sent for inspection.

Inspection

★ (A) Dimensional Inspection

★ (B) Defective "

We always specify minimum dimension

First one or two castings will be inspected dimensionally and
they will be qualified. After wards only Random inspection
will be done. - But every casting must be inspected for

★ Methods for Inspection for Defects:-

(A)

It is qualitative method only. The location and type
of defect can't be estimated.

It is a very simple easier and faster methodology, but
it needs the experience of the inspector.

(B)
(i)

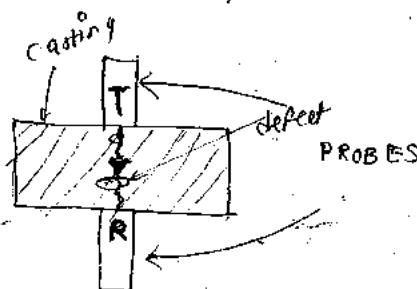
ultrasonic testing (UT)

Through Transmission

PET

X-Ray Radiography

The Magnitude of the signal
Received by Receiver is compared
with the signal transmitted by
Transmitter



In this technique, when the transmitter is producing the ultrasonic signal, it passes through the casting and received by the Receiver.

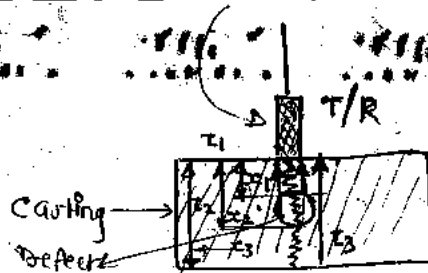
The receiver is compared with magnitude of signal transmitted by transmitter and loss of sound signal is estimated. If the loss of sound signal is less than 5%, the presence of the defect is considered to be small and based on the sound wave pattern it is possible to estimate the type of defect.

★ Disadvantage:

Loss of sound signal is same everywhere in this technique.

(ii)
(B)

Pulse Echo Technique (PET)



Whenever a variation in density is seen, some sound signals are reflected back.

The Receiver measures

velocity of sound signal is known

$$x_1 = \text{vel of sound} \times \frac{T_1}{2}$$

$$x_1 = \frac{V_s \times T_1}{2}$$

$$x_2 = \frac{V_s \times T_2}{2}$$

the time interval b/w transmitted and received signals.

So location can be identified.

This method is also used for measurement of thickness of complex structure.

In the PET, only this itself will be acting as a receiver when the power supply

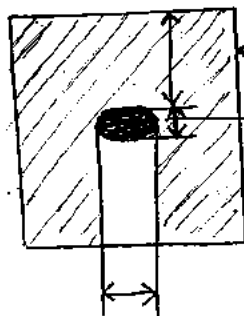
is given, the probe will be transmitted and produces ultrasound signal, then it is converted into Receiver. The ultrasound signal produced is such that some amount of sound signal will be reflected whenever it is finding the density variation in the passage. This Reflected sound signal will be absorbed by the Receiver and it is estimating the time interval b/w the Transmitted signal and first Received signal and so on. Based on this time interval, the distance x_1, x_2, x_3 can be determined as follows.



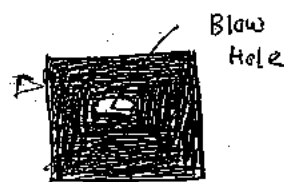
B

X-Ray Radiography

Intensity of x-Ray used is 1000 times larger than ordinary x-ray.



High Density Intrusion



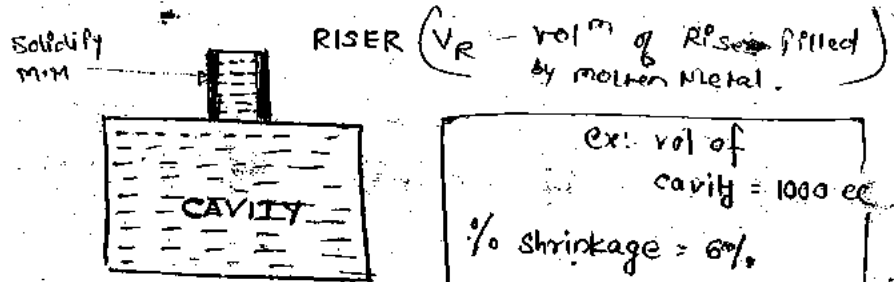
By Doing the Radiography ~~the~~ at the casting the x-ray film will be obtained. ~~based on the~~

~~variation in the~~ it is possible to estimate the ~~type of the~~ location of the

~~exactly~~. But it is a very ~~method~~ and it is

Highly ~~hence~~. This method is preferable only for critical components. Prone to cancer

Riser is acting as a Reservoir for supplying the molten metal to the casting cavity for compensating the volume changes taking place during solidification.



ex. vol of cavity = 1000 cc
 % shrinkage = 6%
 $V_s = \frac{6}{100} \times 1000 = 60 \text{ cc}$
 (shrinkage vol)

* Conditions to be satisfied :-

① $V_R \geq 3 V_s$

200% more

Volume of Riser should be atleast 3 times the shrinkage volume of casting.

$V_R = 180 \text{ cc}$
 120 cc solidified
 60 cc exists for supplying molten metal

② $T_R \geq T_C$

The solidification time of molten metal in the Riser must be atleast equal to the solidification time of molten metal in the casting cavity.

$T_R = T_C$

③ LOCATION OF RISER

three shapes are considered

$$Z \propto \left(\frac{V}{A_s} \right)^2$$

Surface Area

- (H) Cartesian coordinates
- (L) cylindrical
- (M) spherical

$Q_{cyl} : Q_{cyl} : Q_{cyl}$ Z must be as large as possible.

$\Rightarrow 0.439 : 0.411$ Vol - fixed

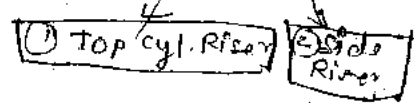
So "As" should be as min as possible. so cylindrical shape selected.

the shape of the Riser is selected such that

① ~~the shape of the riser is selected such that~~ as maximum as possible for this surface area of riser which is

② exposing for ~~the shape of the riser is selected such that~~ out of the available shapes cylindrical shape of the riser is giving with surface area exposed for

Heat transfer next min is for spherical shape. $\therefore$ the Best preferable shape of the Riser is ~~cylindrical shape~~ of Riser and Next preferable is spherical. But Never prefer to use cubical or Rectangular shape of Riser.



Spherical Riser

$$V_R = 3V_s = \frac{4\pi R^3}{3} \Rightarrow R = \text{D-variable}$$

cylindrical Riser

$$V_R = 3V_s = \frac{\pi D^2 H}{4} \Rightarrow \begin{matrix} D = \\ H = \end{matrix} \left\{ \begin{array}{l} \text{Relation b/w} \\ \text{dimensions should be} \\ \text{known.} \end{array} \right.$$

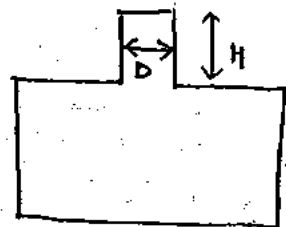
If the shape of Riser is taken as spherical, then dimensions of spherical Riser can be determined easily since only one variable parameter is there. 27

If Riser used is cylindrical Riser, Because 2 variables 'D' and 'H' are there, unless the Relation b/w the dimensions of cylindrical Riser are known, it is not possible to design the cylindrical Riser. For determining the optimum relationship b/w dimension of cylindrical Riser there are 2 types of Riser to be considered.

① Top Riser.

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

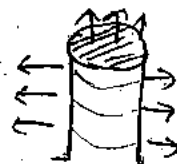
$$H = \frac{4V}{\pi D^2} \quad \text{--- ①}$$



$$A_s = \pi D H + \frac{\pi D^2}{4}$$

A_s = Surface Area

$$A_s = \pi \frac{4V}{\pi D^2} + \frac{\pi D^2}{4}$$



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

For min A_s

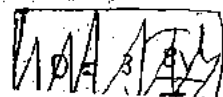
$$\frac{d(A_s)}{dD} = 0$$

$$\Rightarrow \frac{-4V}{D^2} + \frac{\pi \times 2D}{4} = 0 \Rightarrow \frac{-4V}{\pi D^2} + \frac{2D}{4} = 0 \Rightarrow +H = \frac{D}{2}$$

$$\Rightarrow \frac{4V}{D^2} = \frac{\pi \times 2D}{4}$$

$$D = 2H$$

$$8V = \pi D^3$$



$$D = 24$$

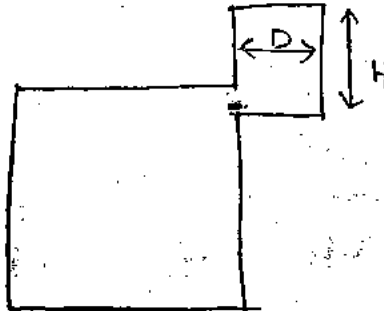


② SIDE RISER

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

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

①



$$A_s = \pi D H + \frac{\pi \times D^2 \times 2}{4}$$

$$A_s = \cancel{\pi D} \frac{4V}{\cancel{\pi D^2}} + \frac{\pi \cdot D^2}{2}$$

$$\frac{4V}{D} + \frac{\pi}{2} D^2$$

$$\frac{dA_s}{dD} = 0$$

$$\frac{-4V}{D^2} + \frac{\pi \times 2D}{2} = 0$$

$$\times \frac{1}{\pi} \quad \frac{-4V}{\pi D^2} + \frac{\cancel{\pi} \times 2D}{2\cancel{\pi}} = 0$$

$$-H + D = 0$$

So





28



for

$$M = \frac{\frac{4}{3} \pi R^3}{4 \pi R^2} \quad , \quad \frac{R}{3} = \frac{D}{6}$$



for

$$M = \frac{\frac{\pi}{4} D^2 H}{\pi D H + \frac{\pi}{4} D^2}$$

$$D = 2H$$

$$H = \frac{D}{2}$$

$$M = \frac{\frac{\pi}{4} \times D^2 \cdot \frac{D}{2}}{\frac{\pi D^2}{2} + \frac{\pi D^2}{4}}$$

$$M = \frac{\frac{\pi D^3}{8}}{\frac{3\pi D^2}{4}} = \frac{D \times \frac{4}{8}}{\frac{3}{1}} = \frac{D}{6}$$



$M = \frac{\pi D^2 H}{4}$
 $\frac{\pi D H + 2 \times \frac{\pi D^2}{4}}{\frac{\pi D^3}{4} + \frac{\pi D^2}{2}} = \frac{\frac{\pi D^3}{4}}{\frac{3 \pi D^2}{4}}$
 $\frac{D}{4} \times \frac{6}{3} = \frac{2}{3}$

→ **METHODS OF RISER DESIGN**

- ① Caines Method
- ② Modulus Method
- ③ Norel Research
- ④ shrinkage not consideration

1. CAINES METHOD

$\frac{V_{As} (RISER)}{V_{As} (CASTING)} \text{ ——— ①}$

$\frac{a + b \sqrt[3]{V_{As} (RISER)}}{c + b \sqrt[3]{V_{As} (CASTING)}} \text{ ——— ②}$

a, b, c are constants taken from casting Table corresponding to metal to be casted

$y = \text{volumetric Ratio} = \frac{V_R}{V_C} \text{ ——— ③}$

1. Equate ① and ②

$$\left(\frac{V}{A_s}\right)_R = \frac{a}{y-b} \cdot C$$

$$\left(\frac{V}{A_s}\right)_C$$

29

$$D \Rightarrow ?$$



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

$V_C = \text{known}$

→ MODULUS METHOD : 2

M_0

$$I_R \gg I_C$$

$$I_R \gg I_C \Rightarrow M_R^2 \gg M_C^2$$

$$M_R \gg M_C$$

$M_R = 20\% \text{ Higher than } M_C \text{ [Assumption]}$

Modulus of
Riser
(M_R)

$$M_R = 1.2 M_C$$

Modulus
of casting (M_C)

$$\frac{D}{6} = 1.2 M_C$$

$$D = 7.2 M_C$$



→ NOVEL RESEARCH : 3

$$\text{Shape Factor of casting} = \frac{L + W}{t}$$

(S-F)

L - Length of casting

W - Width " "

t - thickness " "



(S.F) Hollow cylinder

$$\frac{L + W}{D \cdot E}$$

$$\frac{30 + 25\pi}{25\pi}$$

$$21.5$$

$$W = \pi \frac{(D_o + D_i)}{2}$$

$$\pi \frac{(30 + 20)}{2}$$

$$\frac{\pi 50}{2}$$

$$25\pi$$



Shrinkage vol case ~~det~~

$$V_{sc} = \frac{a}{100} \times V_c$$

a = % shrinkage of metal

V_c = vol of casting

V_R = vol of Riser

$$V_R \geq 3V_{sc} \quad [\text{necessary condn}]$$

$$V_R = 3V_{sc}$$

$$\frac{\pi D^2 H}{4} = 3V_{sc}$$

$$\rightarrow D = \underline{\hspace{2cm}}$$

$$H = \underline{\hspace{2cm}}$$

CHECK

$$T_R \geq T_c \quad [\text{sufficient condn}]$$

If the above conditions are satisfied, then 'D' and 'H' are final dimensions of Riser

$$\text{If } T_R < T_c$$

$$\text{use } T_R = T_c$$

Recalculate the dimensions of riser

$$D' = \underline{\hspace{2cm}}$$

$$H' = \underline{\hspace{2cm}}$$

} final dimensions of riser

After determining the dimensions of Riser using sufficient condition it is not necessary to check the necessary condition because the dimensions of Riser calculated based on sufficient condition will always satisfy the necessary condition also.

But it is not Recommended to design the Riser directly by using sufficient condition because it may not ensure the economic size of the riser.

Here these steps are read. But in other methods, these steps are absent since in other methods some costs are represent. They satisfy these conditions. M_2

Ex:

... Casting ... $15 \times 15 \times 15 \text{ cm}$...

$$a = 6\%$$

[Top cylindrical Riser]

$$V_R \geq 3 V_C \quad \text{--- (1)}$$

$$V_{SC} = \frac{a}{100} \times V_C \quad \text{--- (2)}$$

$$\text{So } D = 2H$$

$$V_{SC} = \frac{6}{100} \times (15 \times 15 \times 15)$$

$$D = 2H$$

$$V_R = V_C$$

$$V_{SC} = \underline{\hspace{2cm}}$$

$$\frac{\pi D^2 H}{4} = 3 V_C$$

$$= 3 \times (15 \times 15 \times 15) \times \frac{6}{100}$$

$$\frac{1}{4} \times \pi H^2 \times H = 3 \times (15 \times 15 \times 15) \times \frac{6}{100}$$

$$\pi H^3 \times \frac{1}{4} =$$

$$H = 5.78$$

$$D = 11.56$$

Sufficient Cond'n

$$T_R = T_C$$

cube

$$M_R = M_C$$

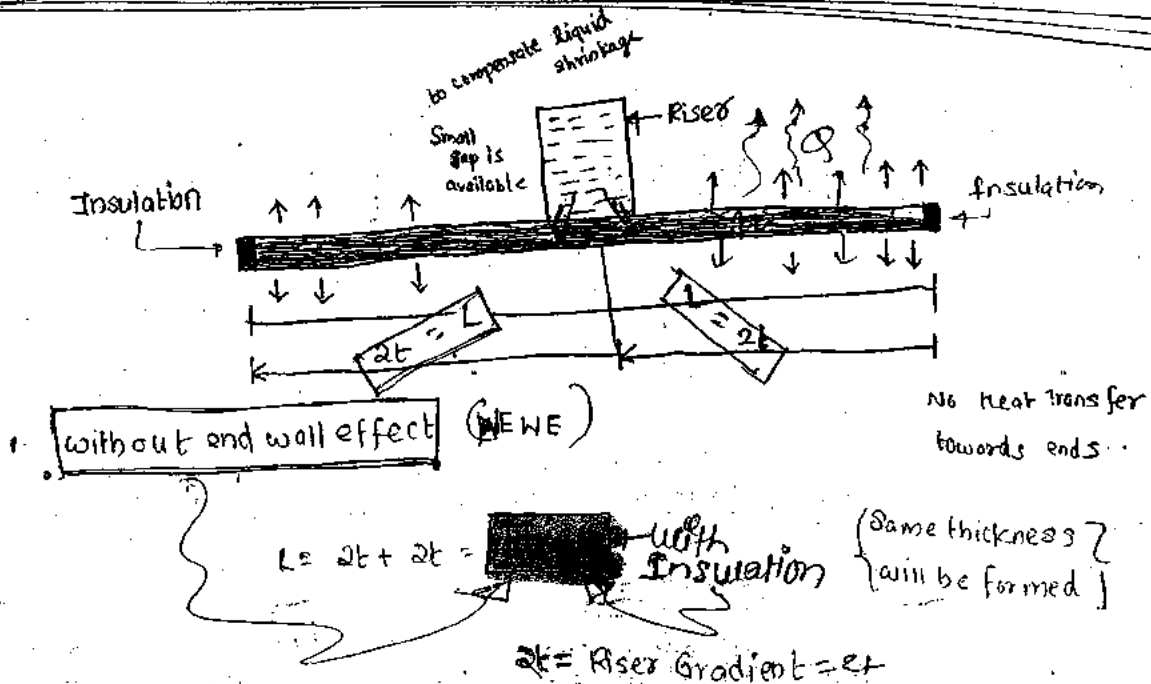
$$\left[\frac{V_R}{A_s} \right] = \left[\frac{V_C}{A_s} \right]$$

$$\frac{D}{8} = \frac{\pi \delta}{6 \times 2}$$

$$\frac{D}{6} = \frac{\pi \delta}{6 \times 2}$$

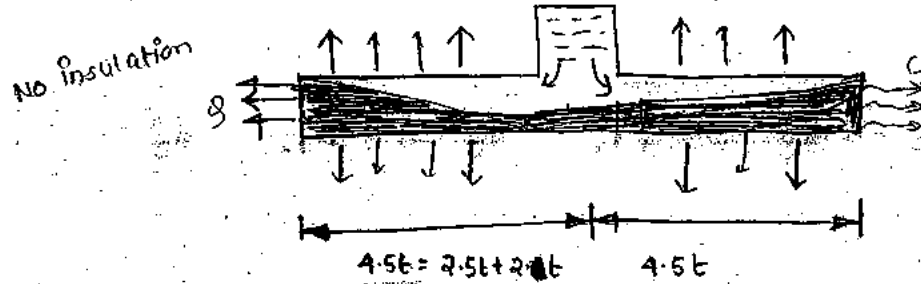
$$D = \pi = 15 \text{ cm}$$

final dimensions,



27. [With End Wall Effect] (WEWE)

At ends Remove insulation. so Heat Transfer occurs at ends also. so At ends 3-directional heat transfer is present. so At ends solidification is more



Because of heat T from the end also it is possible to supply M.M for the longer length of the period. i.e. upto 2.5t - additional amount $L = 4.5t + 4.5t$

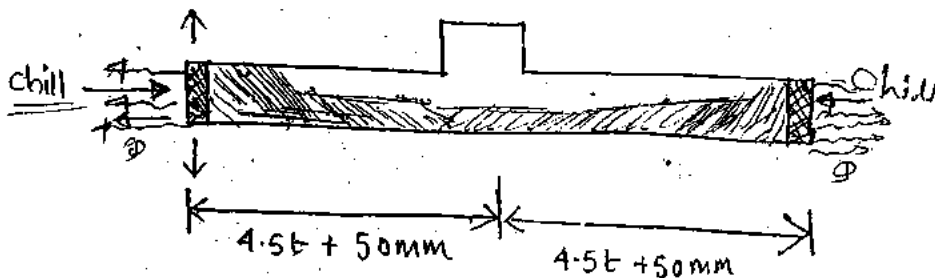
allowing $\frac{1}{2}$ of the available head at the end which is measurable to supply upto the length of $2t$.

without Insulation

③

Providing chills:

By providing chill to the end, H.T. to the end part further, $\therefore$ it is possible to sup. the M.M by the time for longer length of the period also.

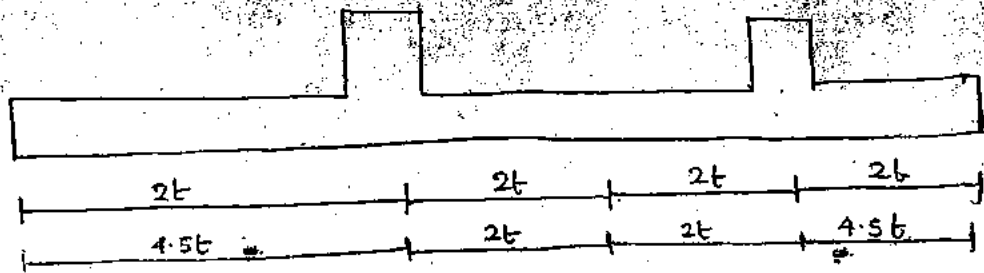


with chill gradient

$$L = 9t + (50 + 50) = 9t + 100$$

with chill

④ Multi Rises



without end wall effect



with end wall effect

$$L = 4.5t + 4.5t + 2t + 2t$$

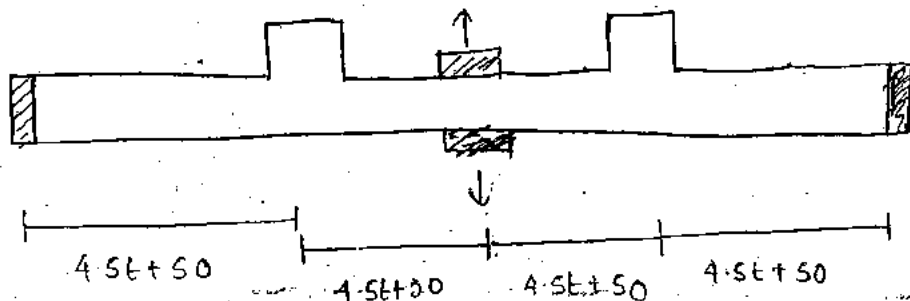


with end chill effect

$$L = (4.5t + 50) + 2t + 2t + (4.5t + 50)$$



⑤ With end and central chills



~~REAL WORLD'S NOT REPRESENTING SINGLE RISER SYSTEM~~

★ SPECIAL CASTING

➤ SHELL Mould CASTING

Normally in molding or casting operations large thickness of mold can be used which is difficult to handle. ∴ sometimes it is preferable to use thin or hollow molds in the casting process.

Mould is made by using a plastic called

~~Phenolic Resin~~

viscosity $\mu = 1500$ to 2000 CP

thick Liquid

As $\mu \uparrow$ thickness of liquid sticking to solid surface increases

$$\mu_{\text{air}} = 1 \text{ CP}$$

$$\mu_{\text{water}} = 25 \text{ CP}$$

$$\mu_{\text{diesel}} = 40 \text{ to } 50 \text{ CP}$$

$$\mu_{\text{oil}} = 75 \text{ to } 85 \text{ CP}$$

$$\mu_{\text{EPOXY RESIN}} = 10,000 \text{ CP}$$

$$\frac{1}{100} \text{ Poise}$$

$$\frac{1 \times 10^4 \text{ dyne}}{100 \text{ cm}^2}$$

$$\frac{\text{Ns}}{\text{m}^2}$$

Dip the pattern in phenolic Resin for 1 to 2mts.
Take out the pattern

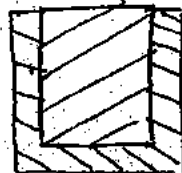
→ keep it in a furnace @ 250°C to 300°C

After 12.0°C phenolic Resin takes 4 hrs to solidify

[At High temp cross linking takes places and within 2 mts it solidifies]

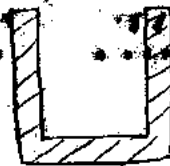
→ take out the pattern

→ Remove the top Layer of phenolic Resin



→ Remove the pattern

thickness of mold is around 8 to 10 mm

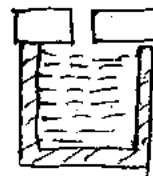


$$\left[\begin{array}{l} \rho_{\text{MOLDING SAND}} = 4.5 \text{ to } 5 \text{ g/cc} \\ \rho_{\text{PLASTIC}} = 1 \text{ g/cc} \end{array} \right]$$

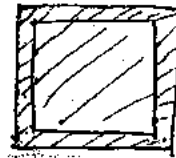
→ Fill the molten metal into mold and allow it to solidify

Phenolic Resin - highly Brittle
↓
Break easily
Very Low porosity

— No Reusability



- Thermal conductivity of mold is less.
- Porosity of mold is also less. ∴ True Risers must be used.
- No Reusability of Phenolic Resin
- only circular and symmetrical parts can be made.



★ Advantages:-

- It is easy to handle because of Uniform Area of the mold and Automatic mechanism.
- Production process can be automated.
- Max time taken for producing 1 mold is upto 5 mts. ∴ At corners Area is more So phenolic Resin will stick to the pattern and chance of Breakage.
- All the activities of mold making can be automated. ∴ production rate can be further increased.

Ex: cylinders, cylinder heads, IC engines, crankshafts, Gear Blanks, Bevel gears

Limitation → surface finish produced will be Better.

- ★ cost is high
- ★ Because of lowest strength of mold, Sand particles can be added to increase strength.
- ★ Vary large size casting can't produced (upto 25-30 kg possibly)
- ★ This preferable for circular or only symmetrical casting.

➤ CERAMIC MOULDING

In shell mold casting in place of phenolic Resin if ceramic slurry is used as a mold material, it is called as ceramic molding.

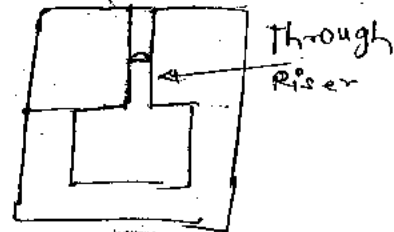
Sometimes in shell molding of phenolic Resin, Some amount of Sand particles also will be added to increase the strength of the mold.

Investment Casting process

Here wax is used as the pattern material.

Adv of this pattern

- Good surface finish
- Easy to Remove the pattern
- Complex shapes can be easily formed
- No Allowances reqd for casting.



In investment casting, cement concrete mould is used as

Some mold can be used for producing a

8. it is also called as

process. Because of cement concrete mold, the

the cooling rate is higher and

the cooling rate is higher and

it will be taking place i.e.

If casting is produced by investment casting it will always

have Hard surface and soft interior. Ex of pattern castings

produced by investment casting process are

Wave Guide for radar

Turbine blades etc, Shuttle eye for view

* Porosity of mold is very low; Through Riser must be used for escaping the gas in casting cavity.

DIE CASTING PROCESS

and are as the mold material. The same

mold can be used for of components.

Hence it is also named

Commonly used metals for making mold are

The mold is having excellent

Surface finishing can be produce in Surface Finishing of component by die casting is also excellent. Hence no machining is reqd on the casting and close dimension tolerance are possible. Hence no post casting processes are reqd after die casting.

★ DisAdvantages:-

- ① It can used for casting of only low melting point materials.
Cast Al, Cu, Sn, Cadmium, Al, zinc below 1400°C
- ② During solidification of molten metal in the cavity. There is a possibility of sand formation b/w solidified metal and mold metal. To avoid this silica sand will be sprinkled on the surface of cavity before filling the molten metal.
- ③ The metallic molds will have the pores to escape the air or gases present in the cavity.

★ ③ GRAVITY DIE CASTING

⑥ PRESSURE DIE CASTING

★ GRAVITY DIE CASTING

If the molten metal is filled into the cavity due to gravitational force the process is called as gravity die casting. The Gravitational force is not sufficient to place the molten metal into each and every part of cavity.

Gravity die casting is used for casting of large parts which are made by investment casting.

Melting point materials.

PRESSURE DIE CASTING

INJECTION CASTING 35

For plastic mat. only

If the external pressure is used for flow of molten metal into casting cavity it is called as pressure die casting.

Because of external force application the molten metal can easily flow into each and every corner of complex shape of cavity. ∴

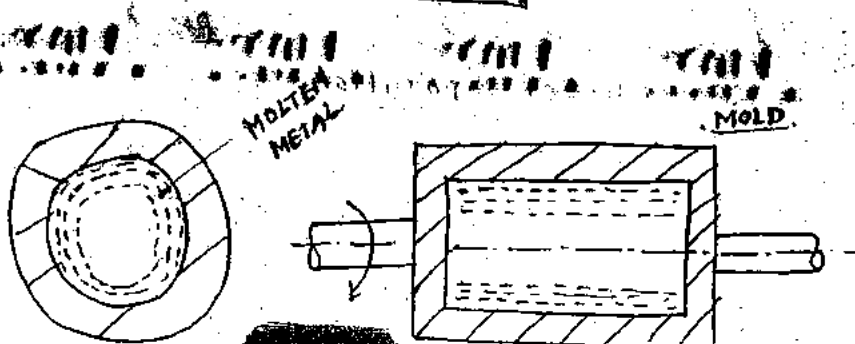
Complex shapes of casting made by using Low M.T materials can be easily produced by using pressure die castings.

This one of the same as "Inject" mould casting which is used for plastic mould casting.

ex:



CENTRIFUGAL CASTING PROCESS:-



Developed
ability for
producing
large size
hollow
casting

g -accel due to gravity

Centrifugal force produced due to rotation of mold can be used for

The Rotation of mold is continued until molten metal gets solidified. Once molten metal is solidified Break the mold and Take out the Castings.

It is used for producing

For producing large size Hollow casting by using core method is difficult because manufacturing

the large size core, ~~is~~ is very difficult and Handling of such large size core is much more difficult.

$$F_c = ma = m\omega^2 r$$

$$= \rho V a = \rho V r \omega^2$$

$$F_c \propto \rho$$

$$a = r\omega^2 = \frac{2\pi N}{60} r$$

$$N^2 r = \frac{60^2 \times 2 \times a}{N^2} = \text{const.}$$

$$N = \sqrt{\frac{60^2 \times 2 \times a}{D}}$$

Because the centrifugal force is directly proportional to density. Any low density impurities present in molten metal on which centrifugal force acting is less, Hence the ~~low density impurities will be~~

$$\rho_{Fe} = 8 \text{ g/cc}$$

$$\rho_c = 1.2 \text{ g/cc}$$

$$\rho_{Fe} = 8 \text{ g/cc}$$

$$\rho_{Fe} = 8 \text{ g/cc}$$

Disadvantages:-

The centrifugally casted components will have ~~low density impurities~~ because of ~~low density impurities~~

ex: take case of steel. Here the

density variation is much High. so

Fe is more for Iron and less for Carbon. But due to the Bonding b/w Fe and C they are not able to ~~form~~

Separate completely. so they form Layered structure

$$\begin{aligned} \rho_{Fe} &= 8 \text{ g/cc} \\ \rho_c &= 1.2 \text{ g/cc} \\ &\text{7 times density} \end{aligned}$$

Poor in C
Rich in C
Poor in C
Rich in C



Layer
Heterogeneous str.

If ρ variation is high, usually Separation is very easy

$$F_c = ma = m\omega^2 r$$

$$a = \frac{D}{2} \left(\frac{2\pi N}{60} \right)^2 \quad N = \text{rpm of mold}$$

$d = \text{dia of casting}$

$$N^2 D = \frac{60^2 \times 2 \times a}{4\pi^2} = \text{const}$$

$$N = \sqrt{\frac{\text{const}}{D}}$$

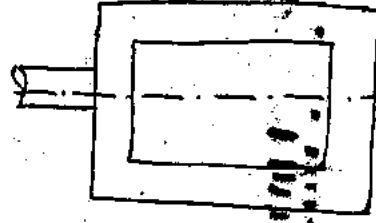
$D = \text{avg dia of casting}$

$$= \frac{D_o + D_i}{2}$$

$\{F_c \text{ acting at the c.g.}\}$

★ - In centrifugal casting process is done with axis of rotation only horizontal.

Why not vertical rotation?



Also producing such High accln is very difficult and during rotation with such High accln, the mold may get Broken.

In centrifugal casting process if the axis of Rotation and axis of mold are the process is called as centrifugal casting. It produces uniform thickness of casting around the circumference.

Sometimes offsetting of axis of Rotation is also possible.



Non-uniform thickness around circumference.

Process, any offset is present b/w the axis of rotation and mold axis it is called Semi centrifugal casting.



Non uniform variation of thickness

ex. used for producing large size pipes like city water supply pipes.



DEFECTS:

①

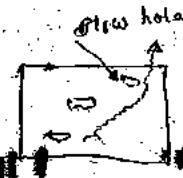
Blow or Blow Holes

Presence of Air or Gas bubbles in the casting is called Blow Holes. The Reasons are

1. Low porosity of the molding sand

2. Aspiration effect of gating system

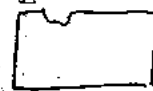
3. Allowing partial flow of molten metal in gating system



②

SCAR

The Air or Gas present at the surface of the casting is called SCAR. [open to atmos]



③

BLISTER:-

The presence of Air or Gas bubble near to the surface of casting is called Blister. [Not open to atmos]



SCAR covered with thin layer of material is Blister.

Reasons are same as above.

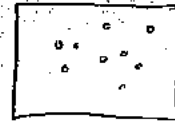
④ POROSITY PROPERTY :-

NOB Bubbles

37

The presence of small size air or Gas particles inside the casting is called porosity.

Reasons are same as Blow Holes.



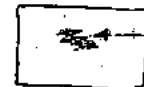
⑤ DROSS

The presence of impurities or foreign particles inside the casting are called as Dross. Reasons

1. improper separation of impurities present in molten metal.
 (By proper protection in pouring basin)
2. the impurities can be separated by using skimmer,

skimming of runner and ingate, providing offset low axis of runner & ingate

⑥ INCLUSION OR SAND INCLUSION



Presence of sand particles inside the casting is called

inclusion or sand inclusion. Reasons are

1. Due to sand taking place due to casting process

which & due to It produces sand particles inside the casting

- ① allowing Turbulent flow into gating syst.
- ② Using TOP Gating for filling the Height > 200 mm for the cavity.
 (sand for the cavity.
 (old core.)
- ③ Using TOP Gating for filling the Height > 200 mm for the cavity.
 (sand for the cavity.
 (old core.)
- ④ pouring molten metal in cavity without flesh gate.

⑦ MISRUN



Partial filling of casting cavity using molten metal is called Misrun. Reasons are

1. Solidification of molten metal has been started before complete filling of casting cavity.

① Reducing the viscosity of molten metal into the cavity

② By increasing the diameter of superheated metal

8. SHRINKAGE :-

the formation of a void in the casting due to non availability of molten metal for compensating the liquid shrinkages taking place during solidification.

Remedy :-

By directional solidification, i.e. providing chills in the casting process.

9. RAT TAIL

tail like elements produced on the surface of castings are called Rat Tail defect. It is because

single was pattern with Green Sand Mold.

10. SHIFT

The pattern is used in a piece

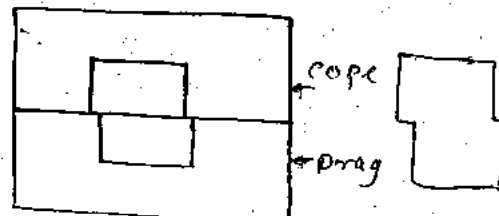
the casting of

Produces

step in the casting which is called as shift defect.

(Matching pin)

Eliminated by using during making of molds

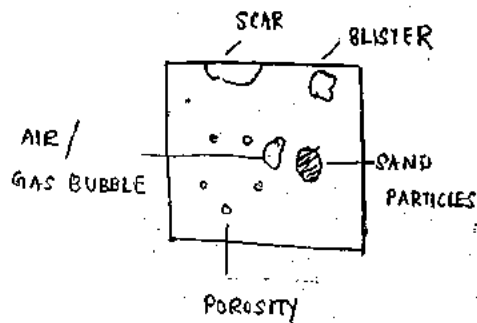


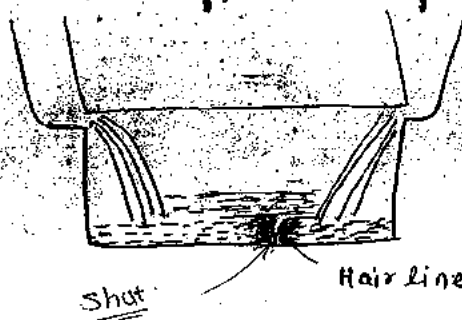
11. COLD SHUT :-

Discontinuity present in the casting due to hindered contact

Mainly produced in step gating system

[In forging op^r]





Reasons:-

Low degree of super-heating of M.M

PROBLEMS

① Vol of casting = 106

$$P.T = \frac{Vol}{A_c \times V_{max}} = \frac{106}{200 \times \sqrt{2 \times 9.81 \times 100}}$$

$$= \frac{106}{200 \times \sqrt{2 \times 10000 \times 175}} = 2.67 \text{ sec}$$

$A_s = 200$

$A_r = 200$

$V_{max} = \sqrt{2gh}$

② $P.N = \frac{501.28}{P.T} = \frac{501.28}{10 \times 0.5} = \underline{\underline{\quad}}$

③ Flow Rate = $A_c \times V_{max}$

$$V_{max} = \frac{\text{Flow Rate}}{A_c}$$

$$= \frac{0.8 \times 10^{-3}}{400 \times 10^{-6}}$$

$$= \sqrt{2gh}$$

$$h = \frac{200 \text{ mm}}{1000} = 0.2 \text{ m}$$

400 mm^2

$= 400 \times 10^{-6} \text{ m}^2$

④ 3 castings of same material

$$\frac{T_{\text{sphere}}}{T_{\text{cube}}} = \left[\frac{M_s}{M_{\text{cube}}} \right]^2$$

$$= \left[\frac{D/6}{a/6} \right]^2 = \left[\frac{D}{a} \right]^2 = \left[\frac{2R}{a} \right]^2$$

$$Vol_{\text{sphere}} = Vol_{\text{cube}}$$

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

$$a = R \sqrt[3]{\frac{4\pi}{3}}$$

$$\frac{T_s}{T_{\text{cube}}} = \left[\frac{2R}{R \sqrt[3]{\frac{4\pi}{3}}}} \right]^2$$

1.54

⑤ ⑥

D = 150mm

H = 200mm

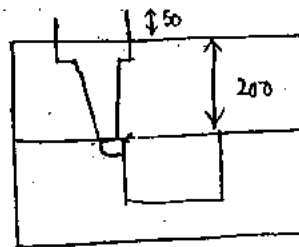
Top Gating

As : Ar : Ag

Gr = ~~1:1~~ 1:1.5:2

~~Ag~~ Ag = 400 mm²

$$A_c = A_s = \frac{400}{2} = \underline{200 \text{ mm}^2}$$



$$h_t = 200 + 50 = 250$$

$$V_{\text{max}} = \sqrt{2gh_t} = \sqrt{2 \times 9.810 \times 250}$$

$$Vol = \frac{\pi D^2 H}{4} = \frac{\pi \times 150^2 \times 200}{4}$$

$$P.T = \frac{Vol}{A_{cx} \cdot V_{max}} = \underline{8 \text{ sec}}$$

88

C₁

Circular

$$d = 20, t = 10 \text{ cm}$$

C₂

Square

$$\text{side } S = 20 \text{ cm}, t = 10 \text{ cm}$$

Freezing Ratio

$$x = \frac{(A_s/V)_C}{(A_s/V)_R} = x_1 = 1.4$$

$$x_2 = 2$$

$$y = \frac{V_r}{V_c} = y_1 = 0.8$$

$$y_2 = 2$$

Same cylindrical Riser is used in Both cases

$$y_2 = \frac{V_r}{V_{c2}}$$

$$\left[\frac{A_s}{V} \right]_R = \frac{(A_s/V)_C}{1.4}$$

$$\left[\frac{A_s}{V} \right]_C = x$$

$$\left[\frac{A_s}{V} \right]_R$$

$$V_R = 9 \times V_{C1}$$

$$= 0.8 \times V_{C1}$$

$$y_2 = \frac{V_R}{V_{C2}}$$

$$= \frac{0.8 \times V_{C1}}{V_{C2}}$$

(11) CASTING = $35 \times 35 \times 36$ mm

$$P.T = 25 \text{ sec}$$

Laminar flow

$$d_g = 8 d_s$$

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

$$P.T = \frac{35^3}{\left(\frac{\pi}{4} d_s^2\right) \times V}$$

$$A_c \times V_{max} = \left(\frac{\pi}{4} d_s^2\right) \times V$$

$$V = \frac{(35)^3}{\left(\frac{\pi}{4} \times d_s^2\right) \times 25} \quad \text{--- (1)}$$

Flow must be laminar

$$Re = \frac{\rho V D_s}{\mu} \quad \text{or} \quad \frac{V D_s}{\nu} \leq 2000$$

$$\frac{V D_s}{\nu} = 2000$$

$$V = \frac{2000 \nu}{D_s} \quad \text{--- (2)}$$

Equation ① and ②:

$$\frac{353}{\pi/4 \times d_s^2 \times 25} = \frac{2000 \times \pi}{d_s}$$

40

$$d_s = \underline{\hspace{2cm}}$$

⑫

$$F_c = m a$$

$$= m r \omega^2$$

$$a = r \omega^2$$

$$a = \frac{D}{2} (2\pi N)^2$$

$$2\pi N \times \frac{D}{2} = \frac{2\pi N^2 D}{4\pi^2}$$

$$a = \frac{2\pi N^2 D}{4\pi^2}$$

$$= \frac{2 \times 75 \times 9810}{4\pi^2} = \underline{37273}$$

⑬

$$D = \frac{0.5 + 0.5}{2} = 0.51$$

$$= \underline{510 \text{ mm}}$$

$$N = \sqrt{\frac{37273}{D}} = \sqrt{\frac{37273}{510}} = \underline{8.57 \text{ rps}}$$

⑭

0.97

⑮

a

⑯

a

(17)

(18)

b.

(19)

3.

(20)

d

$$\frac{\tau_{\text{tube}}}{\tau_{\text{sph}}} = \left[\frac{M_{\text{cube}}}{M_{\text{sphere}}} \right]^2 \cdot \left[\frac{\frac{a}{6}}{\frac{D}{6}} \right]^2 = \left[\frac{a}{D} \right]^2$$

$$V_S = V_C \quad \left[\frac{a}{2R} \right]^2$$

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

$$a = \sqrt[3]{\frac{4\pi}{3} \cdot R^3}$$

$$\left(\frac{4\pi}{6} \right)^2 \cdot \left(\frac{a}{1} \right)^4$$

$$\frac{\left[\frac{4\pi}{3} \right] \cdot R^2}{4R^2}$$

21

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

$$h_2 = 2.0$$

$$\text{Flow Rate} = A_2 V_2$$

$$V_2 = \frac{6.5 \times 10^5}{650} = \underline{\hspace{2cm}}$$

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

$$h_b = \underline{\hspace{2cm}}$$

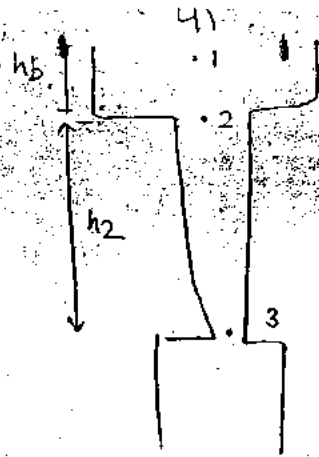
$$h_t = h_b + h_2$$

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

$$\underline{\hspace{2cm}}$$

$$A_2 V_2 = A_3 V_3$$

$$A_3 = \frac{A_2 V_2}{V_3} = \underline{\hspace{2cm}}$$



22

Net Buoyancy force

$$BF = Vg (\rho - d)$$

$$= \frac{\pi \times 120^2 \times 180 \times 9.81 \times 9.81}{4} (11300 - 1600)$$

$$\underline{\hspace{2cm}}$$

23

$$\left(\frac{D}{L} \right)^2$$

(25)

$$L = 4.5t + 4.5 + 2t + 2t$$

$$= 13t$$

$$L = 13 \times 10 = 130$$

(26)

$$C_1 = 100 \text{ mm} \times 100 \text{ mm} \times 50$$

$$V_{sc} = \frac{2.6}{100} \times [100 \times 100 \times 50]$$

$$h = 50 \text{ mm}$$

$$V_R = 4 V_{sc}$$

$$\frac{\pi \times D^2 \times h}{4} = 4 V_{sc}$$

$$I_R > I_c$$

$$I_R = I_c$$

$$D^1 = 58.52$$

$$V_{SC} = \frac{3}{100} \cdot (40 \times 30 \times 0.3) = 10.8 \text{ cc}$$

$$V_R > 3 V_{SC}$$

$$\frac{4}{\pi} D^2 H > 3 V_{SC}$$

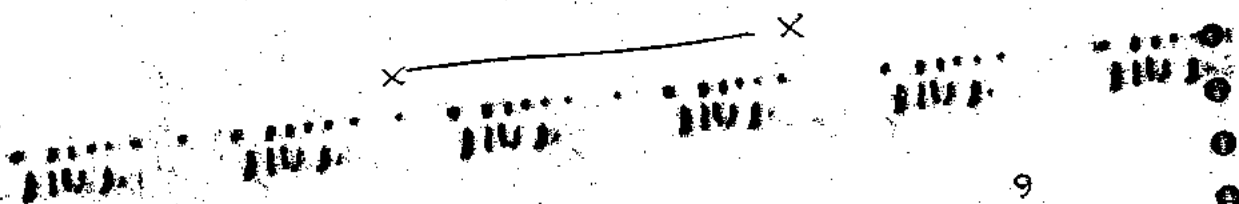
$$\frac{4}{\pi} \times 4^2 \times 4 > 3 \times 10.8$$

$$50 > 30.8 \text{ satisfied}$$

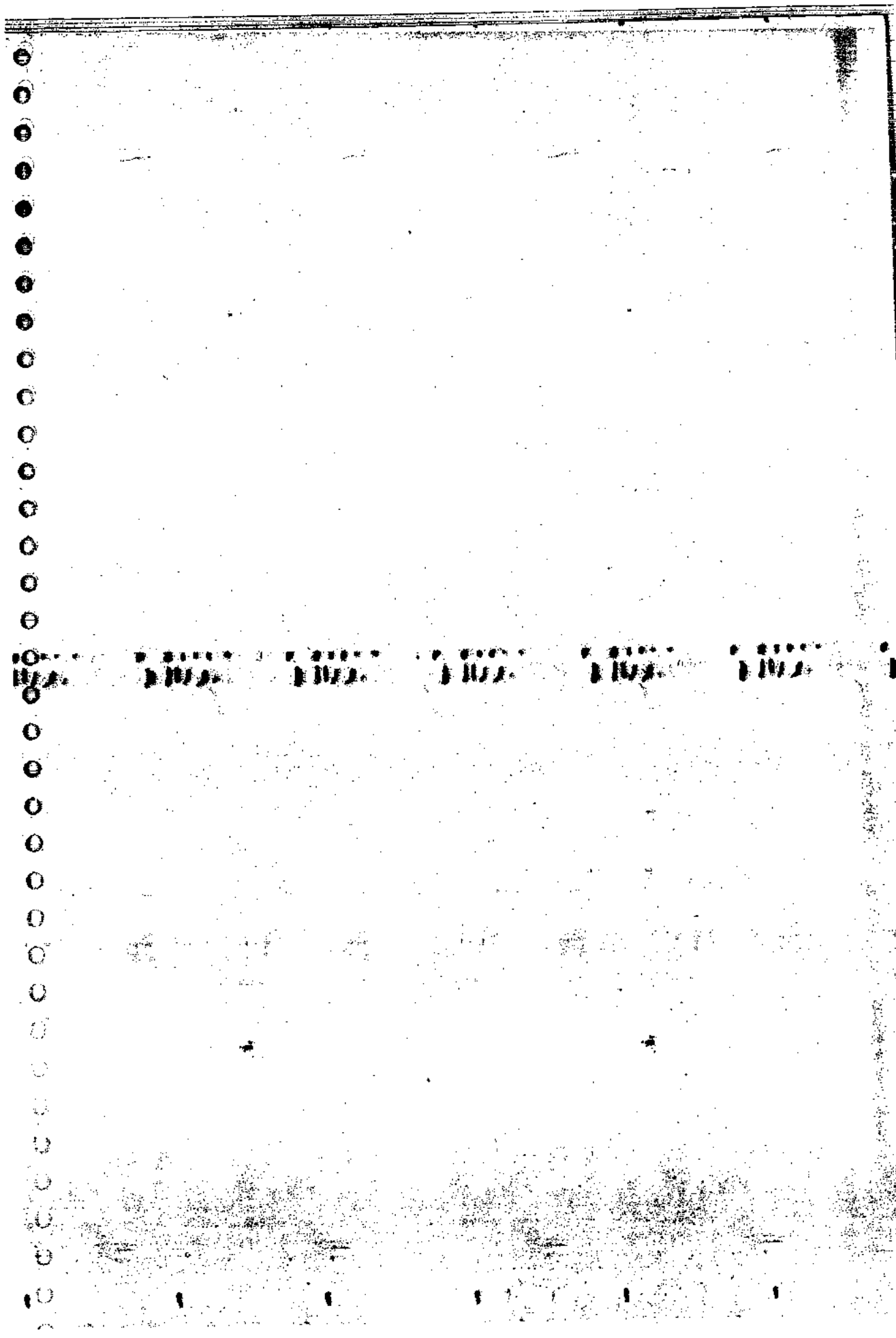
$$t_r \geq t_c$$

$$M_R \geq M_C$$

$$\frac{D}{6} \geq M_C \text{ satisfied}$$



25



1102 1103 1104 1105 1106 1107

113

- WELDING -

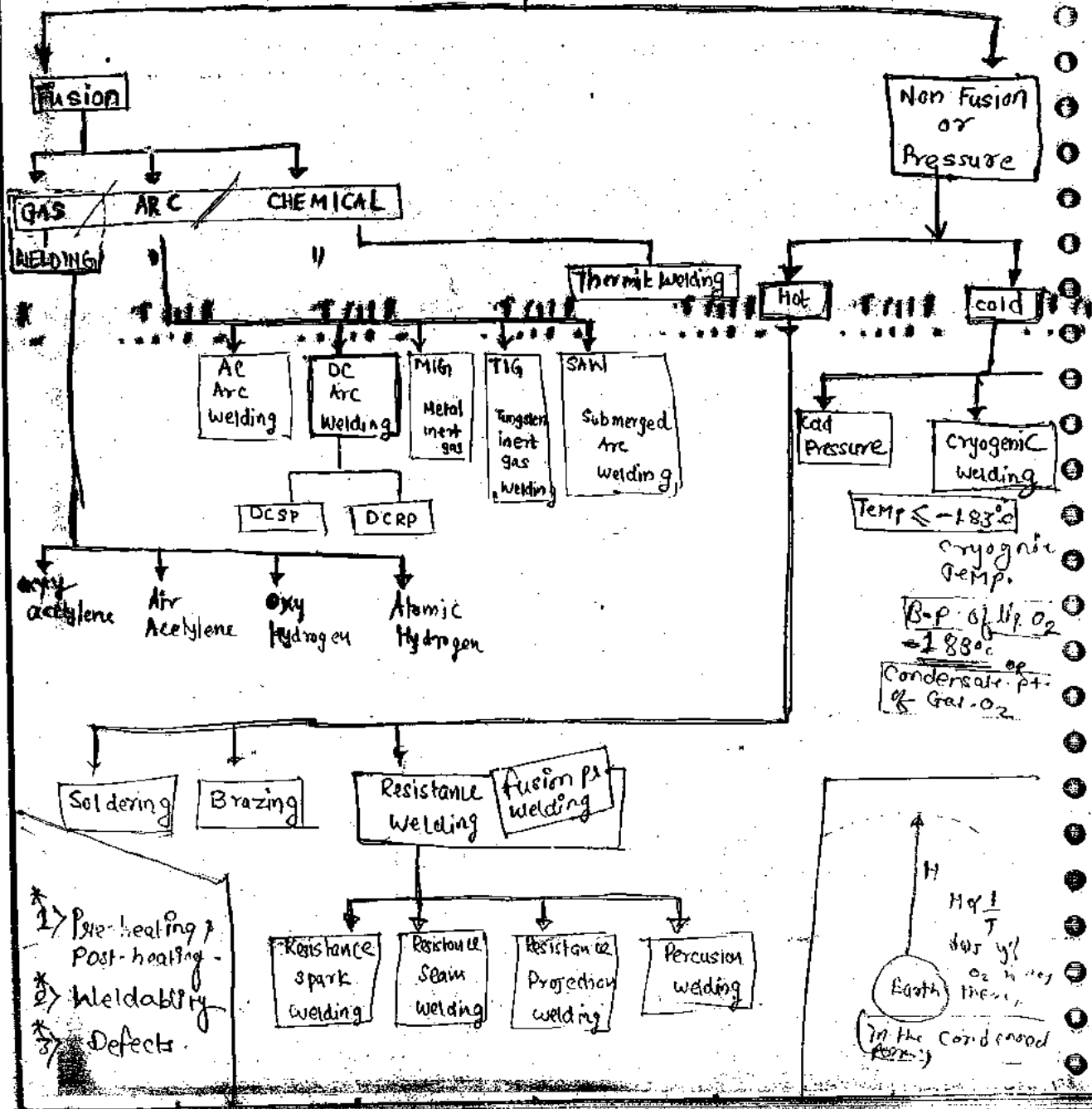
DEF?

Q- It is the process of joining two or more similar or dissimilar metals both or without the application of Heat, with or without the Application of pressure, with/without the application of filler material.

Ref. :- 1) WIT by LIT-Lo
2) WIT by paramory
3) WIT by Weinshburg

Classification

Welding



1. By melting of parent materials if a joint is produced it is called as Fusion welding process.

2. Without melting of parent material if the joint is produced it is called as Non fusion welding process or with application of pressure if the joint is produced it is called as pressure welding process.

FUSION WELDING

GAS

By Burning of Gases if the heat reqd for melting of plates can be obtained, it is called Gas welding operation.

ARC

If the heat reqd for melting of plates is obtained through electrical arc, it is called as ARC welding operation.

CHEMICAL

If heat reqd for melting of plates is obtained through exothermic chemical reaction it is called chemical welding operation.

NON FUSION WELDING

COLD PRESSURE WELDING

When two metals are joined by the application of large amount of pressure it is called cold pressure welding.

CRYOGENIC WELDING

When two metals are joined at a temp below -183°C by application of pressure it is called cryogenic welding.



-183°C Taken as Reference

-182.5°C to be exact

It is the Boiling Temp of Liquid O₂

GAS WELDING

OxyAcetylene Gas welding

In this case heat reqd for melting of plate is obtained by Burning of oxyAcetylene Gas mixture.

Oxygen and Acetylene are drawn from resp. cylinder by flexible hose pipe into the torch Bar. Both the gases are mixed together in the torch Body.

GSLV

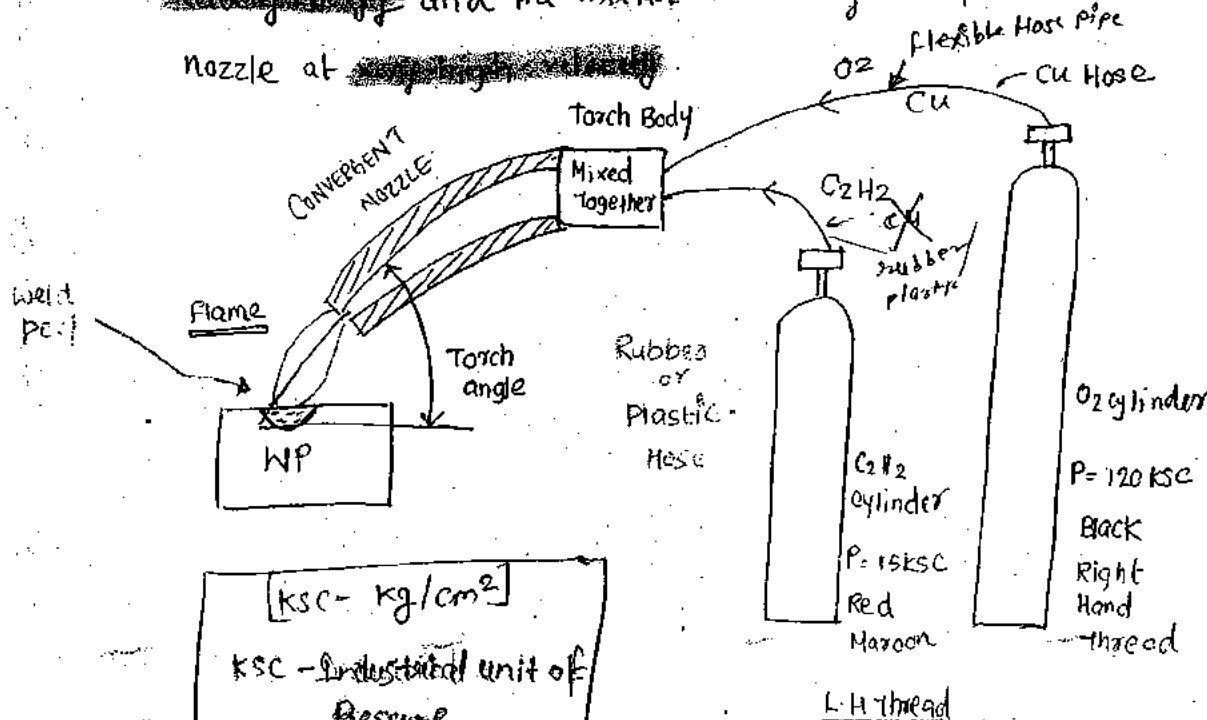
36000 KM from Atmosphere

There temp is -200°C. So

No oxygen, No nitrogen. every thing in condensed form.

So oxygen and Nitrogen carried separately.

When the mixture is passed through the nozzle at high velocity and the mixture is coming out from the nozzle at high velocity.



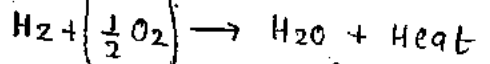
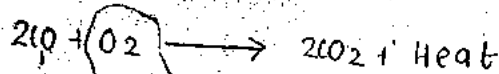
Oxy Acetylene Welding

o₂ cylinder

45



$$KSC = \frac{kg}{cm^2}$$



1.5 unit from Atmosphere

So we have seen that the mixture comes out from nozzle at very high velocity. If this mixer is given initiation for ~~starting~~ the continuous flame will be produced. so the Heat available in the mixture is used for melting/joining of work piece.

* From the Above for complete combustion of 1 unit vol of C_2H_2 ~~1 unit vol of O_2~~ out of this ~~1 unit vol of O_2~~ and Remaining ~~1 unit~~ is obtained ~~from atmosphere~~

* ~~1 unit~~ amount of O_2 obtained from O_2 cylinder ~~that is~~
 ~~can be divided~~

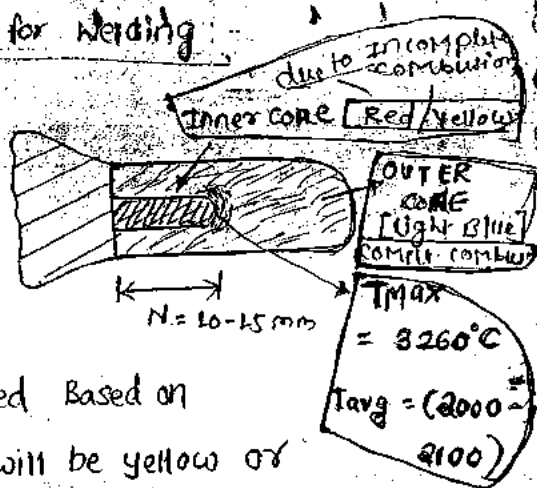
x ——— x

Different Types of flames used for Welding

① Neutral flame



N: 10 to 15 mm



Two cones can be distinguished Based on their colour. The inner cone will be yellow or Red and outer cone will be light Blue colour.

Yellow or red colour indicates incomplete combustion and light Blue colour indicates complete combustion. Max temp of flame is induced at the intersection of inner cone and outer cones.

Average temp is $(2000-2100)^\circ C$. It is the

only $\frac{2}{3}$ of max temp. During combustion of Acetylene large qty of water is produced, to evaporate this water it is carrying away large amount of heat. so avg temp is coming out to $\frac{2}{3}$ of max temp.

USES:-

Neutral flame is used for joining and cutting of all ferrous and non ferrous metals except Brass.

During joining of Brass, the Zinc present in

Brass will get evaporated, only 'Cu' will Left over. In the joint which will not give req. mech. properties to the joint.

*

$T_{max} = 3260^\circ C$
 $T_{avg} = 2000 \text{ to } 2100^\circ C$

②

Oxidising flame



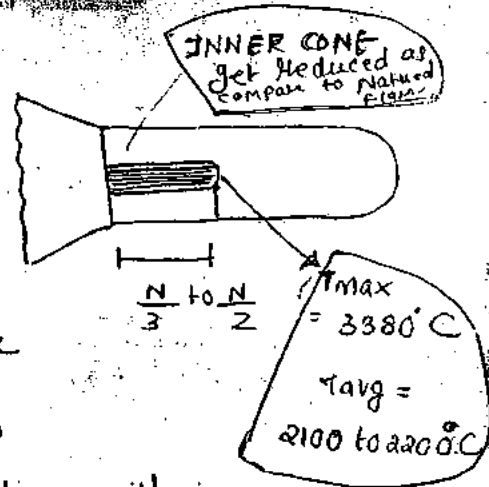
46

Here, excess of oxygen is present.

The

length of Inner cone is

abt $\frac{N}{3} \text{ to } \frac{N}{2}$



Max Temp of Flame in oxidising flame is more than Neutral flame

*

It is a lean mixture

(more O_2)

During combustion slightly lean mixture will always produce highest efficiency of Burning.

It gives higher max Temp.

Application:

* Because excess supply of oxygen, there is a possibility

of free oxygen may present in the flame. If oxidising flame is used for joining of highly Reactive

① metals, the excess oxygen will be present, Hence it should not be used for joining of highly Reactive metals like

Aluminum

②

* Because of higher avg temp it can be used for joining of high mp materials

③

It is used for joining of Brass work piece

During joining of Brass w.p., the excess O_2 present in the flame is combining with some qty of Zn present in the Brass and produce ZnO which is

flowing away from the joint

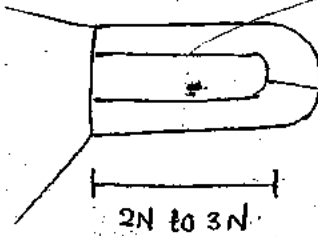
remaining Zn to evaporate

③

O_2 0.85 to 0.95
 C_2H_2

Due to less amount of O_2

Inner Core
Get large in length



$T_{max} = 3040^\circ C$
 $T_{avg} = 1800 \text{ to } 1900^\circ C$

Because of short supply of oxygen, the flame has to travel on a longer distance to completely burn. i.e. length of inner cone is increased to 2N to 3N. Because flame is travelling for large distance. The heat energy is lost. The temperature is lower. i.e. higher Max temp is only about 3040. Also $T_{avg} = (1800 - 1900^\circ C)$.

Application:-

① * Because of lower avg Temp, High M.P material cannot be joined. It is used for only Low M.P material.

* ② Because of short supply of oxygen, the carbon or soot may be present in oxygen flame, this carbon may be absorbed by the metal during joining of ferrous material and increases its brittleness and so it shouldn't be used for joining of ferrous materials.

47 44

025413-1

SECRET

with carbon. % even though free carbon is available in the flame, it cannot be absorbed by the iron. H.C.s can be exactly used by carburising flame.

flexible pipe mat
 1/4" Ag - cost 18
 1/2" Al - head 18
 3/4" cu - 18

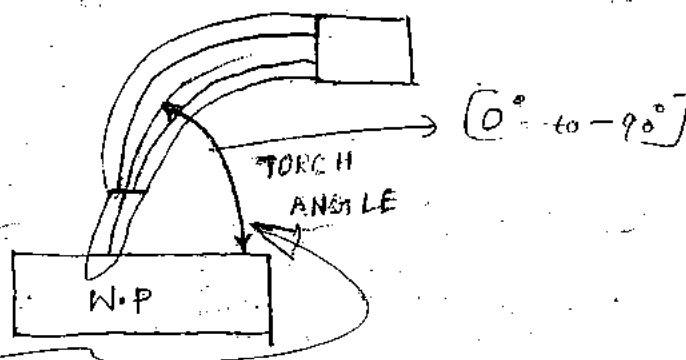
* For connecting a cylinder to Torch Body, the flexible Hose is made by using rubber as a material because it can ~~be~~ withstand for Higher pressure & Has higher flexibility

* If cu Hose is used for connecting CaH_2 cylinder, when Cu is exposed to CaH_2 it get chemically react with CaH_2 and produces paste like material and the pipe will fail.

* If Hose pipes are changed, then Both of the pipes will fail. Hence ~~the size of hose pipe~~
Hose pipe, ~~and its location,~~ size & location of type of the distribution can be used.

Torch

* Angle made by the ~~max~~ axis of the torch with axis of w.p is called ~~angle of~~



* With variation of torch angle the flame density will get changed. $\propto$

$$\text{Flame density} = \frac{\text{Heat energy supplied}}{\text{Unit Area of weldability}}$$

Unit J/mm^2

* With $\uparrow$ of torch angle the exposing $\uparrow$ of flame of weld bead will be $\downarrow$ $\therefore$ flame density $\uparrow$

→ Factors affecting selection of torch angles

(i) Thickness of plate to be joined $\rightarrow$

As thickness of plate $\uparrow$ 

Heat reqd for melting of plate is $\propto$ thickness of plate

(ii) M.P of metal plates to be joined $\rightarrow$

As M.P of plates $\uparrow$ Heat reqd for melting of plates also increases $\therefore$ torch angle $\uparrow$

(iii) Thermal conductivity (K) of plates $\rightarrow$ As $K \uparrow$

Heat loss by conduction is also $\uparrow$ $\therefore$ net Heat available at welding zone $\downarrow$ $\therefore$ torch angle $\uparrow$

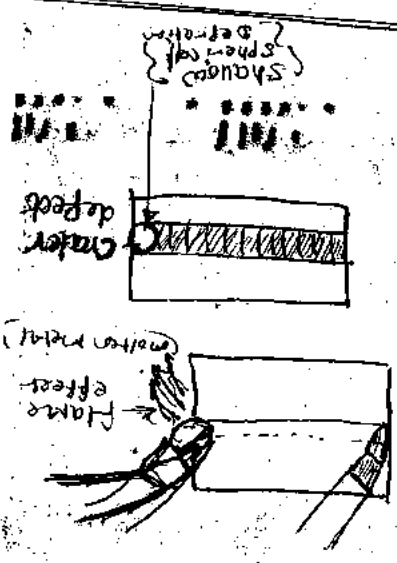
$\rightarrow$ (welding of plate becomes difficult)

$\therefore$ High Heat will be obtained

① Place of welding:- Irrespective of above 3 factors large torch angle is to be used on the beginning of welding and small torch angle is used at the end of welding

Reason:- on beginning of welding the plates are at room temp. To raise the temp of plates above M.P temp large Heat reqd to be supplied and hence large torch angles are to be used.

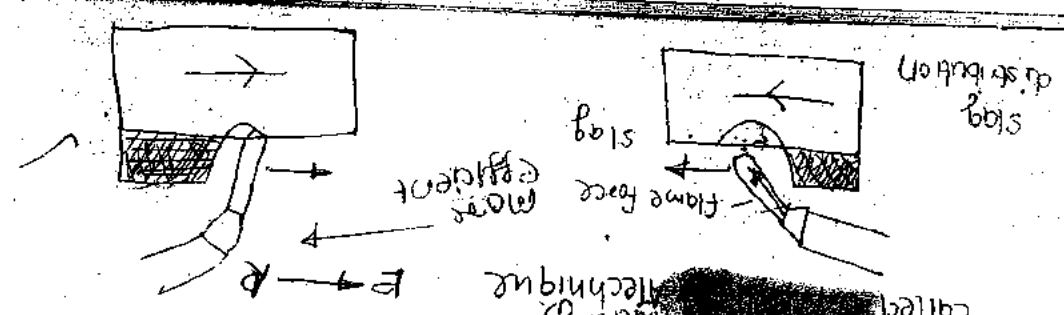
At the end of welding if large torch angle is used then the molten metal is outflowing & produces small crater. If torch angle is used at the end of welding the force of flame will obstruct the flow of molten metal & avoids the formation of crater defect.



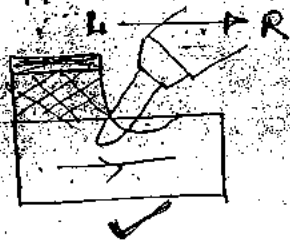
Welding technique

1. Fore Hand or Left Hand w.T
2. Back Hand or Right Hand w.T

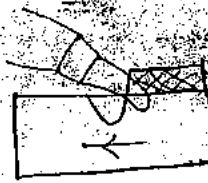
If the flame is focused towards molten metal it is called Back Hand welding technique and if flame is focused towards shield gas it is called Fore Hand welding technique.



it's opposite that for BackHand



effective



BackHand

* Most of welders found that Forehand welding technique is more effective and efficient when it is done from Right to Left direction.

& Backhand is effective when it is done from Left to Right direction.

* In Forehand welding bcoz the flame is focussed towards the non welded portion,

~~backhand welding takes place~~

In Backhand wt bcoz the flame is focussed

towards the already welded portion,

~~backhand welding takes place~~

During welding operation the flame is pushing back the molten slag particles into the weld pool. So

slag inclusion may present in the weld plate.

and also produces non uniform slag layer over the weld plate, which produces atm contamination of

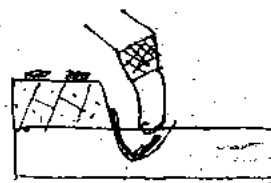
weld plate.

During welding low 'p'

slag is moving upwards but

force of flame pushes back into the weld pool.

slag inclusion



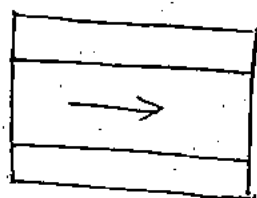
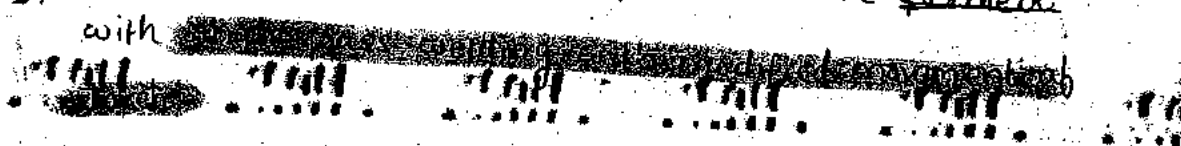
In Back Hand welding the force of flame is pushing the molten slag particles in the upward direction. Therefore uniform slag layer is forming over weld plate and no slag inclusion are present in the weld plate.



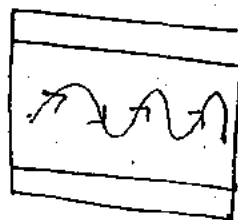
Application of Forehand and Back Hand

Forehand welding technique can be used for joining of plates upto 4mm thickness in single pass welding with slight movement of torch.

where as ~~with modified torch position~~ plates can be joined with ~~single pass~~ Forehand welding.



upto 4mm



upto 6mm

Forehand:

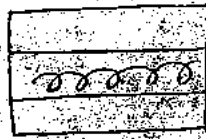
* Backhand w.t can be used for joining of plates upto 6mm thickness in single pass with slight movement of torch.

~~upto 6mm thickness plates can be joined by~~

using ~~single pass~~ Backhand welding.



upto 6mm



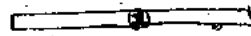
upto 15mm

shape

Back Hand

→ Welding positions

1. Horizontal or flat W.P



2. Vertical W.P

3. Horizontal-vertical W.P
(Circulating) (Rotary)

4. Overhead W.P

① Horizontal W.P

* ~~upto 6mm~~ Forehand or B.H with straight torch movement

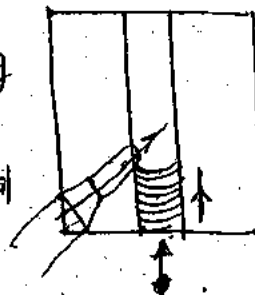
* ~~upto 6mm~~ F.H with modified torch movement or
B.H with straight torch movement

* ~~upto 6mm~~ B.H with modified movement of torch

* ~~upto 6mm~~ multipass welding can be used

② Vertical W.P

Bottom to top welding
can be done becoz
already welded metal
will act as an
obstruction to the
flow of metal.



Fore Handed
Tech.

Here only welding done from Bottom to Top.

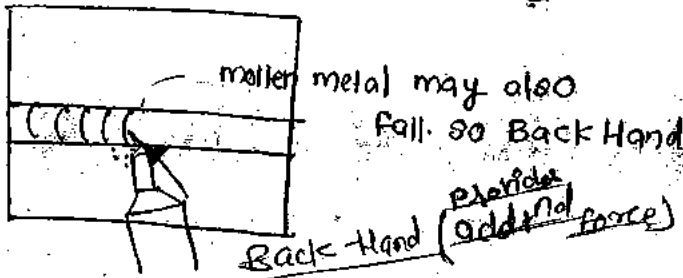
already welded metal will act as an obstruction to

flow of metal in the downward direction. If Forehand

welding technique is used, then the force of flame is, acting as additional force for holding the molten metal particles without falling, only fore hand welding technique is used.

3

Horizontal | vertical w.t.

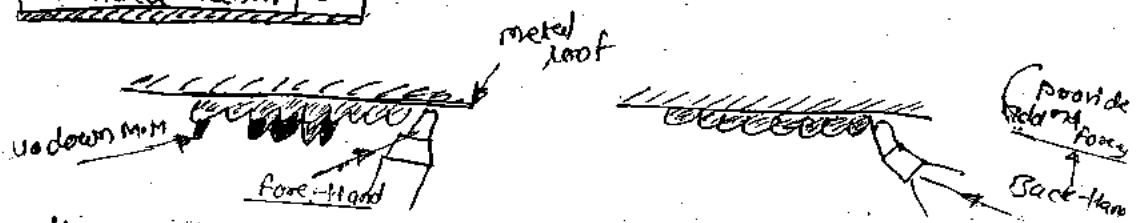


Here Even though Joint is Horizontal because the plates are vertical the molten metal can flow downwards. To obstruct this force of flame acting on Backward welding Technique can be used.

only B.H welding is used.

6

Overhead Technique



Here the surface tension of solid body and liquids molten metal is responsible for holding molten metal particles in position. In addition to this Back hand welding is used. so force of flame acts as an additional force holding the molten metal particles falling down m.m.



Fluxes

FLUXES

During Gas welding operations, the welder is periodically removing the filler rod from the welding zone and dipping into a powder called as flux powder.

→ **Functions to be Satisfied:-**

- ① To deoxidise the melt or molten metal
- ② To ~~absorb the gases~~ present in weld zone.
- ③ To provide the ~~slag~~ of the weld bead for protecting the weld bead from atmospheric contamination.

→ **Properties**

- 1. It can deoxidise the melt
- 2. It can absorb the gases

3. It can provide slag.

4. The density of flux powder must be less than density of parent material.

5. The M.P of the flux must be less than M.P of parent material.

6. It should not produce any harmful gases like SO_2 .

Sulphur - Best deoxidizer. so it can give Best efficiency. But

it can combine with O_2 to produce SO_2 . (Highly poisonous gas)

→ **Applications:-**

- ① During joining of carbon or Nickel alloys, no flux is to be used.

[Presence of ~~flux~~ is not required]

~~flux is not required~~

Borax is the commonly used flux during gas welding of all other metals.

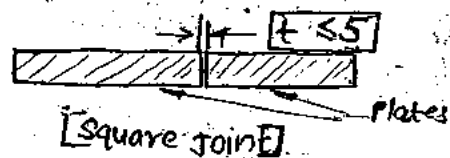
* Filler Rods used in Gas welding

* Function

① It supplies additional molten metal to the weld bead / plate.

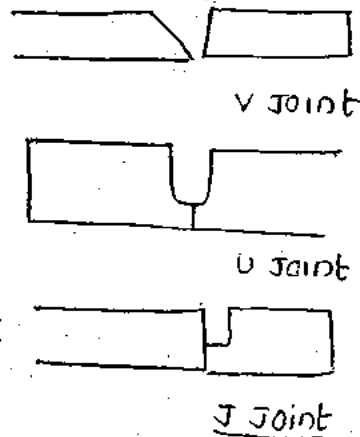
• { Not always Ready }

→ Whenever the ~~length of~~ thickness of plates to be joined is less than 5mm, we can ~~use filler rod~~ so no extra metal is to be required. ∴ No filler Rod is used during gas welding of plates of thickness $< 5\text{mm}$.



Gas welding without use of Filler Rods is called ~~autogenous~~.

Beoz of joint preparation, some amount of gap is present b/w the joints and for this additional metal need to be supplied for this purpose we are using filler Rods.



* PROPERTIES

① - ~~Filler rod material must be nearly equal~~
~~to the base material~~

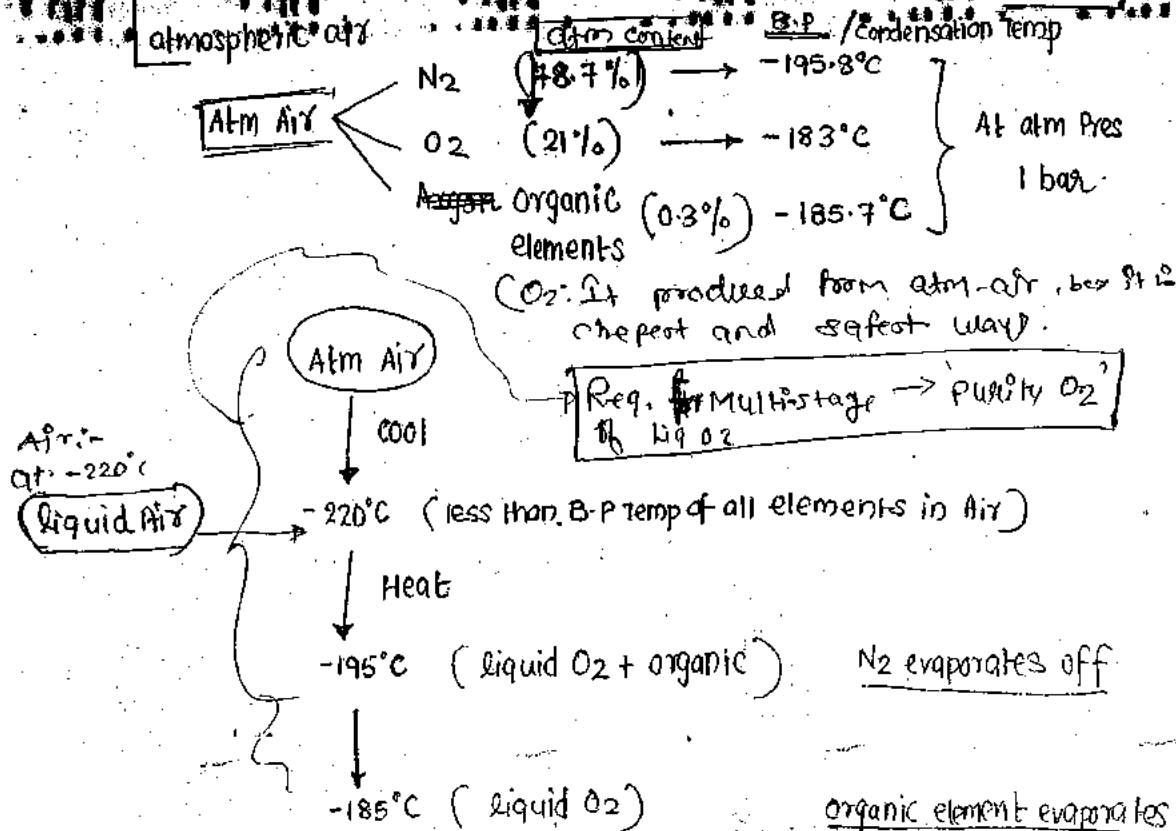
for good bonding b/w them.

Beoz if densities are different they will try to separate. for maintaining the molten metal and molten filler material for certain duration densities need to be atleast close.

- Parent material

Exa: -

The cheapest and safest method of producing oxygen is from atmospheric air.



→ STORAGE OF OXYGEN

The oxygen is always preferable

to store in form of liquid O₂ because

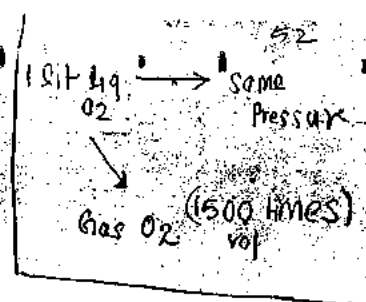
specific volume of liquid O₂ is much less

than specific volume of gaseous O₂. But to avoid the

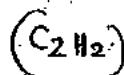
storage conditions of very low temp the liquid O₂ can be

pressurised to 120 ksc, the B.P. of O₂ at this

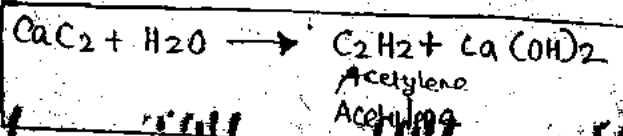
Pressure is 40 to 50°C. Hence the liquid O₂ can be 1x7
stored comfortably in atmospheric temp.



→ PRODUCTION OF ACETYLENE



It is produced by mixing calcium Carbide with water.

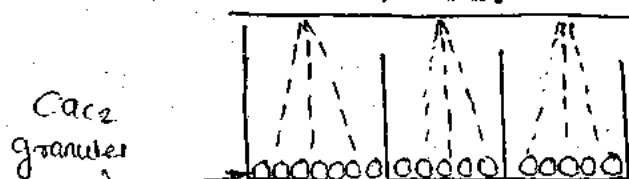


This process can be done in 2 ways

- ① ~~Gas~~ Water to carbide Type
- ② Carbide to water Type

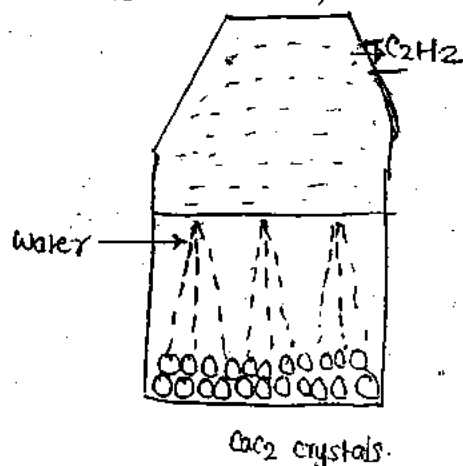
- ① — Low Pressure - Small,
- ② — Portable Production Rate low
- ③ — Portable,

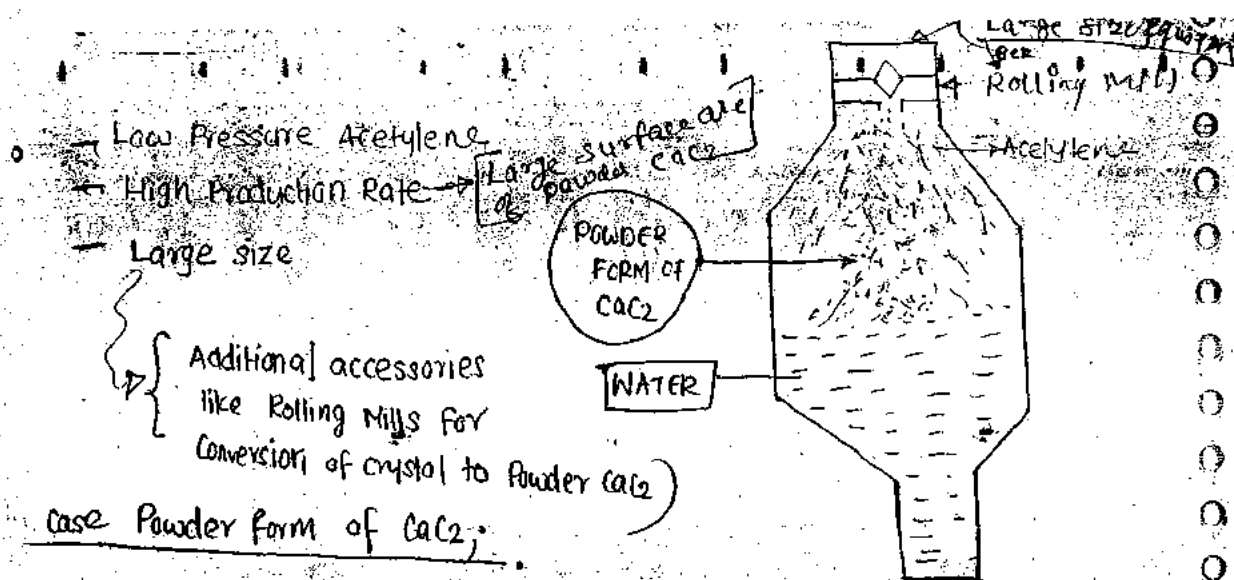
WATER TO CARBIDE TYPE



- used By the job shop people
- can't give continuous acetylene for

small duration only they can give acetylene that too amount is low





Surface area of exposed for chemical reaction is Higher. Hence the Rate of Reaction is Higher so production is Higher.

In earlier case can we use powder form of CaC_2 (water carbide)?
 No since only the top layer of CaC_2 will only undergo Reaction.

Besides Carbide to water type equipment is large size equipment because Besides this equipment there is another equipment called Rolling mill is used for converting the Granular form of CaC_2 to powder form of CaC_2 .

Also produced CaC_2 must be used within mts otherwise it will React with O_2 and produce C_2H_2 which will escape to atmos.

The High pressure acetylene can be prepared by compressing the low pressure acetylene produced by the above mentioned equipments and by using a Compressor.

Acetone

'Acetylene' is always stored in 'Acetone'
 C_2H_2

1 Lit of Acetone

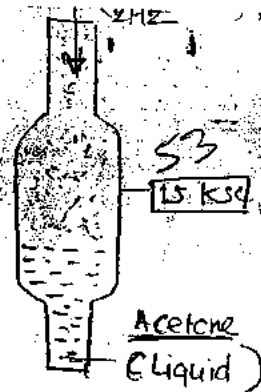
at $P = 1 \text{ ksc}$ can absorb 25 lit of Acetylene

Usually stored at this Pressure

$P = 15 \text{ ksc}$

$25 \times 15 = 375 \text{ lit of Acetylene}$

As $P \uparrow$ Absorbing capacity of Acetylene also increases



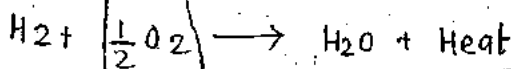
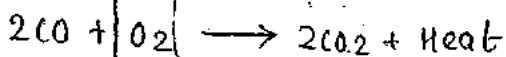
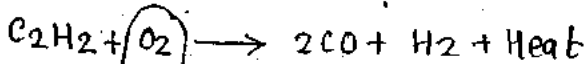
$P = 25 \text{ ksc} = 625 \text{ lit of Acetylene}$
can be Absorbed.

$P = 50 \text{ ksc} = 50 \times 25 = 1250 \text{ lit of Acetylene}$

Safe storage Pressure = 15 ksc

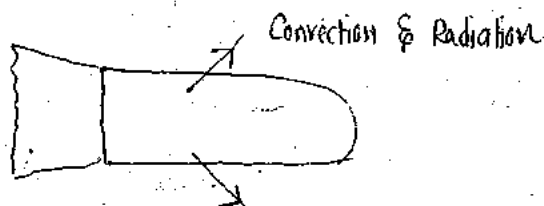
Even though the increase in Pressure causes proportional increase in absorption capacity of Acetone, But it will be always stored at a pressure $\leq 15 \text{ ksc}$ because it is the safe storage pressure of Acetone. [Above this pressure Acetylene will release Acetylene back and explosion occurs.]

AIR ACETYLENE GAS WELDING



(total O_2 - from atm air)

Whatever the oxygen reqd for complete Combustion of Acetylene is obtained only from atmosphere it is called Air acetylene Gas welding



$T_{\text{avg}} = 500 \text{ to } 700^\circ\text{C}$

Flame has to travel for a longer distance - hence heat lost by convection & radiation is higher and the average temp of flame is above 500 to 700°C.

Bunsen burner principle

Principle

Because the oxygen is completely taken from atmosphere for combustion of acetylene the principle by which the

Bunsen burning place is named as Bunsen burner

Principle

Applic:- Because of lower avg temp of flame the air acetylene flame

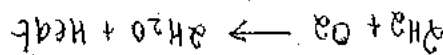
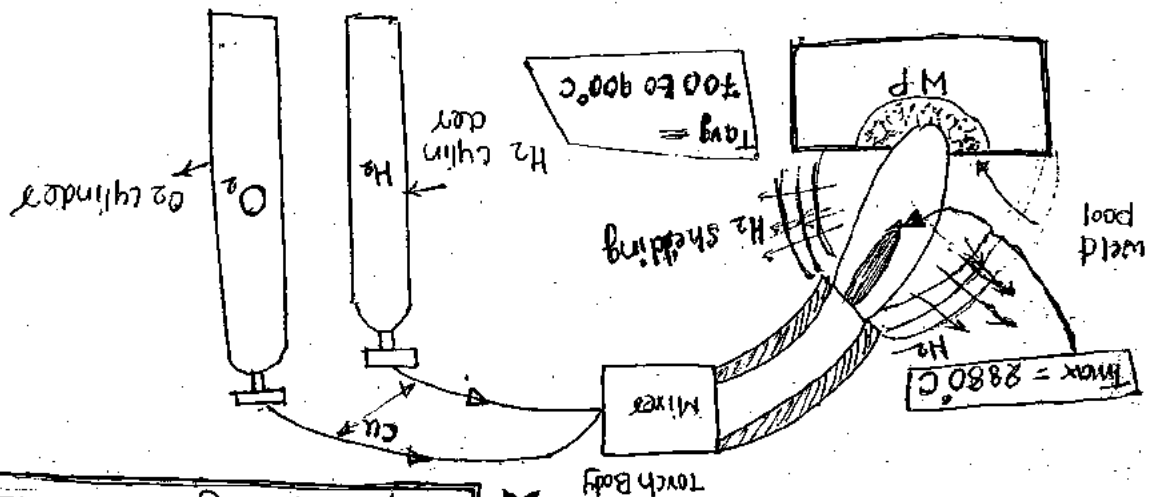
is used for joining of very low m.p materials like lead, tin, zinc, cadmium etc

- Also used as heat source for soldering operation

air acetylene flame

OXY-HYDROGEN GAS WELDING

Oxy-Hydrogen Gas Welding



$$\frac{H_2}{O_2} = 2 \text{ Theoretical}$$

25 to 6 Actual

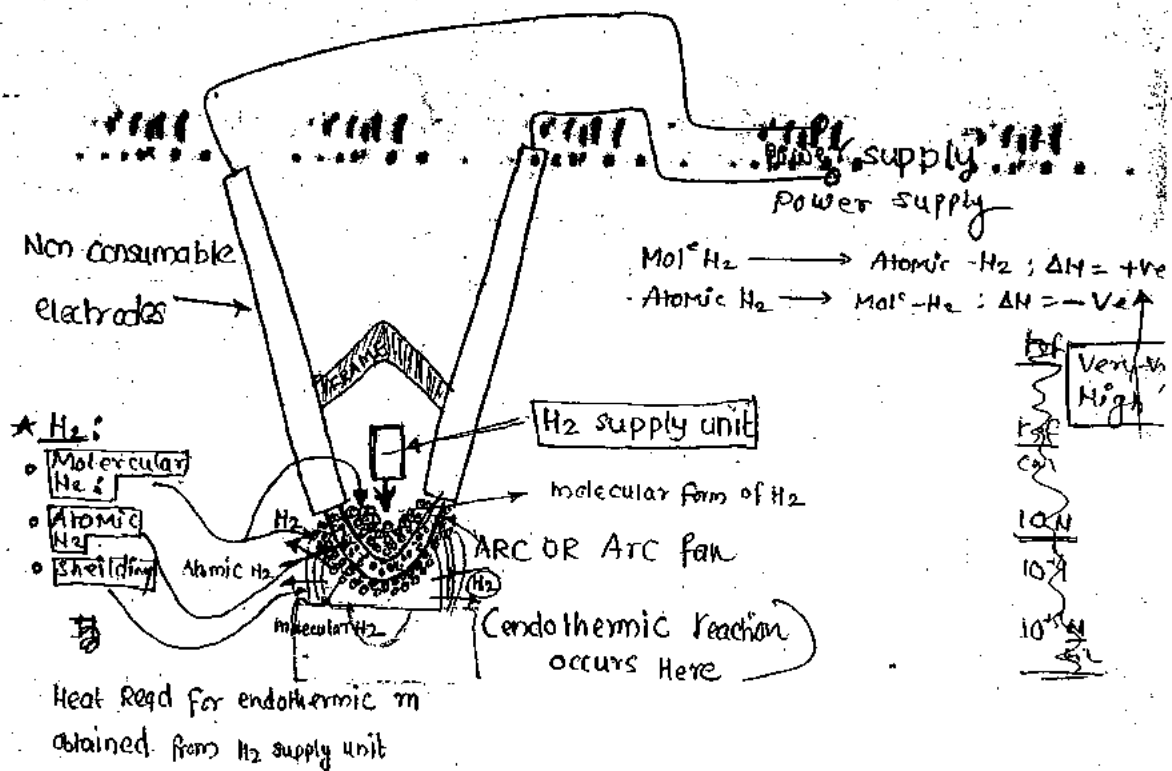
2.5 to 6 [Excess H_2]

In the actual practice of oxy-hydrogen gas welding the Excess amount of H_2 will be supplied to the welding operation so that unburned H_2 is simply moving away from the weld zone acting as a shielding gas for protecting the weld pool (by adding)

from atmospheric contamination. Because of this highly Applicable Reactive metal like aluminium, Mg etc can be easily welded.

- ① Bcoz of Lower Avg Temp of flame only Low MP materials like lead, Tin, Zinc, Cd, Al etc can be joined.
- ② :- Brazing and Soldering op
- ③ Lower Avg Temp is mainly due to the large production of Water

→ ATOMIC HYDROGEN GAS WELDING ←



It is a combination of arc and gas welding operations. Sometimes it is called as "Special gas welding operation".

When a power supply is given and optimum gap is maintained b/w electrode tips, arc / arc fan is produced. The heat generated in the arc fan will be used for endothermic reaction. when the molecular Hydrogen is supplied into the arc fan due to endothermic reaction the molecular Hydrogen is converted into Atomic H and heat reqd is taken from Arc fan. The Atomic H_2 produced in Arc Fan will become unstable gas when it is coming out from Arc fan. $\therefore$ it is reunited to form the molecular H_2 which is an exothermic reaction, Heat generated due to the exothermic reaction is used for melting of plates and joining. In

Exothermic Reaction
Combustion
Reacts always
Exo-Reaction

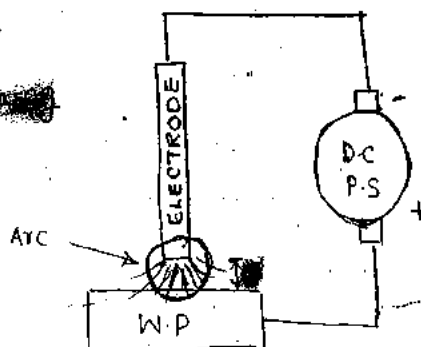
Addition $\frac{1}{3}$ rd of molecular Hydrogen is also burned by taking O_2 from atmos. and giving heat to the Melting of Plates or (weld bead). The Remaining $\frac{2}{3}$ rd of H_2 is moving away from the weld pool acting as a shielding gas

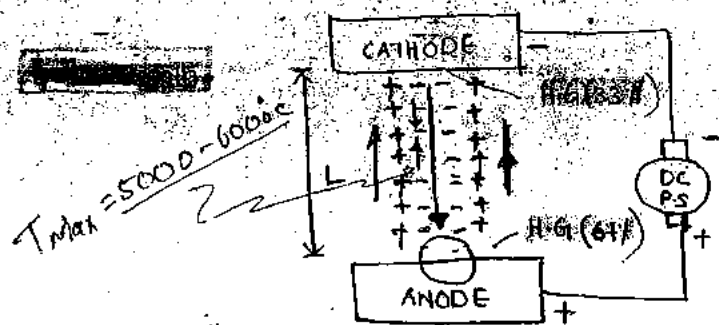
for protecting the weld pool from atmospheric contamination.

!!! this method is Basically developed for joining of Highly Reactive metals like Al, Mg etc and also can be high M.P used for joining of stainless steel. This method gives Better protection for weld pool from atmospheric contamination when compared to oxy-Hydrogen welding operation. After the invention of Atomic H_2 welding became Useless.

ARC WELDING

Whatever heat Reqd for electrical ~~joining and joining~~ of plates, is obtained due to ~~electrical arc~~ is called Arc welding.





When the power supply is given and optimum gap is maintained b/w cathode and anode, the ~~high velocity~~ very charged electrons are generated at the cathode, attracted by the Anode and moving towards the anode. ~~When this high velocity electrons are~~

collide ~~impinging on the anode the kinetic energy of electrons is converted into heat energy.~~ Heat is generated at the Anode.

Simultaneously the ~~high velocity~~ charged ions will be generated at the Anode which are attracted by the Cathode, ~~impinging on the cathode.~~ When this high velocity ions ~~are~~ impinging on to the cathode, the kinetic energy of ions is converted into Heat energy. Therefore the Heat is generated at the cathode.

The Amount of Heat generated at the Anode is much higher than the cathode ~~because of very high~~ velocity of electrons. The Ratio of Heat generated in ~~anode to cathode is 2:1~~

→ SPARKING / ARCING ←

In Arc welding process the e^- s and ions are moving like a mixed flow only. % when an e^- and ion are getting colliding in b/w the passage, ~~the energy~~

~~is converted into heat energy.~~ Both the elements will be spontaneously converted into heat energy. This can be observed as

Due to spontaneous release of energy the maximum temp induced in the Arc will be about 5000 to 6000°C. This

High temp in the Arc produces ultraviolet rays which will be moving around the Arc zone. ∴ If the Arc welding is directly seen with Human eye, the eyes will be started painning after some amount of time.

∴ Hence it is always recommended to see the Arc welding process only through safety goggles.

→ DCSP/DCEN (Direct current Electrode ~~is~~ Negative)

If the work piece is connected to the +ve terminal and electrode is connected to the -ve terminal it is called

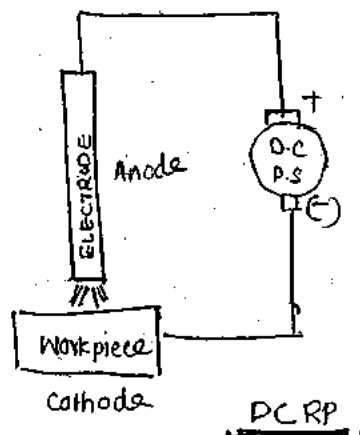
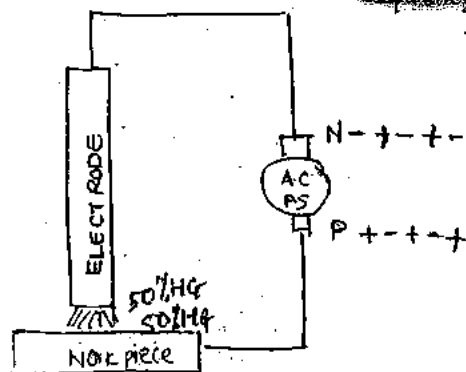
DCSP/DCEN
(Direct current straight polarity)

→ DCRP/DCFP (Direct current Reverse Polarity)

If work piece is connected to -ve terminal and electrode is connected to +ve terminal.

→ ACHF (Alternating current High frequency)

Alternate [Cycle]
Current time
→ 0.02 sec



High frequency (HF) ()

Here +ve and -ve polarity changes continuously. so no fixed polarity.

→ FEATURES OF ARC WELDING ←

56

① In DCSP, The Heat generated at the workpiece is higher

DCSP

② High MP material and Higher thickness plates can be easily welded and Higher depth of penetration is possible

③ Because of Lower Heat generation at the electrodes, Melting rate of electrode is lower, deposition rate is lower Hence

only low welding speeds are possible

It is preferable for non-consumable electrode

④ In DCRP, bcoz of lower Heat generation at work piece (33%) only low MP materials and lower thickness plates can be welded. Also depth of penetration is small.

DCRP

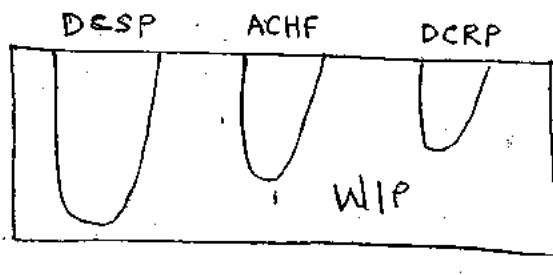
⑤ Bcoz of Higher Heat generation at the electrode, the melting rate of electrode is higher, deposition rate is higher.

High welding speeds are possible

It is used for consumable electrode

ACHF

Bcoz of equal amount of Heat generations at the workpiece and electrodes, the medium MP materials, medium thickness plates, medium depth of penetration and medium welding speeds are achieved.



Penetration depth

→ ARC RECOVERY TIME ←

the blow tip of electrode and work piece is called Arc Recovery Time

ie establishing flow of electrons and ions blow in their respective directions.

Tip of electrode and work piece

★ In case of DC Arc welding, Arc recovery time is not important since the terminals are fixed. It will not have any effect in welding process. ~~In case of~~

★ In case of AC Arc welding/ Beoz the terminals are continuously changing the Arc Recovery Time is very critical.

AC Arc welding

$$f = 50 \text{ Hz}$$

$$\text{cycle time} = \frac{1}{f} = \frac{1}{50} = 0.02 \text{ sec}$$

$$\text{ART} = 0.025 \text{ sec}$$

No Arc

for ~~establishing~~ establishing Arc

$$\text{ART} < \text{cycle time}$$

$$\text{ART} = 0.018 \text{ sec}$$

$$\text{cycle time} = 0.02$$

Arc can be formed. But it is not effective

→ Effective Arc ←



$$\text{ART} = 0.008$$

$$\text{C.T} = 0.02$$

$$\text{Arc Time} = \text{C.T} - \text{ART}$$

$$= 0.02 - 0.008$$

$$= \underline{0.012}$$

$$0.008 < \frac{0.02 - 0.01}{2}$$

$$\begin{array}{r} 0.020 \\ - 0.008 \\ \hline 0.012 \end{array}$$

[Arcing Time is more than Arc Recovery Time]

In ACHE, becoz cycle time ~~is~~ to satisfy the
Above condition A.R.T. must be Reduced, (i.e. 50 Hz) 57

REDUCING A.R.T.

A.R.T can be Reduced by increasing the voltage of power supply. so e^- and ions will travel with Higher velocities. so A.R.T is less.

To ensure that $A.R.T = \frac{\text{cycle time}}{2}$ the voltage of power supply must be equal to ~~50 volts~~ [Optimum voltage.]

LIMITING VOLTAGE

The Max voltage upto which Arc welding can be done.

Max voltage = 70 V

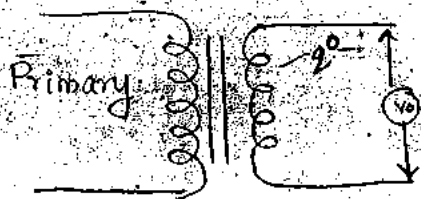
(With High voltage shocking is the problem)
[Most of the welding elements open to arcs and the welder
this elem. continuously, $A.R.T = 18,000 \text{ V}$]
30-70 V

★ SETTINGS IN POWER SOURCE

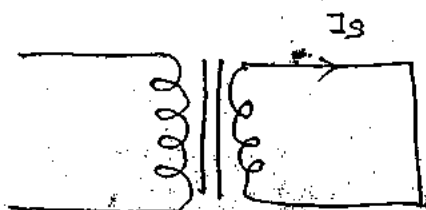
For stable eqbm conditions in welding equipment whatever
supplied by power supply unit has to be "only"
utilised at one point. For this it is necessary to maintain
optimum arc length at one point and welding transformer
has to be set for the optimum voltage for currents.

→ POWER SUPPLY UNITS

welding transformer In case of AC arc welding
welding Generator in case of DC arc welding
(DC)



V_0 is open circuit voltage
 OR Actual emf developed in
 2° windings of transformer
 OR Max voltage possible to
 present in 2°
 (i.e. current = 0)



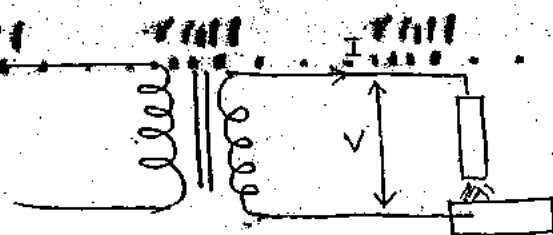
I_s = short circuit current
 OR

Max current possible to
 present in 2°

SHORTING

Resistance of 2° winding

$$R_s = \frac{V_0}{I_s}$$

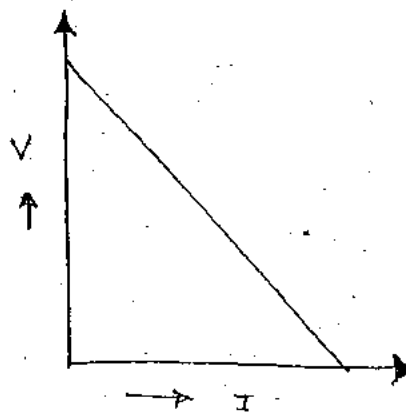


$$V = V_0 - V_{\text{drop}}$$

$$= V_0 - R_s \cdot I$$

$$= V_0 - \frac{V_0}{I_s} \cdot I$$

$$V = V_0 \left[1 - \frac{I}{I_s} \right]$$



$\therefore \frac{V-I \text{ chara}}{\text{Power source char.}}$

ARC CHARA

L = Arc Length

If $L = 0$

$I = I_s$ or I_{max}

$R_{air} = 0$

If L is ~~the~~ Large

$I = 0$

$R_{air} = \infty$ at $L = \infty$

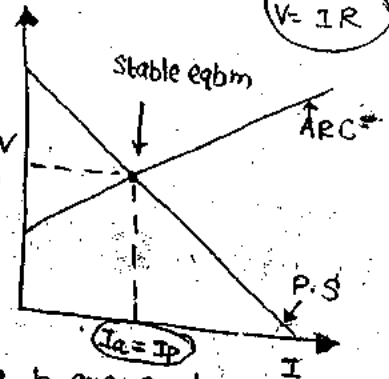
$L \uparrow \quad I \downarrow \quad R \uparrow \quad V \uparrow$
air

$V = V_a = I R_a \Rightarrow V \uparrow L \uparrow$

Voltage at Arc point

$$V = V_a = a + bL$$

(L)



At eqbm condition

$$V_a = V$$

$$a + bL = V_a \left[1 - \frac{I}{I_s} \right]$$

Step 1

$\rightarrow$

$$V \Rightarrow a + bL = \frac{V_0 - V_0 \frac{I}{I_s}}{1}$$

Step 2

$\rightarrow$

$$I \Rightarrow I = \frac{I_s}{V_0} [V_0 - a - bL]$$

Step 3

$\rightarrow$

$$\text{Power } P = VI = (a + bL) \left[\frac{I_s}{I} (V_0 - a - bL) \right]$$

For opt Power

$$\frac{dP}{dL} = 0 \Rightarrow$$

L =

$$(a + b) \left[\frac{I_s}{I} (V_0 - a - bL) \right] + (a + bL) \left[\frac{I_s}{I} (0 - b) \right]$$

$$\left[\frac{I_s}{I} (0 - b) \right]$$

$$\left[\frac{I_s}{I} V_0 - \frac{I_s}{I} a - \frac{I_s}{I} bL \right] + (a + bL) \frac{I_s}{I} (-b)$$

$$\frac{I_s}{I} V_0 - \frac{I_s}{I} a - \frac{I_s}{I} bL + \frac{I_s}{I} a - \frac{I_s}{I} bL$$

$$\frac{I_s}{I} V_0 - \frac{2 I_s}{I} bL$$

$$\frac{I_s}{I} V_0 - \frac{2 I_s}{I} [a + bL]$$

*

$$V_{opt} < V_0$$

$$I_{opt} < I_s$$

GATE 19

$$V_a = 80 - 40I$$

$$V_{max} = V_0 = 80 \text{ V}, I_s = 1500 \text{ A}$$

Calculate optimum arc length, l
(power source)

$$L = 0.5$$

a) 80V, 750A

b) 80V, 750A

c) 40V, 1000A

d) 40V & 750A ✓

by Elimination Method

P.T.O.

Duty % of Time without heating the vital elements of welding equipment

Electrode:- use in Arc welding operations

$$V_{opt} < V_0$$

$$I_{opt} < I_s$$

Conditⁿ

Functions:-

(1) Act as a electrical element for closing the electrical circuit

(2) Sometime electrode is getting melting and supplying additional molten metal to welding (Welded)

If the electrode is to satisfy only one condition ~~not~~ and then it is called Non consumable electrode

Properties of Non consumable electrode materials:-

Must possess high melting point and high electrical conductivity for avoiding the Melting of cond.

ex:- Tungsten, Carbon, Graphite are commonly used for Mfg of Non consumable electrode

Tungsten is used in any type of power supply [D.C.S.P, D.C.R.P, A.C.H.F]

Carbon, Graphite are used only in D.C power supply.

Are considered "Bare wire" electrode and no coating is given.



If electrode satisfy Both the conditions then it is called Consumable electrodes.

The properties to be possessed by consumable electrode material are :-

* Density of material must be nearly equal to the density of parent materials as

* The molten metal of electrode material should readily mix with the molten metal of parent material.

At the molten metal of electrode material can be spread over 59.

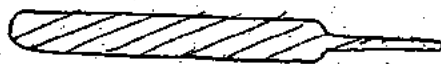
- a weld bead very easily if the viscosity of molten metal of electrode must be as min as possible 59.

- L.C steels, M.C steels, brass etc are commonly used consumable electrode material.

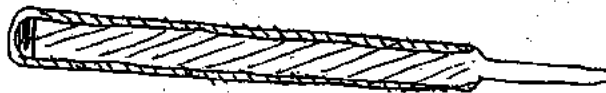
They are classified into 2 types

- 1) Bare wire electrode
- 2) coated electrode

BARE WIRE ELECTRODE:-



COATED ELECTRODE:-



Flux coating

- Most commonly used is the coated electrodes only. Bcoz of following advantages.

CONTD NEXT PAGE

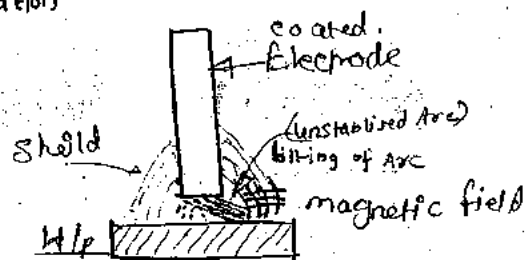
The most commonly used is the coated electrodes only because of the following advantages of coated electrodes.

* Advantages:-

- ① It deoxidises the melt
- ② It absorbs the gases present in the molten metal
- ③ It can form the slag over the weld bead for protecting the weld bead from atmospheric contamination

Other Advantages:-

ARC STABILIZATION



It stabilizes the arc; within the arc normally e^- and ions are present so when a magnetic field is applied the arc will tilt to one side.

* It produces a slag over the weld pool for protecting the weld pool from atmospheric contamination.

* It contains alloying elements for improving the mechanical properties of weld bead.

Types of coatings (Given on electrodes):-

- ① Reduction or Ferromagnetic coating is given for deoxidation of melt and absorbing the gases present in the ^{molten} metal.
- ② Flux coating or Slag Coating is given for producing slag over the weld bead.
- ③ Potassium compounds coatings will be given for stabilization of arc.
- ④ Carbon coatings will be given for producing slag.

• Gases like Hydrogen, Carbon, etc. (shielding)

5) For supplying alloying elements to the weld bead, small quantities of Al, Cu, Ni, Mn, Co, Cr, etc. will be added in the coatings.

→ Designation of electrodes: →

↳ by 6 digit code

xxx xxx

First 2 digits indicate the performance of coating given on the electrodes and applications of electrodes. Last 2 digits indicate mechanical properties of electrode material.

• 1st digit indicates type of coating (0 to 9)

• 2nd digit indicates the electrode position (0 to 9)

• 3rd digit indicates the electrode application (0 to 9)

• 4th and 5th digit combinely indicates the strength of

11 → 110 to 210 MPa

21 → 210 to 310 MPa

31 → 310 to 410 MPa

91 → 910 to 1010 MPa

(1360 MPa) $\sigma_{yp} = 980 \text{ MPa}$. So

only slightly above 980 only we can use.

• Last digit indicates elongation of electrode material at the time of fracture during tensile testing.

* Duty Time

It is defined as percentage of time for which the Arc is on without overheating the vital elements in welding equipments

$$DC = \frac{\text{Arc on Time}}{\text{Total Welding Time}}$$

$$\text{Total Welding Time} = \text{Arc on Time} + \text{Rest Time}$$

* Arc on Time

Time during which actual welding is done

* Rest Time

welding equipment will be completely switched off

*

$$Q_g = I^2 R_s$$

Rate of Heat Generation during Arc on time

During Arc on time because of passage of current through the secondary of a Transformer heat generation will be taking place and simultaneously Heat dissipation also takes place.

During Rest time Heat generation is zero becoz of no current passing and Heat dissipation will continue until the accumulated Heat gets transferred.

$$Q_g = H \cdot G = I^2 R$$

$$Q_d = H \cdot D = hA(T_s - T_a)$$

For a given welding equipment $Q_d = 0$

Q_g is varying since currents used are varying from component to component.

suppose $Q_g \leq Q_d \Rightarrow$ there is no accumulation of Heat

So whatever the Heat ~~is~~ produced during welding will be transferred to surroundings so. No accumulation of Heat is taking place and welding can be done continuously without any rest time. 61

$$Q_g > Q_d$$

Here Heat Accumulation occurs. The difference in Heats

$(Q_g - Q_d)$ will get accumulated in welding equipment and Temp of welding equipment may increase, and welding equipment may fail (ie windings in the welding equipment will get melted). So in order to avoid this failure we are providing ~~as "at certain" periods~~ ~~"overheating"~~ ~~is referred as overheating of~~ ~~welding equipment.~~

~~During Rest time the Accumulated heat gets~~

~~without generation of Heat.~~

$$(Q_A)_{\max} = \dots$$

$$\text{Max Accumulation} = 2000 \text{ kW}$$

2) Duty cycle:-

$$A.O.T = \frac{Q_{\max} \times 60}{Q_d} = \frac{2000 \times 60}{6} = 20000 \text{ sec}$$

$$R.T = \frac{20000}{60} = 333.33$$

$$D.C = \frac{A.O.T}{R.T + A.O.T} = \frac{500}{500 + 333.33} = 60\%$$

$$I = 2000 \text{ A}$$

$$D.C = 60\%$$

$$Q_g \propto I^2$$

$$Q_d = \text{const}$$

$$D.C = \frac{\text{Arc on Time}}{\text{Total welding Time}}$$

$$Q_g \propto A.O.T$$

$$D \propto \frac{1}{Q_g}$$

$$D \propto \frac{1}{I^2}$$

$$(Q_g = I^2)$$

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

$$I = 1500 \text{ A}$$

$$Q_g = 10 \text{ kW}$$

$$Q_d = 6 \text{ kW}$$

$$(Q_A)_{\max} = 2000 \text{ KJ}$$

$$Q_A = Q_g - Q_d$$

$$= 10 - 6 = 4 \text{ kW}$$

Arc on time

$$\frac{2000}{4} = 500 \text{ sec}$$

$$\text{Time taken for dissipation} = \frac{2000}{6} = 333.33 \text{ s}$$

$$D.C = 50.0$$

$$500 + 333$$

$$= 60\%$$

$$I_r D_r = I_d D_d$$

I_r = Rated current

D_r = Rated duty cycle

$$D_d = \frac{I_r^2 \times D_r}{I_d^2}$$

Take

I_d = Desired current

$I_r = 1500 \text{ A}$

$I_d = 2000 \text{ A}$, D_d = Desired duty cycle

$$\left[\frac{1500}{2000} \right]^2 \times 60$$

$$= 35.7\%$$

Rated current and duty cycle will be

present in the Name plate of welding equipment.

The value of I_r , D_r taken from name plate, based on the component.

I_d will be decided, by I_d - Desired duty cycle can be calculated.

$I_d = 1000 \text{ A}$, $D = 2$

if $I_d = 1000 \text{ A}$ then,

$$D_d = \left[\frac{1500}{1000} \right]^2 \times 60$$

$$= 135\%$$

Make it as 100%.

[this is possible with -ve rest time only, so this is not possible]

whenever the duty cycle becomes $\geq 100\%$, it is assumed that the duty cycle is 100%. only so that continuous welding will be done without giving any rest time.

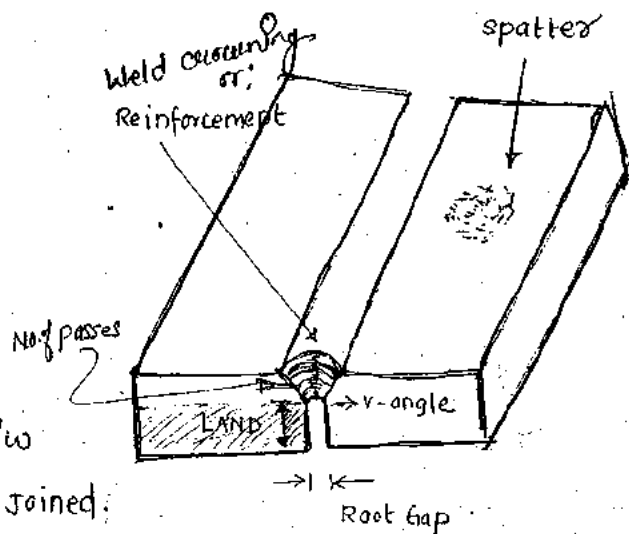
→ DESIGN OF WELD BEAD: ←

1. No of electrodes Required
2. welding Speed Reqd
3. No of passes Reqd
4. Total welding Time

★ Terminologies used:-

① Root Gap:-

The Gap provided b/w the 2 plates to be joined at the bottom most point of weld Bead



Necessity:-

With the provision of Root Gap if complete thickness of plate are not melting at least the molten metal of electrode or filler Rod can flow upto the Bottom of joint and produces the joint.

Generally Root Gap is abt 3 to 5 mm (3- to 4 mm)



Weld joint is
Not formed



LAND:-

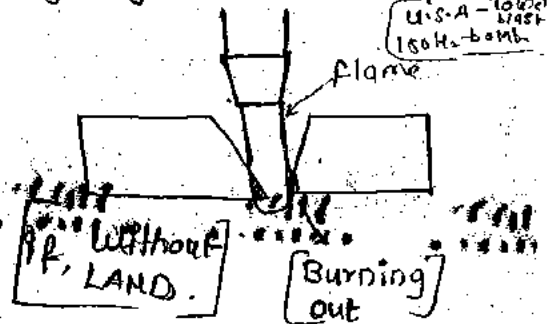
The straight portion of the plates provided at the Bottom most point of joint without preparing any joint is called Land.

~~The land is provided to~~

~~the burning of~~

~~the plate~~

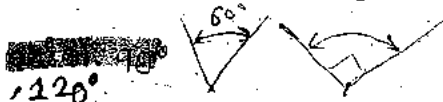
Max Land is used is less than or equal to ~~the~~



V-ANGLE

Whenever the ~~plates~~ ~~to be joined~~ is ~~5 mm~~ it is necessary to prepare some kind of joint like U joint or V joint or J joint. out of which most commonly used is 'V' joint becoz it gives Highest SA to weld ~~area~~ bead and Requires lowest amount of additional molten metal to weld bead.

In 'V' joint the most commonly used angle is



NO OF PASSES

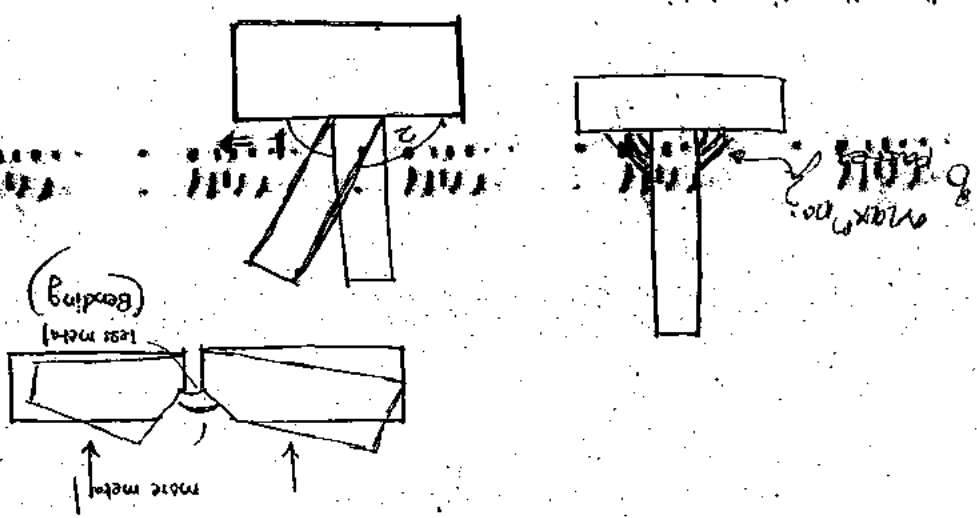
Whenever the thickness of plates is higher it is not possible to join the plates in single pass welding and

It is required to use minimum passes

In general, in most of welding operations as far as possible use single pass welding. If not use as min no of passes as possible expect in T-joint welding.

Always use less no of passes as possible

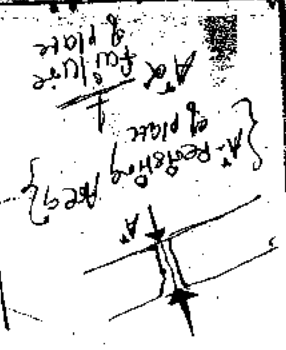
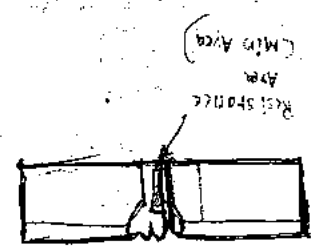
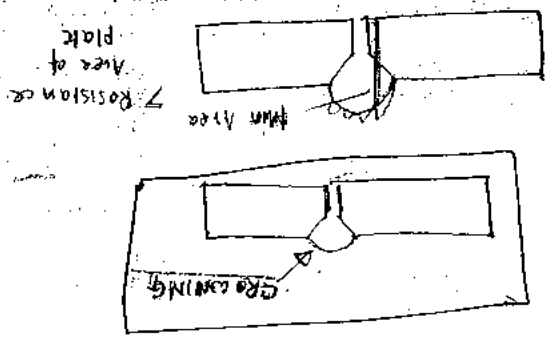
In T-joint welding use as max no of passes as possible. This is to minimise the distortion of plates during welding.



the distortion taking place in weld bead can be arrested by fixing the plates in a fixture. But it develops internal residual stresses in the weld bead which leads to cracking of weld bead and reduces the strength.

* CROWNING / REINFORCEMENT :-

The excess material provided over and above the surface of plates is called crowning.



Crowning is provide to ensure that the Resistance Area available at Joint is at least equal to the Resistance Area of the plate to be Joint.

~~Crowning is (0.15) volume of weld Bead~~

63

→ SPATTER :-

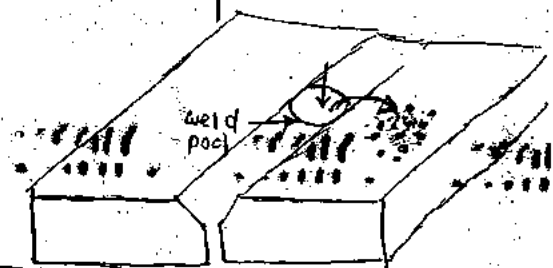
During welding operation becoz of force of arc / flame the molten metal particles are jumping from the weld pool and falling on other areas of plate called as spatter spatter

- ① - is a loss of molten metal to the weld Bead and it
- ② - ~~also~~ has fine surface finish of the plates to be joined

~~Spatter is 5-10% of volume of weld Bead~~

① No of electrodes Reqd :-

$$\frac{\text{Total Volume of weld Bead}}{\text{Vol / Electrode}}$$



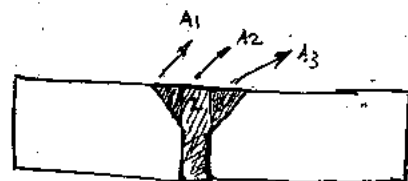
$$\text{Total volume} = \text{Volume of w.B} + \text{crowning} + \text{spatter}$$

$$= 1.15 \text{ to } 1.25 \text{ Vol of weld Bead}$$

$$\text{Vol of weld Bead} = (A_1 + A_2 \times A_3) \times \text{Length of weld Bead}$$

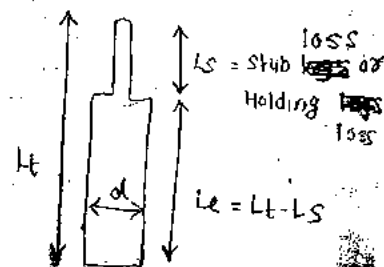
$$= (A_2 + 2A_1) \times L$$

$$\text{Vol / electrode} = \frac{\pi d^2 \times L_e}{4}$$



L_e = effective length of electrode

{ Stub length can't be used for welding }

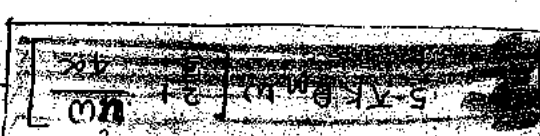


Welding speed

$$Q = \frac{H \cdot S}{\eta} \text{ by welding process} = H \cdot L + H \cdot L \cdot H + \text{Heat loss by conduction}$$

$$Q = H \cdot L \cdot H + \text{Heat loss by conduction}$$

By considering 3-D heat loss



* If length of the plates to be joined is very high. $\therefore$ Heat loss by conduction along the length direction is small and negligible.

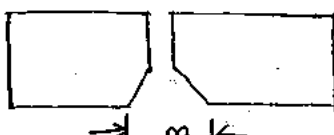
By considering 2-D Heat loss Heat supplied by welding process



k = Thermal conductivity of plates to be joined

E_m = melting point Temp of plates to be joined

w = width of weld bead



u = welding speed

α = Thermal diffusivity

t = thickness of plates to be joined

No of Passes

Let $\dots$ weld bead welded by using $\dots$ This value will be taken from the welding data book corresponding to $\dots$ of plate and $\dots$ to be used.

$$\text{No of electrodes Reqd / pass} = \frac{\text{Length of W.B.}}{x}$$

$$\text{No of Passes} = \frac{\text{Total No of electrodes Reqd}}{\text{No of electrodes / pass}}$$

$$A.O.T / \text{Pass} = \frac{\text{Length of weld Bead}}{\text{welding speed}}$$

$$\text{Total A.O.T} = A.O.T / \text{Pass} \times \text{No of passes}$$

$$\text{Total welding time} = \frac{\text{Total A.O.T}}{\text{Duty cycle}}$$

PAGE 5:

Q6

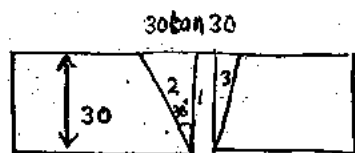
$$L = 1m$$

$$t = 30mm$$

$$d = 4mm$$

$$L_s = 50mm$$

$$L_s = 50mm$$



$$30 \tan 30$$

$$\tan 30 = \frac{30}{30}$$

$$\Rightarrow 1 \leftarrow$$

$$4mm$$

No: of electrodes Reqd

$$A_1 = 4 \times 30$$

$$A_2 = A_3 = \frac{1}{2} \times 30 \tan 30 \times 30$$

Total vol of weld Bead

$$= \text{Vol of W.B.} + \text{Crowning}$$

$$= 1.1 \times \text{Vol of W.B.}$$

$$= 1.1 \times (A_1 + 2A_2) \times 1000$$

$$\text{Vol / Electrode} = \frac{\pi \times D^2 \times L_e}{4}$$

$$\frac{\pi \times 4^2 \times (450 - 50)}{4}$$

No of electrodes Reqd = ~~total No of elect~~

$$\frac{\text{total vol of W.B.}}{\text{Vol / electrode}} = 140$$

Vol / electrode

$$x = 200mm$$

$$\text{No of electrodes / Pass} = \frac{1400}{200} = 5$$

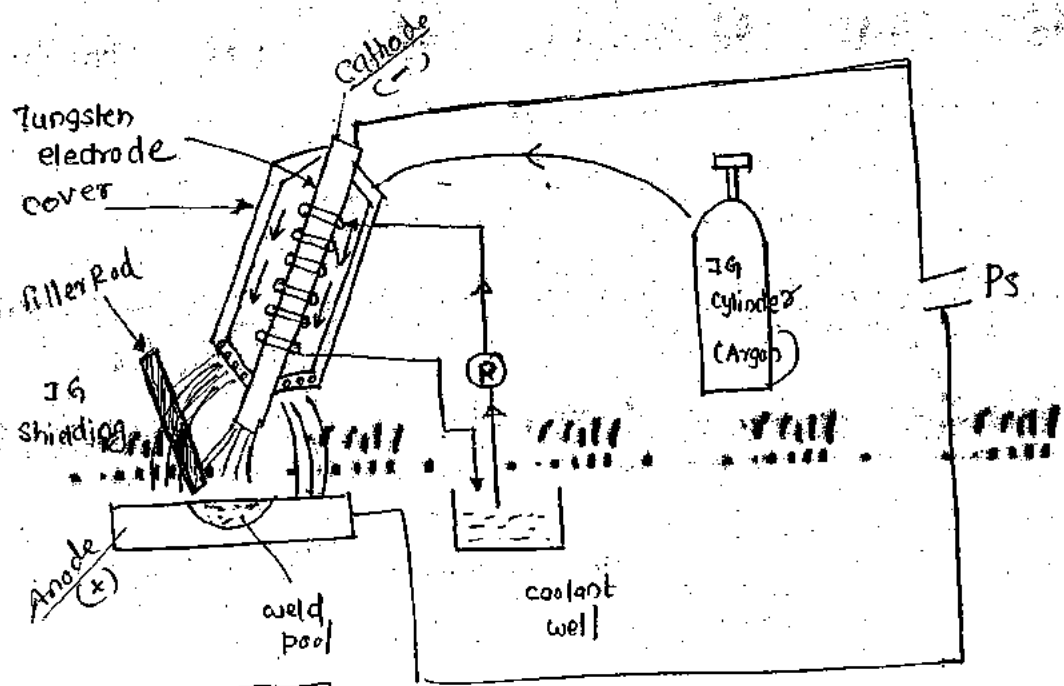
No. of passes = $\frac{140}{5} = 28$

Total A.O.T = $\frac{1000 \times 28}{100} = 280 \text{ min}$

Total weld Time = $\frac{280}{0.6} = 466.67 \text{ min}$

* TIG - TUNGSTEN INERT GAS WELDING

GTAW / AAW / Argon Arc welding



Features of TIG

- ① Because tungsten is the electrode used, the TIG welding operation is considered ~~non-consumable electrode welding~~.
- ② The ~~inert gas~~ will be supplied continuously to the welding pool through a cover acting as a shielding gas for protecting the weld pool from atmospheric contamination.
3. Highly Reactive metals like Al and Mg can be welded very easily.

④ Because of the protection of the weld pool, the inert gas welding process is suitable for welding in all positions.

⑤ By passing the electrode through the small pipe which is covered around the electrode so that the temp of electrode will be kept as low as possible to avoid melting of electrode. The most commonly used for TIG welding is the argon gas.

Limitations:

① Because of usage of inert gas, coolant and coolant pump etc the cost of TIG welding is very high.

② Because of the complexity of the process there is no additional molten metal supply to the weld bead. Hence the max thickness of plate which can be joined by TIG welding directly is upto 12 mm.

③ For joining of above 5mm thickness plate, the electrode must be used. But the electrode is entering into the weld pool and entering into the weld pool which will increase the temperature of the weld pool.

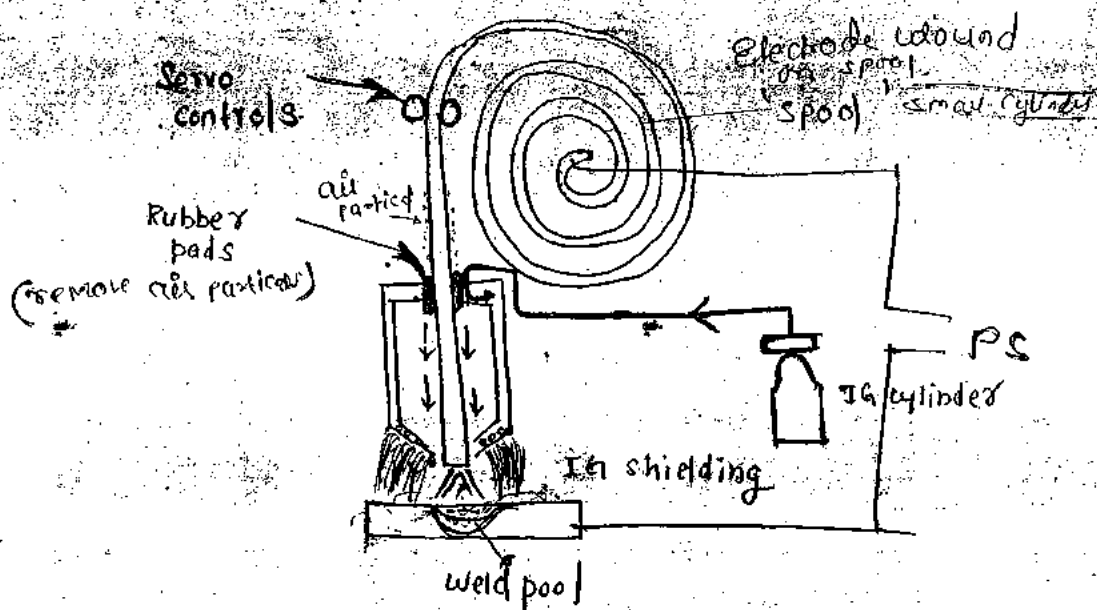
④ Even though tungsten electrode is not melting but the tungsten electrode is entering into the weld pool.

To overcome the disadvantage of TIG the next welding process developed is MIG welding.

MIG - Metal inert gas welding

GMAW - Gas Metal Arc welding

When compared to TIG, in MIG welding



- ~~Auto proc. can continue for long period.~~
- * Because of usage of inert gas the MIG welding also can be continued to use for joining of Highly reactive metals like TIG welding. Because of ~~complete elimination of tungsten~~ and ~~elimination of tungsten~~ ^{20%} ~~elimination of tungsten~~ ^{Eliminated} TIG welding.
 - * Because of ~~insoluble electrode~~ ^{consumable electrode} ~~more than 1mm thickness~~ plates also can be joined easily.
 - * When the electrode is passing through the ~~Rubber pads~~ any Air particle sticking to the surface of electrode will be Squeezed out. Hence No further Contamination of weld pool.
 - * Becoz of Consumable electrodes no tungsten is present. Hence diffusion of tungsten and increase of ~~thickness of weld~~ ^{elimination of tungsten} ~~Bead~~ can be eliminated.

Limitations:

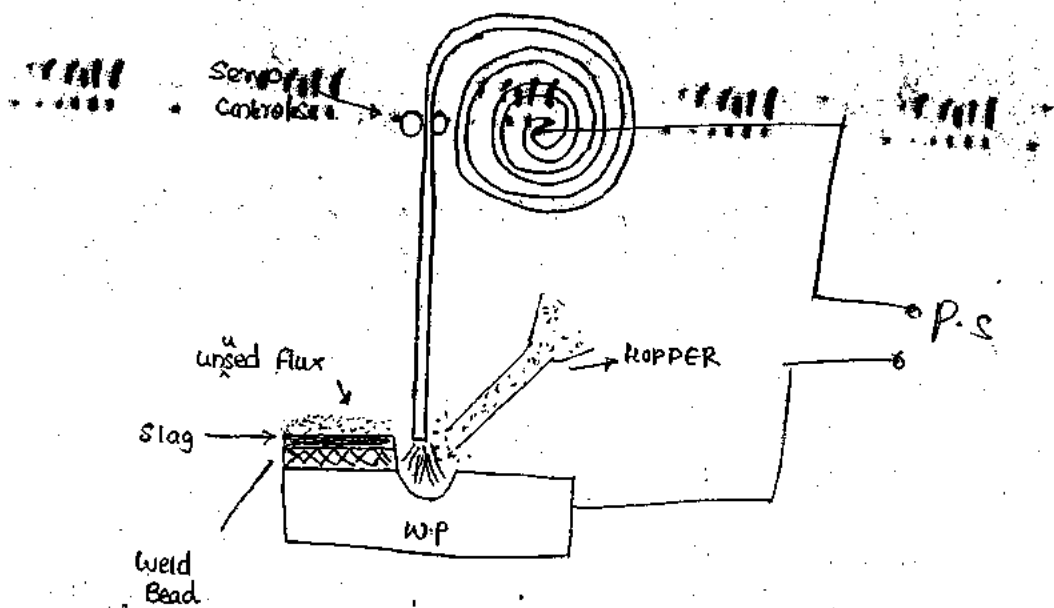
Becoz of continuous electrodes which is wound on to spool
 Max dia of electrode must be less than or equal to 5mm (3-4mm)

When smaller size ~~elements~~ electrode is used for joining of large thickness plate in single pass welding, the ~~welding speed~~ ⁶⁶ must be ~~low~~. At low welding speeds, the size of ~~weld pool~~ produced in front of arc is larger. Hence due to the force of arc, more no. of particles are jumping from the weld pool.

So the ~~spatter loss~~ becomes very high. To keep the spatter loss within the limits of 10%, the max thickness of plate which can be joined by using MIG welding with single pass welding is ~~upto 30mm thickness only~~.

~~Major limitations~~

→ SUBMERGED ARC WELDING OPERATION ←



Similar to MIG welding in submerged Arc welding also continuously consumable electrodes which are wound on to the spool and fed by Servocontrol is used. The arc produced b/w the tip of electrode and workpiece is ~~completely submerged~~ ^{completely submerged} ~~in the flux~~. The name given is SAW.

in the place of inert gas ~~here being a mixture of flux powder~~
is used for protecting the weld ~~lead~~ ^{from} atmospheric
contamination. out of the flux powder used some quantity of
flux powder is melting and forming as slag. But Remaining
flux powder is simply floating on the weld bead called as
unused flux which is collected and reused ⁱⁿ the Hopper.
• Electrode used is same as the MIG

Advantages:-

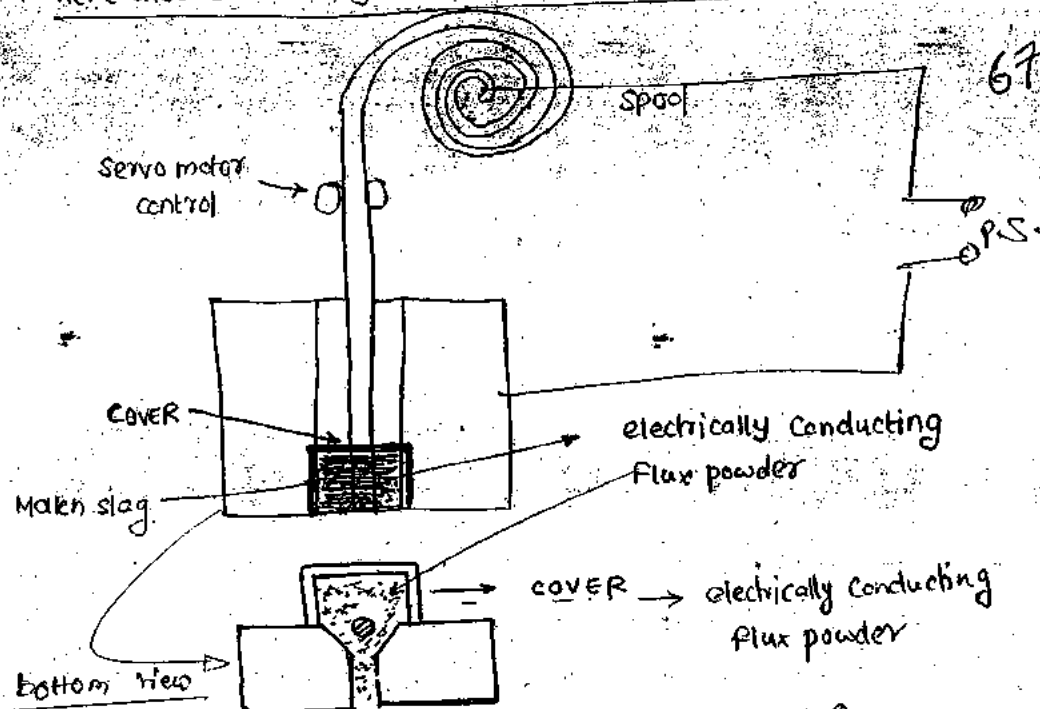
In SAW also, Because of continuous electrodes, ~~size of~~ ^{smaller} Max size
of electrode used is 4 to 5mm only. ∴ welding speeds used must
be lower. At Low welding speeds the size of the weld pool produced
in front of arc is larger and due to the force of arc the molten
metal particles are trying to jump from the weld pool. But the
~~presence of large quantity of flux powder over the weld pool is~~
~~not allow, causing the molten metal particles jump from weld pool~~
Hence ~~spatter~~ ^{spatter} can be minimised.

As the thickness of plates is increasing the qty of flux powder
to be used is also increasing. ∴ the cost of welding is increasing.
To keep the cost of welding lower or for ~~economic welding operation~~
the ~~max~~ ^{thick} thickness of plates which can be welded in single pass
welding is ~~small~~ ^{small} only.

Electro slag Welding operation

- ~~special~~ ^{special} welding operation
- can be used for joining of above 75mm thickness plate
economically in single pass welding.

- Always done in vertical position.
- Here also continuously consumable electrodes are used.



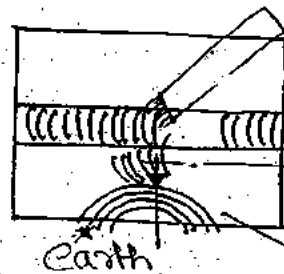
It is performed only in vertical position. When the power supply is given the arc is produced below the tip of the electrode and work piece. The heat generated due to the arc will be used for melting of flux powder and forming as a molten slag so that the tip of the electrode is submerged inside the molten slag. Now the current is passing from electrode to the work piece through the electrical resistance of the molten slag. As the current is passing through molten slag heat of electrical resistance of molten slag is getting generated and this heat will be used for melting of plates and electrodes and joint formation is taking place. As the welding is progressing cover will be moving slowly so that some molten slag will be used from beginning to end of plates to be joined.

The name called submerged arc welding. It is used for welding of plates below 75 mm. But it is not economical due to high cost of electrically conducting flux powder. They can also be used as a electrically conducting flux powder. They can also be used for welding of plates below 75 mm. But it is not economical due to high cost of electrically conducting flux powder.

It is a special welding operation

MAGNETIC ARC BLOW / ARC BLOW

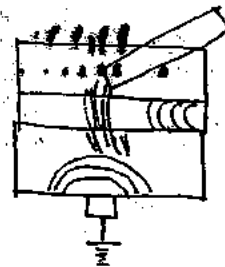
The Magnetic forces created by electrical current will tend to draw the arc in shortest line of action and making the arc fluttering called as Magnetic Arc Blow or simply Arc Blow.



Reasons :-

1. Welding Near to the earth connection:

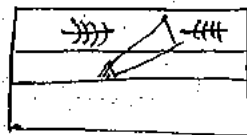
Near to the earth connection, lot of Magnetic forces are created and these Magnetic forces will pull the arc towards one side and makes the welding to be taken place at diff places than Required.



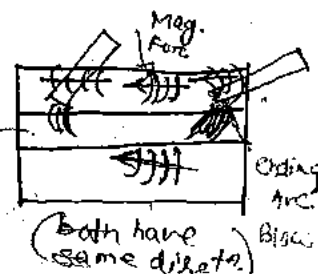
2. Starting Arc Blow:

Whenever Current is passing through a metal magnetic forces are produced.

At starting time
Magnetic forces are
Present on one side
only
not condition during ending



Starting
Arc
Blow



(Both have
same direction)

At centre there will not be any Arc Blow
Since Magnetic forces are present on Both sides.

- ② Whenever a very thin component is to be joined to a thick component so that before melting the thick component large quantity of thin component gets melted and joint formation itself is not possible.

Joining of electric wire to P.C.B (Printed Circuit Board)

- ③ Some metal can never produce the liquid molten metal at all. Such metals can be joined by using Non fusion welding process.

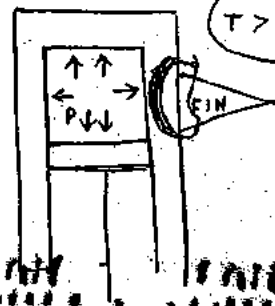
ex: Tungsten (3400°C M.P.) $\xrightarrow{\text{just converted into solid}}$ Powder form

Even abv $10,000^{\circ}\text{C}$ Tungsten can not come in liq. form

- ④ In some places the change in mechanical properties of base metal due to fusion welding process will not be allowed.

ex: joining of Fins to IC engine cylinder

In such cases only Non Fusion welding process can be used.



Non fusion Heating $<$ LCL Temp.
So No change in mechanical properties.

→ Soldering: →

Mechanism: - wetting and surface Alloying

Temperature: $<$ M.P of metals to be joined
 $< 427^{\circ}\text{C}$

eg: A - 550°C
B - 620°C } < 427

C - 350°C
D - 530°C } $< 350^{\circ}\text{C}$

Lead - Tin $\rightarrow$ filler metal
Tin - Evaporated at 427°C

- ① Mechanism
- ② Temp
- ③ Heat source
- ④ Filler rods material
- ⑤ Application

The joint has to be heated to a Temp Below the melting point of the base metal.

~~Alloy~~ The Tin present in the 50-50 Lead and ~~Alloy~~
~~Alloy~~ ~~is evaporated~~ so we are selecting Temp less
than 427°C .

3. Most commonly used Filler Rod

50-50 Lead and Tin alloy [commercially used]

4. Heat Sources:

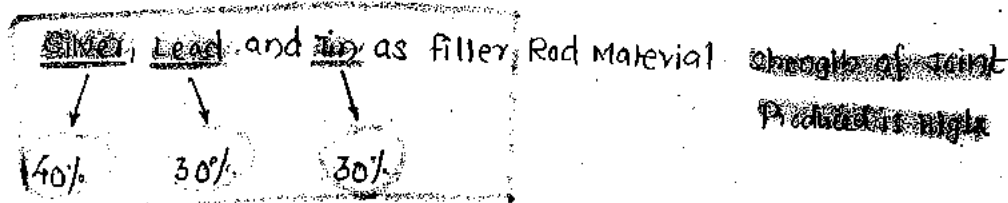
Air Acetylene Flames were used in olden days as Heat Source.

Nowadays Electrical Resistance Heating Method is used called as Soldering Iron.

★ SOFT SOLDERING

Soldering using ~~50-50 Lead and Tin alloy~~ the strength of joint produced with this filler Rod is low. So called as soft soldering.

★ HARD SOLDERING



Mainly used in Space Applications

Aircraft, missiles etc. space shuttle

Boz there are chances of failure with soft soldering
vibrations produced & velocity.
these force act at joints only

Speed $\rightarrow$ 181.

(50-800 km/hr)

Hard Soldering is preferred thus in space applications. In Both Cases of Hard and soft Soldering operations upto a maximum of 2% of Bismuth will be added with which Reduces the M.P Temp of Filler Rod material and also increases the wetability of molten metal of Filler Rod with parent material.

Main Application:

→ Joining of Electronic wires to PCB

★ → BRAZING AND BRAZE WELDING

* Mechanism: wetting and surface Alloy formation

* Temp at which

Joint is to be Heated: < M.P of metals to be joined & more than 427°C

Filler Rod Material

A — 550
B — 620

Lowest melting point temp of Filler Rod material used here is 420°C so we are using temp > 427°C

* Filler Rod Material: Cu alloy

Cu → M.P = 420°C

NOTE:

C — 350
D — 550 / X

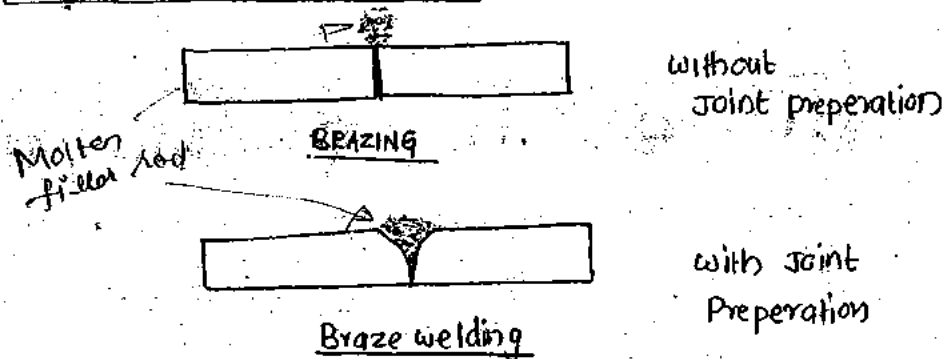
Any metal which has M.P less than 427°C cannot be Brazed or Braze welded and it can be considered

★ Heat source

Avg Temp (700-900°C)

- ① Oxy-Hydrogen Flame
- ② Furnace Brazing or Braze welding
- ③ Resistance Brazing or Braze welding

Brazing and Braze welding



If 2 components are joined with joint preparation it is called Braze welding.

In Brazing the flow of molten metal of filler rod is taking place due to capillary action

Filler Alloy - Brass

Out of diff cu alloys the liquid molten metal of Cu-Zn alloy will have the highest capillary action. ∴ Cu-Zn alloy will be used as Filler Rod material in Brazing.

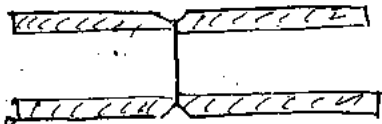
* In Braze welding the Flow of molten metal into the joint is taking place by gravity force

Filler Alloy - Bronze

Out of diff cu alloys whichever the alloy is having highest density will have highest gravity force. The Cu-Pb alloy has highest density. ∴ It is used as filler rod material.

APPLICATIONS:-

Wherever the ~~preparation is possible~~ such places
 Braze welding is used. wherever joint preparation is
 not possible Brazing will be used.



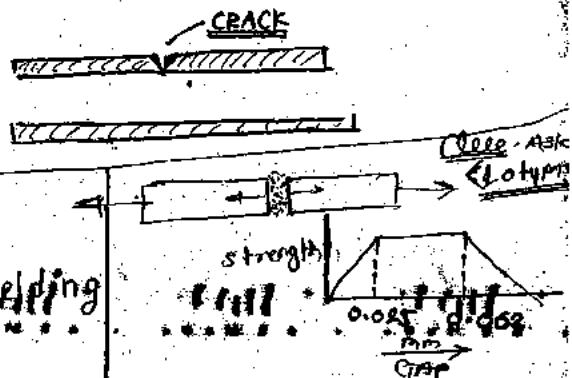
Exa:-

Two C.I pipes can be joined by using Braze welding
 operations. joining fins to the F.C Engine to cylinder
 joining of cable large size of cable-joint.

Exa:- A crack present in C.I pipe can be repaired by using

- Brazing operation,
- Stainless,
- Attaching the Baffle to the Automobile radiator,
- Joining of C.I pipe closed in Ref. Ac. etc.

For a Given material,



It is a ~~preferred~~ preferred Braze welding
 Brazing
 Soldering.

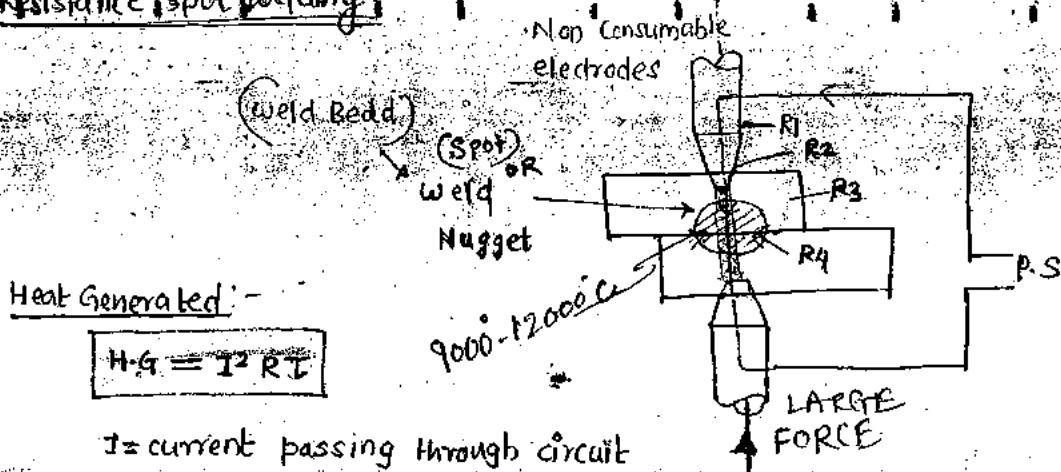


It is a ~~operation~~ operation, beoz of
 application of ~~the Resistance~~ the Resistance
 welding was classified under pressure welding operation.

In Resistance welding ~~the heat~~ the heat ~~is~~ is ~~obtained~~ obtained ~~due to~~ due to ~~electricity~~ electricity
 so the name given as Resistance
 welding operation.

Exa:-

Resistance spot welding



Heat Generated:-

$$H.G = I^2 R T$$

I = current passing through circuit

R = Electrical Resistance of circuit

T = Time during which current is passing

For joining ^{thick} 1.5mm of steel plates current used = 10000 A

Thickness



For eg:

$t = 10 \text{ mm}$

$$\left. \begin{array}{l} H.G \propto I^2 \\ \propto t \end{array} \right\} I^2 \propto t$$

t - thickness

If both simultaneously



$$I_2 = I_1 \sqrt{\frac{t_2}{t_1}}$$

$$I_2 = 10,000 \sqrt{\frac{10}{1.5}}$$

$$I_2 = \underline{\hspace{2cm}}$$

② $t = 1.5 \text{ mm}$, Al plates

$I = ?$

$Q \propto I^2$

$\propto M.P$

Al $\rightarrow 660^\circ \text{C}$ (M.P)

$$I_2 = I_1 \sqrt{\frac{MP_2}{MP_1}}$$

$$I_2 = 10,000 \sqrt{\frac{660}{1400}}$$

$$I_2 = \underline{\hspace{2cm}}$$

Q) Cu plates of $t_2 = 5 \text{ mm}$

$$I^2 \propto M.P. \cdot t$$

$$I_2 = I_1 \sqrt{\frac{MP_2 \times t_2}{MP_1 \times t_1}}$$

$$= 10,000 \sqrt{\frac{1100 \times 5}{1400 \times 1.5}}$$

$$I_2 = \underline{\hspace{2cm}}$$

$$R = 2(R_1 + R_2 + R_3) + R_4$$

R_1 = Electrical Resistance of electrode material

should be as ~~high as possible~~
~~low as possible~~ and higher strength
~~low as possible~~

Properties to be Posessed by Electrode Material

* The Material used for electrode must posess ~~high melting point~~, ~~high conductivity~~ and higher strength

Eg:- ~~Copper~~, ~~Aluminum~~, ~~Tungsten alloy~~

→ Commonly used materials for making electrodes are Cu, Tungsten, Cu-Tungsten alloy

* R_2 = Contact Resistance b/w tip of electrode and work piece

~~Tip of electrode and work piece~~ to ~~work piece~~

R_1 Elect. Resist. of a Electrode Material

R_2 = Contact Resistance

R_1 = Resistance of electrode

R_3 = Resistance of plate to be joined

R_4 = Resistance of joint

mainly depends on roughness and cleanliness of contacting surfaces.

* To minimise R_2 clean and smooth surfaces can be taken.

* R_3 : Electrical resistance of plates to be joined.

R_3 also should be as minimum as possible for avoiding melting of complete thickness of plate.

Minimise R_3 ?

The value of R_3 can't be changed But the "limitation" for the Resistance welding can be taken as Highly electrically Resistant materials cannot be Resistance welded.

* R_4 = contact Resistance b/w joining surfaces or faying surfaces.

~~It should be as max as possible because this is the place where the heat generation and joint formation takes place.~~

formation to be taken place

To Maximise the Resistance R_4 and avoid the formation of defects the contact surfaces must be rough and clean.

⊛ In General

$$R_R = 200 \text{ to } 500 \mu\Omega$$

□ - None

③

Time (T)

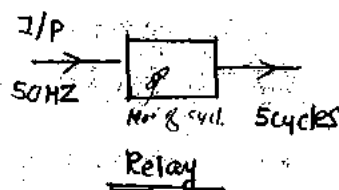
Time during which current passes through circuit.

NOTE

[~~As compared to~~ Resistance welding is 4000-12000]

In Resistance welding current supply has to be controlled for a very short duration bcoz the max Temp induced in Resistance welding operation is 2000°C. At this temperature transfer by induction to surrounding material is higher. ∴ complete thickness of plate may get melted and also at this High Temp most of metals will start evaporating. To Avoid this Time duration must be shorter.

● The very short duration of time for which the passage of current can be controlled by using Relay

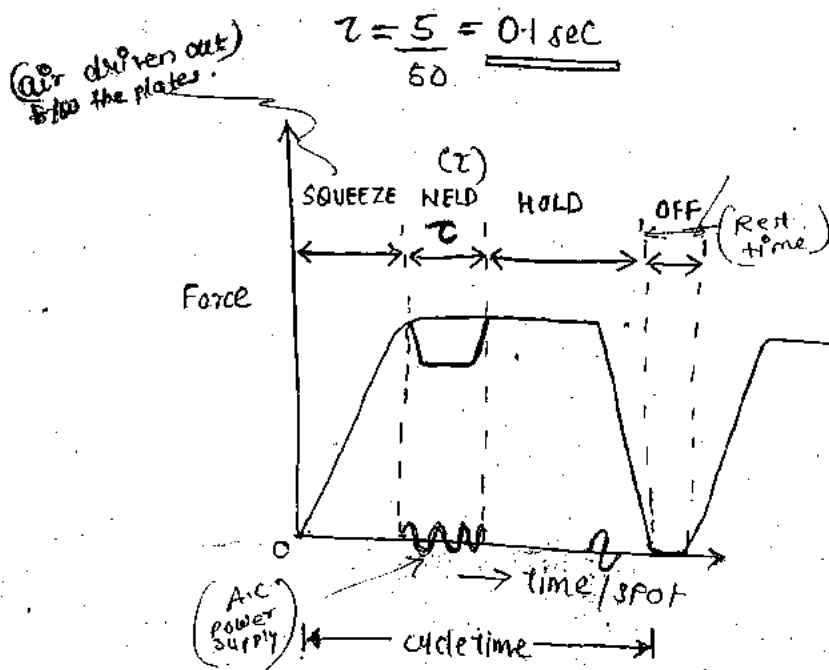


Relay so that in the Relay no of cycles of power

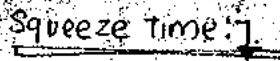
$$T = \frac{5}{50} = 0.1 \text{ sec}$$

supply to be allowed will be set whenever the power supply is given the Relay will allow set no. of cycles of power supply only.

For ex: 50 cycles in a 50Hz power supply means that



Given
Modifications
done



Time during which air present at joint can be squeezed out or driven out so that during welding, formation of defects like blow hole, porosity etc can be eliminated completely.

Weld time: 7

It is the time during which current is passing through "Resistance welding current" / ~~100~~

$$P \cdot Q = I^2 R L$$

2 weld
time
only

1 = 1

~~Re: _____~~

C.T = 5 sec

10 sec

2 1/2 C.T.

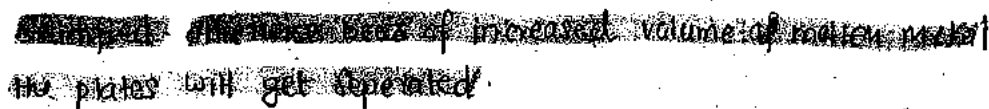
W-T 3-11-67

$$H.G. = T^2 \in \mathbb{C}$$

weld time only

Hold time : 7

time during which force applied on plate will be continued to hold until liquid molten metal produced will get



OFF TIME: 7

E Time : T

Time during which ^{Resistance} ~~the~~ ^{the} equipment is switched off.

This is to account for

- ② The time needed for shifting of ~~encipher~~ from present position to next position.

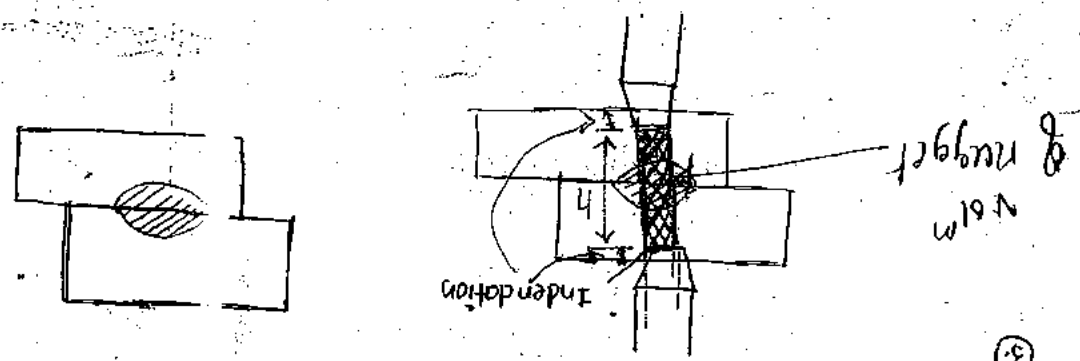
★ Modifications suggested to increase the efficiency of welding cycle are :-

② To Account for the idle time in duty cycle of the equipment.

- ① During weld time the force applied on the plates can be reduced slightly so that roughness of contacting surfaces will be regained back which increases roughness of contact surfaces and hence heat generation. $\therefore$ size of nugget in hold time just before reducing the force, $\therefore$ $\therefore$ Roughness $\uparrow$ due to this will be used as a $\therefore$ $\therefore$ which reduces the brightness and increases the toughness internally.

④ Heat Reqd for producing Nugget

$$\begin{aligned}
 &= \text{Mass of Nugget } (s \cdot H + L \cdot H) \\
 &= \text{Volume} \times \rho \times \text{Heat Reqd/gram} \\
 &= (M \cdot P)_{\text{metal}} \text{ in } ^\circ\text{C Joule} \\
 &= 1400 \text{ J} \rightarrow \text{steel} \\
 &= 660 \text{ J} \rightarrow \text{Al}
 \end{aligned}$$



Hypo-
theoretically

because the exact shape dimensions of elliptical nugget is not known
for the theoretical approximation the shape of nugget produced is assumed
as cylindrical with diameter = size of tip of electrode and height =
distance b/w 2 electrode plates tip

$$\text{Vol of Nugget} = \frac{\pi}{4} D^2 h$$

t = Avg thickness of
Plate to be joined
in mm

$$D = 6\sqrt{t}$$

$$h = 2t \text{ --- (2x indentation)}$$

$$\eta_{\text{Heat input}} = \frac{H.R}{H.G}$$

85 - 95% $\rightarrow$ RW Resistance welding
45 - 65% $\rightarrow$ GAS
65 - 55% $\rightarrow$ ARC-Welding

H.R. Heat reqd

Determination of current: $\downarrow$

ALTERNATE METHOD

$$\eta_{HI} = 100\%$$

$$H.G = H.R$$

$$I^2 R t = H.R \frac{H.G}{H.G}$$

$$= \text{Vol} \times \rho \times \text{Heat Req'd / Gram}$$

★ Methods of Improving strength or Load Bearing Capacity of Resistance welded joint: -

1. By ensuring that Major axis of elliptical Nugget is coinciding with axis of joint formation;

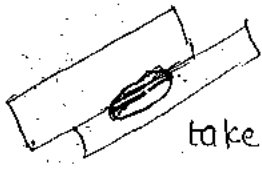
$$R_1 + R_2 + R_3 \neq R_1 + R_2 + R_3''$$

the shifting of major axis of elliptical Nugget will

take place when the ~~major axis is above the joint~~

~~is not~~ The total resistance below joint

variation of Total resistance is mainly during due to



variation of resistance R_3 above and below the joint. This happens when, ~~unequal resistance~~ $a \neq b$ and below the joint, due to ~~unequal resistance~~ $a \neq b$.

④ During joining of diff thickness plate made by using same material:-

- ① Same thickness plate made by using diff materials
- ② Diff thickness plates made by using diff materials

$$R_1 = \frac{\rho L}{A}$$

$$R_1 = \frac{\rho L}{\frac{\pi \times (0.2)^2}{4}}$$

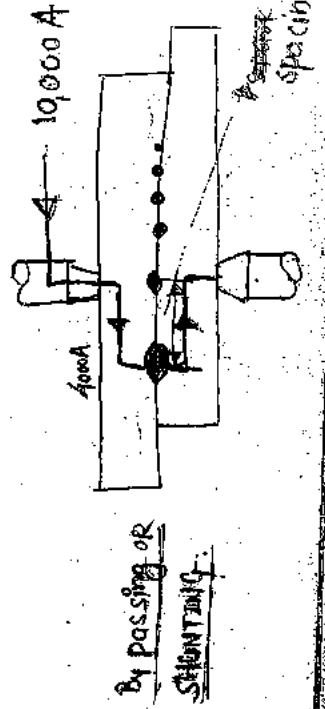
Modification:-

① The major axis of

total resistance of joint must be made equal to

Below, ~~the major axis of the joint must be made equal to~~ This is possible either by changing the ~~material of the plates or by changing~~

- ② ~~By changing the material of the plates and making more~~ than one weld ~~on the plates~~



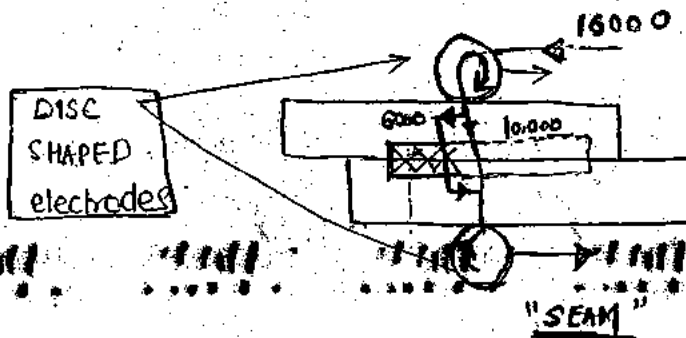
During making of and subsequent nuggets the chances of shunting or By passing of electricity is very high due to which current passing through the joint is reducing Hence the Heat generation and size of Nugget is Reducing.

To Avoid Bypassing the min^m spot spacing b/w 2

Consecutive Nuggets is $4.8t$ 't' - Avg. thickness of joint.

* → SEAM WELDING

Increasing the overlap b/w the plates and making the continuous weld Beads b/w the 2 plates.



* The Method of producing ~~continuous weld bead~~ b/w the 2 plates to be joined is ~~Resistance Seam Welding~~.

Problems:-

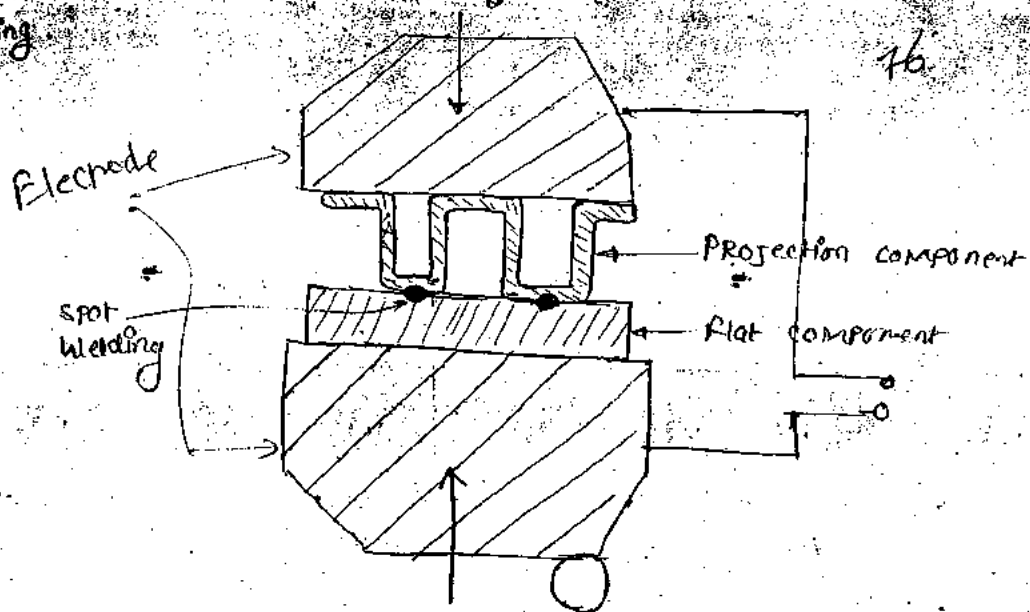
Bypassing of current due to presence of continuous weld Bead. So only soln to this is increasing the supply condition.

* In Seam Welding whatever the ~~amount~~ which is Bypassing the corresponding amount will be ~~increased~~ supply conditions only.

PROTECTION WELDING:-

* PROJECT WELDING :-

8] The method of joining a projected component on a flat component by using Resistance welding is called Resistance ~~Spot~~ projection proj. welding.



Shape of Electrode remain same as the shape of the the Proj compo to be joint.

The above pressure ops are the fusion pressure welding ops. Where ~~flash~~ percussive is a Non-fusion ~~flash~~ welding ops.

4] Percussion Welding - Flash Butt Welding

It is a Non fusion pressure welding Technique.

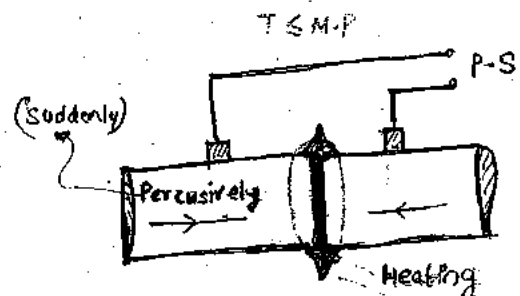
* Butt joint

Earlier Resistance operations are producing only lap joints. But percussion welding is producing Butt joint.

In percussion welding ~~separate electrodes~~ and the [Flash] Components to be joined themselves are acting as electrodes.

Percussively $\Rightarrow$ Suddenly

~~separate electrodes~~ will be given to the Components through



of joint. This Heat generated is sufficient to
 the temp of joint nearly equal to or slightly less than
 M.P temp of material. start the power supply and apply the
 force (perceptively) or suddenly. Bcoz joint is heated to the
 temp near the M.P temp, the atoms present on the surface
 of joint are more active to share the energy with the
 remaining atoms. In addition the sudden force is also applied.
 produces the alloy at the surfaces.

the joint formation will be taking place as a non fusion joint.

Bcoz of sudden application of force at joint the material is
 fractured and produces flash. The process is also called as

"Flash Butt welding". Mainly used for joining of shaft from
 end to end. Due to the surface alloy formation there is ~~some~~ ^{blow} the joints.

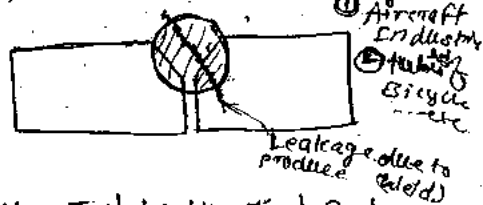
wherever the increase in weight of system
 is not allowed due to joining process such places the
 Resistance welding process is used.

★ Resistance welding: Whenever the ~~the~~ ^{the} proof joints are to be
 produced such places only Resistance welding is used.

Applications: ① Whenever the ~~the~~ ^{the} is not allowed, in such
 cases only Resistance welding will be preferable: Ex:-

Ex: Construction of pressure vessels,

② for: Joining of fuel tanks to the
 Automobile Body,

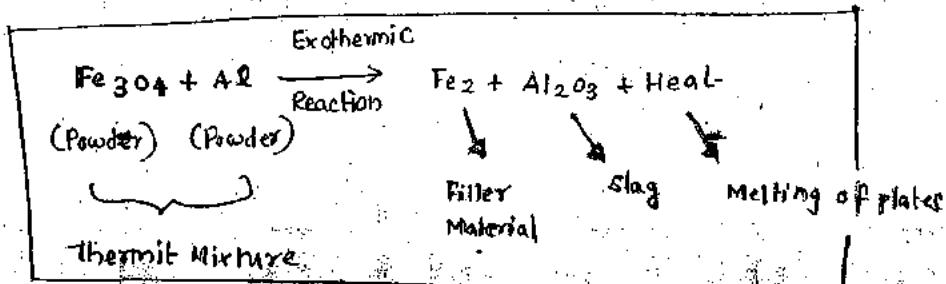
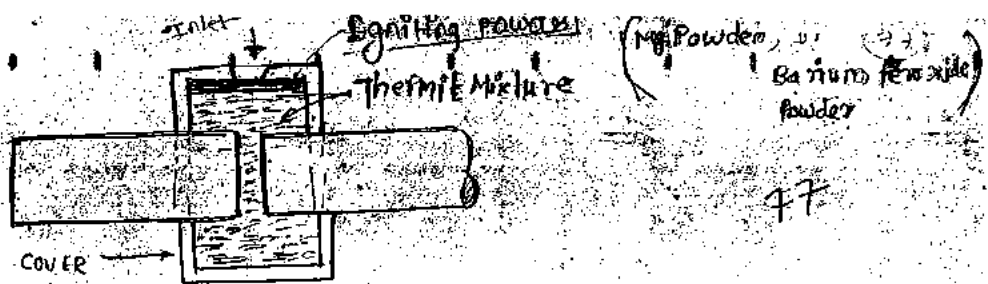


Joining of throw away type of tip of the Tool to the Tool Body

Thermit Welding:

CHEMICAL-WELDING

It is a Exo thermic Reaction chemical welding process bcoz
 whatever the Heat reqd for melting and joining of plates is
 obtained due to the exothermic chemical Reaction.



The joint will be made by using thermite mixture. On the top a thin layer of igniting powder like Barium peroxide or (Mg) powder will be filled. Now the igniting powder will be initiated for burning using so that by burning of igniting powder will be used for initiating exothermic chemical reaction of thermite mixture due to the exothermic reaction the

App: thermite welding is developed for joining for of and available body. Gas cylinders can't be carried.

PREHEATING AND POST HEATING

→ Heating the joint before actual welding operation is called preheating.

- ① present on the weld plate before actual welding. otherwise during welding process this dirtiness gets removed and

as a Result the Net Heat available for melting of plate may not be sufficient and also vapours produced may retain inside the weld Beads and produce defects.

- ② During Joining of High Thermal Conductivity and High m.p materials Heat lost by conduction is greater - so Net Heat available for melting of plates is Reduced - and if m.p of plate is Higher it is not possible to melt the parent material, with preheating the temp diff is Reducing and hence Heat transfer by conduction is Reducing.

- ③ Whenever the welding speeds are to be increased preheating of weld Beads are to be done. with preheating the amount of Heat to be supplied to the weld Bead is Reduced.

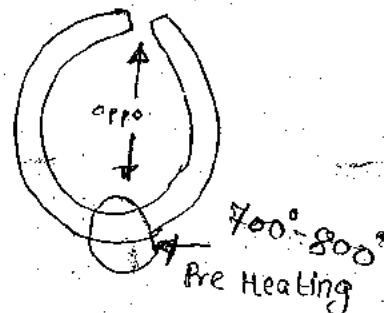


$$Q \propto \Delta T$$

- ④ During joining of High expansion materials with preheating the weld Bead will be cooled slowly so that contraction of the material is taking place slowly and avoids the formation of cracks in weld Bead.

Without Preheating temp diff is High - so cooling will occur at very high speeds inducing Residual stresses and cracks.

- ⑤ Whenever Ring like Components are to be joined Preheating of Ring will be done at a temp. exactly equal to that of weld Bead to be produced.



* Forced Heating - [POST HEATING]

78

~~Heating of joint after welding~~ is called forced heating.
Post Heating of weld Bead is done 78

- ① To Relieve the internal Residual stresses present in weld Bead.
- ② To Reduce the Brittleness and increase Toughness bcz of fast cooling.
- ③ To convert the Martensite structure produced into Troosite or sorbite structure. (present in weld bead)

Martensite can't be used directly in engg applications due to its High Brittleness.

→ WELDABILITY of Metal

The ease with which welding of given material can be done without producing any defect is called weldability.

Factors affecting weldability:-

* ① M.P of Metal

Both High M.P and Low M.P materials are treated as difficult to weld materials and ~~are considered as difficult to weld materials.~~

* ② Thermal Conductivity of Metals to be joint :-

~~High 'K' materials are considered as difficult to weld.~~
~~Materials having low thermal conductivity are high~~
and ~~are considered as difficult to weld.~~

⚡ If a Material is Having High M.P and High thermal conductivity it will be Considered as difficult to weld material

(Al)

~~Materials having high thermal conductivity~~ - Answer Due

④ Reactivity

Highly reactive metals will be considered as difficult to weld materials because they produce oxides very easily and rate of oxidation is also higher.

⑤ Expansion of Metals ↓ [Coefficient of Thermal Expansion]

High expansion materials will be treated as difficult to weld materials bcoz it produces residual stresses and cracks in the weld bead.

⑥ Electrical Resistance ↓ [only for Resistance welding]

Highly Electrically Resistance materials will be treated as difficult to Resistance weld materials.

⑦ Surface Condition ↓

unevenness and dirtiness of the surface.

ie the Dirty surfaces can be treated as a difficult to weld

material bcoz during joining to remove ~~surface~~ ~~material~~ ~~be~~ ~~cause~~ ~~of~~ ~~the~~ ~~dirty~~ ~~surface~~ ~~the~~ ~~large~~ ~~amount~~ ~~of~~ ~~heat~~ ~~will~~ ~~be~~ ~~getting~~ ~~wasted~~.

large amount of heat will be getting wasted.

[From the above which ever the material is influenced by maximum no. of factors the corresponding materials considered as very difficult to weld materials.]



(medium) $\rightarrow$ MS
prop

Al

Cl

Cu

Arrange in decreasing order of Welding.
Inc. order.

dec. $\rightarrow$
MS Cu Cl Al

Defects in Welding ↓

- ① External Defects
- ② Internal Defects

External

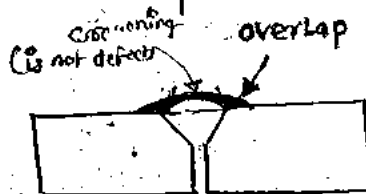
- ① overlap
- ② undercut
- ③ spatter
- ④ crater
- ⑤ Excessive Convexity
- ⑥ " Concavity
- ⑦ Surface porosity
- ⑧ " Cracks

DEFECTS

Internal

- ① Internal Porosity
- ② " Cracks
- ③ slag Inclusion
- ④ Lack of Fusion
- ⑤ Incompletely Filled groove

Overlap



- Use of DSRP with
- Magnetic Arc Blow
- Excessive size of electrodes
- ^{speeds} use of Low welding during joining of small thickness plates
- Excessive current conditions

Undercut

Exactly opp. to Overlap

UNDERCUT



- Use of DSRP with Magnetic Arc Blow
- Insufficient size of electrode
- use of High welding speeds during joining of large thickness plates
- Excessive Arc Length

[Force of Arc will be increasing so it will deform the material]

SPATTER :-

During welding operation ~~the molten metal particles are jumping from weld pool~~ ^{of flame} the molten metal particles are jumping from weld pool

1. use of Low welding speeds during joining of large thickness plates

2. Excessive Arc Length

3. use of Damp electrodes

Excessive cellulose coated electrodes are called as Damp electrodes [cellulose coating given to produce shielding gas]

4. Arc Blow $\rightarrow$ * Magnetic pull inside the material.

CRATER:-



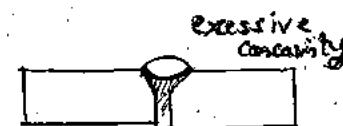
At the end of welding in Gas welding a shallow spherical depression is produced known as crater.

Reason:-

~~At the end of welding~~ use of large Torch angle at the end of weld Bead.

EXCESSIVE CONVEXITY:-

1. use of Low welding speed with DCRP
2. Excessive current conditions.
3. use of Large size electrodes for joining of small thickness plates



EXCESSIVE CONCAVITY:-

Reason:-

1. use of DCSP with High welding speed
2. Insufficient current conditions
3. use of small size electrodes for joining of large thickness plates.

SURFACE POROSITY:-

~~Presence of small gas pockets~~ inside or on surface of weld Bead

~~is called as~~ porosity

1. Gas welding without the use of fluxes
2. Arc welding with use of Bare wire electrodes
3. Use of Damp electrodes
4. Joining of dirty surfaces without preheating



SURFACE CRACKS:-

Presence of Residual stresses

Joining of High thermal expansion materials without Preheating



Joining of Ring like structures without Preheating

welding of Ferrous materials by using Hydrogen as shielding

gas, [Fe it has ability to cook H^+ atoms; if H used as a shielding gas, the Fe absorbs the H^+ and hydrogen gas which leads to cracking]

SLAG INCLUSION

Presence of slag particles inside weld bead is called slag inclusion

1. Use of Fore Hand welding technique in Gas welding



2. Incorrect select of Flux powder

[ρ must be less than Parent material]

3. Improper cleaning of weld bead in multipass welding

[It is not considered as a defect in Non-fusion welding]

Incorrect Torch angle in Gas welding



Incorrect conditions in Arc welding

Joining of High thermal conductivity materials without preheating

Joining of materials without preheating

INCOMPLETELY FILLED GROOVE

Large Amount of Land or small Root gap.



①

welding speed

$$u = \frac{l}{\text{welding time}} \quad \text{length of weld piece } l = 1000 \text{ mm}$$

$$P = 4 + 0.8L - 0.1L^2$$

for opt power

$$\frac{dP}{dL} = 0$$

$$0.8 - 0.2L = 0$$

$$0.2L = 0.8$$

$$L = \frac{0.8}{0.2} = 4 \text{ mm}$$

$$P = 4 + 0.8 \times 4 - 0.1 \times (4)^2$$

$$= H.S$$

Heat Reqd = Mass of WB $\times$ H.R/g

$$= Vol \times \rho \times 1400$$

$$= Area \times L \times \rho \times 1400$$

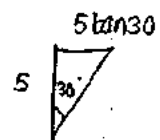
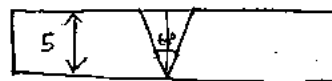
$$5.6 \times 10^3$$

$$W.T = A \cdot O.T = \frac{H.R}{H.S \times \eta_{H.S}}$$

$$= \frac{H.R}{5.6 \times 10^3 \times 0.8}$$

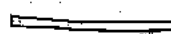
$$5.6 \times 10^3 \times 0.8$$

$2 \times 5 \tan 30$



Area

$$= \frac{1}{2} \times 2 \times 5 \tan 30 \times 5$$



$$V = 20 + 40L$$

$$L = 3 \text{ to } 5 \text{ mm}$$

$$I = 400 \text{ to } 500 \text{ A}$$

At EqBM

$$V_A = V_p$$

$$L = 3 \text{ mm}, I = 500 \text{ A}$$

$$V = 20 + 40 \times 0.3 = 32 = V_0 - \frac{V_0}{I_s} \times 500$$

$$V_0 - \frac{V_0}{I_s} \times 500 = 32$$

$$L = 5 \text{ mm}, I = 400 \text{ A}$$

$$V = 20 + 40 \times 0.5 = 40 = V_0 - \frac{V_0}{I_s} \times 400$$

$$V_0 - \frac{V_0}{I_s} \times 400 = 40$$

$$\frac{V_0}{I_s} = \frac{8}{100}$$

$$V_0 = 32 + \frac{8}{100} \times 500$$

$$V_0 = 72 \text{ V}$$

$$I_s = V_0 \times \frac{100}{8}$$

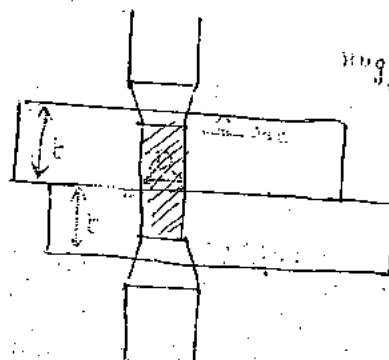
$$= 72 \times \frac{100}{8} = 900 \text{ A}$$

$$\textcircled{3} \quad Q = I^2 R T = 1000^2 \times 200 \times 10^{-6} \times \frac{1}{2}$$

$$\textcircled{4} \quad D = 6\sqrt{t}$$

$$= 6\sqrt{1.5}$$

$$h = 2t - 2 \times 0.1t$$



$$V_d = \frac{A \times 10^{-3}}{4}$$

$$H.R. = V_d \times \rho \times H.P./\text{gram}$$

$$H.P./g = 1380$$

$$\rho = 13500$$

(5)

$$P_r = 50 \text{ kVA}$$

$$D_r = 50\%$$

$$V_r = 25 \text{ V}$$

$$I_r = \frac{P_r}{V_r} = \frac{50 \times 10^3}{25} = 2000 \text{ A}$$

$$I_d = 1500 \text{ A}$$

$$T.W.T = 30 \text{ sec}$$

$$A.O.T = 3$$

$$I_d = I_r \times \frac{D_r}{100}$$

$$D_d = \left(\frac{I_r}{I_d} \right)^2 D_r = \left(\frac{2000}{1500} \right)^2 \times 50 = 55\%$$

$$D_d = \frac{A.O.T}{30 (T.W.T)} \Rightarrow A.O.T = D_d \times 30$$

$$= 26.4 \text{ sec}$$

4-6

(9.8)

$$H = I^2 R T \times \eta$$

$$= 150^2 \times 36 \times 10^{-6} \times \frac{900}{300} \times 60 \times 0.8$$

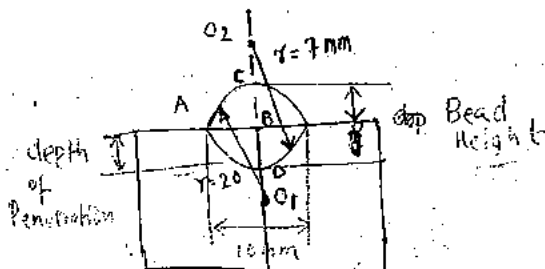
$$= 11.6 \text{ kJ}$$

(10)

Bead Height

$$BC = O_1C - O_1B$$

$$20 = \sqrt{O_1A^2 - AB^2} = 20 = \sqrt{20^2 - 5^2}$$



For cold working of these materials, we have to go for temp below $0.3 T_m$

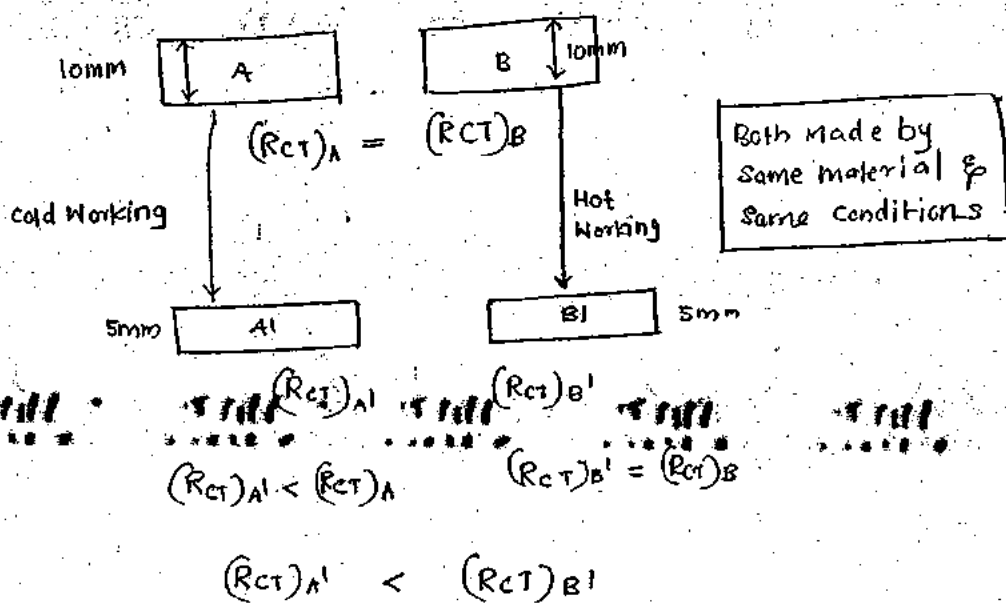
0°C

W

11000°C

$$< \frac{1}{3} M.P.$$

Deforming Tungsten at 11000°C is still considered as a cold working only.



→ NOTE! ←

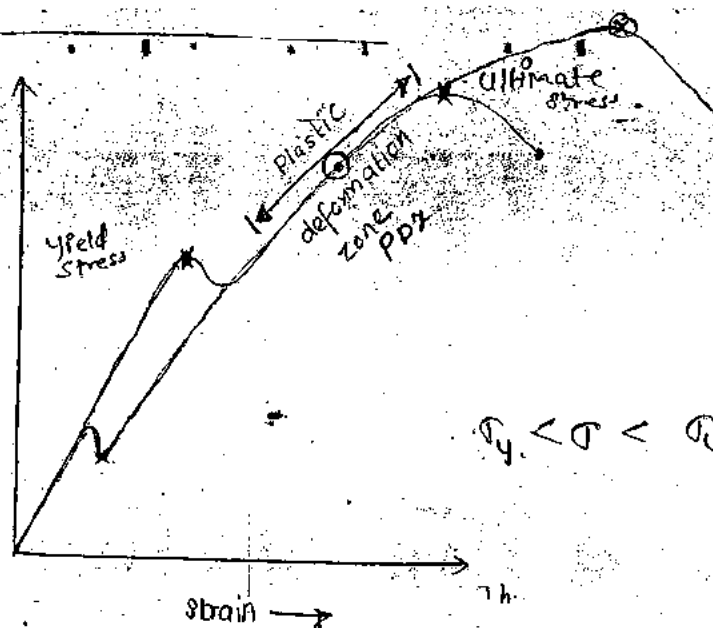
The Recrystallisation Temp of cold worked material will be less than initial R.C.T.

The Recrystallisation Temp of Hot worked material will be same as initial R.C.T.

In a Hot Worked Component and Normal Component whatever the Read Threshold level of energy for changing the Behaviour of the grain is obtained only through Heating whereas in case of cold worked component the Read threshold level of energy can be obtained by Heating as well as distribution

① Metal forming,
by: I.B. Prasad/
② M.F. by: Nagpal/

Stress ↑



To consider a given material as a ~~easy~~ in metal forming material, the plastic deformation zone of material must be ~~as wide as possible~~ as possible.

To make a given material as ~~easy~~ in metal forming process, the width of the plastic deformation zone must be ~~increased~~ increased. This is possible by

- ① Increasing the ultimate strength of material
- ② This is possible by performing the ~~hardening~~ hardening operation.

this is not a preferable method because ~~hardening~~ hardening not only increases the ultimate strength of the material but also increases the ~~strength~~ strength of the material. ∴ width of plastic deformation zone remains constant.

- ② Reducing the yield strength of material

This is done by heating the material. Here reduction in ultimate strength is there but it is very small when compared to reduction in yield strength of material.

∴ width of plastic deformation zone is increased.

→ Except steel all mat. can reduce the yield. st.

STEEL

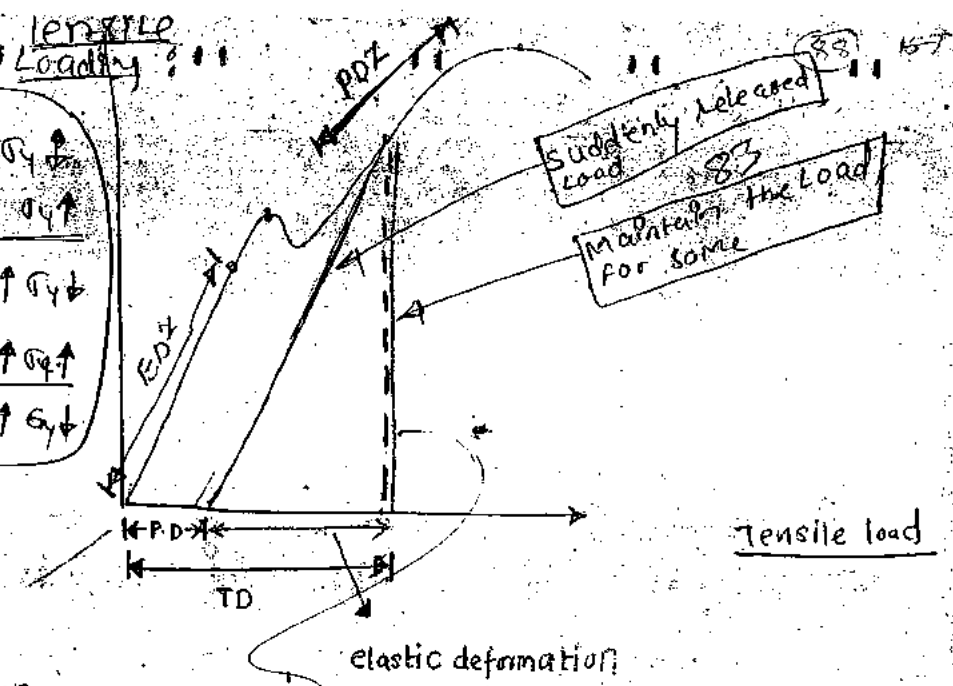
$T < 150^{\circ}\text{C}$ $T \uparrow \sigma_y \downarrow$

$T = 150^{\circ}\text{C} - 350^{\circ}\text{C}$ $T \uparrow \sigma_y \uparrow$

$T = 350^{\circ}\text{C} - 750^{\circ}\text{C}$ $T \uparrow \sigma_y \downarrow$

$T = 750^{\circ}\text{C} - 850^{\circ}\text{C}$ $T \uparrow \sigma_y \uparrow$

$T > 850^{\circ}\text{C}$ $T \uparrow \sigma_y \downarrow$



Plastic/
Permanent
deformation

elastic deformation

If the load is withdrawn slowly the graph will be vertical

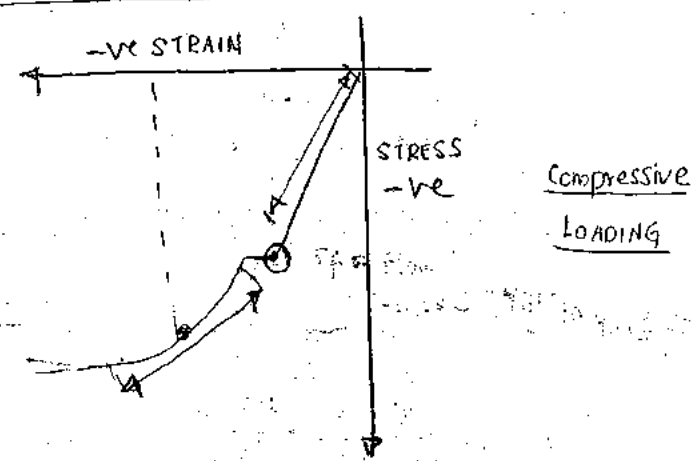
BUT ONLY present in PDZ NOT in EDZ

Even though ~~the load is withdrawn slowly the graph will be vertical~~
~~the plastic deformation is permanent~~
~~the name can be given as a plastic deformation zone~~

So the name can be given as a plastic deformation zone.

From the above whenever the load applied for metal forming process is tensile load, to convert the elastic deformation present in the plastic deformation zone into plastic deformation it is necessary to maintain the load applied for some more time

Compressive Loading



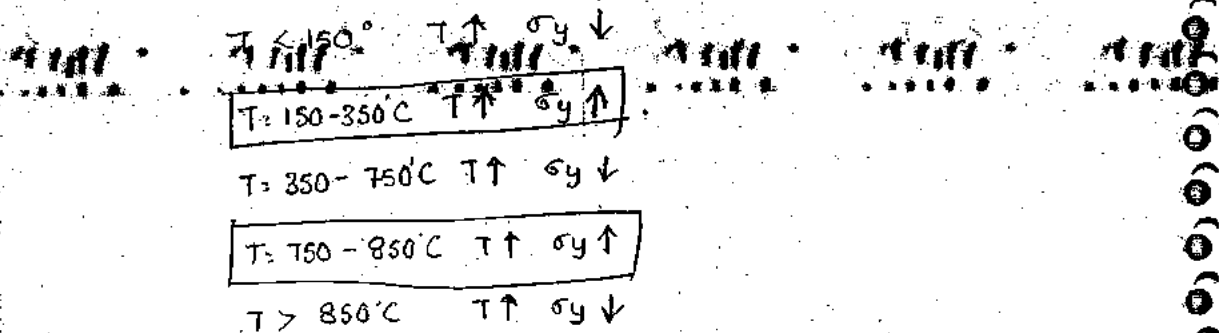
* Similar to yield stress in tensile loading condition, Flow stress can be defined as the stress above which the Flow Behaviour of solid material is like a fluid.

* When the stress is beyond flow stress whatever the deformation produced in the material is 100% permanent deformation only. ∴ it is Not necessary to maintain the load for some more time to convert E.D present in P.D. to P.D.

* From above whenever compressive loads are applied in metal forming process it is not required to maintain the load for some more time as in case of tensile loading.

In all the materials increase in temperature causes Reduction in yield stress of material except steels.

→ Behaviour of steels ←



* Steels should not be deformed in the Temp zones of $150 - 350^\circ\text{C}$ and $750 - 850^\circ\text{C}$.

REASON:-

Allotropic form

Polymorphism

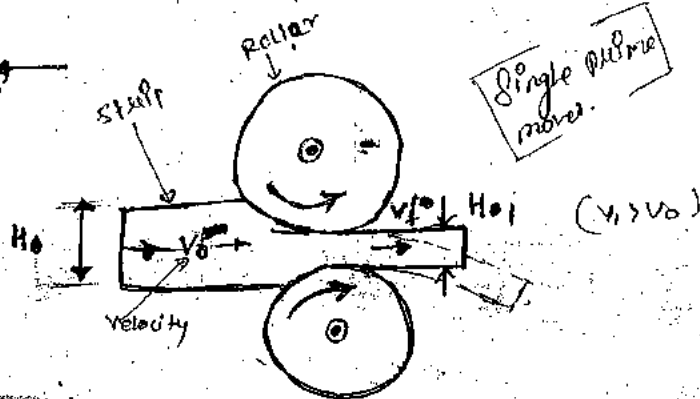
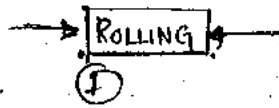
Steel

Major component Fe

Allotropic	
$1539^\circ\text{C} \rightarrow \delta\text{-Fe}$	BCC
$1410^\circ\text{C} \rightarrow \gamma\text{-Fe}$	FCC
$910^\circ\text{C} \rightarrow \alpha\text{-Fe}$	BCC
$723^\circ\text{C} \rightarrow \epsilon\text{-Fe}$	BCC

Metal Forming Operations

- ① Rolling
- ② Drawing
- ③ Extrusion
- ④ Forging



Liquid Fe 189
 ↓
 1539°C - Solid Iron
 (Co-iron)
 ↓
 1410°C - γ Iron
 (FCC)
 ↓
 910°C - α Iron
 (BCC)
 ↓
 723°C - α-iron
 (BCC)
 Magnetic

Rolling of plates surface velocity of both the

rollers should be same. Mat in come and fr' b/w the 2 rotating rollers such that thickness of mat. can be reduced to H_0 to H_1

$$\left[\frac{\pi D N}{\pi D N} \right]_{\text{Top}} = \left[\frac{\pi D N}{\pi D N} \right]_{\text{Bottom}}$$

$$[DN]_{\text{Top}} = [DN]_{\text{Bottom}}$$

$$D_{\text{Top}} = D_{\text{Bottom}}$$

To have the same surface area of contact b/w rollers and strip the dia of both the rollers must be equal so that speed of both the rollers will be

obtained as same which gives an advantage of using

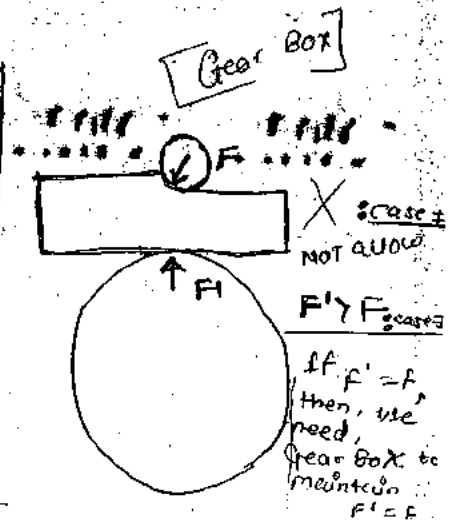
(single)

for rotating both the rollers without

TERMINOLOGY:

Let R = Radius of Rollers

H_0, H_1 are the thickness of strip before and after Rolling operation. $\Delta H = H_0 - H_1$ is the Reduction in thickness



b_0, b_1 etc = width of strip before and after rolling

v = surface velocity of the rollers

v_0 = velocity of strip before rolling

v_1 = " " " after rolling

* Assumptions taken for Analysis of Rolling operation are

(1) Every metal which is undergoing metal forming process is considered as incompressible i.e. vol of material before and after metal forming process are equal

(2) width of strip before and after Rolling operation is considered to be equal

i.e. $b_0 = b_1$

Explanation :-

⇒ In Rolling operation becoz of Reduction in thickness the vol of

material is decreasing in thickness direction so that the

corresponding vol of material has to be increased in

length or width direction but because the rollers are

pulling and pushing the material only in length dir, the

Reduction in vol. in thickness direction will be increased only

in length dir. Hence width of the strip is taken as

remains const.

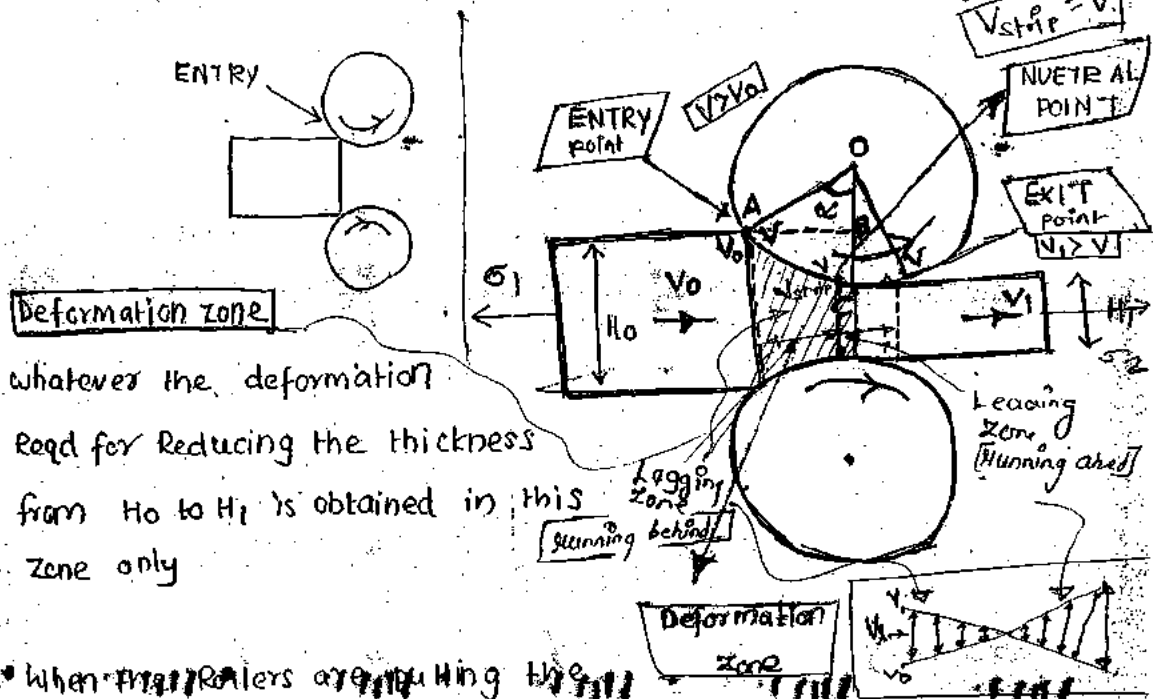
Vol Before = Vol After Rolling

$$H_0 \times b_0 \times v_0 = H_1 \times b_1 \times v_1$$

$$\frac{H_0}{H_1} = \frac{v_1}{v_0} > 1$$

$$v_1 > v_0$$

11. During Rolling operation when the Rollers are started rotating becoz of ~~the force of friction b/w Rollers and strip~~, the strip is automatically pulled into the rollers, so that no pushing force in the back side and No pulling force in front is Reqd.



Whatever the deformation Reqd for Reducing the thickness from H_0 to H_1 is obtained in this zone only

When the Rollers are rotating the strip the surface velocity of Rollers must be greater than the vel of strip at the entry

ie



Along the deformation zone the vel of strip is going on increasing But the surface vel of Rollers is remaining const so that at some point the vel of strip and Rollers become equal, called as ~~Eq. Neutral Point~~. At the Neutral point the stresses induced in material is just becoming equal to flow stress of the material. Beyond the neutral point vel of strip is further increasing but the vel of roller is remaining const. At the exit vel of strip is becoming $>$ vel of roller ie

$$V_0 < V < V_1$$

α = Bite angle

= Angle of Bite

ϕ = Deformation angle

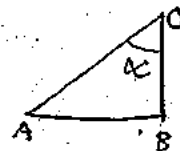
Angle made by the Centre of the Roller with the Entry and Exit is called Angle of Bite.

In ΔOAB

$$\cos \alpha = \frac{OB}{OA} = \frac{OC - BC}{R}$$

$$= \frac{R - \Delta H/2}{R}$$

$$R \cos \alpha = R - \frac{\Delta H}{2}$$



ΔH = Redn in thickness

$$\Delta H = D(1 - \cos \alpha)$$

D = Dia. of Roller

AC = Arc Length of deformation zone

= $R\alpha$

AB = Length of Deformation zone

$$AB = \sqrt{OA^2 - OB^2}$$

$$= \sqrt{R^2 - (OC - BC)^2}$$

$$= \sqrt{R^2 - \left(R - \frac{\Delta H}{2}\right)^2}$$

$$AB = \sqrt{R^2 - R^2 + \frac{\Delta H^2}{4} + 2R\frac{\Delta H}{2}}$$

$$AB = \sqrt{R\Delta H - \frac{\Delta H^2}{4}}$$

$$AB = \sqrt{R\Delta H}$$

From ΔOAB

$$\tan \alpha = \frac{AB}{OB}$$

$$\tan \alpha = \frac{\sqrt{R\Delta H}}{R - \Delta H/2}$$

$$\tan \alpha = \frac{\sqrt{R\Delta H}}{R}$$

$$\tan \alpha = \frac{\sqrt{\Delta H}}{\sqrt{R}}$$

(2)

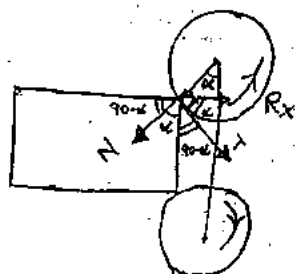
Generally ΔH is small

$$R\Delta H \gg \frac{\Delta H^2}{2}$$

86.

$$R \gg \frac{\Delta H}{2}$$

Maximum value of Angle of Bite Taken in Rolling operation :-



$$R_x = T \cos \alpha - N \cos(90 - \alpha) \geq 0$$

$$R_x = T \cos \alpha - N \sin \alpha \geq 0$$

$$\mu N \cos \alpha - N \sin \alpha \geq 0$$

$$R_x = N (\mu \cos \alpha - \sin \alpha) \geq 0$$

T = Tangential Component

N = Normal Component

R_x = Resultant Resolved Horizontal Component of frictional force

For pulling the strip into the rollers in the rolling operation the value of $R_x \geq 0$

Min of Rolling passes = 8

$$D = 650 \text{ mm} \quad \mu = 0.2$$

$$H_0 = 180 \text{ mm}, H_1 = 95 \text{ mm}$$

Eg:

$$\Delta H_{\text{max}} \cdot \Delta H$$

$$\mu = \tan \beta$$

$$\Delta H_{\text{max}} = (\tan \beta)^2 R = \mu^2 R = \Delta H_{\text{max}}$$

$$\tan \alpha_{\text{max}} = \tan \beta = \sqrt{\frac{R}{\Delta H_{\text{max}}}}$$

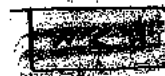
$$\tan \beta_{\text{max}} = \tan \beta = \sqrt{\frac{R}{\Delta H_{\text{max}}}}$$

condition
coulomb friction

$$\mu_{\text{max}} = \beta$$

As α is increasing the Redn in thickness of strip in rolling operation will increase i.e. ΔH is increasing when α becomes maximum the corresponding Redn in Rolling operation is called Maximum possible Reduction

For a given Rolling operation for the Rolling operation to be possible the angle of Bite is less than or equal to Angle of friction



$$\tan \beta \geq \tan \alpha$$

$$\mu \geq \tan \alpha$$

$$N(\mu \cos \alpha - \sin \alpha) \geq 0$$

$$R_x \geq 0$$

$$\mu = \tan \beta$$

friction Retn:

β - Frictional Angle



sufficient to pull the Rollers

force is very small. It is

$$R_x = 5g$$

$$\mu = 0$$

$$= 0.0005 \text{ kg}$$

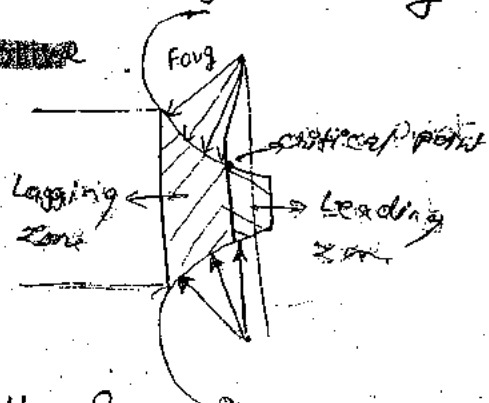
$$\Delta H_{total} = 180 - 95 = 85$$

$$\text{No. of Passes} = \frac{\Delta H_{total}}{\frac{U^2 R}{\Delta H_{max} (\text{pass})}} = \frac{\Delta H_{total}}{\frac{U^2 R}{\Delta H_{max} / \text{Pass}}} = \frac{85}{\frac{4^2 \times 325}{0.2 \times 325}} = \frac{85}{0.2 \times 325} = \underline{6.5}$$

At the entry the Relative vel b/w Rollers and strip is maximum, Along the deformation zone bcoz of increase in vel of strip the Relative vel. Reduces and becomes equal to zero at Neutral Point. Beyond the Neutral point also the velocity of strip is further increasing so Relative velocity starts increasing again in the other direction and becomes maximum at exit. Along

the deformation zone the Relative velocity is first decreasing then increasing. Lagging Zone, Leading Zone. The Neutral point is dividing the deformation zone into 2 partitions i.e. the zone b/w entry and Neutral pt is called Lagging zone and zone b/w Neutral pt and exit is called Leading zone. But in Lagging zone relative velocity is Reducing only and in Leading zone relative velocity is increasing only.

Slip $\propto$ Relative Velocity



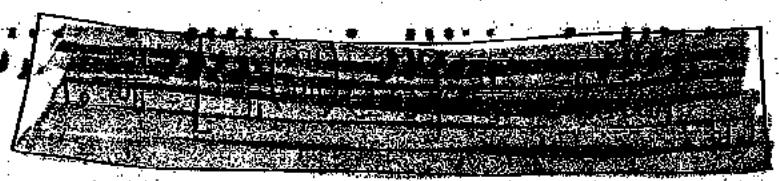
along deformation slip is Reducing 1st and then Increasing.

Pressure of slip
 The max "10" of slip rollers as backward slip $\propto \frac{1}{\sqrt{r}}$
 Pressure acting b/w rollers and strip is inversely proportional to slippage

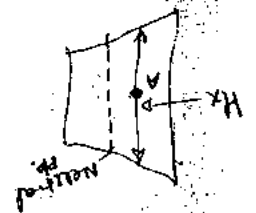
Pressure along the deformation zone is first increasing and then decreasing. i.e. Pressure at the entry is minimum beyond the neutral point pressure is again started reducing and becomes min at exit.

Calculation of Pressure: 1

Let $n = 2.4L$
 $\frac{\Delta H}{4H}$



P_x = Pressure at any point in lagging section
 σ_y = yield stress or yield stress
 H_{ox} = thickness of strip in lagging zone where the pressure is to be determined
 σ_1 = Back tension,



1 Not compulsory
 It is an accessory for improving of Rolling

H_{ox} = thickness of strip in leading zone where thickness of pressure is to be found
 σ_2 = Front tension
 It is an accessory only

Beoz the Neutral pt is belonging to Both lagging and leading (43)
 zone pressure at one pt can't have more than one value so

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$$\left(\frac{\sigma_y}{n}\right) \left[(n+1) \left(\frac{H_0}{H_N}\right)^n + 1 \right] - \left(\frac{H_0}{H_N}\right)^n = \left(\frac{\sigma_y}{n}\right) \left[(n+1) \left(\frac{H_N}{H_1}\right)^n - 1 \right]$$

$$(n+1) \left(\frac{H_0}{H_N}\right)^n + 1 = (n+1) \left(\frac{H_N}{H_1}\right)^n - 1$$

$$(n+1) \left(\frac{H_0}{H_N}\right)^n + 1 = (n+1) \left(\frac{H_N}{H_1}\right)^n - 1$$

By substituting thickness of strip at Neutral point either in Lagging zone pressure or in leading zone pressure eqn the max pressure induced in Rolling operation can be determined



$$H_0 - H_1 = \Delta H$$

ex:-

$$H_0 = 20 \text{ mm}$$

$$H_1 = 14 \text{ mm}$$

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

$$\mu = 0.1$$

$$H_N = 8$$

★ ★

$$V_0 H_0 = V_b H_N = V_1 H_1$$

$$\frac{V_0}{V} = \frac{H_N}{H_0} ; \frac{V_1}{V} = \frac{H_N}{H_1}$$

$$\text{Backward slip} = \frac{V - V_0}{V} = 1 - \frac{V_0}{V}$$

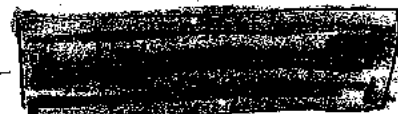
- (a) 18.5 (b) 17.3 (c) 15.3 (d) 14.2

More than avg.

Avg

close to

$$\frac{20+14}{2} = 17 \text{ avg}$$



$$P = 2(Tw)$$

T = Torque Reqd for Rotating Rollers

w = angular velocity

$$= \frac{2\pi N}{60}$$

N = speed in rpm of Roller

2 Tw
2 Rollers

$$\text{Torque} = (F_{avg}) \times a$$

a = Moment arm

Here Moment arm
is taken since, for
Pressure acting is not
uniform

$$a = \lambda L$$

λ = Arm factor

= 0.3 to 0.4

L = Length of deformation



$$F_{avg} = P_{avg} \times (b \times L)$$



H = avg thickness

$$H = \frac{H_0 + H_1}{2}$$

★ ➤ F_{avg} [Roll separating force]

It is the average F acting by the Rollers on to the strip for the Rolling operation to be performed.

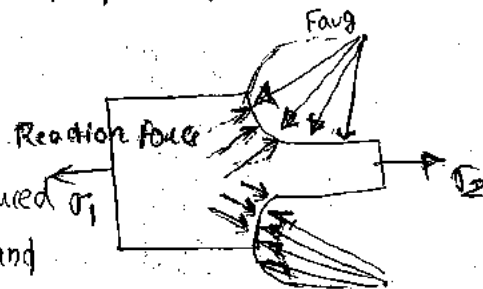
When F_{avg} is applied by

Rollers on to the strip, equal

and opposite Reaction force produced or

by strip is acting on to Rollers and

trying to separate the Rollers. ∴ F_{avg} is also called as



Rolling Force

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Methods of Reducing Roll Separating Force

- 1. Reducing μ - In General rolling opⁿ can be performed by Hot Rolling opⁿ
- 2. Reducing α

μ can be reduced until α becomes equal to β because when $\mu \downarrow \beta \downarrow$ when $\beta < \alpha$ Rolling is Not possible

Reducing R

Here the problem is as $R \downarrow$ Load Bearing capacity

$$R \propto L = \sqrt{R \Delta H}$$

So $R \downarrow \quad L \downarrow \quad$ So $F_{avg} \downarrow$

of Rollers decreases so chances of failure of Roller will increase. To Avoid this. Backup or Supporting Rollers must be used.

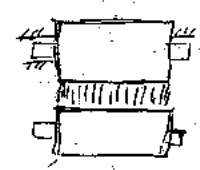
ie Back tension and Front tension

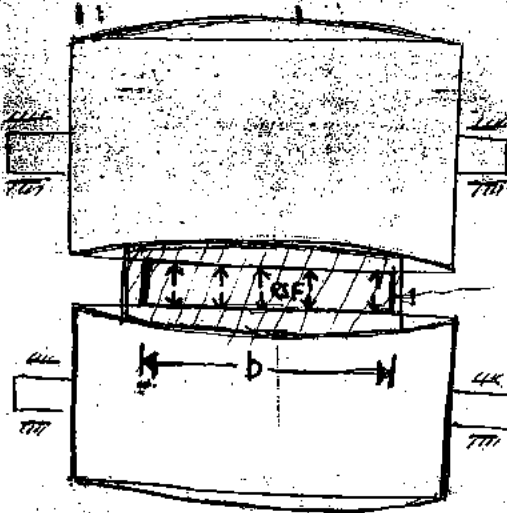
By σ_1 and σ_2 Tensile stresses are induced in the length direction of strip

(Poisson's ratio)

$\Rightarrow$ without applying the forces by using Rollers, $\Rightarrow$ compression of strip will be taking place (Roll separating force, F_{avg})

The Decreasing order of priority of methods of Reducing Roll Separating force are





RSF = Roll
Strip Separating
force

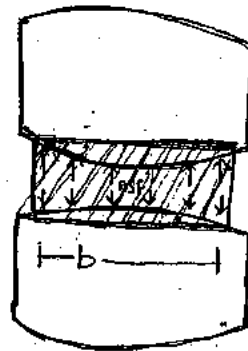
When RSF is acting on to rollers, each roller can be independently considered as simply supported beam with u.d.l.

The simply supported beam with u.d.l. The rollers are bending / deflecting elastically so that the gap present between rollers is filled by using the material of the strip. Hence the thickness of strip along the width direction will become non uniform. To get the uniform thickness of strip in the width direction, the shape of rollers can be made like a

cambering or

Large diameter in the center
small in diam. in the corner

ie dia of roller at the centre is large and at the ends is smaller. It is also called as cambering of rollers. With cambering or convexing during rolling operation when the Roll separating force is deforming the roller, the roller is



becoming straight in deformation zone and

produces uniform thickness of strip in the width direction.



Types of Rolling Mills:

1) Two High Rolling Mill

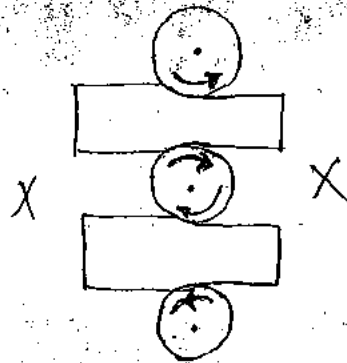
If only Two rollers are used for performing

Rolling operation it is called ~~Two High Rolling Mill~~.

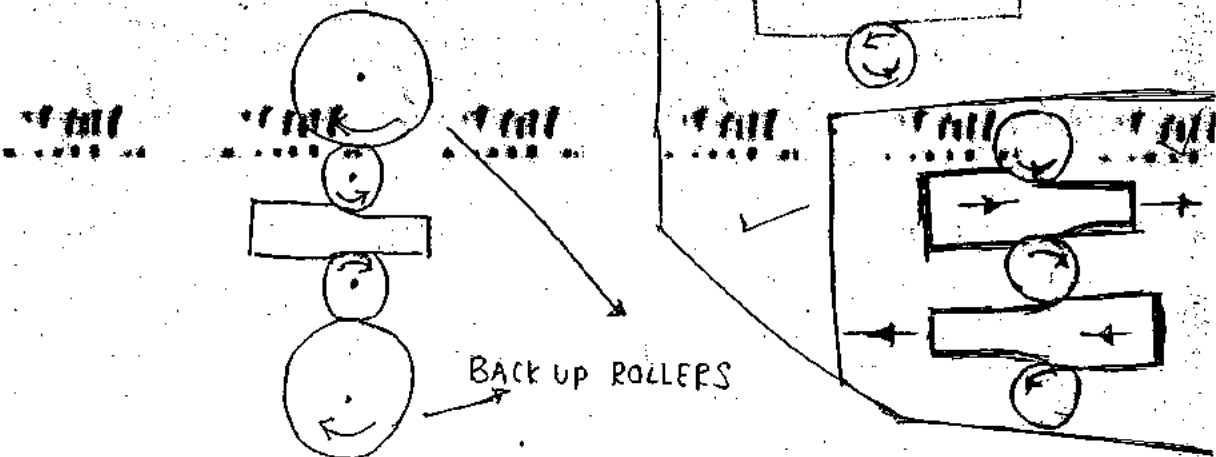
Three High Rolling Mill

If three rollers are used for Reducing two Reduction it is called 3-High Roller

Here extreme Rollers are Rotating in same direction and Centre Roller Rotating in opp direction

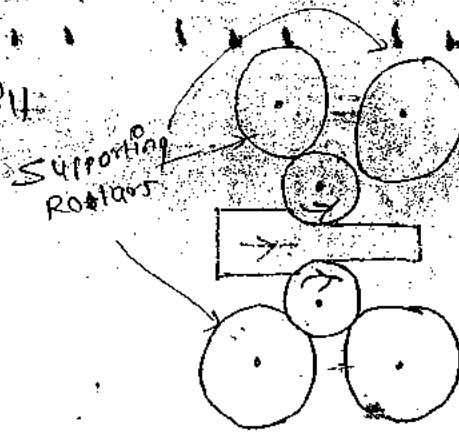


4-High Rolling Mill



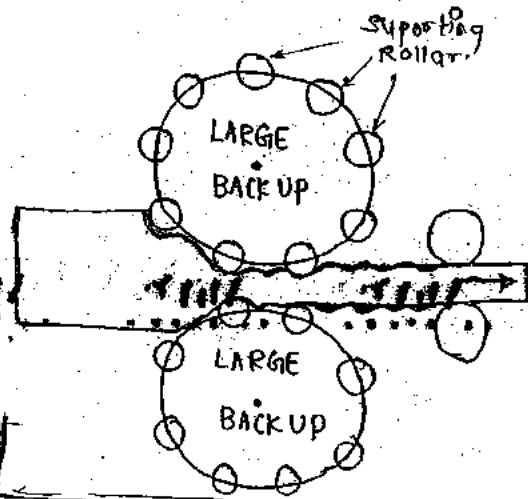
Here the ~~center of all the 4 Rollers~~ must lie on a single vertical line otherwise the rolling system will fail.

CLUSTERING Rolling Mill



Planetary Rolling Mill:-

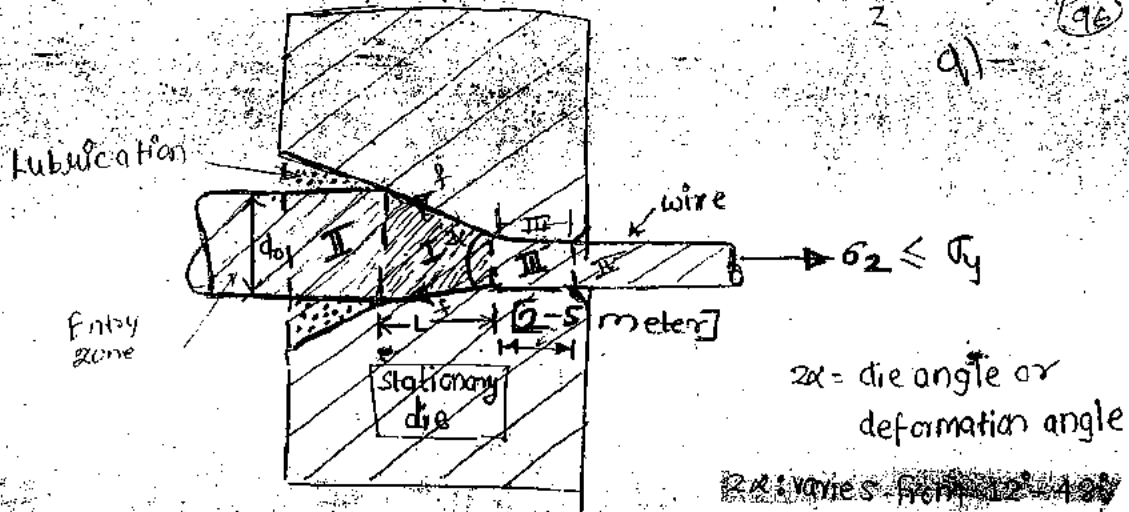
To reduce the ~~Roll~~ separating force as small as possible by reducing the roller radius the best preferable method is Planetary Rolling Mill.



DRAWING OPERATIONS:-

- ① Wire Drawing
- ② Tube Drawing

Wire Drawing :- Method of producing wire from solid rod by passing through a stationary die such that stresses induced is greater than the yield point stress and less than ultimate stress.



→ ~~Zone I is deformation zone~~ So α " " 6-24

Whatever the deformation reqd for converting the rod into wire is obtained in Zone-I only ∴ it is named as deformation zone.

for producing wires using ~~for producing~~ the die angle used is ~~for producing~~ for producing wires by using very ~~small die angle~~

Die Land:- (L)

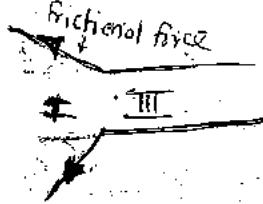
Length of deformation zone

→ During wire drawing operation the frictional force induced at the interface of wire and die is acting in backward direction which can be Resolved into 2 components of forces.

* ~~Horizontal component~~ of frictional force, which is ~~the opposing force~~ is being applied ~~opposite to the direction of motion~~

* ~~Vertical component~~ of frictional force

which is trying to ~~pull the wire back~~



To Reduce the ^{heat} affected can be minimised by Reducing the 'friction' at the interface. This is possible by using lubricants in the wire drawing operation from zone-2.

→ Zone 2 - Lubricating zone ←

Whatever the lubricants Required in wire drawing operation for Reducing friction can be 'supplied' from Zone 2 only. & called as Lubricating Zone.

→ Lubricants used: ←

The Types of Lubricating conditions used in wire drawing operation are

(a) No lubricant condition -

When the lubricant is not used the friction at the interface is higher. Heat generation and Temp are Higher. ~~Black or dark colour~~ is observed.

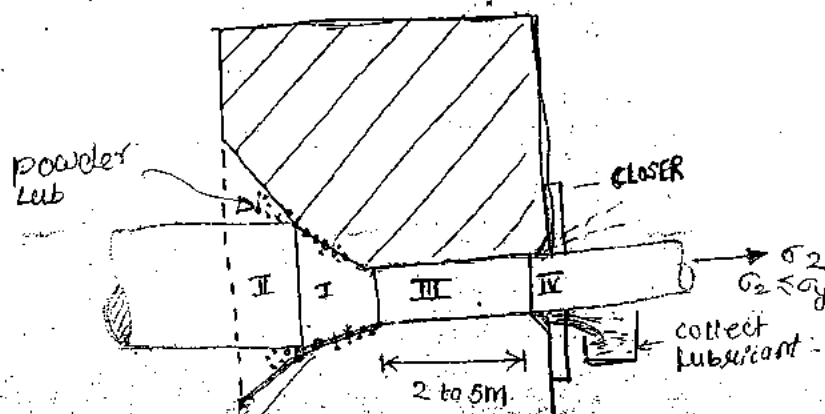
(b) Liquid Lubricant -

Due to the usage of liquid lubricant, friction Heat generation and Temp are Reducing. The surface of wire is observed as dull surface or metallic colour.

ex: vegetable oils, Mineral oils, SAE oils, Soap soln etc

kerosene is highly
harmful to Metal. for
Al, Mg etc.

(c) Solid Powdery Lubricant -



When the solid powdery lubricant is passing through the interface, it

Reduces the friction and also produces ~~microscopic scratches~~ on the wire surface which is making appearance of wire surface as bright shining surface or silvery surface.

Eg:- Carbon powder, Graphite powder, Glass powder

* Plastic deformation zone

It is a uniform dia zone having dia Area equal to the exit cross sectional Area of zone 1. This is used for converting the plastic deformation zone into plastic deformation. Normally the length of sizing zone is

* Exit zone

When lubricants are used in wire drawing operations due to the passage of lubricants at the interface of die and wire, they are experiencing very

high pressure. When this high pressure lubricant comes

into the exit zone, it is called as an exit zone called as 'exit zone'.

The High pressure lubricant comes into the exit zone, its pressure is reduced and drained out afterwards.

If lubricants are not used in wire drawing operations it is not necessary to use the exit zone.

d_o = Rod Dia

d_i = Wire Dia

$$A_o = \frac{\pi \times d_o^2}{4}$$

$$A_i = \frac{\pi \times d_i^2}{4}$$

$A_o = k$ coefficient of elongation

A_i or Draft

$A_0/A_1 = 1$ No Reduction in Area

$\sigma_2 \leq \sigma_y$

$$\sigma_2 = \sigma_y \left[\frac{1+B}{B} \right] \left[1 - \left(\frac{A_1}{A_0} \right)^B \right]$$

Stress applied at Front side

Drawing stress induced in wire drawing operation

$B = \mu \cot \alpha$

μ = coeff of friction at interface

α = Half of die angle

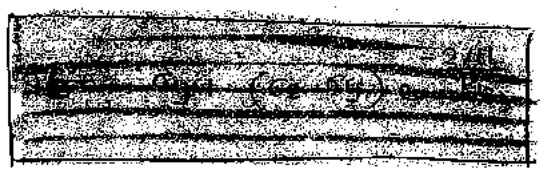
NOTE:-

σ_2 need not be $> \sigma_y$

At Zone 1

$\sigma > \sigma_y < \sigma_u$

In above eqn of σ_2 , the horizontal component of force acting in Backward direction is not considered. But by considering the Horizontal component of frictional force acting in Backward direction, the stresses to be applied in the forward direction is called Total Drawing stresses.



L = Die Land, Length

$R_1 = \frac{D_1}{2}$

DRAWING LOAD:-

$D.L = \sigma_2 \times A_1$

Total Load F

Power req.



$\therefore F = \frac{\sigma_2}{A_1}$

in wire drawing operation, for maximum reduction per pass is obtained by applying drawing stress exactly equal to yield stress of material. (98)

93

$$\sigma_2 = \sigma_y$$

$$\frac{\sigma_2}{\sigma_y} = 1 = \left[\frac{1+B}{B} \right] \left[1 - \left(\frac{A_1}{A_0} \right)^B \right]$$

$$K = \frac{A_1}{A_0} = \underline{\hspace{2cm}}$$

$$K = \frac{A_0}{A_1} = \underline{\hspace{2cm}}$$

$$J = \frac{A_0 - A_1}{A_0} = \underline{\hspace{2cm}}$$

$$K_{max} = 2 \text{ to } 6$$

$$K_{rolling} = \frac{A_0}{A_1} = \frac{H_0}{H_1} = 2 \text{ to } 10$$

Ques.) $\mu = 0.1, \alpha = 6^\circ$
 $K_{max} = ?$

$$B = \mu \cot \alpha$$

$$= 0.1 \cot 6$$

$$= \underline{\hspace{2cm}}$$

For max Reduction

$$\frac{\sigma_2}{\sigma_y} = 1 = \left[\frac{1+B}{B} \right] \left[1 - \left(\frac{A_1}{A_0} \right)^B \right]$$

$$\therefore \frac{A_1}{A_0} = \underline{0.495}$$

$$K = \frac{A_0}{A_1} = \frac{1}{0.495} = \underline{2.02}$$

$$J = \frac{A_0 - A_1}{A_0} = 1 - \frac{A_1}{A_0} = 1 - 0.495 = \underline{50.5\%}$$

TRUE STRAIN

$$\text{True strain} = \ln [1 + e]$$

$$\epsilon = \ln \left[\frac{A_0}{A_1} \right]$$

$$\epsilon = 2 \ln \left[\frac{d_0}{d_1} \right]$$

$e = \text{Avg strain}$
or
Engg strain
or
Natural strain

← IDEAL STRESS →

$$\text{Ideal stress Reqd} = \sigma_y \times \text{True strain}$$

$$= \sigma_y \times \ln \left[\frac{A_0}{A_1} \right]$$

$$(*) \text{ Ideal Force} = A_1 \times \sigma_y \ln \left[\frac{A_0}{A_1} \right] \quad * \text{ Ideal power} = \frac{(\text{Ideal F})}{\times \text{velocity}}$$

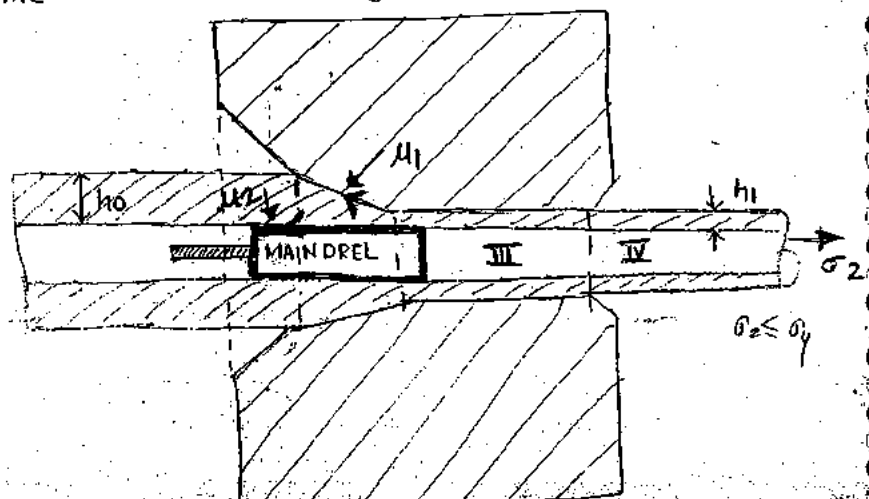
→ **TUBE DRAWING** ←

It is the method of ~~reducing wall thickness~~ of already existing tubes by pulling through a stationary die with mandrel so that the inside dia of tube is maintained Remains constant or varying.

DIE USED - Same as that of wire drawing

Impact extrusion

Methods of producing Tubes from rods by passing thru a stationary die.



It is similar to wire drawing operation, additional used for maintaining the Regd inside dia of tube.

Mandrel:-

Two types are there

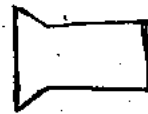
① cylindrical

② conical

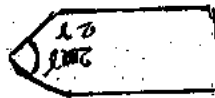
③ Spline

For maintaining same inside dia of tube a cylindrical mandrel can be used which has cone angle equal to zero

② Conical Mandrel:



Processing inside



Processing inside

For drawing inside the conical mandrel is used with cone angle

DRAWING STRESS

$$\sigma_2 = \sigma_y \left[\frac{B}{1+B} \right] \left[1 - \left(\frac{r_1}{r_0} \right)^{2n} \right]$$

$$B = \frac{A_1 \pm A_2}{\tan \alpha - \tan \gamma}$$

A_1 = coeff of friction b/w outside surface of tube and die

A_2 = coeff of friction b/w inside surface of tube and mandrel

In wire drawing $A_2 = 0$ $r = 0$

$$B = \frac{A_1}{\tan \alpha}$$

Based on usage of Mandrel

It is divided into 2 types

① Stationary Mandrel

② Movable or floating Mandrel

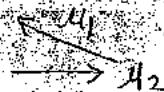
Here Mandrel is Reciprocating. To have the mandrel

Case 1:

Mandrel moving in backward direction

So friction is in ~~backward~~ forward direction

(-ve) sign



Case 2:

Mandrel moving in forward direction

When the mandrel is moving either in forward direction or in backward direction the direction of frictional force on inside surface of tube is in forward direction. ∴ direction of frictional forces on the inside and outside of tube is opposite. Hence -ve sign can be taken.

* In a tube drawing operation

if $u_1 = u_2$ and floating mandrel

So $B = 0$

So Drawing stress

$$\sigma_2 = \frac{0}{0}$$

$$\sigma_2 = \sigma_y \log_{10} \left(\frac{1}{\frac{h_0}{h_1} - 1} \right)$$

* For Maximum Reduction (^{Max^m} outward force $\Rightarrow \sigma_2$ can never be greater than σ_y i.e. $\sigma_2 \leq \sigma_y$)

$$\frac{\sigma_2}{\sigma_y} = 1 \cdot \left[\frac{1+B}{B} \right] \left[1 - \left(\frac{h_1}{h_0} \right)^B \right]$$

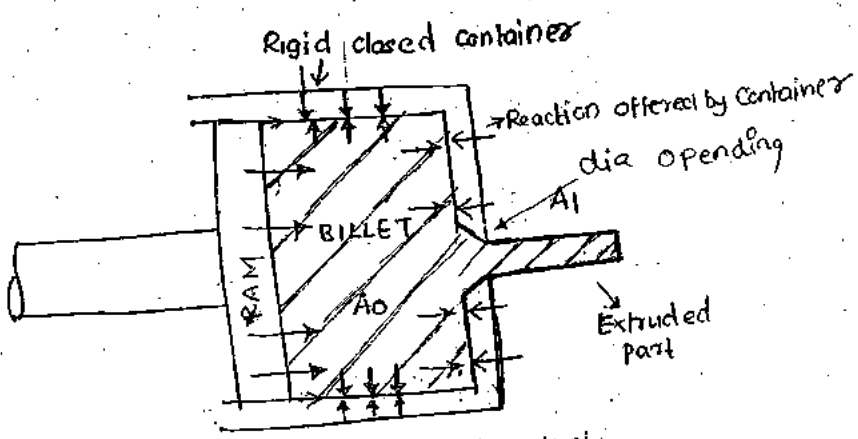
Max^m $\Rightarrow \frac{A_0}{A_1} = 2 \text{ to } 6$
(Reduction factor)



Q5. (100)

Extrusion is an extension of drawing operation only so that ~~by applying pulling force from front side~~ operation for Reducing Q.S Area From A_0 to A_1 , the same Type of Reduction in Area can be obtained by applying the force from Back side as a ~~compressive force~~ called as extrusion process. Hence the advantages of extrusion over the drawing operation are

- ① Becoz of compressive force it is not necessary to maintain the load for sometime to convert the E.D into P.D (plastic deformation) [i.e. σ_2 is not req.] ^(elastic defor)
 - ② Becoz of compressive stresses induced in material, behaviour of material is like a fluid. Any amount of deformation is possible to produce.
 - ③ Becz, Every tensile strength less than compressive strength, the max^m Reductⁿ is possible is limited to avoid this problem. $Max^m = \frac{A_0}{A_1} = 40$ to 50. Draft ~ 50 .
- ED = Elastic deformation
P.D = Plastic deformation
Extrusion are more effective.



FORWARD EXTRUSION

In extrusion Process the forces are applied on the Raw material by using a Ram in a Rigid closed container such that ~~the material is forced to flow~~ Hence ~~the material is forced to flow~~ the material can flow through the small opening Available in the container taking ~~the shape of the opening~~.

Types of Extrusion

- * ① Direct or Forward Extrusion
- * ② Indirect / Backward
- * ③ Hydrostatic
- * ④ Impact Extrusion

Reduction Factor

$$\frac{A_0}{A_1} = k = 40 \text{ to } 50 \text{ (General)} = 400 \Rightarrow \text{(Very soft)}$$

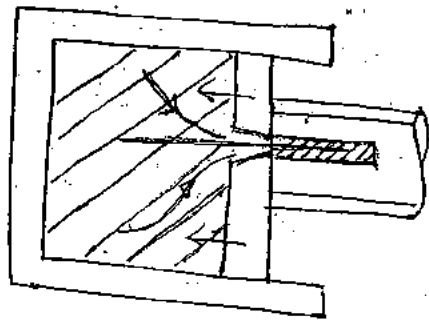
$$\frac{A_0}{A_1} = \frac{V_0}{V_1}$$

$$V_0 \text{ Before extrusion} = V_1 \text{ After Extrusion}$$

$$\frac{V_0}{V_1} = \frac{L_1}{L_0}$$

$$V_0 \times L_0 = V_1 \times L_1$$

BACKWARD EXTRUSION



In forward extrusion the direction of movement of Ram and extruded component are in same direction. whereas

In case of Forward extrusion every point on Ram material has to travel against the container wall friction

...of ramming used type of extrusion is

into the extrusion die. But the extrusion is going

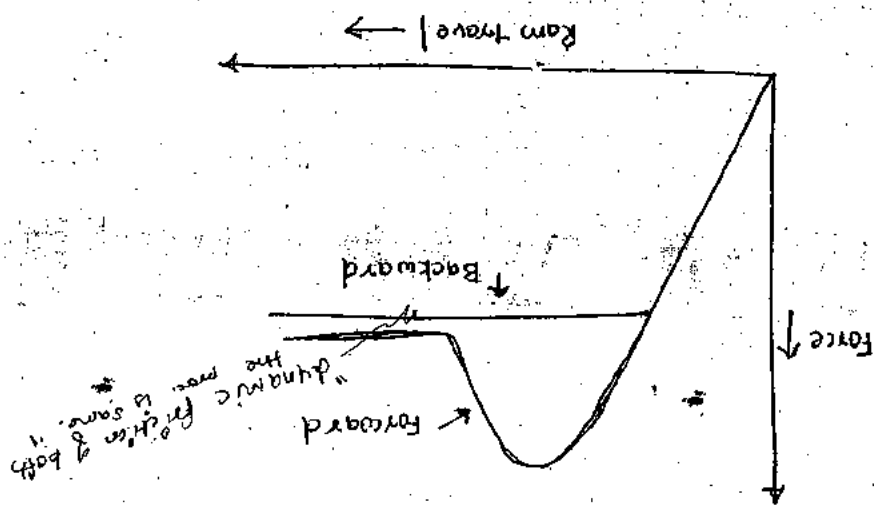
(*) In forward extrusion the extruded component is coming out into the open environment the handling of extruded component is easier.

Backward extrusion is easier whereas forward extrusion is harder. The design and manufacturing of punch and die combination is easier whereas forward extrusion is harder.

(*) Because the Ram and die are separate, in forward extrusion (in open environment) the advantage of forward extrusion

marginally higher than backward extrusion. Afterwards the force reqd for forward extrusion is

(*) From the above diagram the



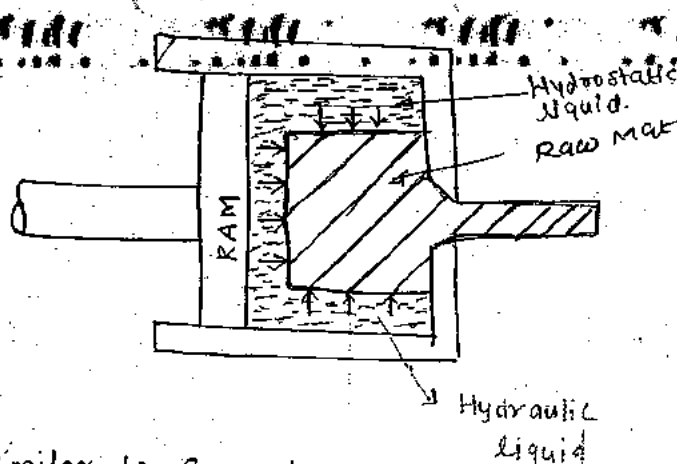
extrusion is higher than backward extrusion. change shape of component

Friction for extrusion to be taken place. But

But $\rightarrow$ forward extrusion, ~~beoz of presence of container wall friction~~
~~the thickness of these materials will be increasing~~
~~which results into increasing in cracking tendency~~. Hence
 the semi brittle and brittle materials cannot be extruded by
 using Forward extrusion whereas with backward extrusion
 with complete absence of container wall ~~friction~~ ^{thickness}, the Semi
 Brittle and Brittle materials can be extruded very easily without
 any cracks.

(A) HYDROSTATIC EXTRUSION

To extrude semi brittle and brittle materials without
 the cracking tendency and with the advantages of forward
~~extrusion~~ the process developed is called as Hydrostatic
 extrusion.



It is similar to forward extrusion. ~~the size of the Raw~~
~~material taken is less than the size of container and gap~~
~~is filled by using hydrostatic liquid~~. Now the force
 applied by using Ram is acting on ~~the~~ to the Hydrostatic
 Liquid, the Pressure of Liquid is increasing which is
 applying uniform force all around the Raw material. $\therefore$
 Raw material is experiencing compressive stresses $>$ flow
 stresses very easily. Bcoz of usage of Hydrostatic liquid

the container wall friction is completely absent, hence it can be used for extruding semi brittle, brittle and high strength super alloys.

Disadvantage:-

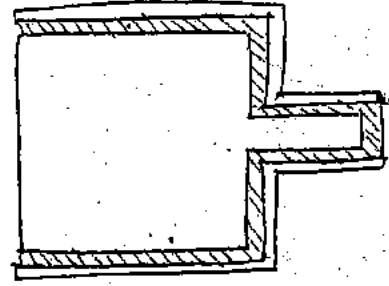
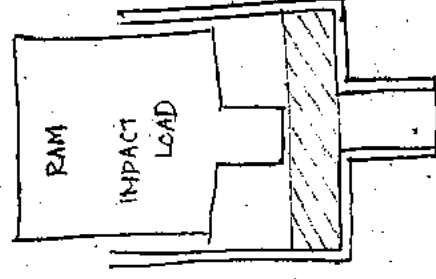
- ⊗ Bcoz of difficulty in arresting the leakages, the hydrostatic extrusion is not preferable for extruding the ductile materials.

Diff Hydrostatic liquids used are:-

1. At Room temp extrusion :- Vegetable oil, silicone, SAE Oils, motor oil, isopentane etc.
(Cold extrusion)
2. At elevated temp of extrusion :- Wax, polymer, liquid glasses etc.
(Hot extrusion)

→ IMPACT EXTRUSION:-

This is the process of producing ~~any~~ tubes from solid rods made up of ~~any~~ by using impact load as extrusion load.



Impact extrusion is mainly used for producing collapsible tubes, Ex: ~~any~~ like ~~any~~ tubes etc.

σ_0 = Extrusion stress Applied in Raw material

$$\sigma_0 = \sigma_y \left[\left(\frac{1+B}{B} \right)^2 \right] \left[1 - \left(\frac{A_1}{A_0} \right)^B \right]$$

$$B = \mu \cot \alpha$$

α = Half of Die angle



$$(EF)_{B.W} = \sigma_0 \times A_0$$

$$(EF)_{FW} = (\sigma_0 + P.F) A_0 \text{ — Forward}$$

P.F = Pressure Req'd for overcoming container wall friction

$$(EF)_{min} = \sigma_y \times A_0$$

$$(EF)_{Actual} = (EF)_{min} \times \eta_{Extrusion}$$

Efficiency :-

$$\eta_{Extrusion} = 0.4 \text{ to } 0.5 \text{ (Forward)}$$

$$= 0.5 \text{ to } 0.6 \text{ (Backward)}$$

Hydrostatic

$$EF = A_0 K \ln \frac{A_0}{A_1}$$

K = extrusion constant — depends on the types of Extrusion & metal to be Extruded.

= σ_y ideal conditions for extrusions...

SPECIAL DEFECTS PRODUCED IN EXTRUSION PROCESS

① **Bamboo defect**

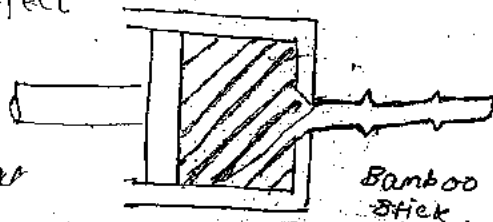
If The outer c/s of the extruded component is like a bamboo stick it is called as Bamboo defect.

Reason:-

① It is produced due to non-uniform

location of

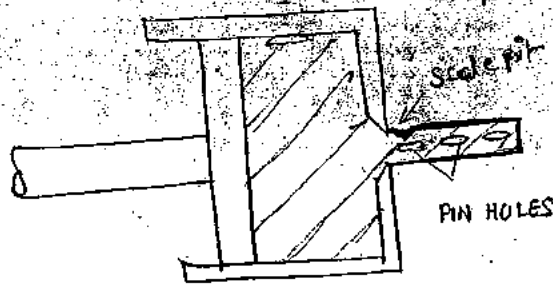
② presence High amount of friction at die surface



Scale Pits

PIPE DEFECT OR CENTRE BURST

In an extruded component Sometimes pin holes are present at the centre of the extruded component called as pipe defect or centre burst.

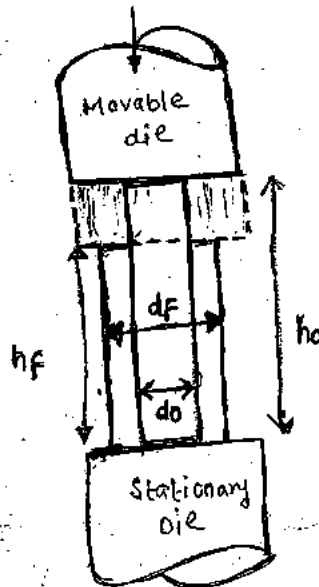


This is because of improper cleaning of raw material before placing into container i.e. the presence of scales or oxides on the raw material will be forming as a central part of the extruded component and produces the pipe defect in the extruded component called as 'pin holes' or 'pipe defect' or 'CENTRE BURST'.

4] Forging

Forging is a process in which the forces are applied on the raw material such that the stresses induced are $>$ yield and $<$ ultimate so that material is experiencing plastic permanent deformation to get reqd shape. But in forging operation force applied on either ~~_____~~ or ~~_____~~.

Continuously Load Press Working op



$$V_1 \text{ vol before } = \text{vol after forging}$$

$$\frac{\pi}{4} d_0^2 \times h_0 = \frac{\pi}{4} d_f^2 \times h_f$$

$$d_f = d_0 \sqrt{\frac{h_0}{h_f}}$$

$$h_f = h_0 \left(\frac{d_0}{d_f} \right)^2$$

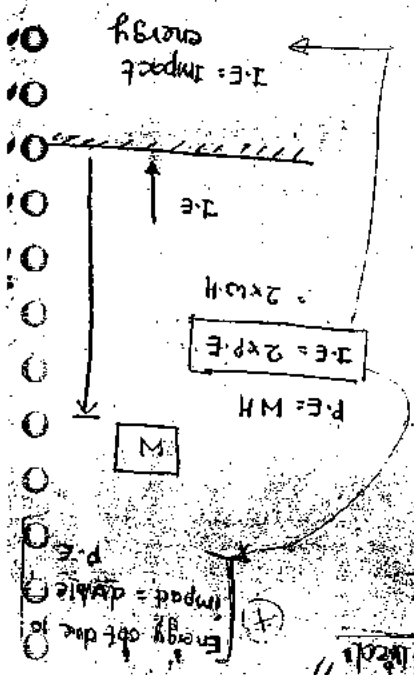
I] Based on method of force Applied

1] Hand Forging

2] Machine Forging

- By using Human Hand

Hand forging always uses drop Hammer type. bcoz the continuous force due to Human hand is not sufficient to produce the deformation in work piece.



In m/c forging bcoz the force required is

obtained from m/c, it is possible to use either

① Hydraulic press or ② Mechanical press

as drop Hammer Type

II] Based on method of shape obtained

① open die forging

③ semi-closed die forging

② OPEN DIE FORGING

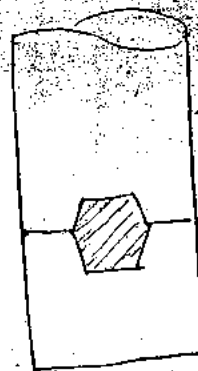
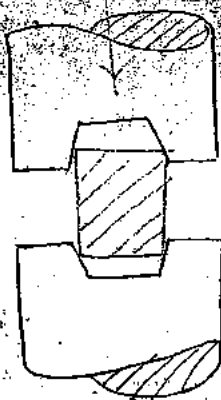
If the ~~shape and size of component is obtained by~~ changing the position of the component ~~in the die~~

It is called as open die forging operation. In open die forging ~~only drop Hammer~~ type of force application will be used.

Press forging is done, changing the position of component. Not used since there is no time for

(b) CLOSED TYPE OR IMPRESSION DIE FORGING

Shape and size of component used is remaining same as that of the shape and size of die used it is called closed die forging i.e.



the die is impressed

on the component. Hence it is also called as impression die forging.

In this the type of force application may be either press type or drop hammer type.

(c) SEMI CLOSED DIE FORGING OPERATION

Shape and size of component obtained is remaining same as that

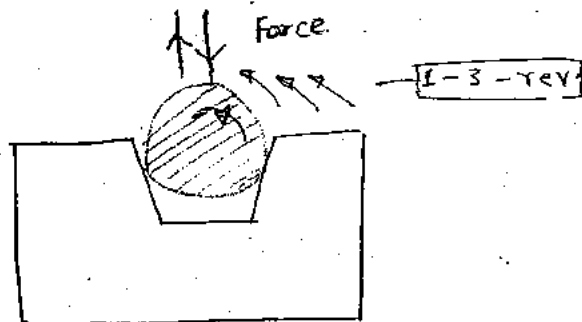
of the die used. The final shape and size of component can be obtained by the die used.

Type of Load Application

1. Drop hammer type of

force application is possible

But in



ANALYSIS OF FORGING

Let $V = \text{Vol of final finished Component}$

In case of open die and semi-closed die forging operations the

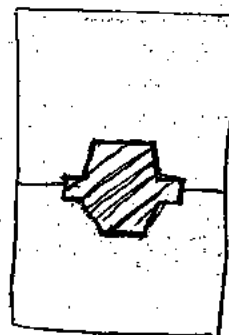
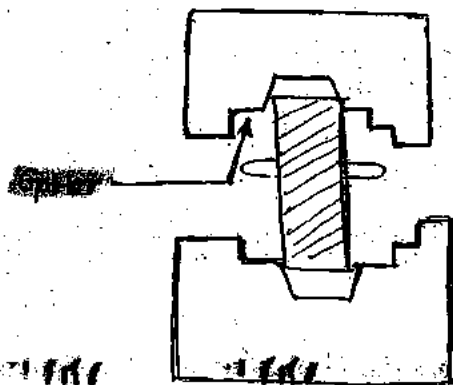
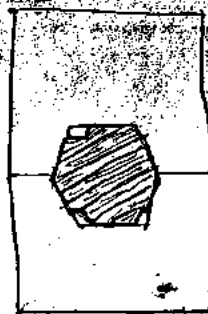
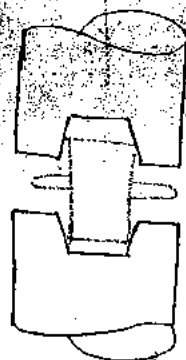
Vol of Raw material used is remaining same as that of

Vol of final finished Component. But in case of closed die

forging operation the Vol of Raw material is about 10-20% higher than

~~10-20% higher than the 30% of closed die forging~~

*** In closed die forging operation ~~the~~
~~die~~ that die can be filled
 completely even though some amt
 of material is flowing outwards
 it needs to provide excess vol
of material . abt 10-20%



To accomodate the excess volume of material it is Req'd to
 provide some open space in dies called ~~gutter~~



Flash

forged component

Bcz of provision of ~~Req'd gutter~~ gutter the excess vol of
 material is getting filled in gutter and produces flash in
 the forged component. This ~~excess material~~ which
 has to be removed by ~~trimming operation~~



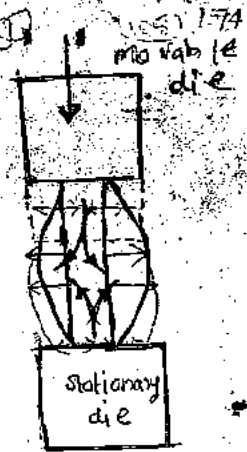
Req. forged
 component

trimming

~~Flash and gutter is used only in closed die~~
 operation but not in open die or semi closed die forging
 operation

Barrelling

At the initial stages of Forging operation when the force is applied by using top die the outward expansion forces and inward frictional forces are acting at the interface of die and raw material. But the magnitude of inward frictional forces are Higher than the outward expansion forces. $\therefore$ the material is sticking to the



surface of die. when we are moving towards the centre Height of component the effect of frictional forces are Reducing

Hence the material is started expanding producing Barrell

shape of the component. $\therefore$ the initial part of forging opⁿ operation is also called as Barrelling operation and becoz

the material is sticking to the surface of die at the ends, the initial process of forging operation can be

analysed by using ~~sticking and sliding friction model~~ and further application of the force using top die and moving the top die; the

~~expansion forces are continuously increasing~~ the

~~inward frictional forces are remaining constant~~. At some point

the magnitude of outward forces become greater than the inward forces Hence ~~material starts sliding over~~

~~the die and forming nearly cylindrical shape of the component~~

This part of forging operation can be analysed by

using ~~sticking and sliding friction model~~

From the above the forging operation can be

Analysed by using ~~sticking and sliding friction model~~.

$$\sigma_h = 2\sigma_e$$

$$E_h = 2E_e$$

In forging operation, when force is applied along the length direction, it induces tensile stresses in the dia direction. ie force application is like a cylinder experiencing internal pressure. So the stresses and strains induced in forged component is similar to thin cylinder.

$$\sigma_h = 2\sigma_l$$

$$\epsilon_h = 2\epsilon_l$$

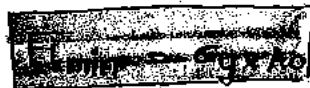
$$e_h = 2e_l$$

σ_h → stress in Hoop direction
 σ_l → longitudinal direction.

ϵ = True strain

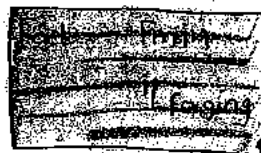
e = engineering strain

(1)



$$\epsilon = \ln \frac{A_f}{A_i}$$

A_i - Initial Min force
 A_f - final " "



$$\text{Fact: } \sigma_y \times A_f \left[1 + \frac{2\mu r_f}{3h_f} \right]$$

μ = coeff of friction

$A_f = \pi/4 d_f^2$

r_f = final radius

h_f = final height



$$= 2x(WH) \quad \{ \text{Drop Hammer} \}$$

Deformation

Obt, if, If energy Reqd is obtained from drop Hammer type of force application with weight of Hammer = 'W' and Height from which it is falling is 'H'.

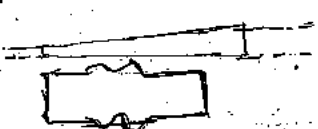
$$WD = 2x(WH)$$

$$H = \frac{F \cdot \text{Fact} (h_0 - h_f)}{2\pi}$$

Types of Forging :-
 Preforming operations or types of forging operations :-

① Fullering

It is a forging method or process used for distributing the material from centre to the outwards non uniformly so that in this process the length of component is increasing and dia is reducing non uniformly.



(Tube drawing) by forging

It is a forging method used for distributing the material

and in this process length is increasing and dia is reducing uniformly.

② Upsetting :- Upsetting is called upsetting by may be both -

used forging method used for reducing the length

and increasing dia is called upsetting by may be both -

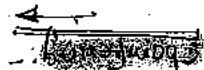
Forging operation used for producing

is called flattening.

③ Edging :-

Forging method used for reducing the material

locally is called edging.



Forging method used for converging



Forging method used for bending the component into

⑧ Forging sequence

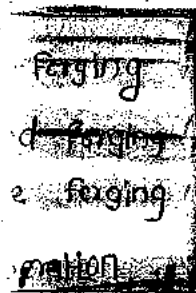
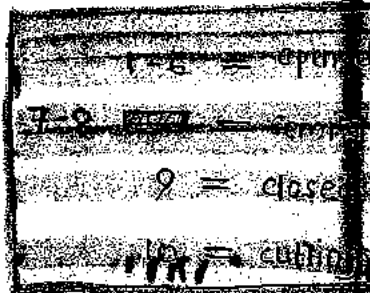
the forging method for producing approximate shape and size of component is called Blocking or Sizing

⑨ Finishing operation:-

Forging operation used for producing exact shape and size of the component

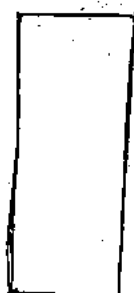
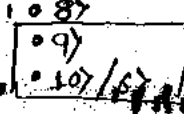
⑩ Trimming:-

cutting operation used for removing the flash present in the forged component



(Except ⑥)

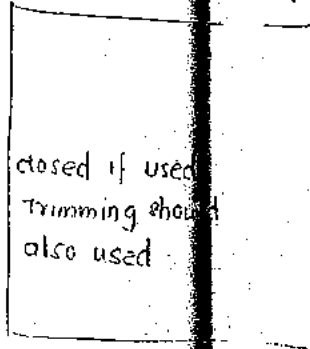
Last op



connecting Rod

Sequence

open die
semi closed
closed

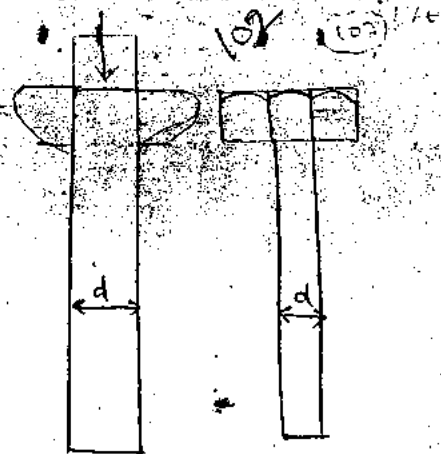


closed if used
Trimming should
also used

1. Fullering
2. Edging
3. Blocking
4. Finishing
5. Trimming

Hexagonal Bolt Head Using Forging

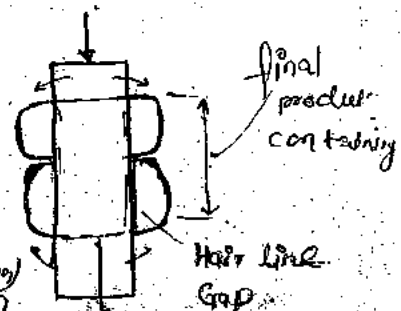
1. upsetting
2. Flattening
3. Swaging
4. chamfering



Defects in Forging :-

Lap or cold shut - Discontinuity present in the forged component due to continuous force application is called Lap or cold shut.

Scams in forged die forging



* **Draft** - $\frac{A_0}{A_1} = 2 \text{ to } 10$ **Rolling** { Hot working }

$\frac{A_0}{A_1} = 2 \text{ to } 6$ **Rolling** { Cold working }

$\frac{A_0}{A_1} = 40 \text{ to } 50$ **Extrusion** { cold or Hot working }
= 400 - very soft material (Al, Cu, etc)

$\frac{A_0}{A_1} = 2 \text{ to } 8$ **Forging** { Hot working }

Rolling : Hot working .

(i) $d_0 = 15 \text{ mm}$, $d_f = 0.1 \text{ mm}$

(a) $\frac{d_0 - d_1}{d_0} = 0.8 \Rightarrow 1 - \frac{d_1}{d_0} = 0.8$

$$d_1 = d_0 (1 - 0.8)$$

$$= 15 (0.2) = 3$$

$$d_2 = d_1 (1 - 0.8)$$

$$= 3 (0.2) = 0.6$$

$$d_3 = d_2 (1 - 0.8)$$

$$= 0.6 (0.2) = 0.12$$

$$d_3 = d_2 (1 - 0.8) = 0.12$$

$$d_4 = d_3 (1 - 0.2) = 0.12 \times 0.8 = \underline{\underline{0.096}} \quad \text{2% error}$$

$$\textcircled{c} \quad d_1 = d_0 (1 - 0.8)$$

$$d_1 = 0.3$$

$$d_2 = 0.6$$

$$d_3 = 0.6 (1 - 0.4) = \underline{\underline{0.36}}$$

$$d_4 = 0.36 (1 - 0.4) = \underline{\underline{0.216}}$$

$$d_5 = d_4 (1 - 0.2) = \underline{\underline{0.17}}$$

$$\textcircled{2} \quad B = \mu \cot \alpha$$

$$= 0.15 \cot 9^\circ$$

$$\sigma_2 = \sigma_y \left(\frac{A_0}{B} \right) \left[1 - \left(\frac{A_1}{A_0} \right)^2 \right]$$

$$\sigma_t = \sigma_y + (\sigma_2 - \sigma_y) e^{-\frac{2\mu L}{R}}$$

$$\text{Total D.L} = \frac{\sigma_t \times A_1}{\sigma_t \times \frac{\pi d_1^2}{4}}$$

$$\textcircled{3} \quad \left. \begin{array}{l} A_0 = 20 \\ H_1 = 14 \end{array} \right\} \Delta h = 7 \text{ mm}$$

$$R = \frac{480}{2} = 240$$

$$\sigma_y = 120 \text{ MPa}$$

$$\tan \alpha = \sqrt{\frac{\Delta H}{R}} = \sqrt{\frac{6}{240}}$$

$$\alpha = \underline{\underline{9^\circ}}$$

At maximum Reduction

$$\alpha = \beta$$

$$\mu = \tan \beta = \tan \alpha$$

$$= \tan 9^\circ$$

$$H_n = H_1 + 20\% \Delta H$$

$$= 15.3 \text{ mm}$$

$$H_n = H_1 + 20\% (\Delta H)$$

⑥ Maximum % slip in lagging zone = Backward slip

$$\frac{V - V_0}{V} = 1 - \frac{V_0}{V}$$

$$= 1 - \frac{H_n}{H_0} = \underline{23\%}$$

Max % slip in leading zone = forward slip

$$= \frac{V_1 - V}{V} = \frac{V_1}{V} - 1 = \frac{H_n}{H_1} - 1$$

⑦ Maximum pressure in kg/cm^2

3.8

$$⑧ H_0 = 3.5$$

$$H_1 = 2.5$$

$$\Delta H = 1$$

$$R = 125 \text{ mm}$$

$$b = 450 \text{ mm}$$

$$\mu = 0.08$$

$$\sigma_y = 140$$

$$R \cdot S \cdot F = F_{avg} = P_{avg} \times bL$$

$$= \frac{2}{\sqrt{3}} \sigma_y \left[1 + \frac{\mu L}{\Delta H} \right] \times bL$$

$$L = \sqrt{\frac{R \Delta H}{\mu}}$$

$$H_1 = 1.8$$

$$\alpha = 12^\circ$$

$$\mu = 0.1 = \mu_1 = \mu_2$$

very small

so neglect

cylindrical mandrel

$$B = \frac{\mu_1 + \mu_2}{\tan \alpha}$$

Stationary Mandrel

$$B = \frac{\mu_1 + \mu_2}{\tan \alpha}$$

$$\frac{\sigma_2}{\sigma_y} = \left(\frac{1+B}{B} \right) \left(1 - \left(\frac{H_1}{h_0} \right)^B \right)$$

10. With movable Mandrel

$$B = \frac{\mu_1 - \mu_2}{\tan \alpha}$$

$$\frac{\sigma_1}{\sigma_y} = \frac{1}{\log_{10} \left[\frac{1}{\frac{h_0}{h_1} - 1} \right]}$$

$$\sigma_2 = \sigma_y \cdot \log_{10} \left[\frac{1}{\frac{h_0}{h_1} - 1} \right]$$

11.

$$A_0 = 25 \times 5 = 125$$

$$\frac{A_0 - A_1}{A_0} = 0.4 \Rightarrow 1 - \frac{A_1}{A_0}$$

$$A_1 = A_0 (1 - 0.4)$$

$$= 125 (0.6)$$

$$\mu = 0.1$$

$$\sigma_y = 30.0$$

$$\alpha = \frac{26.5}{2} = 13.25$$

$$B = \mu \cot \alpha = 0.1 \cot 13.25$$

$$\sigma_2 = \sigma_y \left(\frac{1+B}{B} \right) \left[1 - \left(\frac{A_1}{A_0} \right)^B \right]$$

$$D.L = \sigma_2 \times A_1$$

(12)

$$d_o = 6$$

$$d_f = 1.34$$

$$H = 0.2$$

$$\alpha = 6^\circ$$

$$\sigma_y = 60$$

for Max Red

$$\sigma_2 = \sigma_y$$

$$\frac{\sigma_2}{\sigma_y} = 1 = \left(\frac{1+B}{B} \right) \left[1 - \left(\frac{A_1}{A_o} \right)^B \right]$$

$$= \left[\frac{1+B}{B} \right] \left[1 - \left(\frac{A_1}{A_o} \right)^B \right]$$

$$\frac{d_1}{d_o} = 0.75$$

$$\Rightarrow d_1 = d_o (C) \leq 1.34, n=1$$

$$d_2 = d_1 (C) \leq 1.34, n=2$$

$$d_3 = d_2 (C) \leq 1.34, n=3$$

No of stages = 6

(13)

$$\frac{\pi}{4} d_o^2 L_o = \frac{\pi}{4} d_f^2 L_f$$

$$L_f = \left(\frac{d_o}{d_f} \right)^2 \times L_o = 149.181 \text{ m}$$

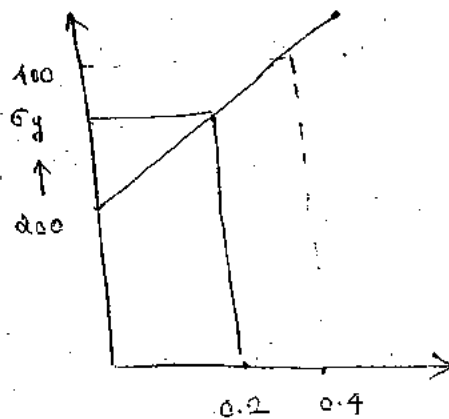
$$\sigma_y \text{ before} = 200$$

$$\sigma_y \text{ after} = 400$$

$$\epsilon = \ln \frac{A_o}{A_1}$$

$$= 2 \ln \frac{d_o}{d_1} = 0.4$$

$$\epsilon = 0.2, \sigma_y = 200 + \left(\frac{400 - 200}{0.4} \right) \times 0.2$$



$$\epsilon = 2 \ln \frac{d_o}{d_1} = 2 \ln (1.34) = 0.4$$

$$\sigma_y = 315 \left(\epsilon^{0.54} \right)$$

$$= \underline{\underline{542 \text{ MPa}}}$$

Q17

$$d_o = 100$$

$$h_o = 50$$

$$h_f = 40$$

$$d_f = 2$$

$$d_f = d_o \sqrt{\frac{h_o}{h_f}}$$

$$F_{i \min} = 80 \times \frac{\pi}{4} d_o^2$$

$$F_{f \min} = 80 \times \frac{\pi}{4} d_f^2$$

$$F_{\min} = \frac{F_{i \min} + F_{f \min}}{2}$$

$$w \cdot D = F_{\min} (H_o - h_f)$$

Q18

$$2wH = w \cdot D$$

$$H = \frac{w \cdot D}{2w}$$

Q19

$$E \cdot F_{\min} = \sigma_y \times A_o$$

$$= 10 \times \frac{\pi}{4} \times 100^2$$

$$E \cdot F = \frac{E F_{\min}}{\eta_{\text{extr}}} = \frac{10 \times \frac{\pi}{4} \times (100)^2}{0.4}$$

$$= \underline{\underline{1961045}}$$

21

$$E F = A_0 k \ln \frac{A_0}{A_1}$$

$$= \frac{4}{\pi} \times 100^2 \times 250 \times \ln \left(\frac{100}{51} \right)$$

Ideal drawing Condition

$$\sigma_2 = \sigma_y \ln \frac{A_0}{A_1}$$

$$P = \text{force} \times \text{vel}$$

$$= \sigma_2 \times A_f \times \text{vel}$$

$$= \sigma_2 \times \frac{\pi}{4} \times d_f^2 \times 0.5$$

$$d_f = (1 - 0.2) d_0$$

$$0.2 = \frac{d_0 - d_f}{d_f}$$

$$0.8 \times 10$$

24

$$V_n = V = \pi D N$$

$$\frac{1000}{1000}$$

$$\frac{1000 \times 60}{\pi \times 300 \times 100}$$

25

$$R.S.F. \text{ } F_{avg}$$

$$P = a \times t \times w$$

$$1 - F_{avg} \times A$$

$$\frac{2}{3} \sigma_y b L \left(1 + \frac{A_1}{A_2} \right) \times 12$$

$$= 15.2$$

$$921$$

$$\text{True stress} = 1400 \left(\frac{1}{3} \right)^{0.33}$$

$$At \text{ Max. load true stress} = \frac{1}{3}$$

105

(26) $\epsilon = \frac{1}{A_0}$

$2 \ln \frac{d_0}{d_f}$

$2 \ln \frac{400}{200}$
1.386

(27) $\tan \alpha = \sqrt{\frac{4H}{R}}$

(28) 37

(29) $EF = A_0 \sigma_y \ln \left(\frac{L}{L_0} \right)$

(30) d

(31)

(32)

(33)

(35) d

(36) $e = \frac{dL}{L} = \frac{2L-L_0}{L} = 1$

(37) c

(38) b

(39) c

(40) d

(41) b

(42) d

(44)

(44) Arc length of Deformation

$= R \alpha$

$= 300 \times \left(\tan^{-1} \left(\frac{\Delta H}{F} \right) \right) \times \frac{\pi}{180}$

$= 300 \left[\tan^{-1} \left(\sqrt{\frac{5}{300}} \right) \right] \times \frac{\pi}{180}$

(46) d

(47)

(47) e

(48) b

(49) e

(42)

$\frac{\Delta}{4} \times d_0^2 \times h_0 = \frac{\Delta}{4} \times d_f^2 \times h_f$

$d_f = d_0 \sqrt{\frac{h_0}{h_f}}$

④

SHEET METAL OPERATIONS

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The operations performed on the sheets to get the Required shape is called sheet metal operations

Cutting/ Shearing	{	1. Punching or Piercing	}	Major operations
		2. Blanking		
Forming	{	3. Deep drawing	}	Minor operations
		4. Bending		
		5. Perforating		
		6. Notching		
		7. Slitting		
		8. Lancing		
		9. Nibbling		
	{	10. Trimming		

A cutting, punching
[Cutting and shearing
action is taking place.]

In cutting operations the material is physically removed from the components to get the Req'd shape. But in Forming Operation the plastic deformation produced in the component will be used for changing the shape and getting the Req'd shape.

PUNCHING AND BLANKING

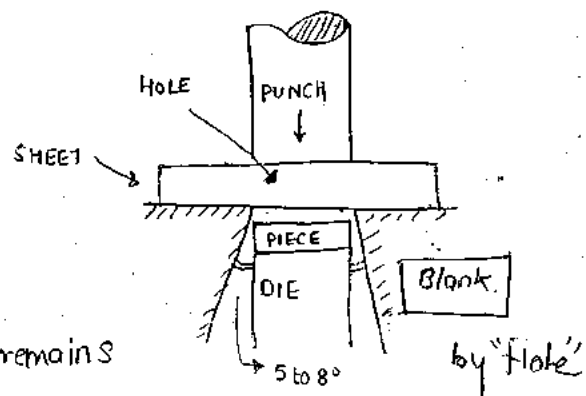
* ~~Punch and die combination~~

will be used for performing
Punching and Blanking operations.

* The shape of punch and die used remains

same as that of the shape of the Component

to be produced. [Punch size is always the less than the die]
Size

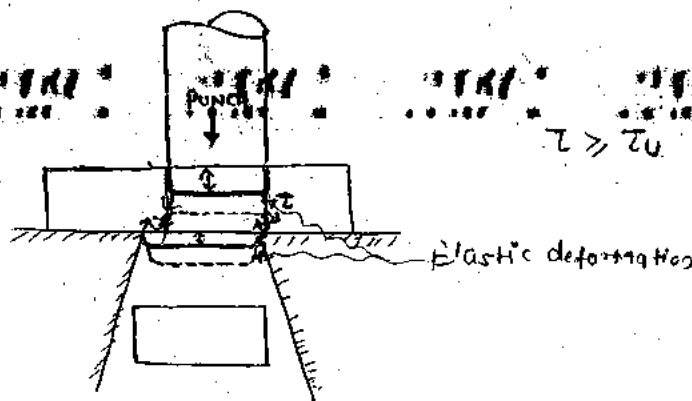


* Die manufacturing operation is called as die casting

Punching:- In punch and die working operation, if the hole produced in the sheet is useful one, it is called as a punching operation. In punching operation the punch size is made equal to the hole size and clearance is provided only on the die. Also in punching operation the shear is provided on the punch only.

Blanking:-

In punch and die working operation if the piece produced is ~~not~~ useful one it is called as Blanking operation. In Blanking the die size is made ~~not~~ equal to Blank size and clearance is provided only on the punch. In Blanking shear is provided ~~only~~ on the die.



Mechanism:-

Shearing and Tearing

When the force is applied by ~~use~~ punch on to sheet the top side of sheet is experiencing elastic compression, Bottom of sheet is experiencing elastic elongation. But the Magnitude of compression is greater than elongation. Due to the diff in compression and elongation the sheet metal present b/w Punch and die experiences shear stresses. on further application of Force by using punch the diff b/w the compression and elongation are increasing, ~~and the diff also increases~~ the diff also increases.

in sheet metal also increases, so that at some point the τ induced in sheet metal will become τ or equal to the " τ_u " of the sheet metal. Hence shearing or ~~cracking~~ ~~is started taking place at~~ the edges of punch and die. [cracking/~~shear~~ shearing occurs at edges since stress conc factor is high at edges] which is propagating in their respective directions and meeting somewhere in mid c/s so that the piece has got separated from the sheet producing hole in the sheet. From the above mechanism by which cutting action taking place is shearing and tearing.

Tearing is actually propagation of shear.

To ensure that crack propagations can meet somewhere in mid c/s the

clearance present b/w Punch and die

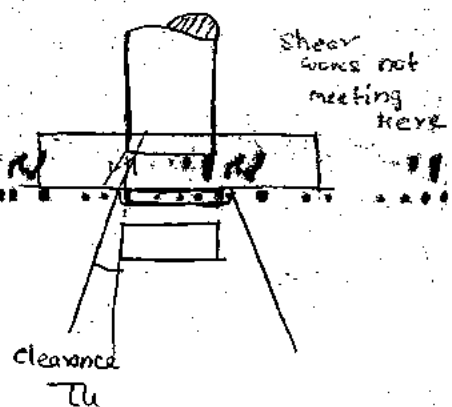
Must be ~~optimum~~

opt clearance = ~~0.0001 Tu~~

[Radial clearance only]

~~0.0001 Tu~~

~~0.16%~~



t = sheet thickness in mm

T_u = Ultimate shear stress.

Case 1:

clearance is $<$ opt clearance

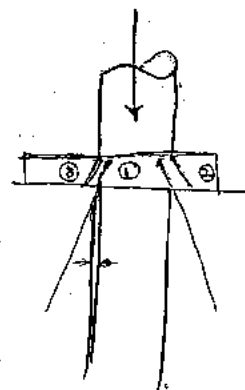
If the clearance present b/w punch and

die is less than optimum clearance, the

crack propagations will not meet somewhere

in the mid c/s and they are propagating

in their own directions. Hence a 3 PIECE CONFIGURATION IS



clearance > opt clearance

If clearance is > than opt clearance, the sheet is simply pulled into the die without producing any shearing/cutting action

Punching

$$P.S = H.S$$

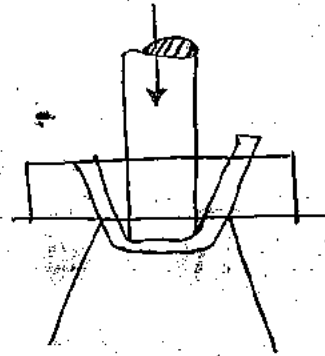
$$D.S = H.S + C$$

P.S - Punch size
D.S - Die size
H.S - Hole size
C.S - Blank size

Blanking

$$D.S = B.S$$

$$P.S = D.S + C$$



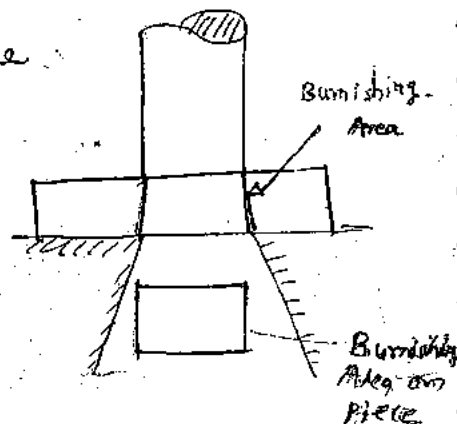
The selection of punch and die sizes in punching and blanking operation is mainly based on the Burishing Area produced on the respective useful components.

★ BURISHING AREA:

Because of shearing action the edges of the components produced will be zig-zag edges. But this zig zag edged components can't be used in engg applications. ∴ it has to be converted into straight and smooth edges. The Area of the Component on which zig-zag edges has got converted into straight and smooth edges is called as Burishing Area.

In punching operation Bcoz hole is the useful component, on the hole

Burishing area is produced, Bcoz of punch only. Hence size is made equal to hole size.



Whereas in Blanking operation

Bcoz Blank is the useful Component on the Blank the Burishing Area is produced Bcoz of the die. Hence the die

Size is made equal to Blank size

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(112)

(a) Hole ϕ 20mm

$t = 1\text{mm}$

$C = 5\% t$

cal dimensions of Punch and Die

Soln:-

P.S = Hole size

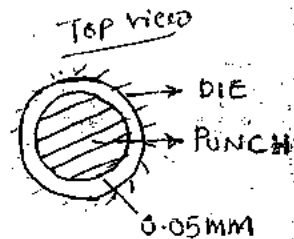
P.S = 20mm

Die size = P.S + clearance

$$= 20 + \left[\frac{5 \times 1}{100} \right] \times 2$$

$$= 20 + (0.05 \times 2)$$

$$= \underline{\underline{20.1\text{mm}}}$$



(b) Blank of Rod = 30mm

$t = 2\text{mm}$

$C = 5\% t$

cal dimensions of ~~Blank~~ Punch and die

Ans:

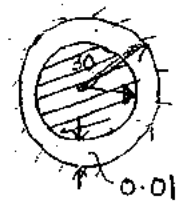
B.S = die size

30mm Rod

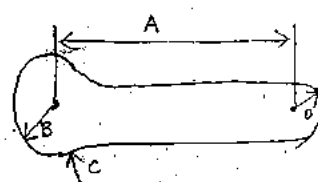
P.S = Die size - clearance

$$= 30 - \left[\frac{5 \times 2}{100} \right]$$

$$= 30 - 0.1 = \underline{\underline{29.9\text{mm}}}$$



(c)



	A	B	C	D
Part size	30	20	10	15
P.S	30	20	10	15

POUNDS PER INCH

P.S = Hole size

LOAD ESTIMATION : ↓

$$F_{\max} = \tau_u \times A_s$$

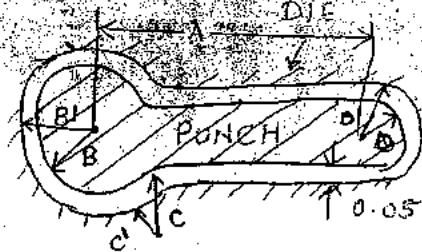
A_s = shearing Area = $P \times t$

τ_u = property of material
ultimate shear stress

$P = 4a$ Square

$P = 2(a+t)$ Rectangle

$P = \pi d$ Circular



ENERGY REQD / WORK DONE : ↓

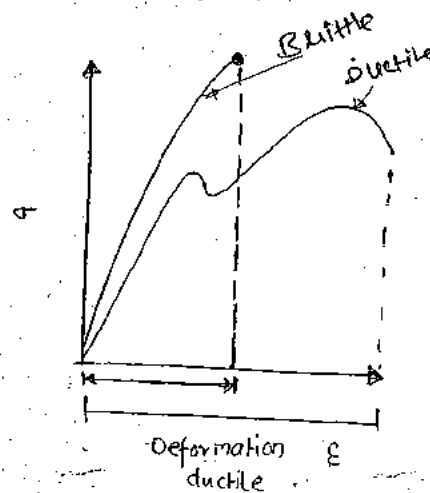
W.D = Force $\times$ distance

$$F_{\max} \times Kt$$

$K = 20$ to 60%

$K = 0.2$ to 0.6

$K = \% \text{ Penetration Reqd}$
for Completing the
shearing Action



$$\begin{aligned} \tau_u &= 60\% \sigma_u \\ \tau_u &= 0.6 \sigma_u \\ \sigma_y &= 0.5 \sigma_u \end{aligned}$$

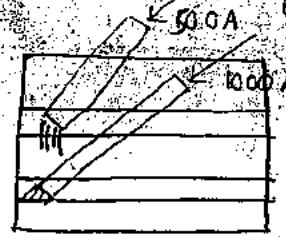
$K = 0.6$ for Soft Material / Ductile

$K = 0.2$ for Brittle material / Hard

- ③ Simultaneous welding with more than one electrode using different current conditions at two places.

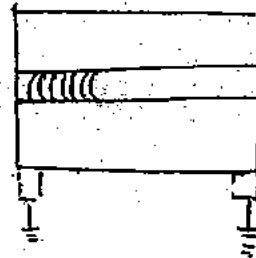
Remedies:

To Avoid Magnetic Arc Blow



- ① welding away from earth connection

When the welding is started from one end of plate, the earth connection is given at other end. After half of the plates to be welded, stop the welding operation and change the earth connection to other end and then continue the welding:-

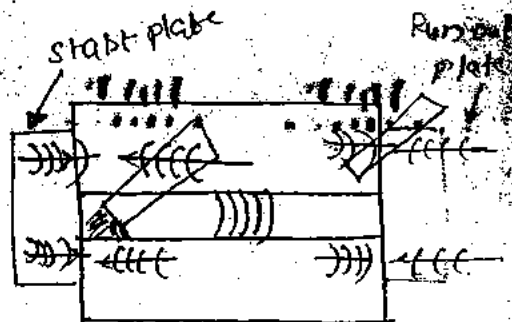


To Avoid starting and ending Arc Blow:-

- * By using start on plate and ~~end on plate~~

By using these plates it is possible to produce magnetic forces in start on opposite direction also. Hence it is possible to focus the Arc wherever Reqd. But these plates will get adhered

to the main plate. Hence it has to be Removed after the welding



- * Whenever the Multiple electrode welding is done use ~~same current conditions~~ for all the electrodes.

Plate

Arc Blow is taking only with Dc power supply.

[The Best Solution for eliminating the Arc Blow is using AC power supply instead of DC power]

① DC is the most commonly used power supply for welding.

- Even though AC power supply is completely eliminating magnetic Arc Blow, The Most commonly used power supply condition in Arc welding is DC only. Bcoz in DC arc welding the Heat generation is controllable By changing the polarity.

★ NON FUSION WELDING

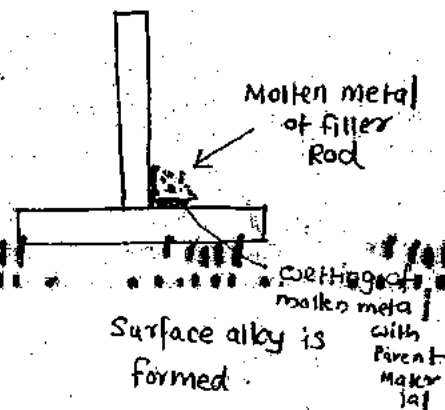
→ SOLDERING, BRAZING AND BRAZE WELDING ←

they are considered as a pure Non Fusion welding operation.

Mechanism of Joint formation:

Wetting and Surface Alloy Formation:

In Non Fusion welding process, when the molten metal of Filler Rod is pushed into the joint it is getting wetted to surface of parent material and during solidification the surface atoms present in the molten metal will try to share the energy with the surface atoms of the parent material and produces surface alloy.

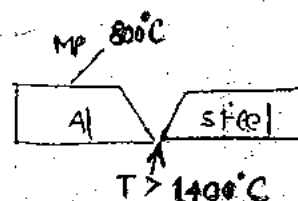


Advantages of Non Fusion Welding:-

{ strength of Non Fusion welded joints are less than Fusion welded joints - }

- ① Whenever two metal are to be joined which has large diff in melting point Temp so that before melting one material other metal decomposes

eg. Brazing of steel and Al



FORCE REDUCTION IN PUNCHING AND BLANKING

$$F_{\max} = \tau_u \times A_s$$

" A_s → shear Area"

τ_u → ultimate shear stress

To Reduce the force Reqd in Punching and Blanking operation either ultimate shear strength of sheet metal has to be Reduced or sheared Area has to be Reduced. But it is Not possible to Reduce " τ_u " of sheet metal Bcoz the sheet metal operations are always performed only at Room Temp.

$$A_s = P \times t$$

$$P = \pi d t$$

$$= 4a$$

$$= 2(a+b)$$

In Normal Punching and Blanking operations the total sheared

Area will be cut at a time. Instead of this if the sheared Area is divided into No of partitions and each and every partition of sheared Area will be cut slowly and progressively so that at any one point of time the sheared Area under cutting Action is less than the total sheared Area. Hence the force Reqd can be Reduced.

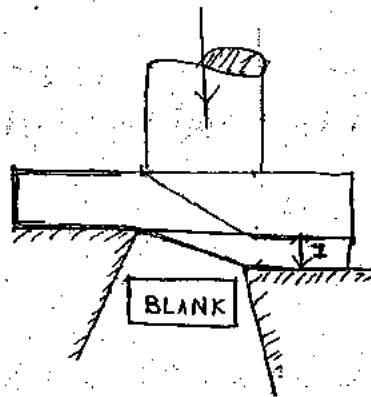
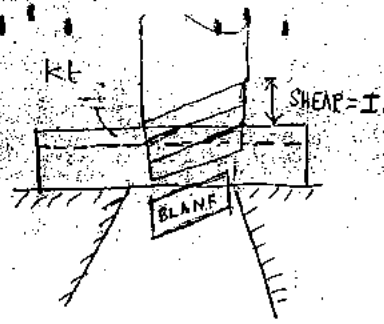
Methods:-

1. By Providing shear

Making the face of a Punch or die inclined is called

Providing the shear

At any instant of time the sheared area under cutting action is less than the total sheared area. $\therefore$ The force reqd. for punching or blanking operation is less than the total force.



Shear on Punch
→ Inclination Provided

$I =$ shear provided

In punching operation because the Hole produced in the sheet is useful. $\therefore$ shear is to be provided only on the PUNCH. In Blanking operation coz blank is useful. Component shear is provided only on DIE. But Never provide shear on Both Punch and die Bcoz Hole produced in sheet and Blank will become unuseful.

The work done / energy Required for the Given operations Remains const irrespective of provision of shear.

As amount of shear Incr, no doubt the force reqd. is reducing continuously but simultaneously the strength of the punch is reducing (Crushing)

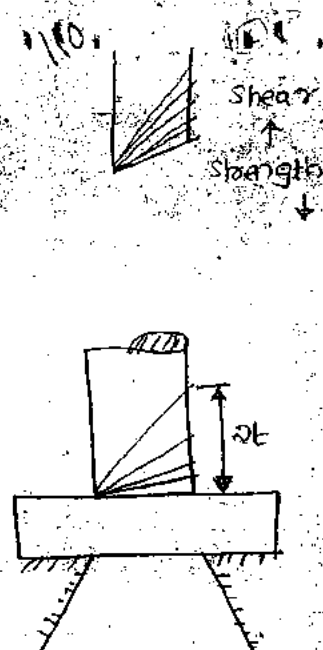
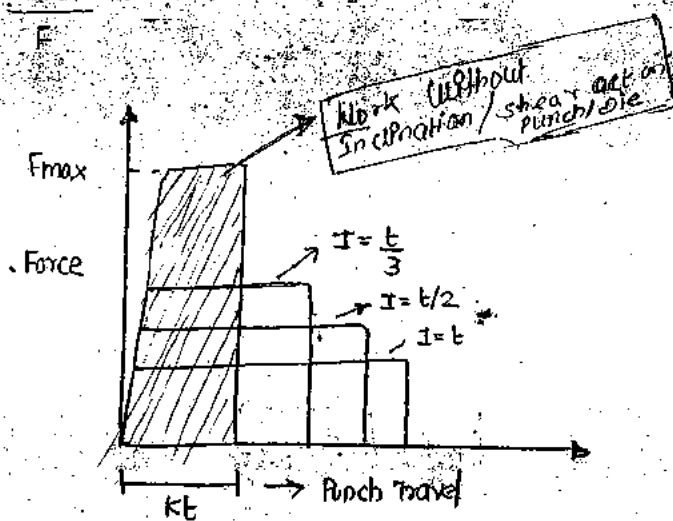
Work done with shear = ~~to distance travelled~~

Work done without shear

$$F \cdot (kt + I) = F_{max} \times kt$$

$$kt + I = \frac{F_{max} \times kt}{F}$$

$$I = \frac{F_{max} kt - kt^2}{F}$$



Area under diag = Energy/W.D

(ex) $k = 50\%$

$$I = \frac{t}{3}$$

$$F = \frac{F_{max} \times 0.5t}{0.5t + \frac{t}{3}} = \frac{0.5 F_{max}}{0.5 + \frac{1}{3}}$$

40% Redn in force

$$\rightarrow I = \frac{t}{2}$$

$$F = \frac{F_{max} \times 0.5t}{0.5t + \frac{t}{2}} = \underline{0.5 F_{max}}$$

$$\rightarrow I = t \quad \frac{F_{max} \times 0.5t}{0.5t + t} = \frac{F_{max}}{3} = \underline{0.33 F_{max}}$$

$$\rightarrow I = 2t$$

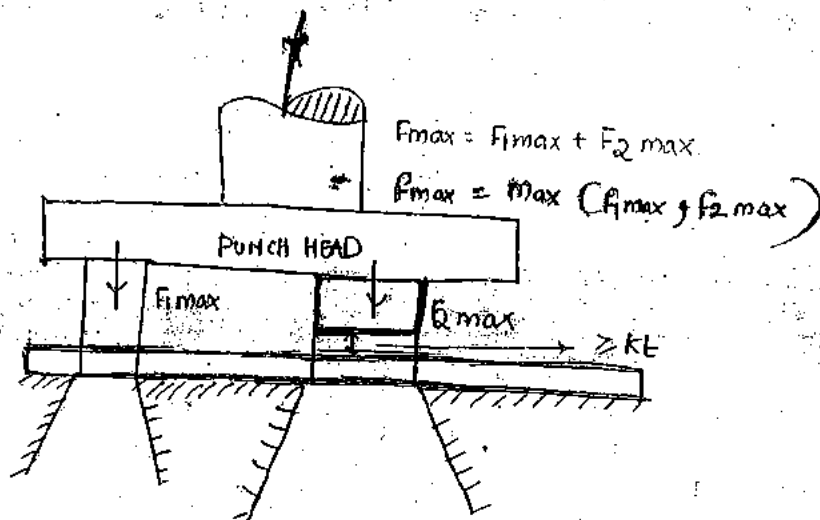
$$F = \frac{F_{max} \times 0.5t}{0.5t + 2t} = \underline{0.2 F_{max}}$$

From the Above analysis the Maximum amt of shear one can provide on Punch or die must be less than equal to thickness of sheet

4. By staggering of punches

This method can be useful only when more than one operation will be performed in one stroke.

ex:



$$F_{max} = \text{Max} (F_{1max}, F_{2max}, \dots, F_{i0max})$$

5. By staggering of punches

By staggering the length of successive punches is reduced by an amount greater than or equal to kt

so that at any given point of time only one punch is in contact

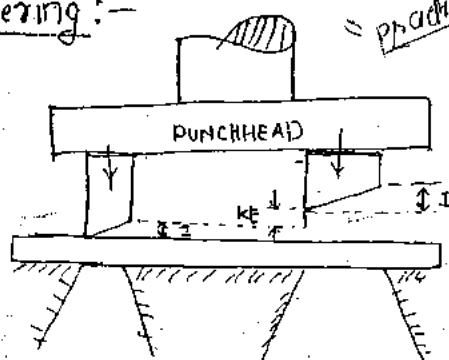
with the sheet. $\therefore F_{max} = \text{Max} (F_{1max}, F_{2max}, F_{3max}, \dots, F_{nmax})$

Disadv:-

With staggering of punches the Balancing of forces on the Punch Head is difficult.

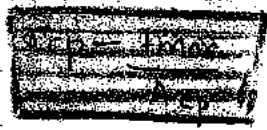
3. Combination of shear and staggering:-

$$F = \text{Max} (F_{1max}, F_{2max}, \dots, F_{nmax})$$

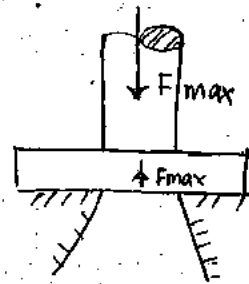


Even though the combination method is reducing the force Req'd to a min value But practically it is impossible to balance the forces on Punch Head with combination method.

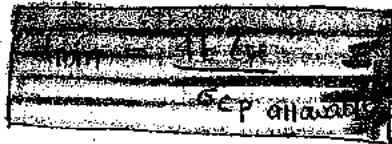
In Puching operation when F_{max} is the force applied by punch on to the sheet, the equal and opp reaction force produced by the sheet is acting on to the punch which induces crushing $\times$ Compressive stress in punch material.



$$= \frac{\pi d t \times \tau_c}{\frac{\pi \times d^2}{4}}$$



$$= \frac{4 t \tau_c}{d}$$

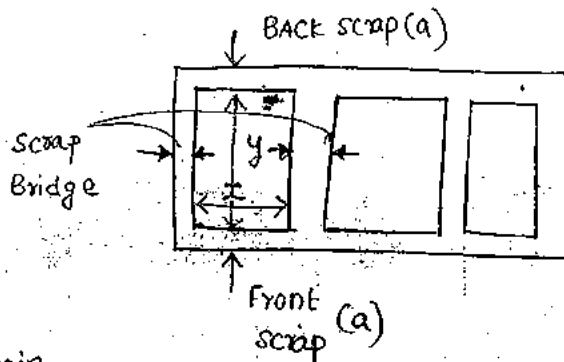


$$\text{at } d_{min} = 4t ; \therefore \frac{4t}{d_{min}} = t$$

As the dia of Hole to be produced is Reducing the compressive stresses induced in punch material are increasing - ∞
at some pt when Compressive stresses @ in punch are Beyond allowable Compressive stresses, the punch may fail any time. To Avoid this it is necessary to Restrict the Min dia of Hole to be produced

Scrap strip layout

The Layout by which blanks are produced from the sheets such that % utilisation of the sheet is maximum or % wastage of sheet is minimum

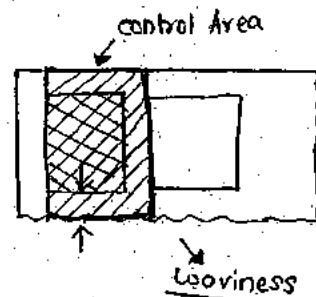


Margin

$$a = 0.8 \text{ mm}, t < 0.8$$

$$a = t \quad t = 0.8 - 3.2$$

$$a = 3.2 \quad t \geq 3.2$$



Necessity of Margin

Margin will be provided to-
 ① Remove the edge damage present on sheet during transportation and
 ② removing the waviness present on the sheet due to Rolling operation used for Manufacture of sheet

Let S = Feed of the sheet

Feed η Distance travelled by the sheet during Return stroke of Punch.

$$S = x + a$$

$$L = \text{Length}$$

n = No of Blanks produced from given sheet

$$= \frac{L - a}{S} \quad \text{if } L \text{ is very large}$$

Then

$$\eta = \frac{L}{S}$$

a is very small

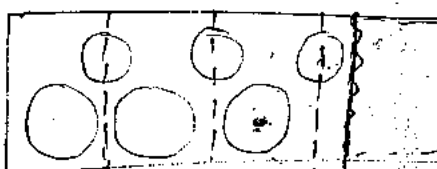
$$\% \text{ utilisation} = \frac{\text{Area utilised}}{\text{Total Area of sheet}} = \frac{n \pi (x \times y)}{L \times h}$$

116

$$= \frac{n \pi (xy)}{L \times h}$$

$$h = y + 2a$$

$$\% \text{ utilisation} = \frac{\pi y}{sh}$$



$$S \cdot h = \text{Control Area}$$

$$\% \text{ utilisation} = \frac{\text{Area of Blank}}{\text{Control Area}}$$

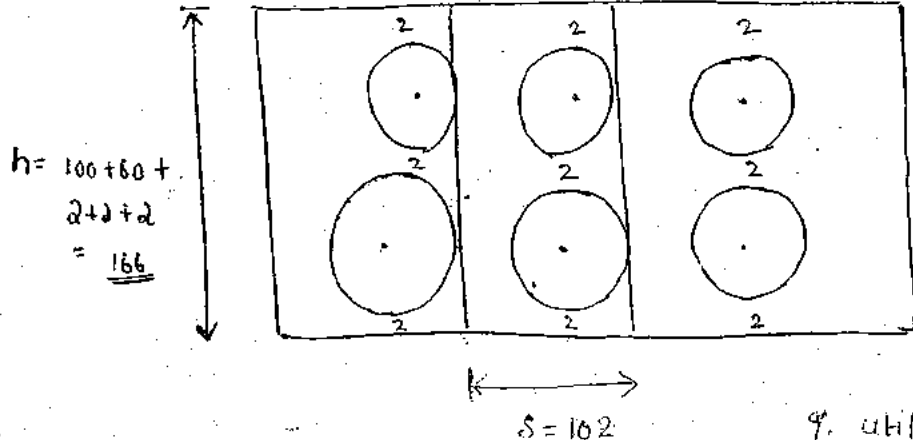
Q. Equal No. of Circular Blanks of dia 100mm and 60mm are to be produced from a sheet of thickness 2mm with margin = 2mm. Design a shop shop layout which is giving maximum % utilisation of the sheet.

:- Which of the following is sheet having "Max % utilisation"

NOTE:-

Produce equal No of Circular Blanks only
ie if ^{two} 100mm blanks, then 2 60mm blanks that way

17



$$h = 100 + 60 + 2 + 2 = 166$$

$$S = 102$$

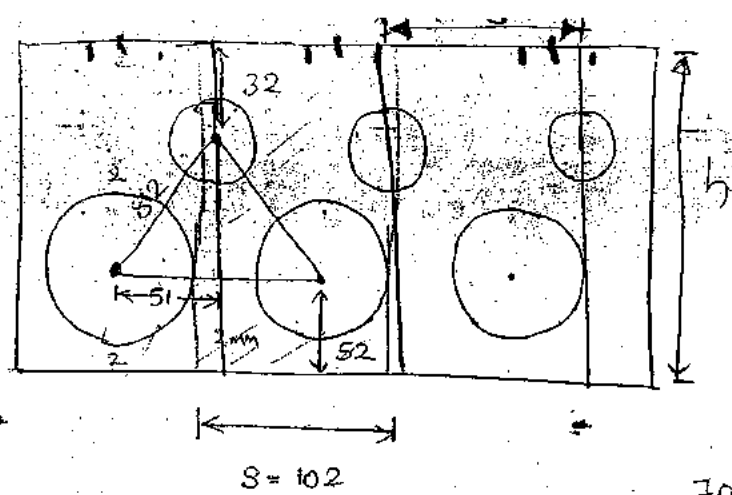
$$(100 + 60 + 2)$$

% utilisation

$$= \frac{\pi/4 (100^2 + 60^2)}{102 \times 166}$$

6.5%

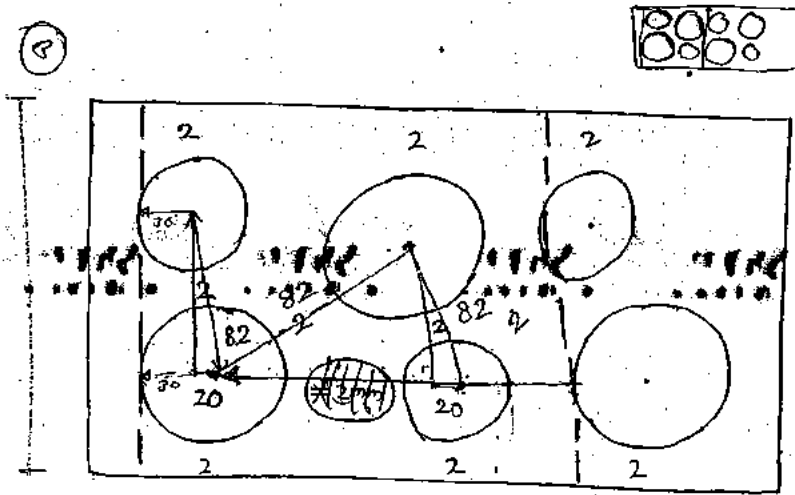
$h = 32 + 52 + \sqrt{82^2 - 51^2}$
 $= 148 \text{ mm}$



% utilisation = $\frac{\pi}{4} \frac{100^2 + 68^2}{102 \times 148}$

70%

②

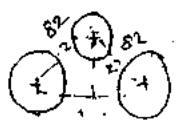


$50 + 82 + 20 = 152$

% utilisation = $2 \times \frac{\pi}{4} \frac{100^2 + 68^2}{S \times h}$

S x h

73%

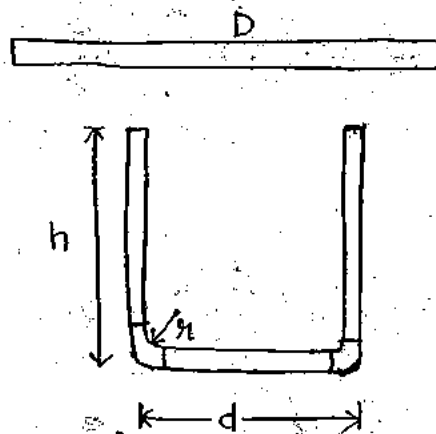


$80 + 52 + 32 = 164$

* Deep Drawing:-

It is a forming operation in which the forces are applied on the material such that the stresses induced is greater than the yield and less than the ultimate so that the material is experiencing plastic or permanent deformation to ~~shape~~ change the shape of a component:

$$\sigma_y < \sigma < \sigma_u$$



cup shaped components

Deep drawing operations is used for producing cup shaped components only.

$$\frac{h}{d} > 0.5 \quad \text{Deep Drawing}$$

$$\frac{h}{d} < 0.5 \quad \text{Shallow Drawing}$$



Stress on c.
So failure
chances are
high

r = corner radius of cup used to the Avoid the formation of cracks on the outer surface of a component

~~Surface~~ if $\frac{d}{r} \geq 20$ corner Radius is negligible

When corner Radius is negligible one side surface Area of Component will be made equal to the one side surface

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

$$D = \sqrt{d^2 + 4dh} \rightarrow \frac{d}{h} > 20$$

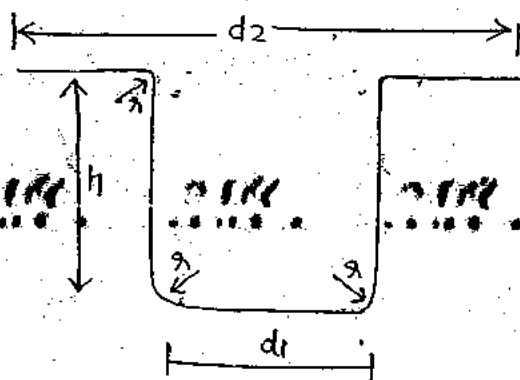
$$= \sqrt{d^2 + 4dh} - \frac{h}{2} \rightarrow \frac{d}{h} = 15 \text{ to } 20$$

$$= \sqrt{d^2 + 4dh} - h \rightarrow \frac{d}{h} = 10 \text{ to } 15$$

When $\frac{d}{h} < 10$ Total Surface Area of Component must be

Equal to Total surface Area of Blank

To find
Diameter
of Blank
'D'



$$\frac{\pi \times D^2}{4} = \pi d_1 h + \frac{\pi d_1^2}{4} + \frac{\pi}{4} \left[\frac{d_2 - d_1}{2} \right]^2$$

$$D = \sqrt{d_2^2 + 4d_1 h} \rightarrow \frac{d_1}{h} > 20$$

$$= \sqrt{d_2^2 + 4d_1 h} - \frac{h}{2} \rightarrow \frac{d_1}{h} = 15 \text{ to } 20$$

$$D = \sqrt{d_2^2 + 4d_1 h} - h \rightarrow \frac{d_1}{h} = 10 \text{ to } 15$$

[most of the Utensile are used in kitchen are
form by deep drawing process]

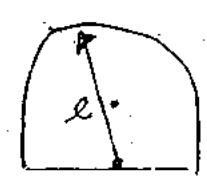
to produce the

$$R = 882 \text{ mm}$$

$$D = 484 \text{ mm}$$

$$D^2 = \frac{200^2}{2} \times 4$$

$$\frac{4}{\pi} D^2 = 2 \pi \frac{1}{2} d^2$$

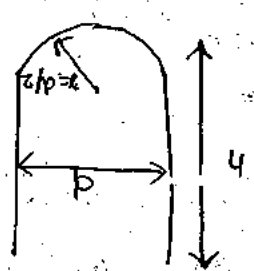


a hemispherical cup of radius 200 mm

Determine the radius of blank reqd to produce

already available

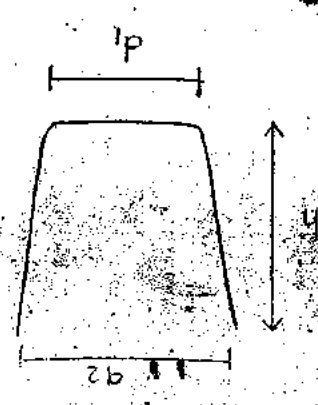
No corner radius reqd. It is not reqd



$$\frac{d}{2} \geq 20$$

$$D = \sqrt{2d^2 + 4dh}$$

$$\frac{4}{\pi} \times D^2 = \pi d^2 + \pi d^2$$

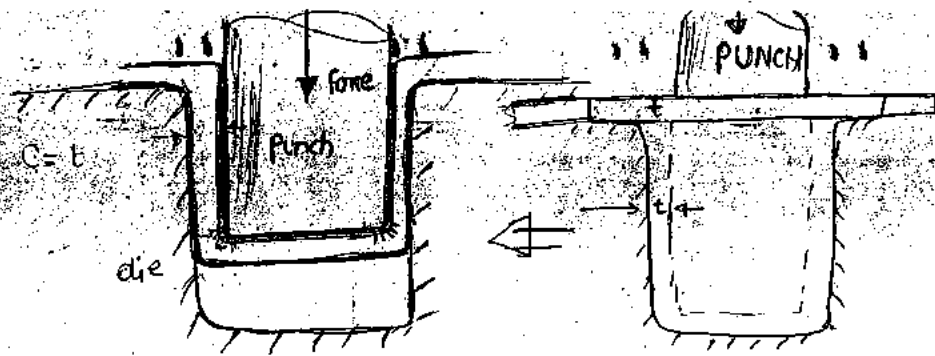


$$\frac{d}{2} \geq 20$$

$$D = \sqrt{d_1^2 + 2(d_1 + d_2)h}$$

$$\frac{4}{\pi} d_1^2 + \pi (d_1 + d_2)h$$

$$\frac{4}{\pi} \times D^2 = \frac{4}{\pi} d_1^2 + \pi d_2 \times h$$



For deep drawing operation also punch and die combination can be used for producing cup shaped components. But the clearance present b/w Punch and die is equal to sheet thickness. When force is applied by ~~used~~ by punch without shearing or cutting action the sheet will be simply pulled into the die to produce the Req'd shape.

If the deep drawing operation is performed

in ~~sto~~ a single stage even though the

~~average stress induced in the component is the~~

found to be less than ultimate; some

localised areas are experiencing the stresses

greater than ultimate stress due to ~~stress~~

~~this problem~~. Hence localised areas may experience cracks which lead to leakages

taking place during usage of component. To

avoid this problem it is always recommended to

~~perform the deep drawing operation in more than one stage so~~

~~that the force applied in a given stage is less and cracking~~

~~tendency will be eliminated.~~

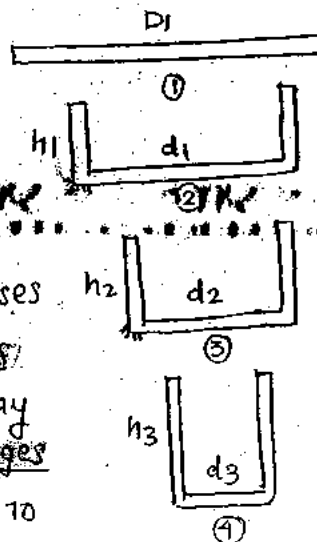
In each and every stage the punch and die

combination used is different.

$$D = \sqrt{d^2 + 4dh} \Rightarrow h_1 = \frac{D^2 - d^2}{4d}$$

$$= \sqrt{d_1^2 + 4d_1h_1} \Rightarrow h_2 = \frac{D^2 - d_1^2}{4d_1}$$

$$= \sqrt{d_2^2 + 4d_2h_2} \Rightarrow h_3 = \frac{D^2 - d_2^2}{4d_2}$$



*** LEAD ESTIMATION - I ***

$$P = \pi d l \sigma_y \left[\frac{D}{d} - C \right]$$

$$P_1 = \pi d_1 l \sigma_y \left[\frac{D}{d_1} - C \right]$$

$$P_2 = \pi d_2 l \sigma_y \left[\frac{D}{d_2} - C \right]$$

$$P_3 = \pi d_3 l \sigma_y \left[\frac{D}{d_3} - C \right]$$

$C = \text{const to cover friction, bending, corner radius}$

corner radius

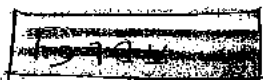
In general

$$C = 0.6 \text{ to } 0.7$$

By Neglecting friction, bending and corner radius $C = 0$

So Eqn becomes

$$P = \pi d l \sigma_y \cdot \frac{D}{d}$$



$$P_1 = \pi D l \sigma_y$$

$$P_2 = \pi d_1 l \sigma_y$$

$$P_3 = \pi d_2 l \sigma_y$$

$D = \text{Diameter of blank}$

$l = \text{thickness of blank}$

$C =$

$D = \text{dia of blank}$

d_1, d_2, d_3 are dia of component after 1st, 2nd and 3rd draws resp.

$$\text{Work done} = \text{Force} \times \text{distance}$$

$$W.D_1 = P_1 \times l_1$$

$$W.D_2 = P_2 \times (l_2 - l_1)$$

$$W.D_3 = P_3 \times (l_3 - l_2)$$

When the force is applied by using punch on to the blank the edges of the blank are lifting upwards which produces wrinkles/foldings on the deep drawn components and makes the appearance of the component very bad. To avoid this it is necessary to avoid the lifting of the edges of the blank. For this same amount of force has to be applied on the blank without lifting the edges of the blank. This force is called Blank Holder force.

$$BHF < D.F$$

D.F. Drawing Force

$$BHF = \frac{D.F}{3}$$

The optimum BHF which is avoiding the lifting of the edges and also minimising the force Reqd in deep drawing operation is $\frac{1}{3}$ rd of drawing force.

$$BHF_1 = \frac{P_1}{3}$$

$$BHF_2 = \frac{P_2}{3}$$

$$BHF_3 = \frac{P_3}{3}$$

(How to apply this req. wt.?)
Application of BHF: ↓

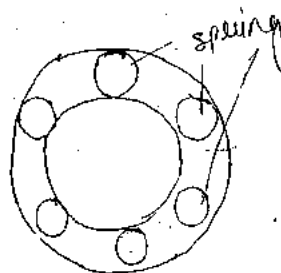
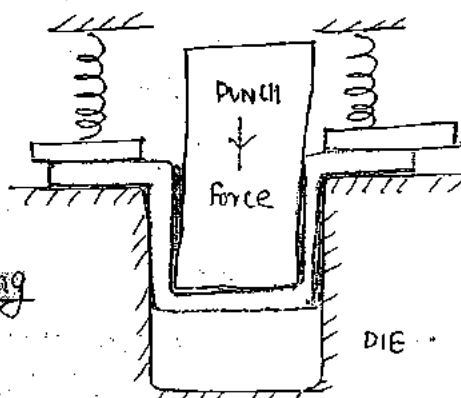
Whatever the Blank Holder force Reqd to be Applied on the blank is obtained by using spring loaded stripper plate.

The BHF applied by using spring loaded stripper plate is continued to maintain until the punch

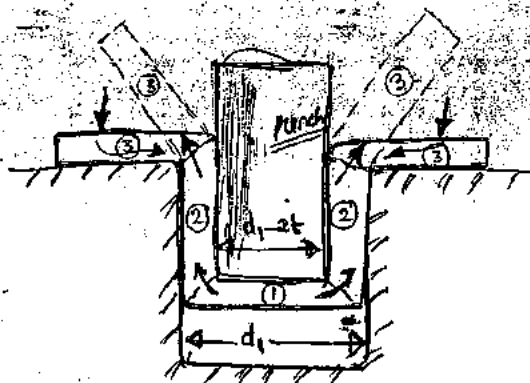
completely withdrawn from the component.

So that the Component is always left

over inside the die which can be removed or ejected by



using ejector pins provided in die.



If force is not provided until removal of punch the component will stick to punch and removal becomes difficult.

The partially deep drawn component is divided into 3 zones.

* Zone-1: (Bottom of Punch plate zone)

stresses induced:-

Without BHF :- No stresses will be induced

With BHF :- Tensile

* Zone-2 (Forming Zone)

Without BHF :-

With BHF :-

Tensile

Responsible for producing

change in shape
 $\sigma_y < \sigma < \sigma_u$

* Zone-3: (Flange portion)

Without BHF :- Tensile in 2 directions and compressive in 3rd direction

With BHF :- Pure Tensile

{ wrinkles inside = comp outside = Tensile

Along - Tensile length

Stresses induced in Zone-2 are only responsible for changing

the shape of the component. ∴ If the stresses induced in Zone

2 must be greater than yield and less than ultimate. Hence it

is Req'd to determine the magnitude of stresses induced in Zone-2.

$$F_{d1} = \frac{\text{Force}}{\text{Area}} = \frac{P_1}{\frac{\pi}{4} [d_2^2 - (d_1 - 2t)^2]}$$

$$\sigma_{22} = \frac{P_2}{A_2}$$

$$= \frac{\pi}{4} [d_2^2 - (d_2 - 2t)^2]$$

$$\sigma_{23} = \frac{P_3}{A_3}$$

$$= \frac{\pi}{4} [d_3^2 - (d_3 - 2t)^2]$$

$$\sigma_{24} = \frac{P_4}{A_4}$$

$$= \frac{\pi}{4} [d_4^2 - (d_4 - 2t)^2]$$

only σ_{2n}

$$\sigma_y < \sigma_{2n} < \sigma_u$$

★ No. of draws :- or [stage]

★ (1) Draw Ratio Method

Draw Ratio = DR = $\frac{\text{Dia before}}{\text{Dia after}}$

$$DR_1 = \frac{D}{d_1} \quad \dots \dots \dots \quad \text{In General}$$

~~Limiting~~

★ Limiting Draw Ratio

$$DR_2 = \frac{d_1}{d_2}$$

$$DR_3 = \frac{d_2}{d_3}$$

$$LDR = DR_1 = DR_2 = \dots \dots \dots$$

1.6 to 2.3

1.6 to 2.0 → Hard Material

2 to 2.3 → soft Material

$$\text{So } d_1 = \frac{D}{DR_1} \leq d, n=1$$

$$d_2 = \frac{d_1}{DR_2} \leq d, n=2$$

$$d_3 = \frac{d_2}{DR_3} \leq d, n=3$$

d = final diameter

Q. A cap of dia. = 30 mm, h = 150 mm. is to be produced with negligible corner Radius. $DR_1 = 1.6$, DR_2 and above = 1.8. det the No of Blows 2

$n = 2$

Soln:-

$$DR_1 = 1.6$$

$$1.6 = \frac{D}{d_1}$$

$$d_1 = \frac{138}{1.6} = \underline{85 \text{ mm}} > 30$$

$$d_2 = \frac{d_1}{DR_2} = \frac{85}{1.8} = 47 > 30$$

$$d_3 = \frac{d_2}{DR_2} = \frac{47}{1.8} = 27 < 30$$

$$\text{So } n = 3$$

Method 2:-

2. DRAW REDUCTION RATIO: 1

$$DRR = \frac{\text{Dia Reduced}}{\text{Dia Before}}$$

$$DRR_1 = \frac{D - d_1}{D} \Rightarrow d_1 = D(1 - DRR_1) \leq d, n=1$$

if not

$$DRR_2 = \frac{d_1 - d_2}{d_1} \Rightarrow d_2 = d_1(1 - DRR_2) \leq d, n=2$$

if not

$$DRR_3 = \frac{d_2 - d_3}{d_2} \Rightarrow d_3 = d_2(1 - DRR_3) \leq d, n=3$$

To ensure

$$\sigma_y < \sigma < \sigma_u$$

$$DRR_1 = 45 \text{ to } 50\%$$

$$DRR_2 = 30 \text{ to } 35\%$$

$$DRR_3 = 20 - 25\%$$

$$DRR_4 \text{ and above} = 16\%$$

Need not study

$$D = \sqrt{d^2 + 4dh}$$

$$= \sqrt{30^2 + 4 \times 30 \times 150}$$

$$= \underline{138}$$

3rd stage will have a capability to Reduce up to 27 mm. When $d_3 = 30 \text{ mm}$ we will stop operation

Final finished dia

$h = 150 \text{ mm}$

$DRR = 40\%$

Decrease above 25%

Soln:

Blank Dia

$$D = \sqrt{d^2 + 4dh}$$

$$= \sqrt{30^2 + 4 \times 30 \times 150} = \underline{138}$$

$$d_1 = D(1 - DRR_1)$$

$$= 138(1 - 0.4) = 83 > 30 \quad n = 1$$

$$d_2 = d_1(1 - DRR_2)$$

$$= 83(1 - 0.25) = 62 > 30 \quad n = 2$$

$$d_3 = d_2(1 - DRR_3)$$

$$= 62(1 - 0.25) = 46 > 30 \quad n = 3$$

$$d_4 = d_3(1 - DRR_4)$$

$$= 46(1 - 0.25) = 35 > 30 \quad n = 4$$

$$d_5 = d_4(1 - DRR_5)$$

$$= 35(1 - 0.4) = 26 < 30 \quad n = 5$$

$$\underline{\text{No of draws} = 5}$$

cup of dia = $\phi 12 \text{ mm}$

$h = 30 \text{ mm}$

$n = 2$

NOTE 8-

$\times$

Whenever the draw Ratio values or draw Reduction Ratio

are not mentioned in the problem it is always assumed

that the draw Ratio method with Limiting Draw Ratio = 2

Here Nothing mentioned abt
DR, and DRR

Soln $\rightarrow d = \sqrt{12^2 + 4 \times 12 \times 30} = 40 \text{ mm}$

$d_1 = \frac{d}{DR_1} = \frac{40}{2} = 20 \text{ mm} > 12$

$d_2 = \frac{20}{2} = 10 < 12$

no of draws = 2

Defects in Deep Drawing operations:-

① Wrinkling

The Method of producing wrinkles or foldings on a deep drawn component is called wrinkling.

② Elimination ↓

→ ① By providing Blank Holder Force (BHF)

→ ② Spinning operation

In Deep drawing operation the

die is present blow punch and

die is less than sheet thickness

so that the material will be squeezed out so that any wrinkles present in the component will be automatically removed.

3. By using Draw Bead:

② Earing →

(or waviness)

The edge wrinkles or edge foldings on the flange edges of a deep drawn component are called as Earing defect.

The Earing defect is produced becoz of the anisotropic properties of

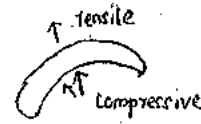


* Work Hardening or STRAIN HARDENING: ↓ Effect

Beoz the Deep Drawing operation is performed at Room Temp Any deformation produced in the

Component will increase the strength and Hardness of Material. During deep drawing when

a wrinkle is produced at the inside surface of a wrinkle the compressive stresses, outside surface of a wrinkle tensile stresses are induced. The Magnitude of compressive and Tensile stresses are different. ∴ the amount of Work Hardening taking place in the inside and outside surface of a wrinkle are different. Hence the mechanical properties of material becomes different. ∴ the material has changed to anisotropic which induces earing defect in the deep drawn component.



$$\text{Temp} = R.T \text{ or } < L.C.T$$

When material is undergoing deformation at a Temp below $L.C.T$, strength and Hardness of Component increases. This is called Work Hardening.

No of Earrings produced $= 2^n = 2, 4, 8, 16, 32, 64, \dots$
where n is an integer

$$n = 1, 2, 3, 4, 5, \dots$$

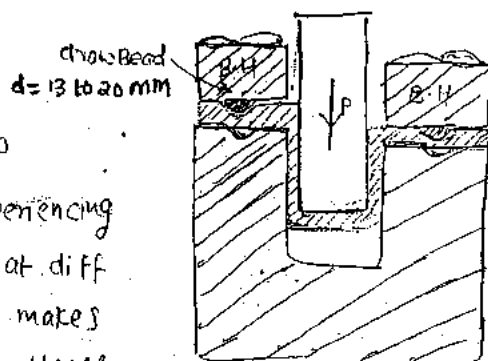
No method is available for eliminating the earing defect completely. But the earing defect can be minimised by using draw Beads.

DRAW BEAD:-

Beoz of usage of

DrawBead near to the draw

Bead. The sheet metal is experiencing different type of deformations at diff at different locations, which makes the material nearly isotropic. Hence



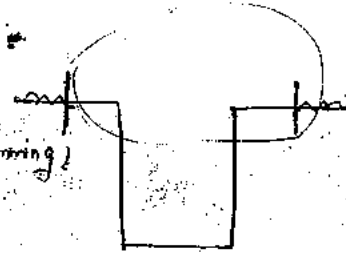
Effects of Draw Bead:-

1. Wrinkling defect is eliminated completely
2. Earing defect is minimised
3. Blank Holder force to be applied is Reducing (due to Bending of sheet)
due to draw Bead
4. Drawing force is increasing

Beoz the complete elimination of earing effect is not possible, it can be

removed by trimming operation. Edge turning (trimming)

Beoz of Trimming operation the size of Component produced by deep drawing operation will be Reduced. to maintain Req'd size of Component the original Blank size has to be increased.

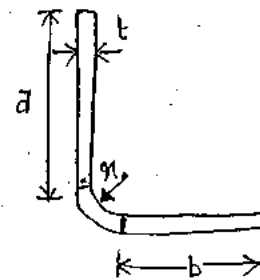
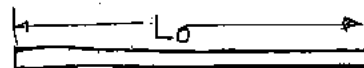


BENDING OPERATION:-

Bending also is a forming operation in which the Plastic deformation produced in the sheet will be used for changing the shape of the component.

- ex:-
- Tubelight Frame
 - Window Frame
 - Drawing Board clip
 - Automobile Body
 - Fan wings

L_0 = original Length of Flat starting strip or developed length of the strip



$$L_0 = a + b + B$$

B = Bend Allowance

Final Finished dimensions will be known

It is length of Flat starting strip Req'd for producing the bent portion of component.

$$\theta = \ln \times \theta$$

= θ in radians

Art = Neutral plate Radius

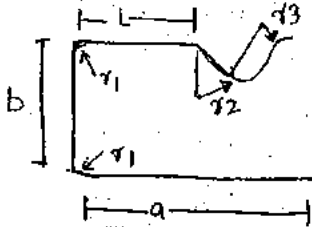
$$r_n = r_1 + k t$$

r_1 = Inside Radius

where k = stretch factor
or Bend factor

$$k = \frac{1}{3} \text{ if } r < 2t$$

$$k = \frac{1}{2} \text{ if } r \geq 2t$$



$$L_0 = a + b + c + 2B_1 + B_2 + B_3$$

$$B_1 = \ln r_1 \theta_1$$

$$B_2 = \ln r_2 \theta_2$$

$$B_3 = \ln r_3 \theta_3$$

BENDING FORCE:-



where L_0 = developed length

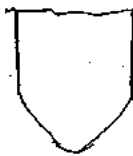
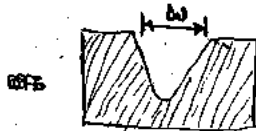
σ_y = yield stress

t = thickness

w = width of die opening

Methods of Bending

① V-Bending



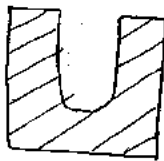
$$= 8t \text{ or } 16t$$

c = die opening factor

$$= 1.2t \text{ if } w = 16t$$

$$= 1.33t \text{ if } w = 8t$$

② U-Bending:-



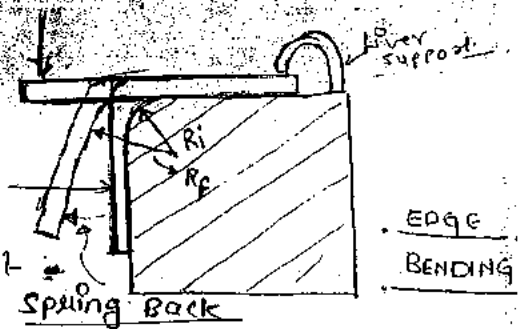
③ Edge Bending:-

If a given component is produced by using all the three methods of bending, the edge bending requires smallest amount of force. U-Bending requires 1.33t amount of force and V Bending is in b/w them.

Edge Bending Requires less amount of force due to lever effect.

Ratio of force for, UV edge = 1.6.015

During Bending operation with the application of force to the sheet can be bend to the reqd radius and angle. After Bending when the force is withdrawn from the component



Some amount of the regaining of the shape of sheet will be taking place due to ^{elastic deformation in the material} spring back action producing the final Radius R_f . This ~~amount of Regaining of regaining~~ of the ~~shape of sheet~~ is called Spring Back action.

Spring Back = $R_f = 1$ Spring Back = 0

$\frac{R_f}{R_i} > 1$ spring back is increasing

$$\frac{R_f}{R_i} = 4 \left(\frac{R_i \sigma_y}{E \cdot t} \right)^3 - 3 \left(\frac{R_i}{E \cdot t} \right) + 1$$

R_i = initial Radius

R_f = final Radius

Spring Back (S.B) ↑	$\frac{R_i}{E} \uparrow$
	$\sigma_y \uparrow$
	$E \downarrow$

Let R_{min} = Min Radius to which the sheet can be bend without producing cracks on the outer surface of Bend component

$$R_{min} = t \left[\frac{\sigma_a}{a} - 1 \right]$$

t = thickness of sheet to be bent

a = % Redn in Area at the time of Fracture during tensile Testing

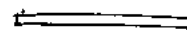
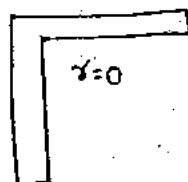
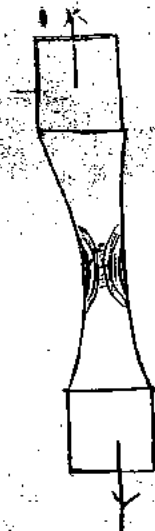
$\alpha = 50\%$ - very soft materials like
Al, Cu, Brass, M.S etc

$$r_{min} = t \left[\frac{50}{50} - 1 \right] = 0$$

$$r_{min} = 0$$

ie They can Be Bend to zero
Radius without producing an
cracks on surface

$$\alpha = \frac{A_0 - A_t}{A_0} \times 100$$



→ For titanium

$$\alpha = 14.5\%$$

$\alpha = \%$ Red. in. area. $\approx 50\%$ (Max)
→ Al, Cu, Brass, M.S etc.
Min =

$$r_{min} = t \left[\frac{50}{14.5} - 1 \right]$$

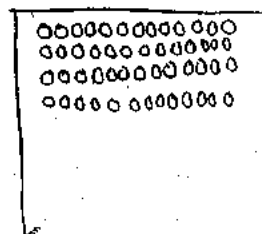
$$= 2.4t$$

MINOR OPERATIONS

★ PERFORATING

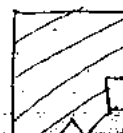
The Method of producing many nos of smaller size of
Holes in the sheet is called perforating.

Sheet



★ NOTCHING

The Method of removing a piece of
material from the edge of the
sheet is called Notching



→ Notching

★ LANCING:- (Centre)

the method of producing an incomplete Blank or Hole at the edge of sheet is called Lancing. (25)

★ SLITTING:-

the method of producing an incomplete Hole or Blank at the edge of sheet is called slitting.

★ NIBBLING:-

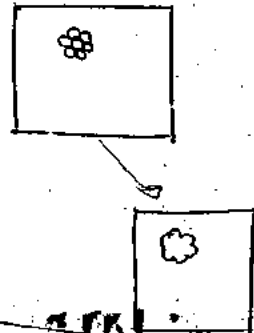
The Method of producing large size hole using small size punch in many no. of Repetitive strokes is called Nibbling.

★ TRIMMING:-

The Method of removing a small amount

~~of material from the edge of a blank~~

is called Trimming operation or edge trimming operation.



★ TYPES OF DIES

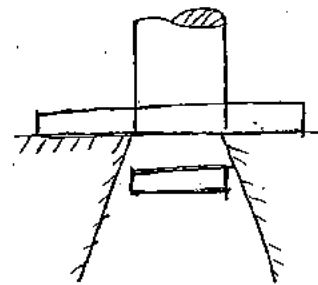
★ (1) Simple Die

If ~~only one~~ operation is performed in one

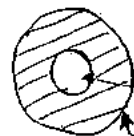
stroke at one stage is called as a Simple die.
When more than one op. is req.,
∴ the production rate is low.

★ (2) COMPOUND DIE

If ~~more than one~~ cutting operation is performed in one stroke at one stage it is called as Compound die



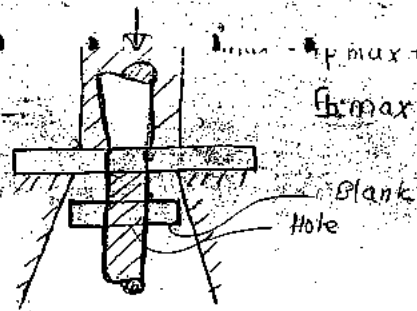
ex: production of Washer



Here Both Blank and Hole are used.

★ Advantages

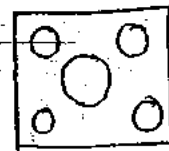
Even though more than one operation is to be done one component can be produced per stroke - ∴ production Rate is High.



★ Limitations

Both the Methods of Reducing the Punch force cannot be used. Hence the Force Reqd is Higher.

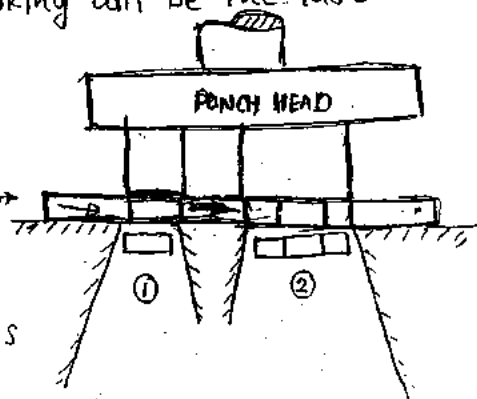
It is difficult to design and Manufacture the punch and die combination for producing more than 3 operations



★ PROGRESSIVE DIE

In Progressive Die also ~~more than one cutting operation is performed in one stroke~~ but at diff stages so that the punched out sheet is travelling from one to another stage for completing the Punching operation and Blanking will be the last operation.

In progressive die bcoz the operations are performed at diff stages either provision of shear or staggering of punches method will be used for



Reducing the punch force. First one or two strokes the components may not be produced. But afterwards one component will be produced. Hence production Rate is Same.

194
Bcoz the operations are done at diff stages the design and manufacture of punch and die combination is easier for producing any no. of operations. 192

Disadvantage:-

Balancing of force on punch head is difficult

* TRANSFER DIE:-

In Transfer Die more than cutting operation is performed in one stroke at diff stages. But here the Blanking operation will be the first operation and Blank produced in first stage is travelling from one to another stage for completing the Remaining punching operation.

191 out of the two progressive die is preferred

Bcoz sheet need to be set every stage at every time it is difficult to set at every stage.

* COMBINATION DIE:-

If more than one cutting and forming operations are performed in one stroke at one stage is called as combination die.

⇒ For ex: → Blanking combined with Deep drawing

→ " " " Bending

→ Punching " " Deep drawing etc.

* MULTIPLE DIE:-

All the above Dies are producing only one component per stroke. To produce more than component per stroke more than one of the above dies are kept in parallel.

for a. to produce 10 washers per stroke, 10 compound and
 or 10 progressive dies are kept in parallel
 Exa: - To produce 10 washers per stroke 10
 compound die or 10 progressive die
 will be kept in parallel.

3 MARKS

METAL CUTTING

The Method of Analysing the ~~Material~~ ^{Manufacturing} Process is called Metal cutting or Machining Analysis:

M.C. by Redford and
(Best) Booth Royal

M.T. Engg. By Nagpal
V.C. Venkatesh
[Research Grant]

FPT²

The Analysis of Machining will be done for determining the forces induced during Machining, the Power Consumption during Machining, temp induced during Machining, Tool life etc.

- * By knowing the forces induced during Machining the Stiffness Requirement of M.C. tool can be estimated. By knowing the Power Consumption during Machining, the Stiffness of prime mover Req^d can be estimated. By knowing the temp induced during Machining, the action of cutting tool material will be taken such that Hot Hardness temp of tool material is greater than temp induced during machining. By knowing the temp ~~the~~ process parameters can be adjusted or tool material can be changed such that tool life must be greater than tool changing time and so on.

$$T > T.C.T$$

* Hot Hardness temp:-

T is the min temp above which increases in temp causes rapid reduction in the Hardness of the tool material

Ex: High carbon steel

At RT (30°) RC 65

100°	RC 64
200°	RC 63
250°	RC 62
260°	RC 61
270°	RC 60

Hot Hardness
Temp of
H.C.S > RC 62
(210°C)

By knowing the

Diff Types of cutting tools

* ① Single point cutting tool

* ② Multi point cutting tool

⇒ If only one cutting edge is available for removing the material from work piece is called single point cutting tool

eg: Tools used in Lathe, shaping, planing etc.
Chisel

⇒ If more than one cutting edge is available for removing material from work piece is called Multi point cutting tool

eg: Milling cutter, Drill Bit, Grinding Wheel

* SINGLE POINT CUTTING TOOL ANALYSIS

FACTORS AFFECTING MACHINING OPERATIONS :-

① Properties of workpiece material :-
[Mechanical]

As the hardness of work is increasing the forces and temp power consumption will increase and as the ductility of work piece material is increasing the forces and power consumption during Machining will Reduce.

③ Cutting fluid : It carry away Heat generated during M/C & it act as a lubricant in friction zone.
∴ Force ↓ Power consumption ↓ Tool-life ↑

2) Tool Geometry

The Geometric properties of single point cutting tool are also influencing the Machining operations like increase in ~~Back Rate~~ ^{angle} will ~~increase~~ ^{reduce} the forces induced during machining, and power consumption, and ~~increase~~ ^{increase} tool life:

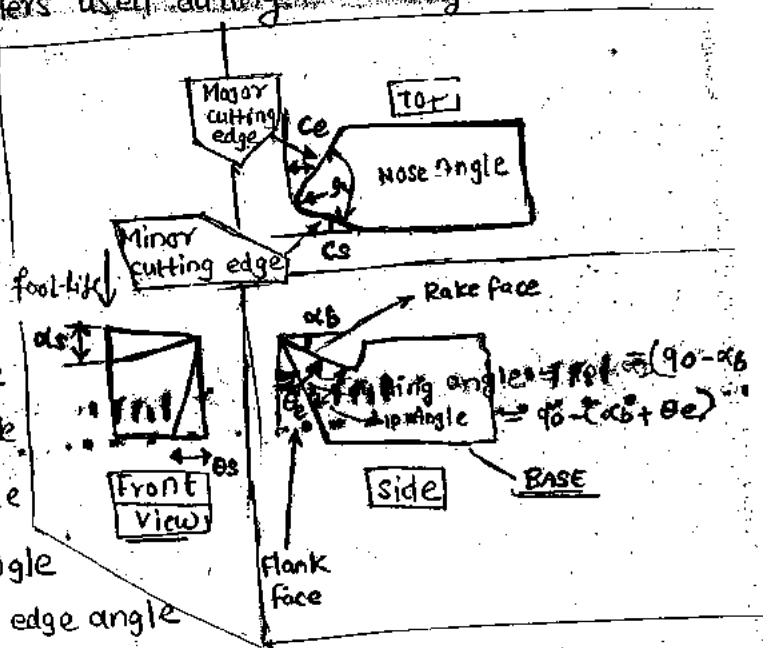
Interaction b/w Tool and Work Piece :

ie Process parameters used during machining

1. Speed
2. feed
3. depth of cut

With inc. in proc. param. $\uparrow$ Heat $\uparrow$ TEMP $\uparrow$
 $\uparrow$ Power $\uparrow$ Consumed $\uparrow$ Gen. $\uparrow$

- $\rightarrow \alpha_b$ - Back Rake angle
- $\rightarrow \alpha_s$ - side Rake angle
- $\rightarrow \theta_e$ - end Relief angle
- $\rightarrow \theta_s$ - side Relief angle
- $\rightarrow \phi_e$ - End cutting edge angle
- $\rightarrow \phi_s$ - side cutting edge angle
- $\rightarrow r$ - Nose Radius



dependant
Parameters

$$\text{Cutting Angle} = 90 - \alpha_b$$

$$\text{Lip Angle} = 90 - (\alpha_b + \theta_e)$$

TOOL SIGNATURE

The standard method of specifying Basic Geometric properties of a single point cutting tool on the tool itself is called tool designation or tool signature.

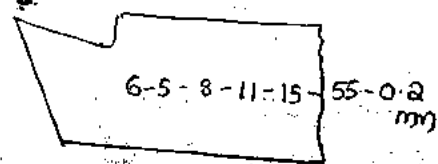
- ① ASA system (American steel association system)

For designating single point system different methods are used.

① **A.S.A** [American standard Association system]

$\alpha_b - \alpha_s - \theta_e - \theta_s - \phi_e - \phi_s - \eta$

The Angles specified in the A.S.A system are measured w.r.t. three mutually perpendicular planes.



* Adv:-

Bcoz the angles are measured w.r.t 3 mutually $\perp$ planes the measurement of angles and indication will be easier.

$\alpha_b = 6^\circ$
 $\alpha_s = 5^\circ$
 $\theta_s = 11^\circ$

* Disadv:-

During Machining operation the formation of chip and flow behaviour of chip is mainly depends on the major cutting edge of the tool. $\therefore$ If

Basic Geometric properties of a single point cutting tool are measured w.r.t major cutting edge of the tool the analysis of Machining will be easier but in A.S.A system the angles specified are measured w.r.t three mutually $\perp$ planes. Hence if the tool is designated in A.S.A system the analysis of Machining will be difficult. To overcome the disadv of A.S.A; O.R.S system has been defined.

② **O.R.S** [Orthogonal Rake system]

* $1 - \alpha - \theta_s - \phi_e - \phi_s - \eta$

$1 =$ inclination angle, $\alpha =$ Side/Effective/orthogonal Rake angle

⇒ ϕ_s = side relief angle

⇒ ϕ_e = end Relief angle

⇒ ϕ_c = End cutting edge Angle

⇒ λ = Approach / entering / principle cutting edge Angle

⇒ r = nose Radius

* Limitations *

Beoz the angles specified in O.R.S designation are measured wrt major cutting edge of tool. ~~to indicate these angles diagrammatically it is required to draw the isometric views. Hence it is diff to indicate the angles specified in O.R.S~~

* Adv: In O.R.S =

Because the angles specified are measured wrt cutting edge of tool, ~~in analysis of machining operation~~

Preferable method of designation of single point cutting tool is A.S.A system beoz in the industry more than 99% of people are machine operators. Based on their convenience the A.S.A system is preferable. Both the methods of designation can be used for designating one tool itself. $\therefore$ there must be a relationship existing b/w angles of A.S.A and O.R.S.

[If Nothing is given in the syst. use A.S.A only].

* A Given tool can be designated by both Method i.e. A.S.A or O.R.S.

There must be relationship b/w both syst.

$$\begin{bmatrix} \tan i \\ \tan \alpha \end{bmatrix} = \begin{bmatrix} \sin \lambda & -\cos \lambda \\ \cos \lambda & \sin \lambda \end{bmatrix} \begin{bmatrix} \tan \alpha_b \\ \tan \alpha_s \end{bmatrix}$$

$$\tan i = \sin \lambda \tan \alpha_b - \cos \lambda \tan \alpha_s$$

$$\tan \alpha = \cos \lambda \tan \alpha_b + \sin \lambda \tan \alpha_s$$

$$\begin{bmatrix} \tan \alpha_b \\ \tan \alpha_s \end{bmatrix} = \begin{bmatrix} \sin \lambda & \cos \lambda \\ -\cos \lambda & \sin \lambda \end{bmatrix} \begin{bmatrix} \tan i \\ \tan \alpha \end{bmatrix} \quad \underline{\text{A.S.A} \rightarrow \text{O.R.S}}$$

$$\begin{bmatrix} \cot \theta_s \\ \cot \theta_e \end{bmatrix} = \begin{bmatrix} \sin \lambda & -\cos \lambda \\ \cos \lambda & \sin \lambda \end{bmatrix} \begin{bmatrix} \cot \theta_s' \\ \tan \theta_e' \end{bmatrix} \quad \begin{array}{l} \text{A.S.A} \rightarrow \text{O.R.S} \\ \text{conversion of} \\ \text{Relief Angles} \end{array}$$

$$\star \begin{bmatrix} \cot \theta_s' \\ \cot \theta_e' \end{bmatrix} = \begin{bmatrix} \sin \lambda & \cos \lambda \\ -\cos \lambda & \sin \lambda \end{bmatrix} \begin{bmatrix} \cot \theta_s \\ \cot \theta_e \end{bmatrix}$$

$\star$ $\boxed{\begin{array}{l} \theta_e = \text{End C.E angle} \\ = \text{same in A.S.A and O.R.S} \end{array}}$

$$\star \boxed{\lambda = 90 - \theta_s}$$

$$\theta_s = 90 - \lambda$$

$\star$ $\boxed{\text{Tool Radius same in A.S.A and O.R.S}}$

Q. A single point cutting Tool is designated as

$10^\circ - 4^\circ - 11^\circ - 8^\circ - 12^\circ - 65^\circ - 0.2 \text{ mm}$

Identify whether it is O.R.S & A.S.A ?

$\boxed{7 \text{ parameters}}$

A.S.A system - if Nothing Specified in Problem

When a tool is designated, the identification of designation of single point cutting tool is done by taking that the given designation is a A.S.A system if nothing is mentioned in designation bcoz it is the most commonly used method of designation. If at the end of designation it is O.R.S Assume that the given designation is O.R.S

★ N.R.A : [Normal Rake System] [III]

α_n, θ_n

normal Relief angle = θ_n

normal Rake angle = α_n

$$\tan \alpha_n = (\tan \alpha \cdot \cos i)$$

$$\alpha_n = \tan^{-1} (\tan \alpha \cdot \cos i)$$

$$\theta_n = \tan^{-1} \left(\frac{\tan \theta \sin i}{\cos i} \right)$$

~~Direct~~

- * Parameter
- * Basic prop.
- * Geometric par

Effect of Tool Geometry on Machining

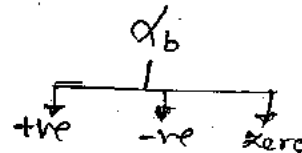
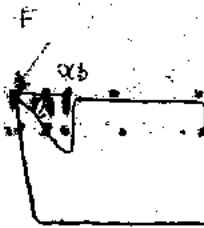
BACK RAKE ANGLE - α_b

$\alpha_b \uparrow$ strength $\downarrow$

Forces

Power $\downarrow$

Tool life $\uparrow$

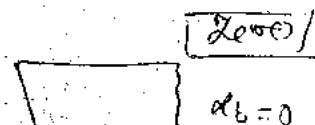
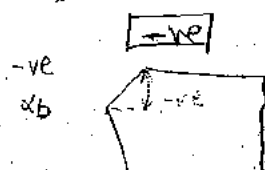


Back Rake angle will be taken

as -ve or positive or zero

Back rake angle

Positive Back Rake angle is the most commonly used Back Rake angle.



★ $\alpha_b = 0$

When the strength of tool is very high. ∴ the Maximum +ve Back Rake

angle used is 45° only

★ $\alpha_b = 0$

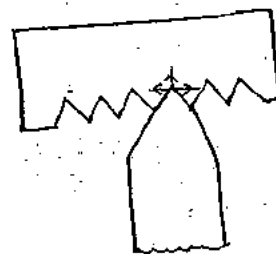
Zero Back Rake angle is used during Machining of Brass work pieces and also during thread cutting operations.

During Machining of Brass with zero Back Rake Angle the surface finish produced on the w/p will be better

During Thread cutting operation if zero Back Rake angle is used, the chip produced will be lifted upwards directly. Hence No sideward flow of the

chip is taking place. No sideward thrust force is acting on the thread. Hence

the weakening of thread will be eliminated.

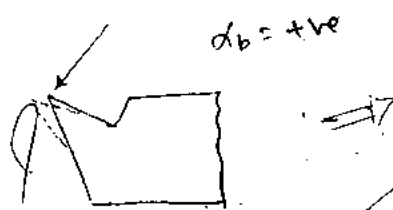


chip movement $\alpha_b = 0$

$\alpha_b = 0$



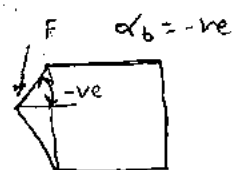
★ $\alpha_b = -ve$



$\alpha_b = +ve$

CARBIDE TOOL

Weak in Tension



Here Resistance Area is High

The usage of -ve Rake angle has been started with the

introduction of carbide tipped tools only becoz Carbide

tools are very weak in Tension. i.e whenever Carbide

tools are used, there is a possibility of deformation of

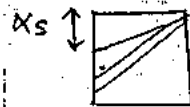
deflection it is immediately get failing

Max -ve Back Rake Angle = -10°

↑ -ve α_b is nothing but Reducing the Rake Angle. ∴ forces and power consumption will increase. Hence Max -ve α_b used is -10° only.

* SIDE RAKE ANGLE (α_s)

As $\alpha_s \uparrow$ strength ↓



Con

Forces ↓

Power ↓

} slightly

Tool Life ↑

Line contact of chip is thr with Tool

With increase of side Rake angle of tool the amount of chip bending in the width direction Reduces.

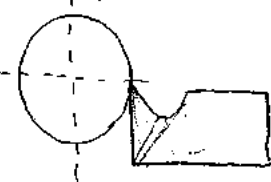
$\alpha_s = 5^\circ$

* RELIEF ANGLES

End Relief Angle & side Relief Angle
(θ_e) (θ_s)

The Relief angles are provided mainly to Avoid Rubbing Action b/w tool and work piece.

If the Relief Angle is equal to $\neq$ zero the Tool is simply rubbing on to the work piece, without doing Any machining

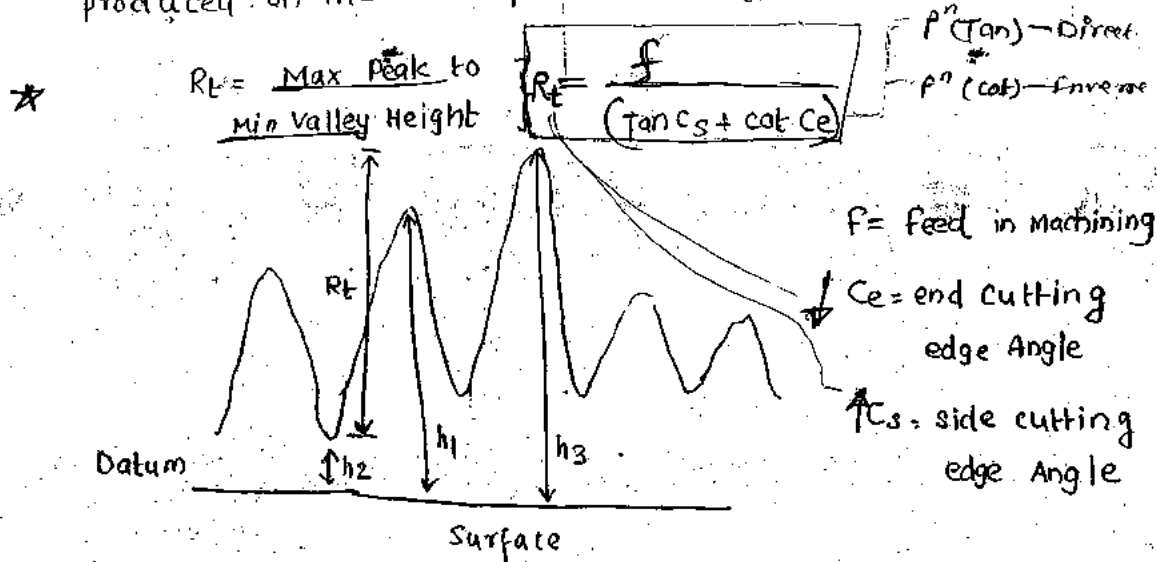


$\theta_e, \theta_s \uparrow$ strength ↓ forces & power ↓ Tool Life ↑

★ Cutting edge Angles

End & side Cutting edge Angle

the cutting edge angles are mainly influencing surface finish produced on the work piece



★ (I) { on a Given surface as the value of R_t is increasing }
 the surface finish of surface is becoming poor.

★ (II) { As C_s is $\uparrow$ }
 $R_t \downarrow \Rightarrow \text{Better surface finish}$

★ (III) { As C_e is $\uparrow$ }
 $R_t \uparrow \Rightarrow \text{Poor surface finish}$

★ { Normally $C_e = 8 \text{ to } 15^\circ$ }
 $C_s = 0 \text{ to } 90^\circ$

★ Nose Radius

It is also mainly influencing surface finish produced on work piece.



keeping F constant feed of cut

As r ie nose Radius increases the value of R_t is reducing. $\therefore$ the surface finish is Becoming Better

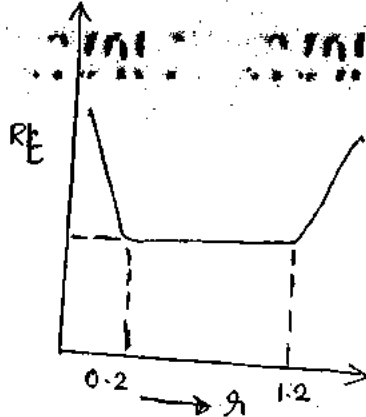


with $r = 0$
Nose Radius
Nose Radius

Defect:-

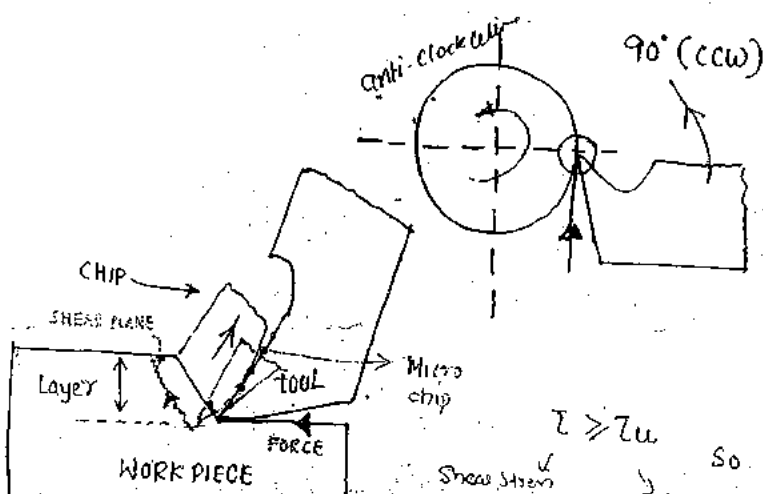
Here As Nose Radius is increasing the contact length b/w Tool and work piece is increasing. So F is increasing in Machining operation. Due to this vibrations and chattering will be taking place. This causes the surface finish produced on the work piece will become poor.

the optimum Nose Radius which is giving the Better surface finish is 0.2mm to 1.2mm.



* Mechanism:-

Mechanism by which chip formation is taking place in machining operation



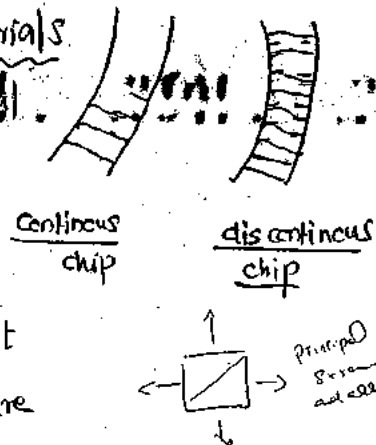
During analysis of machining when compared to actual machining done the machining done is shown by rotating the tool in 90° in counter clockwise direction.

$\tau \geq \tau_u$
Shear stress
So chip will form.

When the force is applied by using cutting tool, to remove the layer of work piece material, the material is started deforming plastically and sliding over the rake face of tool inducing shear stresses in the layer of work piece material. on further application of the force by using the tool the shear stresses induced in the layer of work material are increasing continuously. At some point the shear stresses induced will become greater than or equal to the ultimate shear stresses of work material. ∴ shearing or cracking is started taking place at the tip of the tool and it is propagating towards the surface of the work piece producing shear plane. from the above the mechanism by which chip formation taking place is "shearing and tearing Action".

During Machining of soft and ductile materials
beoz. of Higher toughness of work piece material.

the crack wave propagation [energy wave propagation] will be absorbed by the material and disappearing somewhere in the middle so that continuity of chip will be maintained at the top side of chip. Hence Continuous chips are produced.



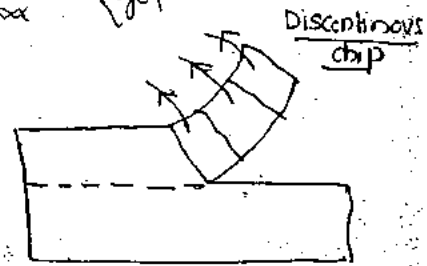
Whereas During Machining of Hard and Brittle Work piece materials beoz. of Lower toughness the energy wave or crack wave can propagate very easily upto the surface. ∴ the chips will become discontinuous.

★ Microchips or powdered particles

Always during Machining operation with whatever may be the type of chips, microchips or powdered particles are producing.

When this microchips are moving on to the rake face of tool they will get exposed to the High temp environment. Hence they may get adhered or welded on to the Rake face of the Tool called as "Built up edge formation (BUE)".

★ BUE formation is taking place only with continuous chips bcoz when the discontinuous chips are produced during machining, ~~the~~ as the chips are producing it is simply thrown away



No BUE

from the machining zone so that microchips also will get thrown away. ∴ there is no chance of adhering of microchips to Rake face of Tool. whereas with continuous chips as the chip is moving along the Rake face of Tool the microchips also moving along the Rake face and somewhere along the Rake face the microchips will get adhered and forming the BUE on the Tool.

Bcoz of formation of BUE whatever the wear taking place on Rake face is the only BUE is wearing out but not the Tool. ∴ Tool life will be increasing.

Simultaneously when the BUE is forming on the Rake face of tool the surface finish on the Rake face of tool is getting damaging. Hence the friction is increasing which increases the forces and power consumption during machining.

★ TYPE OF CHIPS SRTF

① Discontinuous chips

② continuous chips

③ without BUE

④ with BUE

S :- speed of cutting tool

R :- Rake angle

T :- Thickness (uncut chip)

F :- fluid

Factors promoting discontinuous chips

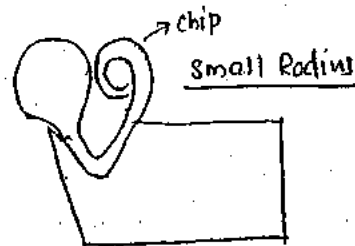
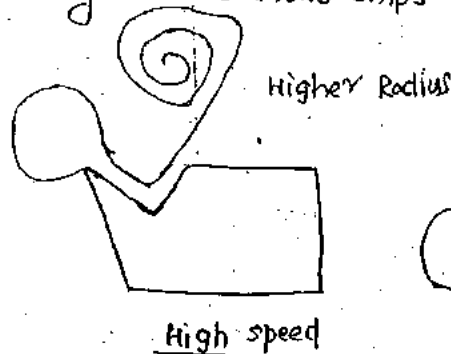
Hard and Brittle work piece material

Soft materials

Low speed Machining - discontinuous chips

★ Discontinuous chips

- * Hard work piece ✓
- * Low speed ✓
- * Small rake ✓
- * Large uncut chip ✓
- * Little use of cutting fluid ✓



Factors affecting

cutting speed

Rake angle

uncut chip thickness

Life of cutting fluid

During low speed Machining
time available for cutting ^{curling} cutting
of chip is Large - ∴ chip

will get curled to the Lower

Radius ⇒ Bending of chip is Higher so that the cracks which
are already present in chip will propagate easily and
produces discontinuous chips

With small Rake angle the forces in machining are Higher, ∴
Magnitude of energy wave propagation is also High. Hence
the energy wave can propagate upto the surface easily
and produces discontinuous chips.

(Depth of cut) ↑
With increase of uncut chip thickness the forces
induced during Machining is High, the magnitude of
energy wave is Higher. Hence energy wave can propagate

~~both the~~ During Machining operation according to 1st law of thermodynamics whatever the energy supplied for machining is simply converted into Heat energy. $\therefore$ ~~chip~~ Temp of chip will be Higher due to High Temp and coeff of thermal expansion of metal the chip is expanding. When the coolant is poured into the machining zone the Heat available in the chip will be immediately carried away by the coolant and chip Temp is Reducing so that the chip is contracting. [Within short duration of time the chip is getting expanding and contracting so that any cracks which are already present in the chip will get propagated and produces discontinuous chip]

* Continuous chips without BUE

Soft and Ductile work piece

To Avoid BUE conditions to be maintained

- * Cutting speed ✓
- * Rake angle
- * uncut chip thickness
- * Life of cutting fluid

At High vel machining the Time available for Adhering for microchips is Reduced. Hence avoids the formation of BUE.

Rake angle

With Large Rake Angle Tool $\uparrow$ the forces and power consumption during machining will Reduce, The Heat Generation will Reduce which Reduces the Temperature $\downarrow$ Hence the chances of Adhering of microchips will be eliminated.

* On a machining operation i.e. always preferable to have discontinuous chips because it is easy to dispose them. In certain machining operation it is compulsory that only continuous chips are produced. To convert continuous to discontinuous the chip breaker will be used. In chip breaker bending is the principle used to convert continuous to discontinuous.

Uncut chip thickness

Small uncut chip thickness

Cutting Fluid

with use of cutting fluid

Continuous chips with BUE ★

with BUE

Soft and ductile w.p

Low speed

small Rake

Large uncut chip

without cutting fluid

Que. ★

During face turning of a ductile work piece material with optimum cutting velocity from surface towards centre the types of chips produced are

- (a) continuous throughout (b) Discontinuous throughout
- (c) continuous in Beginning and discontinuous at end
- (d) discontinuous in 1) 1) continuous at end.

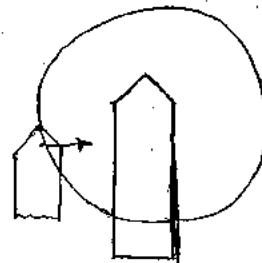
As moving towards Centre

$$V = \frac{\pi DN}{1000}$$

~~change~~

D ↓

V ↓



Methods of Machining

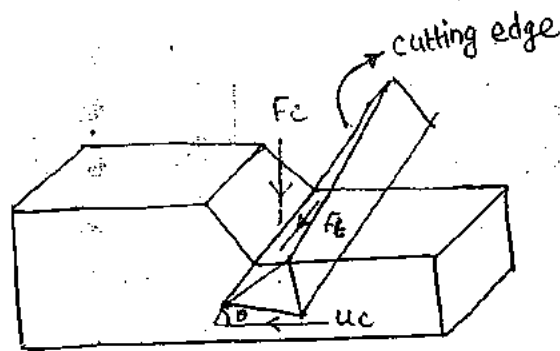
→ Orthogonal Machining

→ oblique Machining

ORTHOGONAL MACHINING

If the cutting edge of the tool is $\perp$ to the cutting velocity vector, it is called as orthogonal Machining operation.

If the cutting edge of tool is not $\perp$ to the cutting velocity vector, it is called as oblique Machining.

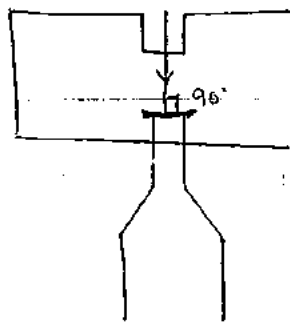


$\theta = 90^\circ$ orthogonal

$\theta \neq 90^\circ$ oblique

Examples of orthogonal

Parting



Jack plane operation also orthogonal

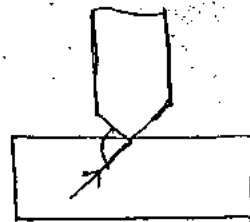
Breaching $\theta = 90^\circ$

Sawing $\theta = 90^\circ$

Examples of oblique machining

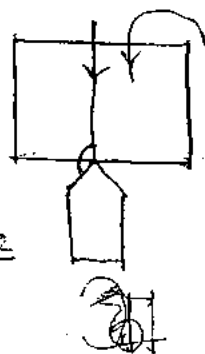
Plane turning, face turning, Milling, Drilling, shaping, planing

Shaping



Not orthogonal

Turning



oblique

Orthogonal machining only 2 components of forces are acting i.e. cutting force F_c and thrust force F_t . $\therefore$ The orthogonal machining is also called as 2-D Machining.

In oblique Machining operation because $\theta \neq 90^\circ$ the thrust force F_t can be resolved into 2 components of force as

$$F_t \begin{cases} F_a = \text{Axial Component of Force} \\ F_r = \text{Radial Component of Force} \end{cases}$$

i.e. in total there are three components of forces are acting in the oblique machining. Hence it is also called as 3-D machining operation

Because there is no direct methods are available for the Analysis of oblique machining operation, the oblique problem will be converted into orthogonal and then analyze it as orthogonal.

* ANALYSIS OF ORTHOGONAL MACHINING

Let κ_b
 $\kappa =$ Back Rake angle in A-S-A

$\kappa = \kappa$ (side Rake angle in case of O.R.S)

$t_1 =$ uncut chip thickness

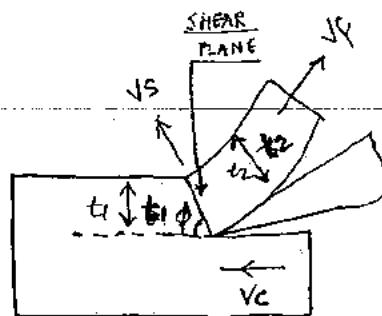
$t_2 =$ chip thickness after machining op.

$\frac{t_1}{t_2} = \eta =$ chip cutting ratio or cutting ratio

$\frac{t_2}{t_1} = \frac{1}{\eta} = k$ chip Reduction coefficient

$b_1, b_2 =$ width of chip before and after machining

$l_1, l_2 =$ length of chip before and after machining or



V_c = cutting velocity or vel of Tool relative to workpiece

V_f = chip flow velocity or vel of chip relative to Tool

V_s = shear velocity or shear plane velocity or vel of chip Relative to work piece.

ϕ = shear angle / shear plane Angle or angle made by shear plane wth cutting vel vector.

Assumptions:

① Every metal which is undergoing machining operation will be considered as incompressible. i.e. ~~volume~~ ~~changes of material~~

~~during machining is zero~~

$$Vol\ Before = Vol\ After$$

$$t_1 b_1 L_1 = t_2 b_2 L_2$$

$$t_1 b_1 V_c = t_2 b_2 V_f$$

② width of chip is assumed to be constant

~~By this~~

During machining operation when the

force is applied by using tip of the

Tool along the Length direction of

chip as a compressive force, the vol^m of material is Reducing

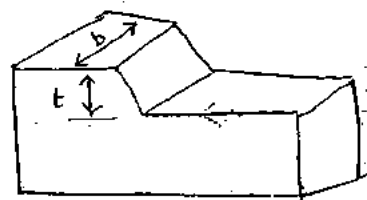
in the Length direction. The Corresponding vol^m of material

has to be increased either in the width direction or

in thickness direction. But ~~since~~ the width of chip is

~~higher~~ than thickness the Resistance offered by the

~~material~~ in the width direction is higher % whatever the



vol^m of material is reducing in length direction but will be increasing only in thickness direction by keeping width of chip constant.

So $\frac{\text{'vol' before}}{L_1 b_1 L_1} = \frac{\text{'vol' after}}{L_2 b_2 L_2}$

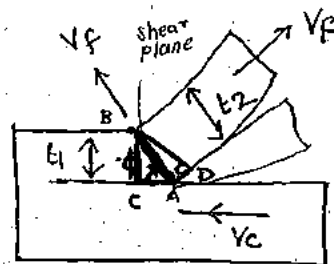
$b_1 = b_2$

$$\frac{L_1}{L_2} = \frac{L_2}{L_1} = \eta$$

$$\eta = \frac{t_1}{t_2} = \frac{L_2}{L_1} = \frac{V_f}{V_c}$$

$L_1 b_1 V_c = L_2 b_2 V_f$

$$\frac{L_1}{L_2} = \frac{V_f}{V_c} = \eta$$

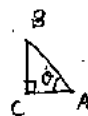


$\eta = \frac{\text{cutting ratio}}{\text{chip thickness ratio}}$

Because the force Applied by using the tip of tool is acting like a compressive force along the length direction of chip the length of chip after machining must be less than length of chip before Machining. $\therefore$ chip thickness ratio η must be always less than 1.

From ΔABC

$$\sin \phi = \frac{BC}{AB}$$



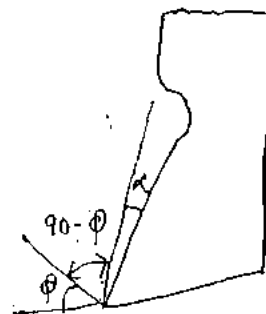
(L_s - shear length)

$$\Rightarrow L_s = AB = \frac{L_1}{\sin \phi} \quad \text{--- (1)}$$

In ΔABD



$$\sin (90 - \phi + \alpha) = \frac{BD}{AB} = \frac{t_2}{AB}$$



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204

AB = $\frac{t_2}{\cos(\phi - \alpha)}$ → (2)

Equating (1) and (2)

$\frac{t_1}{\sin \phi} = \frac{t_2}{\cos(\phi - \alpha)}$

(3) $\frac{t_1}{\sin \phi} = \frac{t_2}{\cos(\phi - \alpha)}$

$\eta = \frac{\sin \phi}{\cos \phi \cos \alpha + \sin \phi \sin \alpha}$

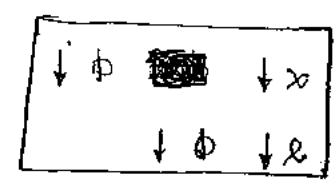
$r = \frac{\sin \phi / \cos \phi}{\cos \phi \cos \alpha + \sin \phi \sin \alpha} = \frac{\cos \phi}{\cos \phi \cos \alpha + \sin \phi \sin \alpha}$

$\tan \phi = r \cos \alpha + \eta \tan \phi \sin \alpha$

$\tan \phi [1 - r \sin \alpha] = r \cos \alpha$

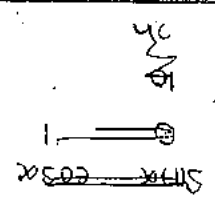
$\tan \phi = \frac{r \cos \alpha}{1 - r \sin \alpha}$

$\phi = F(r, \alpha)$

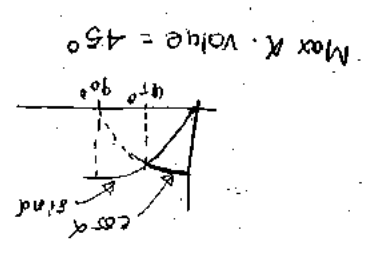


Chf Thickness Ratio

$\tan \phi = r \cos \alpha \uparrow \text{small}$
 $1 - r \sin \alpha \downarrow \text{large}$



$\tan \phi = \frac{r \cos \alpha \uparrow \text{small}}{1 - r \sin \alpha \downarrow \text{large}}$



and using this force machining process continued to be analysed.

★ MERCHANT'S CIRCLE

For establishing the Relationship b/w measurable and Actual Forces Merchant's circle will be used.

Let R = Resultant Force

$$R = \sqrt{F_c^2 + F_t^2}$$

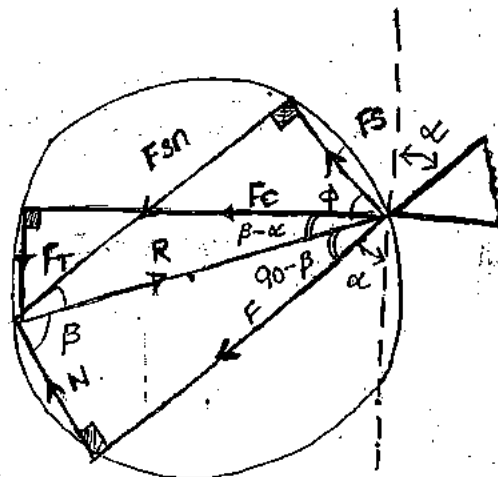
R = Dia of Merchant circle

3 Rt Angled Δ 's

$$180 - (90 + \beta) = 90 - \beta$$

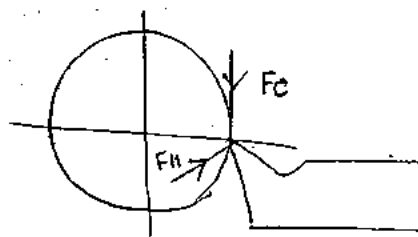
$$180 - (90 + \alpha) = 90 - \alpha$$

$$90 - (90 - \alpha) = \alpha$$



Machining zone diagram

Actual conditions



$\left. \begin{array}{l} F_t \text{ \& } F_c \text{ defined} \\ \text{Based on} \\ \text{Actual Machining} \\ \text{Conditions} \end{array} \right\}$

From the above Merchant's circle it is found that there are three right angled Δ 's are present and all the three right angled Δ 's are possessing common hypotenuse.

this is used for establishing Relationship b/w measurable and Actual Forces

$$\sin \beta = \frac{F}{R}$$

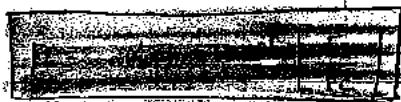
$$R = \frac{F}{\sin \beta} = \frac{N}{\cos \beta} = \frac{F_s}{\cos(\phi + \beta - \alpha)}$$

$$\frac{F_{sn}}{\sin(\phi + \beta - \alpha)} = \frac{F_c}{\cos(\beta - \alpha)} = \frac{F_t}{\sin(\beta - \alpha)}$$

$$\frac{F_s}{\cos(\phi + \beta - \alpha)} = \frac{F_c}{\cos(\beta - \alpha)}$$

$$F_s = F_c \times \frac{\cos(\phi + \beta - \alpha)}{\cos(\beta - \alpha)}$$

$$\tan(\beta - \alpha) = \frac{F_t}{F_c}$$



$\mu = \tan \beta$ coeff of friction for chip tool interface

$$\tan[\beta - \alpha] = \frac{F_t}{F_c}$$

$$\frac{\tan \beta - \tan \alpha}{1 + \tan \beta \tan \alpha} = \frac{F_t}{F_c}$$

$$F_c \tan \beta - F_c \tan \alpha = F_t + F_t \tan \beta \tan \alpha$$

$$\tan \beta [F_c - F_t \tan \alpha] = F_t + F_c \tan \alpha$$

both are correct
① & ②

$$\tan \beta = \mu = \frac{F_t}{F_c - F_t \tan \alpha}$$

In General

$$F_c > F_t$$

$$F_c < F_t \left\{ \begin{array}{l} \text{- Face Turning} \\ \text{- Broaching} \\ \text{- Grinding} \end{array} \right\}$$

$$\left[\frac{F_t}{F_c} = 2.5 \text{ (Grinding)} \right]$$

In machining operations where the F_t is $> F_c$

the value of β is becoming greater than

45° . So the coeff of friction μ will become

Always μ should be less than 1.

$\mu > 1$. But in general the coeff the coeff of friction

must be less than 1. So in cases where μ is becoming

> 1 , in such cases use classical friction theorem for determining the coeff of friction in machining; According

to classical friction theorem

$$\mu = \frac{\ln \left[\frac{1}{1 - \lambda} \right]}{\lambda - \alpha}$$

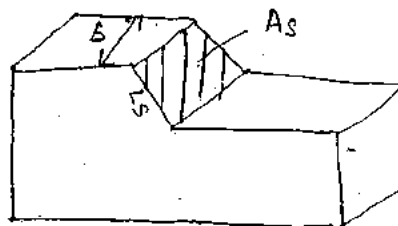
USE ONLY
WHEN μ BECOMES
 > 1

where λ = chip thickness ratio and α

α = Back Rake angle in radians

$$\tau = \frac{F_s}{A_s} = \frac{F_s}{L_s \times b}$$

$$A_s = L_s \times b$$



$$A_s = AB \times b$$

$$s = \frac{b \cdot l}{\sin \phi} \times b \rightarrow L_s$$

$$f_s = \frac{A_o}{\sin \phi}$$

$A_o = b \times t_1$ ch Ar. of uncut chip

$$\tau > \tau_u \quad \text{Possible Machining} \Rightarrow \eta = \frac{F_{sn}}{A_s} = \frac{F_{sn}}{A_o} \times \sin \phi$$

$$\tau < \tau_u \quad \text{Impossible Machining}$$

cont. p. T. 01 at 14

W.D = energy Reqd for shearing + Energy Reqd for overcoming friction

$$= F_s \times A_s + F_f \times V_f$$

$$W.D = (F_s \times V_s) + (F_f \times V_f)$$

$$W.D = (F_c \times V_c) + (F_t \times \text{feed velocity})$$

$$W.D = F_c \times V_c + (F_t \times 0.000 \dots)$$

very small

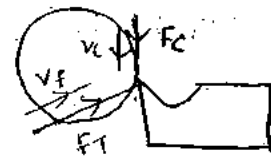
Work done = Energy Reqd

$$W.D = E = F_c \times V_c$$

$\tau > \tau_u$ - Energy lost
During Machining operation

if it is possible to ensure that the stresses induced in the work material is just equal to the ultimate shear stress of the work material, the corresponding energy Reqd or work to be done is considered as a minimum Energy Required for Machining operation.

$$\tau = \tau_u \quad [\text{Min Requirement}]$$



f = feed

$$\begin{aligned} \text{feed velocity } (V_f) &= F \times N \\ &= 0.1 \times 500 \\ &= 50 \text{ mm/min} \\ &= \frac{0.05 \text{ m}}{60} \text{ s} \\ &= 0.0008 \dots \end{aligned}$$

②

By varying shear angle ϕ during machining operation it is possible to vary the shear stresses induced in the layer of work material. So to ensure that stresses induced is equal to ultimate shear stresses, it is Req^d to determine the optimum shear angle.

$$\tau = \frac{F_s \times \sin \phi}{A_0}$$

$$W.D = E = F_c \times V_c$$

$$= \frac{F_s}{\cos(\phi + \beta - \alpha)} \cdot \cos(\beta - \alpha) \times V_c$$

$$= \frac{\tau \times A_0 \cdot \cos(\beta - \alpha) \times V_c}{\sin \phi \cdot \cos(\phi + \beta - \alpha)}$$

$$W.D = \frac{\tau_u \cdot A_0 \cos(\beta - \alpha)}{\sin \phi \cdot \cos(\phi + \beta - \alpha)} \cdot V_c$$

For minimum work done differentiate

or opt shear angle

$$\frac{d(W.D)}{d\phi} = 0$$

$$2\phi + \beta - \alpha = 90^\circ \Rightarrow \text{opt shear angle Relation for min W.D.}$$

→ Min energy shear angle

→ Merchants shear angle or Merchant criteria for maching.

$$\phi = \frac{90 + \alpha - \beta}{2}$$

The Above Merchants shear angle is a theoretical proven shear angle Relation. To validate this optimum shear angle Relation ~~and~~ the ~~Lee and Shaffer~~ has conducted the expt but they Failed in proving the Merchants shear angle Relation becoz of some of the ~~assumptions~~ taken during Analysis.

Energy used for producing thrust force is negligible but they are derived another optimum shear angle relation by expt

(14)

Let ϕ shaper shear angle

$$\phi + \beta - \alpha = 45^\circ$$

Optimal shear angle

Simultaneously stabler also tried to validate the merchants shear angle Relation but he also failed and derived another shear angle relation experimentally

$$\phi + \beta - \alpha = 45^\circ$$

Stabler shear angle relation

Optimal shear angle

Machining constant or Merchants constant (C_m)
 $C_m = 2\phi + \beta - \alpha$
 Expt - indicating the mag. of shear stress induced in cutting op.

Case-I, $C_m = 90^\circ \Rightarrow T = T_u \Rightarrow W.D = (W.D)_{min}$

$$\Rightarrow \eta_{Energy} = 100\%$$

entire energy supplied is utilized for machining

Case-II: $C_m > 90^\circ \Rightarrow T < T_u \Rightarrow W.D < (W.D)_{min}$
 impossible case of Machining
 $\eta_{Eu} > 100\%$

Case-III: $C_m < 90^\circ \Rightarrow T > T_u \Rightarrow W.D > (W.D)_{min}$
 $\eta_{Eu} < 100\%$

From the Above Machining cost is used
 of workpiece energy

for machining the magnitude of shear stress induced in the machining operation and efficiency utilization during machining

④

⇒ 1% Reduction in the efficiency of energy utilisation will be taking place in the machine. } nearly 1% Reduction in the Energy utilisation take place.

eg: $\eta_{EU} = 65\%$

$\eta_{EU} = 75\%$

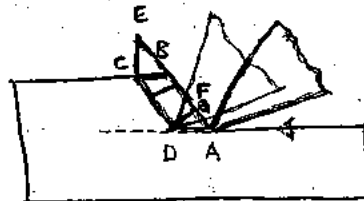
Redn in $\eta_{EU} = 90 - 65 = 25$

$\eta_{EU} = \frac{100 - 25}{100} = 75\% \quad (\approx \text{approx.})$

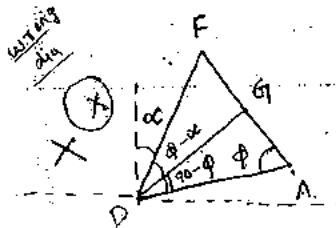
P.T.O. → Shear strain induced during machining (in chip).

A-B-C-D ⇒ initial chip

F-E-C-D ⇒ final chip



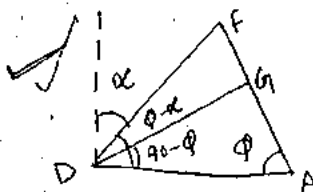
Shear strain = $\frac{\text{deformation in chip just before shear}}{\text{shortest distance b/w 2 shear planes}}$



$= \frac{AF}{DG}$

$= \frac{AG + GF}{DG}$

Point A has travelled upto F



$\frac{AG}{DG} + \frac{GF}{DG}$

$\tan(90 - \phi) + \tan[\phi - \alpha]$

$S.S = \cot \phi + \tan[\phi - \alpha]$

Shear strain depends on ϕ and α for a given tool

So shear strain depends on ϕ and α

For Min shear strain:-

$$\frac{d(ss)}{d\phi} = 0$$

$$\Rightarrow 2\phi - \alpha = 90$$

$$\phi = \frac{90 + \alpha}{2}$$

$$\begin{aligned} \text{shear strain rate} &= \frac{\text{strain}}{\Delta t} \\ &= \frac{AF}{DQ \Delta t} = \frac{AF}{DQ} \cdot \frac{1}{\Delta t} \\ &= \frac{V_s}{DQ} \Rightarrow \frac{V_c \cos \alpha}{\cos(\phi - \alpha) DQ} \end{aligned}$$

$$\text{Shear Strain Rate} = \frac{V_c \cos \alpha}{\cos(\phi - \alpha) DQ}$$

* Specific cutting energy:-

Energy Reqd for removing unit vol of material from the work piece is called Specific cutting energy.

$$= \frac{W.D}{M.R.R} \quad \frac{J}{mm^3}$$

Material Removal Rate = M.R.R

$$= \frac{F_c \times V_c}{t \times b \times V_c}$$

$$= \frac{F_c}{A_o} \quad N/mm^2$$

$$F_c = \frac{F_c}{A_o} = \frac{F_c}{t \times b}$$

Specific cutting pressure or
Specific cutting force.

A_o - crs Area of cutting chip.

* Significance:-

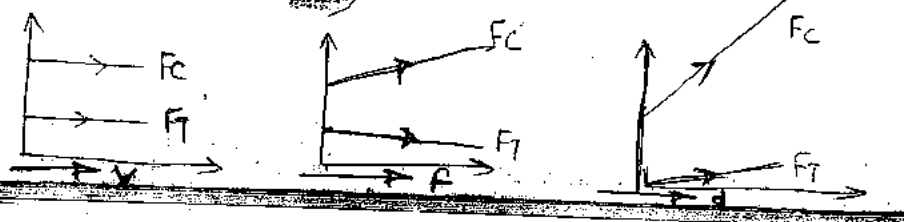
It is used for indicating the machinability of the given work piece material.

* Higher the specific cutting energy indicates Lower (poor) Machinability.

* FACTORS INFLUENCING FORCES IN MACHINING

① Process Parameters

$\left. \begin{aligned} V_c &= \text{speed} \\ f &= \text{feed} \\ d &= \text{depth of cut} \end{aligned} \right\}$



⑤ In oblique machining

★ Heat Generation :-

Machining operation also takes place according to 1st law of thermodynamics i.e. whatever

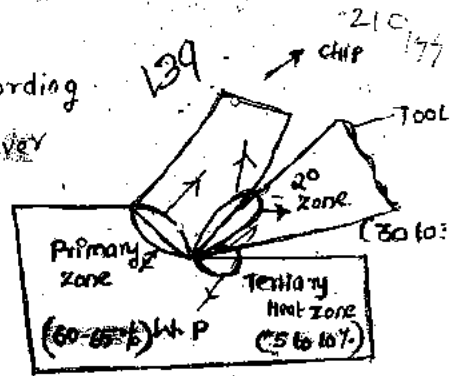
the energy supplied for machining operation

is simply converted to Heat energy.

$$H \cdot G = Q_g = W \cdot D = F_c \cdot V_c$$

Heat energy =

$$\text{Heat Generated} = F_c \cdot V_c$$



★ Primary Heat Zone :-

In the primary Heat Zone, when the shearing is taking place the

⇒ energy will be used for breaking the atomic bond b/w the

atoms of material so that atoms are releasing equivalent

amount of energy in the form of Heat energy. ∴ Heat

generation is taking place in the primary Heat Zone.

~~about 60-65%~~ of the energy supplied is converted into Heat energy in the Primary zone.

Out of the Heat generated in primary Heat Zone, ~~about 5-10%~~

~~amount of energy~~ is carried by chip and small amount of

energy is ~~transferred~~ to the work piece.

★ Secondary Heat Zone :-

Energy supplied is converted into Heat energy due to the

~~presence of friction~~ at chip/tool interface ~~about 5-10 to 35%~~

energy supplied is converted into Heat energy in 2nd Heat

Zone. Out of the Heat generated max amt of Heat is

~~carried away by chip~~ and a small portion is ~~transferred~~

to the tool.

★ Tertiary zone :-

In Tertiary zone Heat energy is generated due to the ~~friction~~ between tool and work piece. "About 5 to 10%" of energy supplied is converted into Heat energy. Out of Heat generated in tertiary zone ~~max amt~~ of Heat is transferred to work piece and a "small amt is transferred to the tool". By Assuming that Heat carried away by environment is negligible and cutting conditions, whatever the Heat generated during Machining will be carried away by chip, work piece and tool in decreasing order:

(chip, work piece, tool)

$$H.G = W.D = F_c \times V_c = \begin{matrix} H.C \text{ by [chip + w.p + tool]} \\ \downarrow \quad \quad \downarrow \quad \quad \downarrow \\ \text{Tool 5\%} \quad \text{Work piece 10\%} \quad \text{Chip 85\%} \end{matrix}$$

Assumption

From the Above the amount of Heat carried away by the tool is very small and Negligible so whatever the Heat generated will be assumed to be carried away by chip and work piece

$$W.D = W = H.C \text{ by [chip + w.p]}$$

$$H.C \text{ by chip} = W - H.C \text{ by work piece}$$

$$= W - a W$$

a = fraction of H.G is carried away by w.p

$$a = 0.15 = 0.2$$

$$m c_p \Delta T = W (1-a)$$

$$\Delta T = \frac{F_c V_c (1-a)}{m c_p} = \frac{F_c V_c (1-a)}{8 \times 10^{-3} \times V_c \times c_p} = \frac{F_c (1-a)}{8 \times 10^{-3} \times c_p}$$

$$T_{chip} = \Delta T + \text{Room temp.}$$

From the above if the temp of chip is becoming $\approx$ M.P of W.P. $\approx$ 145. material the chip may get adhered or welded back on to the tool or work piece - To Avoid this, adjust the process parameters such that the temp induced in the chip is less than the M.P of W.P material or use cutting fluids or coolants during machining. (1)

From the Above figure all the three Heat Zones are meeting at one point known as "Tip of Tool". Tip of Tool may experience very High temperature.

When the temp of tip of tool goes beyond Hot Hardness Temp of Tool material Tool tip is losing hardness considerably. Tip of Tool may deform plastically, can't perform



the Machining operation properly. To avoid the plastic deformation failure of Tool it is PLASTIC DEFORMATION OF TIP OF TOOL

needed to measure the temp of Tip of Tool. If it goes Beyond Hot Hardness Temp of Tool material, Adjust the process parameters such that the temp induced at the Tip of Tool is less than Hot Hardness Temp of Tool material.

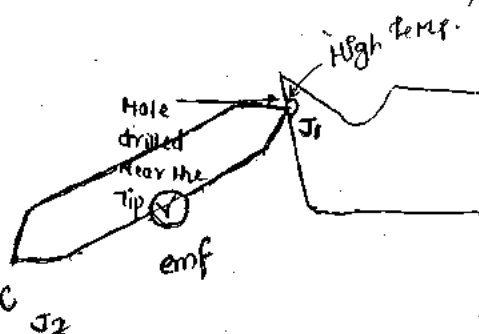
(2) - Select the Tool Mat. having Hot Hardness Temp. ↑

★ Methods of measurement

(1) Tool-Work Thermocouple

$emf \propto (T_1 - T_2)$ (Room Temp)

$emf \propto T_1$ { $T_2 = 0^\circ C$ }



When one end of the thermocouple is kept in Hole drilled near to the Tip of Tool, other end of Thermocouple

It is kept at 0°C so that emf generated in the circuit is measured by voltmeter and is directly proportional to Temp of Tip of Tool. If voltmeter is graduated in terms of Temp units, the Temp of Tip of Tool can be measured directly.

Limitations:-

(1) Thermocouples can be used for measurement of temperatures upto 800°C accurately, beyond which Error comes very high.

(ii) Generally during Machining of Titanium alloys the temp induced at tip of Tool is about 15000 to 18000°C .

It needs a method for measurement of temp above 800°C .

(iii) The tool work thermocouple must be used for determining the temp of stationary Tool Tip only. (drilling/milling cutting tool)
~~circuit measure.~~

Pyrometer:-

Pyrometer is a noncontact type of temp measuring method. It can be used for measurement of higher temp.

optical pyrometer
OR
disappearing filament
Type of pyrometer

(3) Calorimetric setup:-

this is used for measurement of temp of moving or rotating type of Tool Bit. (milling cutter, shaping, drill bits.)

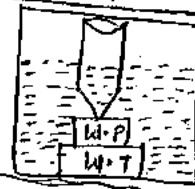
Based on the temp of diff elements in setup the heat equivalent of calorimetric setup will be calculated. Now the machining is performed for few seconds of time so that heat generated is absorbed by diff elements of set-up and its temp is increased. using this increase

in temp the Heat equivalent of calorimetric set up will be calculated again. using this Heat equivalent of set up before and after machining. Avg. Temp of tip of tool can be determined.

TOOL FAILURE: Whenever the tool is not performing machining operation satisfactorily it is called 'TOOL FAILURE'.

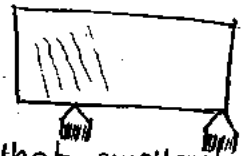
★ **TOOL FAILURE**

$$T_{tip} = \frac{T_{avg}}{0.4-0.5}$$



Online parameters used for measurement of surface finish in machining is

① **Surface finish produced on work piece.**



At the Beginning of Machining operation it is found that excellent and mirror like finish is produced on work piece. After Sometimes when the lines are produced on machined surface, it is assumed that surface finish is Reduced and tool is failed.

② **FORCES**

Connecting dynamometer to the work table the forces in machining will be measured online. Whenever the increase in forces is taking place more than 15% from the original forces it is assumed that Tool has been failed.

$$F_c = 150 \pm 10 \text{ N} \Rightarrow 1300 \pm 10 \text{ N.}$$

↑ 15%

③ **Power consumption**

Connecting ammeter to the input of electrical motor the current drawn by motor will be measured online, whenever the increase in current drawn by motor is greater than 15% from its original value, it is assumed that Tool has been failed.

④ **Temp of chip**

The Temp of chip can be measured by ...

- 1 - Surface Finish
- 2 - Forces
- 3 - Power

4) Colour of chip :-
 The colour during normal ~~cutting~~ satisfactory machining conditions the colour of chip is "light Blue" or "Metallic colour". When the machining is done with failure tool, becoz of higher heat generation the colour of chip is turned to "Black or Burned colour" from the above ~~the~~ whenever the colour of chip is observed to be Black or Burned colour tool is assumed to be failed.

5) During machining of (High carbon workpieces) whenever white coloured gases are observed, it is assumed that tool is failed. Due to ↑ in temp & ↑ pressure in chip can easily combine with O₂ present in atm and produces CO₂ which is observed as white coloured gas.

★ Modes of Tool Failure

1. Failure through plastic deformation
2. Failure through Mechanical Breakage
3. " " Gradual wear

★ PLASTIC DEFORMATION FAILURE :-

whenever the tip of tool is ~~experiencing temp~~ $\text{Temp} > \text{Hot Hardness of Tool material}$, it is losing its hardness considerably and the tip of tool is deforming plastically called as plastic deformation failure of the tool

Reasons :-

- (1) Wrong selection of tool material (Abnormal)
- (2) Wrong selection of process parameters (Normal)

It is a Abnormal failure of tool.

★ MECHANICAL BREAKAGE :-

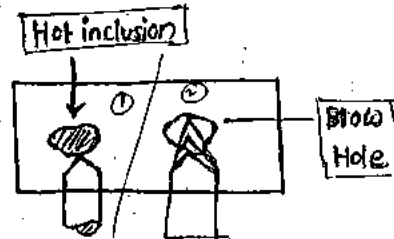
During machining operation due to the sudden increase in forces acting on tool, the tool tip getting chipping away suddenly, called as mechanical breakage.



Failure of the Tool. The sudden increase in the forces taking place is due to presence of Blow Holes in work piece or Hot 147

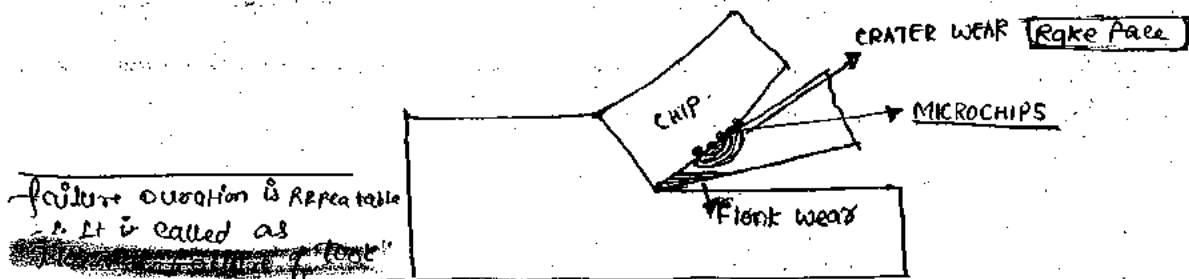
Inclusions in the work piece.

In this also the failure duration is Not Repeatable. ∴ It is also considered as "Abnormal failure of tool".



★ GRADUAL WEAR FAILURE:-

As the Machining Continues the wear ^(out) of the tool will be taking place continuously, whenever the wear ^(out) becomes considerable, the Tool cannot able to perform Satisfactorily called as Gradual wear failure of the Tool.

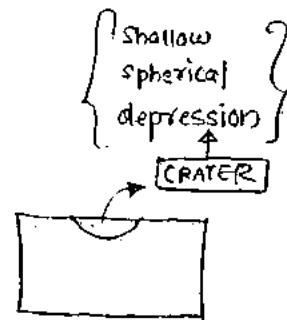


During Machining operation the tool is experiencing 2 types of wear

- CRATER WEAR
- FLANK WEAR

CRATER WEAR:-

The Wear Taking place on the Rake face of tool like a crater is called crater wear. i.e. the shape of wear taking place on Rake face is like a Crater. [A shallow spherical depression present on surface]

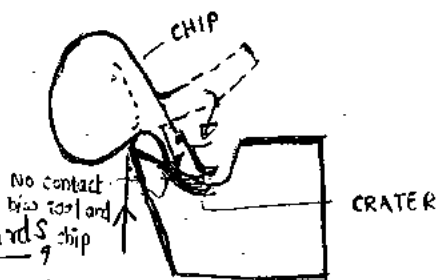


REASONS:-

- ① Presence of Friction b/w chip-tool interface
- ② Abrasive Action of Microchips present at chip-tool interface
- ③ Abrasive Action of Fragments of Built-up edge present @ chip-tool interface
- ④ DIFFUSION WEAR:- Sometimes bcoz of presence of atomic attraction b/w atoms of w/p and tool, the tool material atoms are diffusing from the tool and depositing over the work piece, so that wear of tool will be taking place called as diffusion wear. But it will not be taking place in all the cases. During machining of ferrous work pieces using diamond cutting tool diffusion wear is very high. To avoid this diffusion wear diamond tools should not be used for machining of ferrous work pieces.

⚡ In General During machining operation the crater wear takes place at some distance away from the tip of tool. this is bcoz of

When the upward force is acting by the tool on the layer of w/p material the chip will be directly lifting upwards,



but because of presence of self cut of

chip it is falling back on rake face of tool. In process of lifting up and falling back the chip does not have any contact with the

(Tool tip & chip) ~~Rate face of tool~~ ∴ No friction, No abrasive action, No diffusion. When the chip is falling back on to rake face of

- ② Tool ^(CMT) is trying to penetrate into the tool material. Hence it produces large amount of friction at some distance away from tip of tool; At that point the temp are higher, the mechanical properties of tool material are deteriorating. Hence the tool wear is high at some point away from the tip of tool which produces shape of wear like crater.

★. FLANK WEAR:-

Wear taking place on flank face of tool is called Flank Wear.

Reasons:-

1. Presence of Friction at tool work interface.
2. Abrasive action of microchips present at tool work interface.
3. Diffusion Wear.

As long as Machining parameters are kept constant the failure duration of the tool is ~~Remains constant or~~ Repeatable. ∴ It is considered as "Normal Failure".

TOOL LIFE:-

The Actual Machining Time b/w a successive Regrinds of a cutting tool is called Tool Life.

Regrind →

1. ~~Min~~ → General Method → Most Common
2. ~~No. of pieces produced~~ b/w 2 successive Regrinds of a cutting tool → ~~Mass production~~
3. vol of material removed b/w 2 successive Regrinds of a cutting tool is also termed as Tool Life → ~~Round machining~~

(MMVR)

★ FACTORS INFLUENCING TOOL LIFE :- 7

① Properties of Work piece Material :-

With increase of Hardness of W/P forces ↑ and power ↑
consumption increases, tool wear ↑ increasing % tool life ↓ decrease
(TEMP ↑)

When ductility of w/p increases, forces and power
consumption decreases, Tool wear decreases % tool life increases

But there is No quantitative relationship available
b/w prop of work and Tool life

② Tool GEOMETRY :- 7

As the Tool Geometry changing, like when Rake angle is increasing
the tool life will increase. But No quantitative relationships
are available b/w tool geometry and tool life.

③ USE OF CUTTING FLUID :-

When the cutting fluid is used during machining it is acting
as a lubricant in friction zone and carrying away the Heat generated
during machining. ∴ ~~friction~~ friction ~~machining~~ machining are Reducing and tool life
is increasing. with the use of cutting fluid, tool life is increasing
approximately by 25-40%.

④ PROCESS PARAMETERS :-

highest Influence
on Tool Life

Speed
feed
Depth of cut

Boz of uniqueness of
process parameters the Research
try to establish relationship
b/w process parameters and

Tool life. Taylor has assumed that cutting velocity is the
major parameter influencing the tool life. Hence he derived
the relationship b/w cutting velocity and ...

★ Taylor's Tool Life eqn:-

$$V T^n = \text{const} = C$$

$$V = \text{m/min}$$

Cutting
velocity

$$T = \text{min} / \text{No of pieces / vol of material removed}$$

$$C = \text{Taylor's const.}$$

= cutting vel for 1st tool life

n = Taylor's exponent depending mainly on cutting tool material.

$$n = \begin{cases} = 0.05 \text{ to } 0.1 \text{ for H-C steels} \\ = 0.1 \text{ to } 0.2 \text{ for H.S.S} \\ = 0.2 \text{ to } 0.4 \text{ for carbides} \\ = 0.4 \text{ to } 0.6 \text{ for ceramics} \\ = 0.7 \text{ to } 0.9 \text{ for diamond / CBN} \end{cases}$$

3★

Modified Taylor's Tool Life eqn: ↑

$$V T^n = C_1 F^{C_2} d^{C_3}$$

F = feed mm/rev

d = depth of cut in mm

P, Q are const

< 1

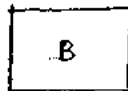
* ORDER OF INFLUENCE ON Tool-life: $P > Q$

$$V T^n = C$$



Machinability:

The Ease with which Machining of a given material can be done is called Machinability.



When more than one work piece is given, the Machining experiment will be conducted on the materials, during Machining one of the following parameters will be measured and Based on the value of measured parameter it is possible to decide which w/p will be easy in Machining.

① Specific cutting energy :- $\downarrow$ mc

* Lower the specific cutting energy, Better the Machinability.

② Tool Life :- $\uparrow$ mc

under Similar Conditions of Machining the workpiece on which higher tool life is obtained is taken as Better Machinability work piece.

③ Surface Finish :- $\uparrow$ mc

under similar Conditions of Machining the workpiece on which Better surface finish is obtained is called as Better Machinability work piece.

④ Forces and Power Consumption :- $\downarrow$ mc

under similar conditions of Machining Lower the forces and Power Consumption better will be the Machinability.

⑤ SHEAR ANGLE :- $\uparrow$ mc

under Similar Conditions of Machining the workpiece on which Higher:

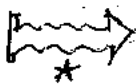
Shear angle can be used is considered as Better 216
Machinability work piece 135

⑥ MRR (Material Removal Rate): - $\uparrow$ m/c

under similar conditions of machining higher the MRR, higher will be machinability.

⑦ Type of chips:

under similar conditions of machining the work piece on which discontinuous chips are produced is considered as Better Machinability work piece

 The above method is used only when more than one work piece is given. If only one work piece is given, the machinability of each work piece will be compared with standard work piece and determine the machinability index (MI) for deciding the Machinability of work piece.

$$\text{Machinability index} = \frac{M.I. = \frac{V_T}{V_S}}$$

V_T = cutting velocity
for 60 mts Tool life
on test w/p

V_S = cutting velocity for 60 mts
Tool life on the standard
w/p

standard work piece:-

At the time of definition of machinability index it is found that cutting steel / free machining steel is having Highest Machinability. $\therefore$ it is taken as standard work piece.

So $M.I. < 1$

After the definition of machinability index there are many materials have been developed which has machinability greater than free cutting steel. But, still the free cutting steel is only taken as standard material and the value of machinability index has been changed to any value.

Composition of Free cutting steel

Any steel with upto 0.5% of sulphur, upto 0.5% phosphorus and 2-4% of Lead is nothing but free cutting steel.

ie the addition of {sulphur or phosphorus or lead} into the materials will increase the machinability of work material.
 { addition of S beyond 0.05, further increases machinability }
 { It also increases brittleness of W.P. we can't use in Eng. Appl. }
 Instead of using comparison with standard material

↑ - Brittleness

Lead ↑ M.P. ↓
W.P.

if the parameters during machining are measured and based on this the UMI (universal machinability index) can be determined sometimes without std. W.P. the

$$UMI = \frac{\cos(\beta - \alpha)}{\cos(\phi + \beta - \alpha)}$$

From Merchants circle

$$\frac{F_c}{\cos(\beta - \alpha)} = \frac{F_s}{\cos(\phi + \beta - \alpha)}$$

$$\frac{F_c}{F_s} = \frac{\cos(\beta - \alpha)}{\cos(\phi + \beta - \alpha)}$$

$$UMI = \frac{\cos(\beta - \alpha)}{\cos(\phi + \beta - \alpha)} = \frac{F_c}{F_s}$$

ECONOMICS OF MACHINING

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The method of determination of optimum process parameters for a given economic criteria of machining is called economics of Machining.

- ① Min cost criteria.
- ② Max prodn Rate criteria -- (lyk during war.)
- ③ Max profit criteria

Even though 3 process parameters are there, the cutting velocity is the one which has Highest influence on the Machining. $\therefore$ it is Req'd to determine the optimum cutting velocity for the given economic criteria of machining.

MIN COST CRITERIA

Total cost

$$T.C = C_A + C_E \text{ and } C_L + \underbrace{C_{mb} + C_t}_{+ C_{u \text{ and } I}}$$

C_A = Cost of Raw material

C_E and C_L = cost of Transportation and Loading

C_{mb} = cost of Machining

C_t = cost of Tooling

$C_{u \text{ and } I}$ = cost of unloading and inspection

out of above costs only Machining cost and Tooling cost are influenced by cutting velocity. $\therefore$ Total cost will be taken as

$$T.C = k_1 + C_m + C_t$$

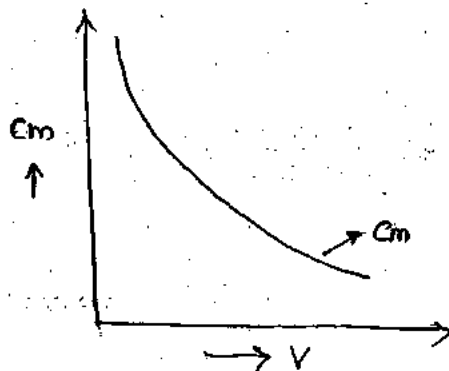
★ Cost of Machining :-
CASE OF MACHINING :-

★ $C_m = T_m \times L_m$

$= \frac{L}{FN} \times L_m$

$C_m = \frac{\pi L D}{1000 F V} \times L_m$

ie $C_m \propto \frac{1}{V}$



L_m = Machining Labour charges
in Rs/mt

T_m = Machining Time
in MTS

$T_m = \frac{L}{FN}$

L = Length of Tool Travel

F = feed

N = speed in rpm

$V = \frac{\pi D N}{1000}$

$N = \frac{1000 V}{\pi D}$

Cost of Tooling :-

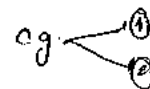
$C_t = \text{No of Tools Reqd} \times \text{Cost of one Tool}$

ex:

$T_m = 20$

Tool Life $T = 5 \text{ min}$

No of tools = $\frac{20}{5} = 4$



∴

$C_t = \frac{T_m \times C_g}{T}$

① C_g = cost of Regrinding

the tool one

Time, LA & tu

less, more Tip

② C_g = cost of one cutting edge if it is a throw away type of tool

For ex:



Cost of 1 cutting edge = 100 Rs/-

4 cutting edges

So $4 \times 100 = C_g$

$C_g = 400$

$$C_t = \frac{T_m}{T} \times C_g$$

$$= \frac{\pi D L}{1000 F V} \cdot C_g$$

$$C_t = \frac{\pi D L V^{\frac{1}{n}-1}}{1000 C^{\frac{1}{n}} \cdot f} \cdot C_g$$

$$C_t \propto V^{\frac{1}{n}-1}$$

We have

$$V T^n = C$$

$$T = \left[\frac{C}{V} \right]^{\frac{1}{n}}$$

$$n < 1$$

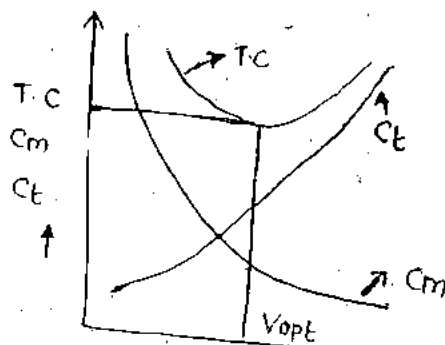
$$T.C = K_1 + C_t + C_m$$

$$T.C = K_1 + \frac{\pi D L V^{\frac{1}{n}-1}}{1000 C^{\frac{1}{n}} \cdot f} \cdot C_g + \frac{\pi D L \cdot L_m}{1000 F V}$$

For Min Total cost

$$\frac{d(T.C)}{dV} = 0$$

$\Rightarrow$



$$V = V_{opt} = C \left[\frac{n}{1-n} \cdot \frac{L_m}{C_g} \right]^{\frac{1}{n}}$$

$$T_{opt} = \left[\frac{C}{V_{opt}} \right]^{\frac{1}{n}} = \left[\frac{1-n}{n} \cdot \frac{C_g}{L_m} \right]^{\frac{1}{n}}$$

C = Taylor's const.
 n = -ve exponent.
 L_m = miling labour charge in ₹/min.
 C_g = cost of Replacing the tool ₹-time.
 cost

* Cutting vel. $\uparrow$. The total cost of component is Reducing $\uparrow$ and then Increasing $\therefore$ Total cost at some pt become min. corresponding to velo. is known as Optimum. velo.

★ MAXIMUM PRODUCTION RATE CRITERIA 'or' Min. total time criteria

For Maximising the Production Rate, the total time reqd for producing a component should be as minimum as possible.

this is also called minimum total time criteria.

$$T.T = T_{\text{Loading and Setting}} + T_m + T_{tc} + T_{\text{unloading and Inspection}}$$

$\downarrow$ Machining $\downarrow$ Total Tool change time

only the Machining time and tool change time are influenced by cutting velocity $\therefore$ other time's will be assumed as constant

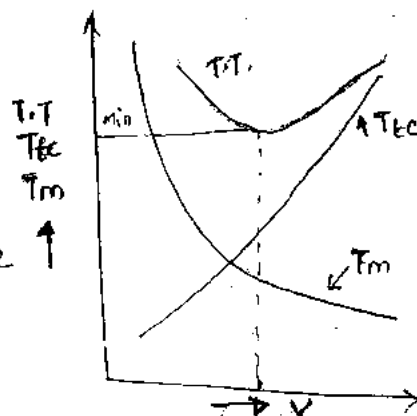
$$\therefore T.T = K_2 + T_m + T_{tc}$$

$$* T_m = \frac{L}{F \cdot N} = \frac{\pi D L}{1000 F V}$$

$$T_m \propto \frac{1}{V}$$

* $T_{tc} = \text{NO of Tools Reqd} \times \text{Time/change}$

$$T_{tc} = \frac{T_m}{T} \times T.c$$



$$T_{tc} = \frac{\pi D L V^{\frac{1}{n}-1}}{1000 F C^{\frac{1}{n}}} \cdot T_C$$

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$$T_{tc} \propto V^{\frac{1}{n}-1}$$

$$T.T = k_2 + T_m + T_{tc}$$

$$k_2 + \frac{\pi D L}{1000 F V} + \frac{\pi D L V^{\frac{1}{n}-1}}{1000 F C^{\frac{1}{n}}} \cdot T_C$$

With increase of cutting velocity the time reqd for producing a component is reducing first and then increasing. So at some point the time reqd will become minimum and corresponding velocity is called optimum cutting velocity

$$\frac{d(T.T)}{dv} = 0$$

$$V = V_{opt} = C \left[\frac{n}{1-n} \cdot \frac{1}{T_C} \right]^n$$

$$T_{opt} = \left[\frac{C}{V_{opt}} \right]^{\frac{1}{n}} = \left[\frac{1-n}{n} \cdot T_C \right]^{\frac{1}{n}}$$

optimum cutting velocity for the Maximum production Rate is the maximum velocity out of all the economic criteria of machining

Maximum profit criteria:-

$$\uparrow \text{Profit} = \uparrow S.P - T.C \downarrow$$

In General ~~price~~ price of a product depends on the market ~~fluctuations~~ market competition, but ~~not~~ on cutting velocity.

cutting velocity. $\therefore$ profit can be maximised by minimising the total cost for producing a component.

$$V_{opt} = \left[\frac{n}{1-n} \cdot \frac{L_m}{C_g} \right]^{\frac{1}{n}}$$

$$T_{opt} = \left[\frac{1-n}{n} \cdot \frac{C_g}{L_m} \right]$$

{ Min cost criteria }

Qualitatively :- (There is no sp. relation / Eqⁿ)

$$\begin{array}{c} V \uparrow \quad S.F \uparrow \Rightarrow \text{Quality} \uparrow \Rightarrow \text{selling Price} \uparrow \\ \downarrow \\ \text{Surface finish} \end{array}$$

V_{opt} for Maximum profit $>$ V_{opt} for min cost

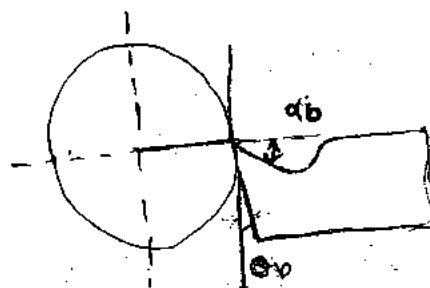
conclusion :-

$$(V_{opt})_{\text{Max profit}} > (V_{opt})_{\text{Min cost}}$$

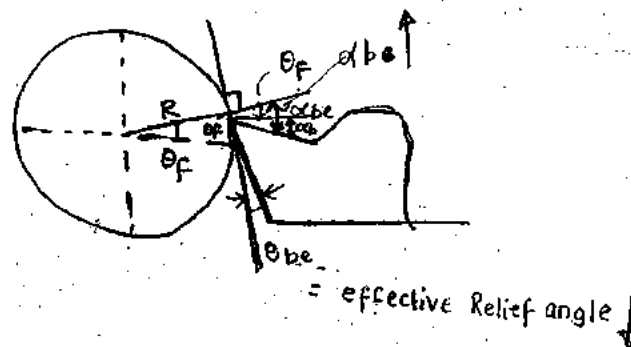
$$(V_{opt})_{\text{Min cost}} < (V_{opt})_{\text{Max profit}} < (V_{opt})_{\text{Max prodn Rate}}$$

$$(T_{opt})_{\text{Max prodn Rate}} < (T_{opt})_{\text{Max profit}} < (T_{opt})_{\text{Min cost}}$$

Effective Rake and Relief angles:-



Setting grinding operation tool can be set such that the tip of tool will coincide with centre of work piece. This setting will be done with reference to the tail stock dead centre only using eye judgement. So there is a possibility of setting the tool above or below the centre line of the work piece - If the tool is set above the centre line



$$\sin \theta_f = \frac{of}{R}$$

$$\Rightarrow of = \sin^{-1} \left(\frac{\theta_f}{R} \right)$$

$$\alpha_{be} = \alpha_b + \theta_f$$

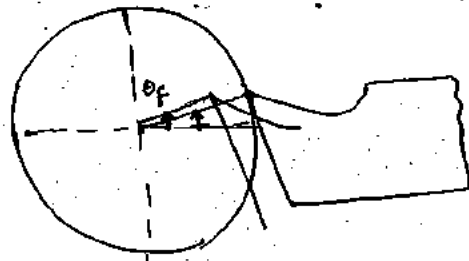
$$\theta_{be} = \theta_e - \theta_f$$

By setting the tool above the centre line of work piece the effective rake angle is increasing and effective relief angle is reducing:

Due to increase of effective rake angle, the chip flow become easier, the forces and consumption are power reducing, tool wear is reducing and tool life is increasing.

Due to decrease in effective relief angle, rubbing action between the tool and work is increasing.

During parting operation when the tool is set above the centre line. As the tool proceeds towards the centre even though the offset remains same bcoz of reduction in radius of work piece offset angle $\uparrow \theta_f$ increases which reduces effective relief angle. At some point the effective relief angle becomes equal to zero so that the tool is simply rubbing on to w/p without doing any machining. The corresponding diameter of w.p is taken as D' .



$\theta_f = \text{offset}$

$$\uparrow \theta_f = \sin^{-1} \left(\frac{\theta_f}{R_f} \right)$$

$$\theta_e = 0 = \theta_e - \theta_f$$

$$\theta_e = \theta_f$$

$$\sin \theta_f = \sin \theta_e = \frac{D_f}{R_f}$$

$$R_f = \frac{D_f}{\sin \theta_e}$$

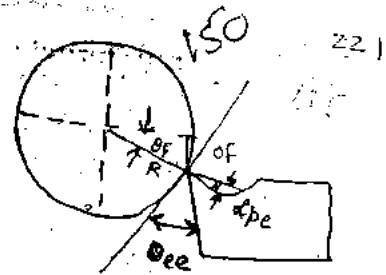
$$D' = 2R_f$$

Setting of Tool below centre line :-

$$\theta_f = \sin^{-1} \left(\frac{OF}{R} \right)$$

$$\alpha_{be} = \alpha_e - \theta_f$$

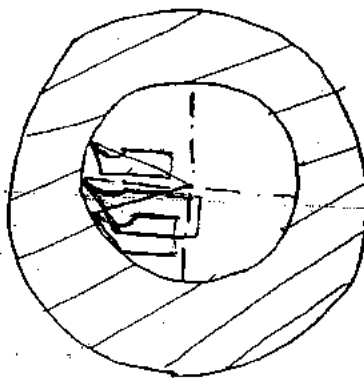
$$\theta_{ee} = \theta_e + \theta_f$$



Due to the decrease of effective rake angle, the forces ↑ and ↑ consumption will be increasing, tool wear is increasing ∴ tool becoming blunt very fast.

Because of increase of effective relief angle the rubbing action b/w Tool and work piece is completely eliminated.

Internal Turning or Boring operation :-



The effects of setting the tool above centre line in case of internal turning operation is remains as that of effects of setting the tool below centre line in the case of external turning operation and viceversa.

External Turning / parting off operation

$$D = 50 \text{ mm}$$

$$\alpha_b = 10^\circ$$

$$\theta_e = 6^\circ$$

$$of = 1.5 \text{ (above)}$$

$$\theta_f = \sin^{-1} \left(\frac{of}{R} \right) = \sin^{-1} \left[\frac{1.5}{25} \right]$$

$$= \underline{3.43^\circ}$$

$$\alpha_{be} = \alpha_b + \theta_f$$

$$\theta_{ee} = \theta_e - \theta_f$$

At Rubbing

$$\theta_{ee} = 0$$

$$\theta_e = \theta_f = 6^\circ$$

$$\sin \theta_e = \sin \theta_f = \frac{of}{R'}$$

$$R' = \frac{1.5}{\sin 6^\circ}$$

$$\underline{D' = 2R'}$$

$$\underline{\theta_e = 6^\circ}$$

BASIC PARAMETERS Req'd for Analysing the Given Machining operation as a orthogonal machining operation.

① $\alpha = \text{rake angle}$
 $= \alpha_b \text{ (A.S.A.)}$

} Property of (tool designation),
Tool

- 222
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- (2) t_1 = uncut chip thickness
 - (3) b = width of chip
 - (4) F_c = cutting force / vertical component of force
 - (5) F_T = Thrust Force / Horizontal component of force
- } "Measurable quantities"

$$\left. \begin{array}{l} t_1 = F \\ b = d \end{array} \right\} \text{ if } F, d \text{ are given} \\ \text{(Plain turning)}$$

$$\left. \begin{array}{l} t_1 = d \\ b = w \end{array} \right\} \text{ if } F, d, w \text{ are given} \\ \text{(Face turning)}$$

$$\left. \begin{array}{l} t_1 = F \\ b = w \end{array} \right\} \text{ if } F, w \text{ are given} \\ \left\{ \begin{array}{l} \text{face turning performed} \\ \text{in the method of} \\ \text{plain turning} \end{array} \right\}$$

F = feed

d = depth of cut

w = width of cut

★ OBLIQUE MACHINING ↓

ANALYSIS ↓

Because there is ~~no~~ direct methods are available for the analysis of oblique machining, the oblique machining has to be converted into orthogonal and then analyse it as orthogonal. For the conversion of oblique into orthogonal the above five parameters must be determined for the given oblique problem and then analyse it as a orthogonal machining problem.

② Shaping and planing operations (considered as)

shaping and planing are the single point cutting tool oblique machining operations and it has to be converted into single point cutting tool orthogonal M/c-ing.

$$\begin{aligned} \alpha &= \alpha_b [A-S-A] \\ &= \alpha [O-R-S] \end{aligned}$$

$$t_l = F \cos \lambda = F \sin \phi_s$$

$$b = \frac{d}{\cos \lambda} = \frac{d}{\sin \phi_s}$$

F_c = largest force

F_a = Next largest

F_r = smallest

$$F_a = F_T \cos \lambda$$

$$F_r = F_T \sin \lambda$$

$$F_T = \frac{F_a}{\cos \lambda}$$

$$F_T = \frac{F_r}{\sin \lambda}$$

$$* MRR = t_l b \cdot V_c = F d V_c$$

* TURNING AND BORING:

Turning and Boring are the single point cutting Tool oblique machining operations which is to be converted into single point cutting tool orthogonal machining operation.

$$\begin{aligned} \alpha &= \alpha_b [A-S-A] \\ &= \alpha [O-R-S] \end{aligned}$$

$$t_l = F \cos \phi_s = F \sin \lambda$$

$$b = \frac{d}{\cos \phi_s} = \frac{d}{\sin \lambda}$$

F_c = largest force

F_a = next largest force, F_r = min force

$$F_q = F_T \cos C_s \Rightarrow F_T = \frac{F_q}{\cos C_s}$$

$$F_r = F_T \sin C_s \Rightarrow F_T = \frac{F_r}{\sin C_s}$$

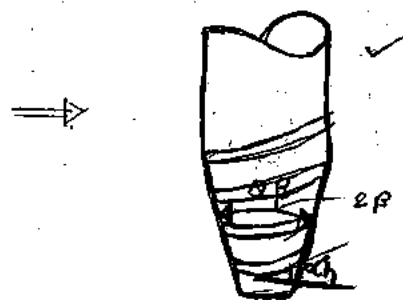
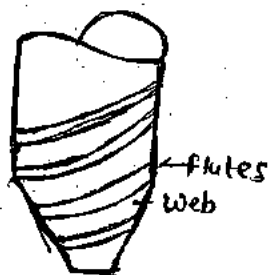
$$MRR = t_i \cdot b \cdot V_c$$

$$MRR = f \cdot d \cdot V_c$$

* DRILLING:-

Drilling is a multi-point cutting tool oblique machining operation, which is to be converted into single point cutting tool orthogonal machining.

$$\begin{aligned} \text{No of Flutes} &= \frac{\text{No of}}{\text{web}} \\ &= \text{even No.} \end{aligned}$$



Even No. is taken to balance the forces acting during machining

$$\alpha_h = \alpha_n = \tan^{-1} \left[\frac{\frac{1}{2} \tan \alpha_n}{\sin \beta} \right]$$

α_h = helix angle

β = half of point angle

$$2\beta = 118^\circ \text{ std}$$

$\alpha_h \rightarrow$ Angle made by flute or web with horizontal is called Helix angle

Helix angle :- α_h

Helix angle of a drill bit is varying from min at centre and Maximum towards periphery. The helix angle of

a drill bit is varying from min at centre to Maximum towards periphery. As helix angle ↑

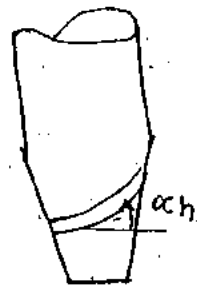
is varying the Back Rate angle of tool also is varying from min at centre to maximum towards

periphery. [Because of lower Back Rate at centre the tool

* tip will become very strong] [As the rake angle is

increasing towards periphery chip disposal becomes easier]

* [The variation of Helix angle is possible only in conical portion of drill bit]



Point Angle :- (2ϕ)

* $2\phi = 118^\circ$ (std angle)
std Point angle

* $2\phi > 118^\circ$ (during Machining of Hard work pieces)

* $2\phi < 118^\circ$ (soft work pieces)

* $= 45^\circ$ to 50° (very soft work pieces)
Ex:- Al, Cu, Brass

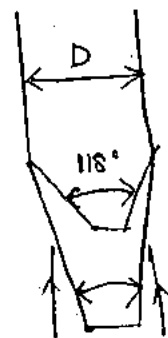
During Machining of Hard work pieces

the forces induced will be higher. ∴

if smaller point angles are used, conical

length of drill bit will be increased

∴ The chances of Buckling failure of drill bit increases.



Total Thrust force

length of drill Bit reduces. % even though forces are Higher the Buckling failure Reduces. 153

During machining of soft work pieces becoz the continuous chips are produced, for disposing them easily, it's need Higher helix angles and Rake angles are Required. for this longer conical length of drill Bit is Req'd. To get this smaller point angles must be used.



In final product. Drill Bit are producing the twisting op.

The twisted portion of drill Bit can be joined to shank by using "Friction welding operation".

$$t_1 = \frac{F \sin \beta}{2}$$

$$b = \frac{D}{2 \sin \beta}$$

Even though drilling is a oblique machining operation it is Not possible to measure the 3 components of forces acting during machining. The Measurable quantities of in drilling are

① Total Thrust force = $5 F_t \cdot \sin \beta$

$$F_t = \frac{\text{Total Thrust}}{5 \sin \beta}$$

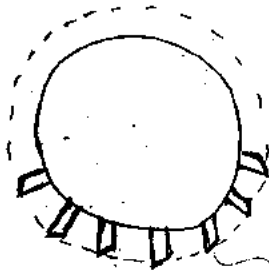
② Torque Required :-

$$T = 0.6 F_c \cdot D$$

$$F_c = \frac{\text{Torque}}{0.6 D}$$

1) MILLING

Milling also will be considered as a multi point cutting tool orthogonal machining operation which is to be converted into single point cutting tool orthogonal machining.



{ No. of cutting tool mounted on circular disc }
MILLING CUTTER:-

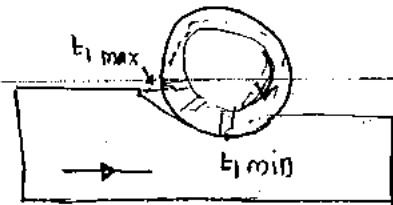
α - rake angle

If many No. of single point cutting tool tips are mounted around the circumference of a circular disc the milling cutter will be formed.

α = Rake angle

Seperate designation is used

* $t_1 = (t_1)_{\min} \text{ to } (t_1)_{\max}$
Rang
 $t_1 = \frac{t_1 \min + t_1 \max}{2}$



$t_1 \min = 0$

* $t_1 \max = \frac{2 f_m}{N Z} \sqrt{\frac{d}{D}}$

* $f_m = \text{Table speed / feed in mm/min}$

$= F \cdot N = F_t \cdot Z \cdot N$

$M = \frac{1000 V}{N D}$

F = table feed in mm/rev

F_t = table feed in mm/tooth

N = rpm of cutter

Z = No of teeth

d = depth of cut

*
c.o.

$$F_{max} = a f_t \sqrt{\frac{d}{b}}$$

$$f_t = \frac{f_m}{N Z}$$

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($f_t \Rightarrow$ Table speed
in mm/tooth)

$b = \min(\text{width of wp, width of Tool})$

$F_c =$ largest force

$F_a =$ Next largest

$F_r =$ smallest force

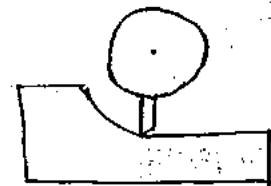
$$F_a = F_t \cos \gamma \Rightarrow F_t = \frac{F_a}{\cos \gamma}$$

$$F_r = F_t \sin \gamma \Rightarrow F_t = \frac{F_r}{\sin \gamma}$$

*
c.o.

$$MRR = L \times B \times F_m$$

in place of V_c
in other operations



SHAPING

Cutting Tool materials:

Basic properties which must be possessed by cutting tool material are

- (1) Tool material must be atleast 30 to 50% harder than the work piece material
- (2) Tool material must have high hot hardness temp
- (3) Higher toughness for withstanding the impact loads
- (4) High wear resistance to minimise the wear of the tool
- (5) High thermal conductivity for easy distribution of heat and
Avoid the High heat concentration at the tip of tool

- ⑦ Lower coefficient of friction
- ⑧ Easiness in fabrication and cheap

① High Carbon steel (H.C.S)

Olden days

very first cutting
Tool material

- ④ Rc 65
- ④ High Toughness
- ④ 250°C (Hot Hardness Temp)
- ④ Forging (Manufacturing method used)
- ④ Because forged components can be Regrinded, the Total Body of tool is made by using same material so that whenever Tool is failuring it can be resharpened by Grinding.
- ④ Maximum cutting velocity used (5m/min)

MATCH
THE FOLLOWING

Applications:-

used for Machining of very soft materials like Aluminium, copper, Brass etc. ~~mild~~ steel etc.

Even today chisels are made by using H.C.S as tool material
it has because the highest Toughness.

② High speed steel (H.S.S) or High Alloy steel

18-4-1 H.S.S



18% Tungsten
Mo + 4% Chromium + 1% Vanadium

{ 23% alloying
elements }

Steels	Low Alloy	< 5%	(% alloying elements other than Carbon)
	Medium Alloy	5-10%	
	High Alloy	> 10%	

⇒ The Tungsten or molybdenum is added to increase the Hot Hardness ↑ Temp of the Tool material

⇒ Chromium is added to increase the strength / resistance to deformation ↑ of material

⇒ Vanadium is added to improve the wear Resistance ↑ of Tool Material.

* If 18% W is used in H.S.S it is called Tungsten Based H.S.S

* If 18% Mo is used in H.S.S it is called as Molybdenum Based H.S.S

Even though Molybdenum is cheaper than Tungsten, Tungsten Based H.S.S will be the most commonly used, because the wear Resistance ↑ of Tungsten Based H.S.S is very much Higher than Molybdenum Based H.S.S.

④ Toughness < H.C.S

* Hot Hardness Temp = 600°C

* Forging (Manufacturing proc)

* Total Body can be made by using same material, { Regrounding / Reshaping }

* $(V_c)_{max} = 40-50 \text{ m/min}$

* Toughness < H.C.S

Applications:

Even today single point cutting tools used in Lathe, shaping and planing operations, multipoint cutting tool used in drilling and milling are used by H.S.S.

Beoz of presence of 76% of Iron in H.S.S, during Machining of High Carbon work pieces the Carbon atoms will get diffused from the workpiece and get deposited over the Tool forming a built up edge on the tool.

Hence H.S.S. tools should not be used for machining of High Carbon work pieces.

3) Stellite

(Non ferrous Cast Alloy)

① Cobalt $\rightarrow$ 40 to 50%

Chromium $\rightarrow$ 27 to 30%

Tungsten $\rightarrow$ 15 to 22%

Carbon $\rightarrow$ 2 to 5%

$\rightarrow$ All other prop. are same as H.S.S.

- ② Casting is the manufacturing method used.
- ③ Total Body can be made by using same material (Reshaping)
- ④ Hot Hardness Temp = 800°C
- ⑤ $(V_c)_{\text{max}} = 40$ to 50 m/min.
- ⑥ Toughness same as that of H.S.S.

STELLITE is developed as a substitute cutting tool material for machining of High carbon work pieces in place of H.S.S.

4) CARBIDE / TUNGSTEN CARBIDE / CEMENTED CARBIDE / SINTERED CARBIDE

① Tungsten is the major constituent element

② Manufactured by using powder Metallurgy

* Hot Hardness Temp = 1000°C

③ Throw away type of tips can be used

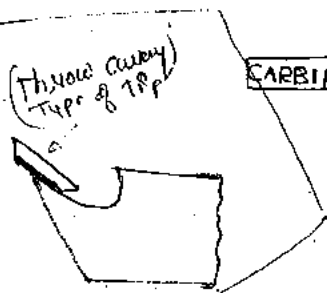
* ④ High Hardness $\uparrow$ so it can be Grinded _{not}

ECG can be used for Grinding but the cost is very high
Electro. chem. Grinding

⑤ Carbide cutting tools are very weak in tension i.e. even when small amount of deformation is experienced by the tool it breaks away.

Based on slight variation in composition of carbide, the carbides can be divided into three types.

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CARBIDE

- P type (Machining of steels & Ferrous Materials)
- K type (Machining of c.i, Non ferrous metals & Al, Cu, Non metals, Plastics, Composites etc.)
- M Type [General purpose cutting Tool Material]

P TYPE

P10 to P50

P10, P20, P30, P40, P50

K TYPE

K10 to K50

M TYPE

M10 to M50

The classification is Based on pressure applied during Compacting stage in Powder Metallurgy Manufacturing.

- ⊗ Lower the Number indicates Higher Hardness and Brittleness
- ⊕ Higher No indicates Higher ductility and Toughness

⇒ Rough Machining uses Higher No & Finish Machining uses Lower Number [May causes to produce large amount of Impact load. To withstand to this High Toughness is Req. and]

* $(V_c)_{max} = 300 \text{ to } 350 \text{ m/min}$ [Lower No. → ~~Higher No.~~]

⑤ CERAMICS -

- ⊕ Al_2O_3 major Constituent element
- ⊕ Powder Metallurgy
- ⊕ Throw away tips

(b) Hot Hardness Temp = 1200°C

(c) Low μ

(d) Very Low Toughness so Brittleness is very High so even small amount of force variation takes place on the tool also causes to failure the tool easily. Hence ceramic cutting tools are used only for continuous machining applications but not used for discontinuous machining.

[i.e. ^{for} ~~ex~~ shaping, Milling etc it can't be used]

$[V_c]_{\text{max}} = 400 \text{ to } 500 \text{ m/min}$

(6) CERMETSL

Ceramics + metals

(90%) (10%)

Here some qty of metal powders are added to increase the toughness ↑

When 10% of metal powders are added into ceramics, the properties of ceramics will be maintained nearly same but toughness ↑ will be increased by reducing the Brittleness ↓. ∴ Properties of cermets is same as that of ceramics but Toughness is higher and Brittleness is lower than that of ceramics. Hence cermets can be used for discontinuous machining operations also.

(7) DIAMOND :-

- Carbon is major component.
- Powder Metallurgy / Graphitisation*
- Throw away tips can be used.
- High Hot Hardness Temp around 2000°C
- High Thermal conductivity
- Higher Wear Resistance
- High Hardness
- High Toughness { Because of orderly oriented crystallographic structure of diamond }

* $(V_c)_{max} = 1500 \text{ to } 2000 \text{ m/min}$

Limitations:-

- ① High cost
- ② It can't be used for machining of ferrous materials because of ^(66°C) high diffusion wear.

⑧ CBN (Borazone) [cubic Boron Nitride] ♂ -

- ~~Diamond~~
- Powder Metallurgy*
- $2000^\circ\text{C} \rightarrow \text{HOT Hardness}$
- $(V_c)_{max} = 1500 \text{ to } 2000$
- cost is almost same as that of diamond

~~It can be used as a cutting tool material for machining of~~
~~ferrous materials~~ in place of diamond cutting tools.

⑨ UCON ♂ -

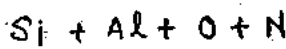
~~Composition:-~~

Titanium - 30%
Tungsten - 20%

The final Manufacturing Method used during manufacturing of UCON cutting Tool is, it can be rolled into sheets and cut in form of throw away type of Tool using wire cut EDM process

Properties of UCON is Better than diamond and CBN and cost also will be Higher than diamond and CBN. % it is not a commercially useful cutting tool material.

10) SIALON:



Highest

- ⊛ Powder Metallurgy
- ⊛ Properties of SIALON is better than UCON
- ⊛ cost of SIALON is higher than UCON. % it is also not a commercially useful cutting tool material.

Toughness ★

1-2-3-7-8-10-4-6-5

* Ceramics have lowest Toughness.

* H.C.S ↑ have Highest Toughness

★★★★★

Expect Toughness
it is in increasing
order

3 Types of Cer

$$V_c = 320 \text{ m/min}$$

which Type of cutting tool material can be used?

* Selection Based on cost

3 - types of Cer

- ① Inc. order of prop. of M. Tool
- ② Match the prop.
- ③ selection of tool

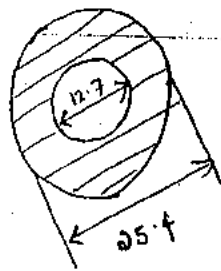
POINTS

- ① check whether orthogonal Machining is indicated in the problem if so analyse the problem as orthogonal Machining problem
- ② If it is not indicated as orthogonal check whether the problem belongs to part off operation, sawing operation, Broaching operation etc. If so it is assumed as orthogonal machining problem directly and solve it as orthogonal.
- ③ If it is Not indicated as orthogonal check whether the problem belongs to Tool life problem, economics of machining problem, effective rake and Relief angles etc, it need not worry not orthogonal or oblique, solve it by orthogonal machining.
- ④ If the problem doesnot belong to above three cases, it is assumed as oblique machining problem, convert into orthogonal and then analyse it as orthogonal.

SHEET METAL

P35

①



$B.S = 25.4 \rightarrow$ Blanking

$$B.S = D.S = 25.4$$

$$P.S = D.S - 2 \times C = 25.4 - 2 \times 0.04$$

$$= 25.32$$

$$C = 0.04$$

$$H.S = 12.7$$

Piercing operation

$$P.S = H.S = 12.7$$

$$D.S = P.S + 2 \times C$$

$$= 12.7 + 2 \times 0.04$$

$$= 12.78$$

$$F_{max} = F_{ax} + F_{bmax}$$

$$= 2.7 \times 12.5 \times 800 + \pi \times 25.4 \times 1.25 \times 800$$

$$40 \text{ kN} + 80 \text{ kN}$$

$$= \underline{120 \text{ kN}}$$

with shearing

$$F_{max} = \max(F_{pmax}, F_{bmax})$$

$$\max(40, 80)$$

$$= \underline{80 \text{ kN}}$$

$$F(kt) = F_{max} \cdot kt$$

$$F = \frac{120 \times 0.6 \times 1.25}{0.6 \times 1.25 + 1}$$

$$0.6 \times 1.25 + 1$$

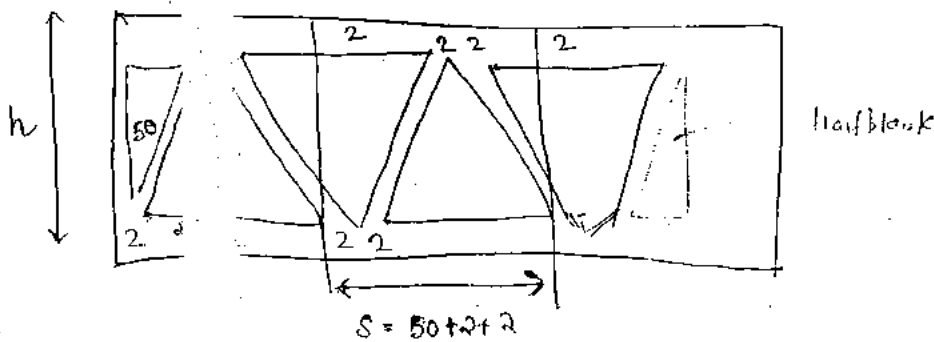
$$F = \frac{F_{max} \cdot kt}{kt + 1}$$

$$= \frac{F_{bmax} \cdot kt}{kt + 1}$$

$$= F_p + F_b$$

$$= \underline{\hspace{2cm}}$$

⑥



$$h = \sqrt{50^2 + 2^2 + 2^2}$$

$$= 54$$

$$\% \text{ utilisation} = \frac{2 \times \frac{1}{2} \times \text{height} \times \text{Base}}{h \times s}$$

$$= \frac{43.33 \times 50}{47.3 \times 54}$$

$$= \underline{84\%}$$

$$\text{No of pieces} = \frac{L}{s} = \frac{220 \times 2 - 1}{54}$$

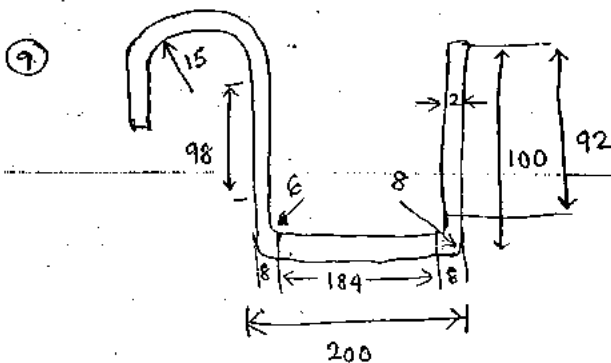
$$= \underline{7}$$

$$(F_b)_{\max} = \text{Perimeter} \times t \times \tau_u$$

$$= 317.5 \times 1 \times 420$$

$$(F_p)_{\max} = 2 \times \pi \times d \times t \times \tau_u$$

$$= 2 \times \pi \times 12.5 \times 1 \times 420$$



$$L_0 = 98 + 184 + 92 + B_1 + 2B_2$$

$$B_1 = \left(15 + \frac{1}{2} \times 2\right) \times 180 \times \frac{\pi}{180}$$

$$B_2 = \left(6 + \frac{1}{2} \times 2\right) \times 90 \times \frac{\pi}{180}$$

(9)

$$D = \sqrt{d^2 + 4dh}$$

(10)

$$= \underline{13.2}$$

$$d_1 = \frac{D}{DR_1} = \frac{13.2}{1.8} = 7 > 5$$

$$d_2 = \frac{d_1}{DR_2} = \frac{7}{1.8} = 4 < 5$$

$$P_1 = \pi d_1 t \sigma_y \left(\frac{D}{d_1} - C \right)$$

$$C = 0$$

$$P_1 = \pi D t \sigma_y = \pi \times 13.2 \times 1.5 \times 315$$

$$E_1 = W D_1 = P_1 \times h_1 = \underline{\hspace{2cm}}$$

(13)

$$F_{max} = P \cdot t \times 7u$$

$$= p \times 2 \times 145 = \underline{83.6 \text{ kN}}$$

$$\text{Work done} = F_{max} \times k t$$

$$= 83.6 \times 0.4 \times 2$$

$$= \underline{66.8 \text{ J}}$$

$$F = 24 \text{ kN}$$

$$F(k t + 1) = F_{max} \cdot k t$$

$$1 = \frac{F_{max} \cdot k t}{F} - k t$$

$$I = \underline{1.98 \text{ mm}} \approx \underline{2 \text{ mm}}$$

(16)

$$D = \sqrt{d^2 + 4dh}$$

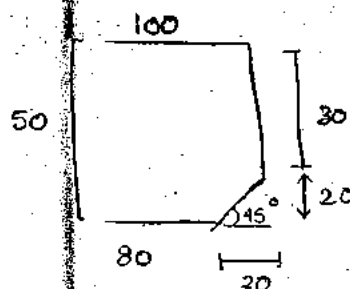
$$= \underline{30.2 \text{ mm}}$$

12

(18)

$$0.4 = \frac{D - d_1}{D} \Rightarrow d_1 = D(1 - 0.4)$$

$$= 30.2 \times 0.6 = 18.12 \approx \underline{18}$$



$$d_2 = d_1 (1 - 0.25) = 18 \times 0.75$$

$$13 > 12$$

$$\therefore n = 3$$

$$(17) \quad \sigma_{a1} = \frac{p_1}{\frac{\pi}{4} [d_1^2 - (d_1 - 2t)^2]}$$

$$\sigma_{a1} = \frac{\pi D t \sigma_y}{\frac{\pi}{4} [18^2 - 14^2]} = \frac{\pi \times 30.2 \times 2 \times 35}{[]}$$

$$\sigma_{a1} = \underline{\hspace{2cm}}$$

$$(21) \quad \frac{d}{n} = \frac{100}{6} = 16.6 \dots = 15 \text{ to } 20$$

$$D = \sqrt{d^2 + 4dh} - \frac{\lambda}{2}$$

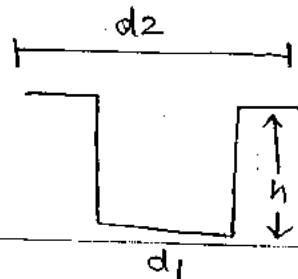
$$D_{\text{total}} = D + 2 \times T.A$$

$$= \underline{145}$$

$$(22) \quad D = \sqrt{d_2^2 + 4d_1 h}$$

$$D_{\text{total}} = D + 2 \times T.A$$

$$= \underline{99.25}$$



$$(23) \quad d$$

$$(24) \quad k = 0.5$$

$$I = t$$

$$F(kt + I) = F_{\text{max}} kt$$

$$F = \frac{F_{\text{max}} \times 0.5t}{0.5t + t} = \frac{F_{\text{max}}}{3} \cdot \underline{\hspace{2cm}}$$

(26)

b

(27)

25.13 kN

$$F_{\max} = \pi d t \tau_u$$

(28)

$$= \pi \times 10 \times 2 \times 400$$

$$= \underline{25.13 \text{ kN}}$$

(29)

$$5 = \pi d t \tau_u$$

$$d t \tau_u = \frac{5}{\pi}$$

$$F_{\max} = \pi \times 1.5 d \times 0.4 t \tau_u$$

$$= \pi \times 1.5 \times 0.4 (d t \tau_u)$$

$$= \pi \times 1.5 \times 0.4 \left(\frac{5}{\pi} \right)$$

(29)

$$D.S = B.S$$

$$P.S = D.S - a \times C$$

$$= 35 - 2 \times 0.04$$

$$= \underline{34.92}$$

(30)

$$K = 0.2$$

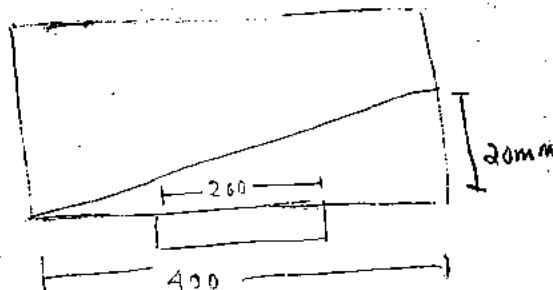
{ Penetration to }
{ Thickness Ratio }

$$F_{\max} = P \times t \times \tau_u$$

$$= 200 \times 5 \times 100$$

$$W.D = F_{\max} \times K \cdot t$$

$$= 200 \times 5 \times 100 \times 0.2 \times 5$$



400 - 20

200 - 2

$\frac{200 \times 20}{400} = 10$

$F(kl + I) = f_{max} \cdot kt$

$F = \frac{f_{max} \times 0.2 \times 5}{0.2 \times 5 + 10}$

- (32) a
- (32) b
- (34) 5% t
- (35) (a)
- (35) (b)
- (36) b

- (37) d
- (38) a 19.98
- (39) d 115.5
- (40) c 60%
- (41) d 43.98

- (42)
- (43) 14.3

37 without shear

- (43) c

* Parts in Lathe

- ① Bed
- ② Head stock
- ③ Tail stock
- ④ Carriage
- ⑤ Lead screw

- ① Function (s)
- ② Material
- ③ Mfg Method
- ④ shape etc

① Bed:-

Functions →

- * - Rigid enough
- * - Absorb vibrations (High Damping Qualities)
- * - It should act as house for keeping some other parts in

Material

Grey Cast Iron:

- because of Higher Rigidity and Higher & absorb vibration

[In this cementite will be in the form of granular form and having Rigidity] "Cementite → High Damping qualities"

Manufacturing Method:-

casting - becoz casted material have Higher strength & when compared to welded etc

Shape

X, I, H, C, S
shap. such that the reduction of rigidity of bed as min as possible and it should provide Max^m Area (space).

* Guideways



Guideways are used for guiding major part of m/c. It needs the High wear Resist. also guide ways acting as a mediator for transmitting the forces from tool to the bed of m/c tool. & it needs Higher toughness.

MGT:- High Carbon Steel, Iron, Carbon Steel, becoz it is wear resistant; by performing surface Hardening Heat Treatment, the surface of guideway, made Harder so that wear Resist of guideway will be more.

MFG:- The final Mfg Method used for producing the Guideway of m/c tool surface. Hardening Heat Treat more. The most common proc. is Flame Hardening.

SHAPE:- V-type gives automatic alignment bet bearing & is min. ∴

* Lead screw :-

Function :-

It is converting the Rotational movement into Linear movement

Material :-

Brass is used since it has the Highest wear Resistance. (split nut).
{ High Ductility, deflection prob. }

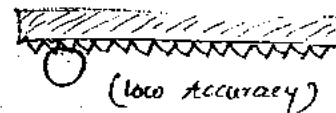
Maximum Length of Lead screw by using Brass is 2m.
(See Appl. - High Corrosion Resist)

Machining steel or stainless steel have the Next Highest wear

Resistance. i.e. over 2m if we have to increase the length upto - 10m

over 10m ~~length~~ Rack and pinion is used

Manufacturing Method :-



SHAPE :- ϕ Machining (or Gutter) or B

Square thread or Acme thread is used for power transmission

since it has highest efficiency of power transmission.

Prime Mover :-
① IC - Engine
② Electrical Motors

Whatever the energy Required for performing the Machining operation can be obtained from the prime mover. In the

(Initially) The very first M/c tool the IC engine was used as the

prime mover. But with IC engine the Noise pollution is very high and bcoz of presence of Reciprocating parts, the vibrations induced in M/c tool is also very High. $\therefore$ once after the

② invention of electric motors, the electrical motors are only used as prime movers in M/c tool.

Reciprocating parts create unbalancing of forces. The Reciprocating parts can't be tool balanced

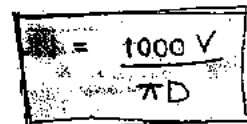
* Types of Motors:

- Induction Motors ✓ : (1440 rpm)
- Stepper Motors
- Servo Motors

Because of lower cost, the induction motors are the most commonly used ~~motors~~ in the prime movers in conventional M/C tools.

In the induction motor whenever the power supply is given to the motor it always starts rotating at one particular rpm i.e. designed rpm:

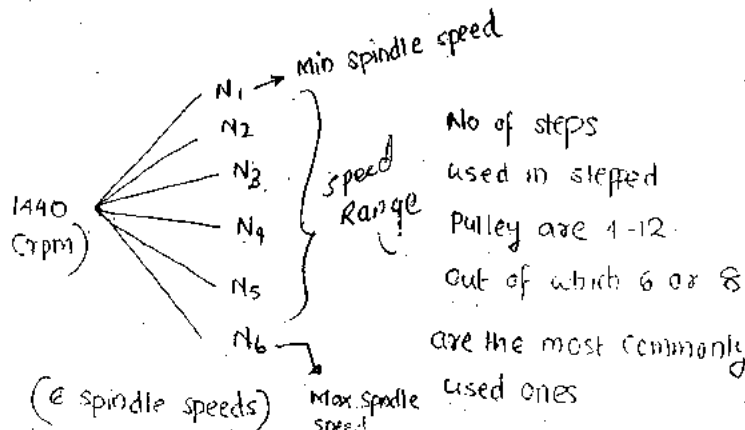
(1440 rpm)

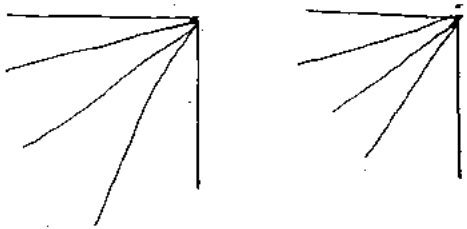


~~When the prime mover~~ Even though prime mover is rotating at designed rpm, to get the variable rpm of spindle or job to machine diff materials having different diameters it needs to use a mechanical transmission system b/w the prime mover and the spindle.

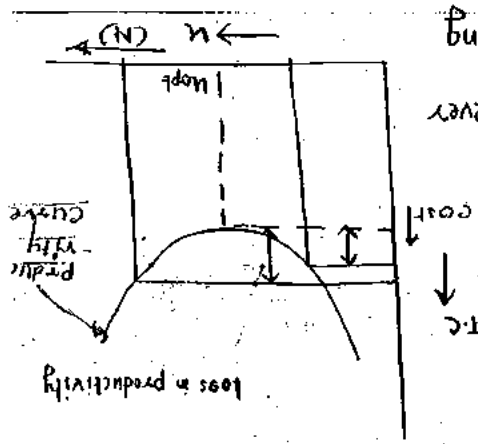
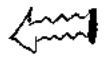
* Transmission system:-

"The belt drive with stepped pulley" is used as a mechanical transmission system for obtaining the variable rpm because any sudden increase in the forces during machining will cause to ~~slip the belt~~ only and the prime mover and mechanical transmission system are always safe.





of spindle speeds. The best optimum spindle speeds may not be available in m/c tool. So it is always recommended to use the nearby spindle speeds. When nearby spindle speed is used always some amount of productivity loss will be taking place. This productivity loss is minimum if spindle speeds are designed in geometric progression.



the calculation of spindle speeds in m/c tool is always done by using geometric progression because with whatever may be the progression used in designing

A.P.
G.P.
H.P.

$$N = \frac{1000 V_{opt}}{D}$$

$$\text{eg } N = 162 \text{ rpm}$$

* Geometric progression is used for design of m/b/w speeds. Calculation of m/b/w spindle speeds: ↑

$$\frac{N_{max}}{N_{min}} = \text{Speed Range Ratio} = \frac{V_{max} \cdot D_{max}}{V_{min} \cdot D_{min}}$$

N_{max} to N_{min} = Speed Range of a m/c tool

$$N_{max} = \frac{1000 V_{max}}{\pi D_{min}}$$

Max spindle speed

$$N_{min} = \frac{1000 V_{min}}{\pi D_{max}}$$

Min spindle speed

9)

Suppose $N_1 = N_{min} = 35$

$N_6 \rightarrow N_{max} = 353$

6 spindle speeds are there

cal the inbtw spindle speeds

?

Ans:-

$$\frac{N_6}{N_1} = \frac{N_6}{N_5} \times \frac{N_5}{N_4} \times \frac{N_4}{N_3} \times \frac{N_3}{N_2} \times \frac{N_2}{N_1} \quad \text{--- (G.P.)}$$

$$= \phi \times \phi \times \phi \times \phi \times \phi$$

$$\frac{N_6}{N_1} = \phi^5$$

ϕ = COMMON RATIO

$$\phi = \sqrt[5]{\frac{N_6}{N_1}} = \sqrt[5]{\frac{353}{35}}$$

*

$$\phi = \sqrt[5]{\frac{N_{max}}{N_{min}}}$$

General Eqn 8-

$$\left\{ \begin{array}{l} N_1 = 35 \\ N_2 = N_1 \phi \\ N_3 = N_1 \phi^2 \\ N_4 = N_1 \phi^3 \\ N_5 = N_1 \phi^4 \\ N_6 = N_{max} = 353 \end{array} \right.$$

COMMON PARAMETERS USED IN MACHINING PROCESS:-

1. $V = V_{opt} = V_c$ - cutting velocity

V_c is the relative velocity b/w the Tool and Workpiece.

optimum cutting velocity is decided Based on the criteria of machining, properties of work material and Tool

Geometry

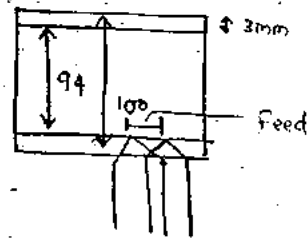
(2) N = spindle speed

$$N = \frac{1000 \text{ Vopt}}{\pi D}$$

For the calculation of spindle speed

it is always Recommended to use

Maximum dia to which the Tool is getting exposing in a given cut.



(3) F = Feed

The Linear distance travelled by the Tool along the length of Tool for one Revolution of work piece is called feed. It is always specified in mm/Revolution.

$$\begin{aligned} \text{Feed Velocity} \rightarrow FN &= \frac{\text{mm}}{\text{rev}} \times \frac{\text{rev}}{\text{min}} \\ &= \frac{\text{mm}}{\text{min}} \end{aligned}$$

It is the Linear velocity of tool along the length of workpieces

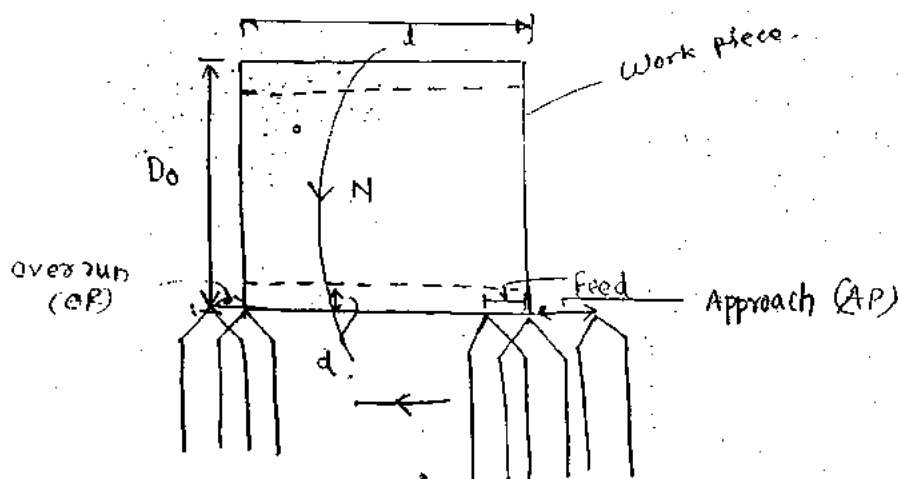
(4) Depth of cut = d

It is the depth by which the Tip of Tool is penetrating into workpiece from surface. It is always specified in mm.

Eg: LATHE MACHINE : 1 Diff. Op. perform on Lathe Mle.

(1) PLAIN TURNING -

the Turning operation used for Reducing the dia of work piece is called plain turning operation



$$\text{Time/cut} = \frac{\text{Length of Tool Travel}}{\text{Feed velocity}}$$

$$= \frac{L}{FN}$$

$$L = l + \text{Approach} + \text{Overrun}$$

$$L = l + AP + OR$$

D_0 = Initial diam.
 D_f = final diam.

f = feed

N = rpm

$$N = \frac{1000 V}{\pi D_0}$$

$D_0 =$

eg if $D_0 = 100\text{mm}$

$D_f = 80\text{mm}$

$d_{\max} = 3\text{mm}$

$$\text{No of cuts} = \frac{\text{Total dia Reduced}}{\text{Dia Reduced / cut}} = \frac{D_0 - D_f}{2d_{\max}}$$

$$= \frac{100 - 80}{6} = \frac{20}{6} = 3.3 \approx \underline{4 \text{ cuts}}$$

$$\text{Total Time (TT)} = T_1 + T_2 + T_3 + T_4$$

Here L and f are Remaining same but N is changing as dia goes on changing.

$$TT = \frac{L}{f} \left[\frac{1}{N_1} + \frac{1}{N_2} + \frac{1}{N_3} + \frac{1}{N_4} \right]$$

$$TT = \frac{L}{f} \left[\frac{1000V}{\pi D_0} + \frac{1000V}{\pi D_1} + \frac{1000V}{\pi D_2} + \frac{1000V}{\pi D_4} \right] \quad 165 \quad \begin{matrix} 230 \\ 120 \end{matrix}$$

$$D_1 = D_0 - 2d_{\max} = 100 - 3 \times 2 = \underline{94 \text{ mm}}$$

$$D_2 = 94 - 2d_{\max} = 94 - 3 \times 2 = \underline{88}$$

$$D_3 = 88 - 3 \times 2 = 82 \text{ mm}$$

$$\star \text{ Total Time} = \frac{NL}{1000V} [D_0 + P_1 + D_2 + \dots]$$

$$n \leq 5$$

$\star T_{\text{avg}}$

$$TT = T_{\text{avg}} \times \text{No of cut}$$

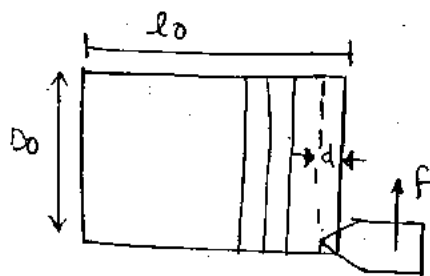
{ It can used when? }
The No. of cut ≤ 5

$$n > 5$$

$$\left. \begin{aligned} T_{\text{avg}} &= \frac{L}{f N_{\text{avg}}} \\ N_{\text{avg}} &= \frac{1000V}{\pi D_{\text{avg}}} \\ D_{\text{avg}} &= \frac{D_0 + D_n}{2} \end{aligned} \right\}$$

② FACETURNING

Turning operation used for Reducing length of the component is called Face Turning



$$L_1 = L_0 - d$$

$$L_2 = L_1 - d$$

$$\text{Time/cut} = \frac{\text{Length of Tool Travel}}{\text{Feed velocity}} = \frac{L}{fN}$$

$$L = \frac{D_0}{2} + AP + OR \rightarrow \text{solid}$$

$$\frac{D_o - D_i}{2} + AP + OR \rightarrow \text{Hollow}$$

f = feed in mm/rev

$$N = \frac{1000 V}{\pi D_o}$$

$$T.T = \text{Time/cut} \times \text{No of cuts}$$

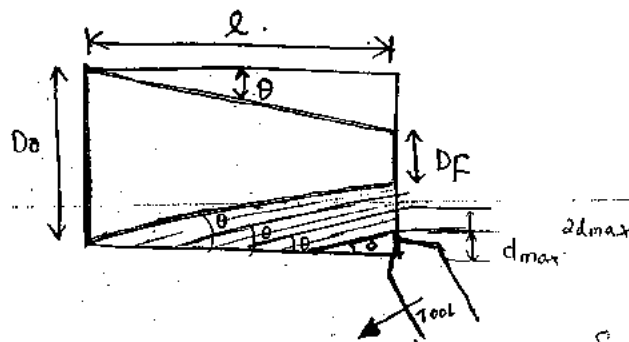
$$\frac{L}{fN}$$

$$\text{No of cuts} = \frac{\text{Total Length Reduced}}{\text{Length reduced/cut}}$$

$$= \frac{L_o - L_t}{d_{\max}}$$

③ TAPER TURNING:

The turning operation used for producing tapered components on a lathe machine is called taper turning.



$d_{\max}$ = max depth of cut

θ = taper angle

$$\text{Time/cut} = \frac{L}{fN}$$

f = feed in mm/rev

$$N = \frac{1000 V}{\pi D_o}$$

L = inclined length of Tool Travel

N - remains const since during every cut Tool is exposed to Max dia

$$\tan \theta = \frac{D_o - D_f}{2L}$$

237
166 101

$$\sin \theta = \frac{d_{\max}}{L_1}$$

$$L_1 = d \times \operatorname{cosec} \theta$$

$$L_2 = 2d \times \operatorname{cosec} \theta$$

$$L_3 = 3d \operatorname{cosec} \theta$$

$$L_n = nd \operatorname{cosec} \theta$$

$$T.T = T_1 + T_2 + T_3 + T_4 + \dots$$

$$= \frac{1}{FN} [L_1 + L_2 + L_3 + \dots]$$

$$= \frac{1}{FN} [d \operatorname{cosec} \theta + 2d \operatorname{cosec} \theta + 3d \operatorname{cosec} \theta + \dots]$$

$$T.T = \frac{d \operatorname{cosec} \theta}{FN} [1 + 2 + 3 + \dots]$$

$$T.T = \frac{d \operatorname{cosec} \theta}{FN} \left[\frac{n(n+1)}{2} \right]$$

④ THREAD CUTTING:-

$$\text{Time/cut} = \frac{L}{FN}$$

$$L = l + AP + OR$$

$F = \text{Pitch} \rightarrow \text{Single start}$

$F = \text{Lead} \rightarrow \text{Multi start}$

$$\text{Lead} = p \times \text{no. of start}$$

In case of plain, face & taper turning operations large

operation. But in case of thread cutting feed is taken as pitch or lead of threads only.

$$\text{Lead} = P \times \text{no of starts}$$

Multistarts Applications:-

① For leak proof joints

eg: water bottle

② Higher mechanical Advantage

$$M.A = \frac{Q/P}{F/P}$$



{ min 4 start threads will be there }

Rules of Heavy Vented
(Screw Jack)



single



Double



triple

$N = \text{rpm of JAB}$

$N = 5 \text{ to } 10 \text{ rpm}$

Min speed possible in m/c tool

30 rpm

But in General min rpm available in a lathe m/c is 30 or

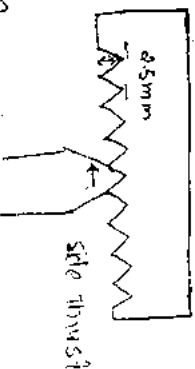
40 rpm only. But to get this very low rpm reqd for ^{ONLY} thread cutting operation is obtained by using Back gear arrangement available in Head stock of lathe m/c.

or

Reverted Gear TRAIN

Suppose $d_{\text{max}} = 3 \text{ mm}$

depth of thread 2.5 mm



$d_{\text{max}} = 3 \text{ mm}$

Even though total Depth of threads is less than max depth of 2.58 cut possible in a m/c tool it is always recommended to use more than one cut because when Thread cutting is 16T done with large amount of depth of cut there is some amount of sideward Thrust force is Acting which will try to shear off the threads and make the threads weak. To Avoid this problem many no. of cuts will be used.

$$\text{No of cuts} = \frac{25}{\text{TPC}} \rightarrow \text{external thread}$$

$$= \frac{30}{\text{TPC}} \rightarrow \text{internal thread}$$

$$\text{total time} = \text{time/cut} \times \text{No of cuts}$$

In The Earlier Turning operations, the feed used will be either Manual or Automatic. But in the case of thread cutting operations the feed used must be only Automatic.

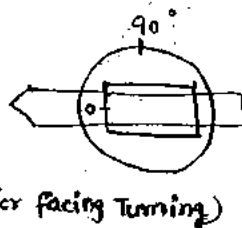
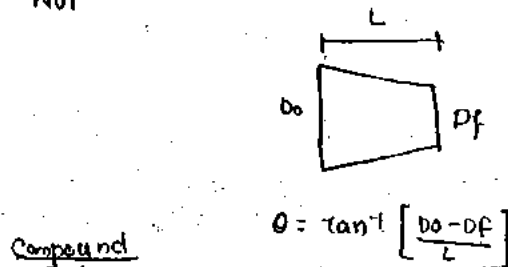
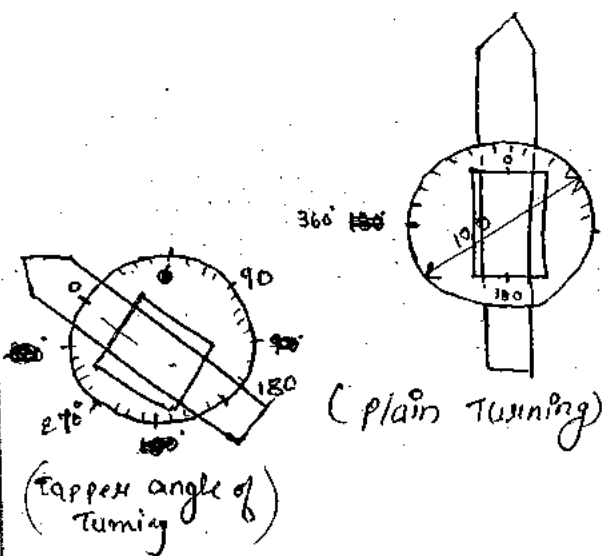
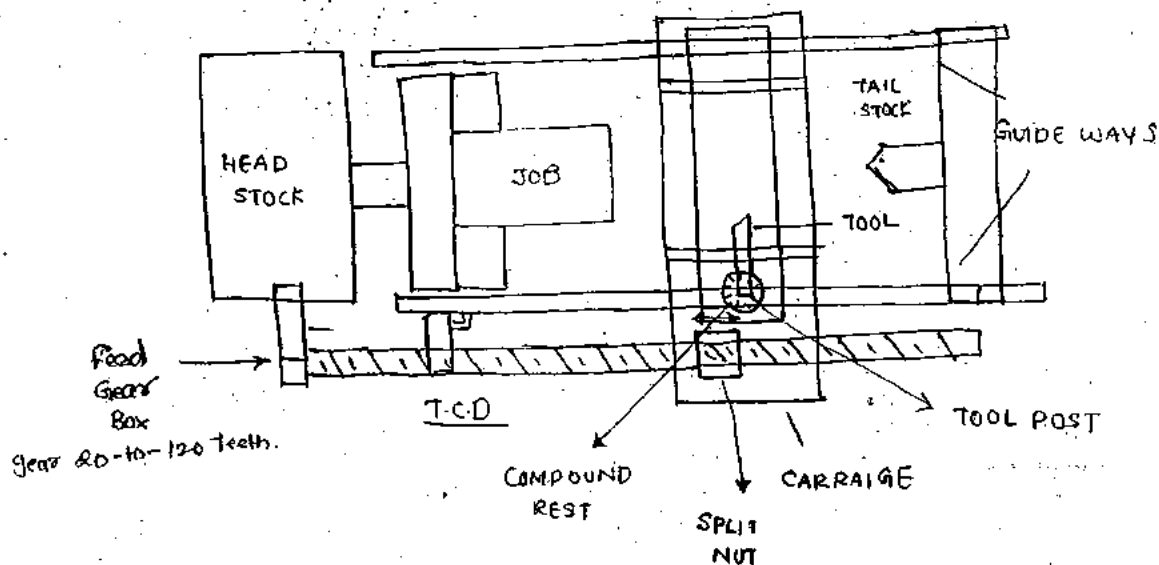
~~The~~ different Automatic feeds used for thread cutting operation is obtained from spindle through a feed Gear Box ^{with} Lead screw and split Nut Mechanism.

* Methods of Taper Turning:-

- ① compound Rest Method
- ② Tail stock offset
- ③ Taper attachment
- ④ Form Tool Method

The selection proper No. of teeth in gear box, sup. amt of the feed can be obt.

In feed gear box The 127 teeth gear is used for producing the Metric Thread on English lathe or English thread on metric lathe.



For plain turning operation the zero of compound Rest is coinciding with fixed mark. For face turning and Internal turning the 90° of compound Rest is coinciding with fixed mark. In Taper Turning the compound Rest is swiveled by an angle equal to Taper angle of the component. Compound Rest method is also used for Internal/External taper turning of work with any angle upto 45°.

Features of compound Rest Method

- ① It can be used for Both internal and external Taper Turning.
- ② Any Angle of Taper can be produced upto 45°.

circumference

314 → 720 divisions

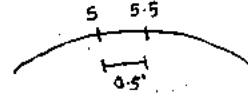
2.57

$$\frac{314}{720} = 0.44 \approx 0.5 \text{ degrees}$$

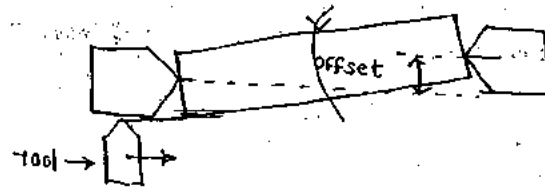
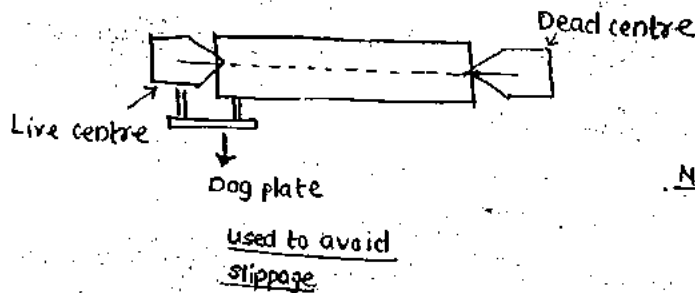
168

(Limitation):-

- ③ The Accuracy of Angles produced is upto 0.5° only



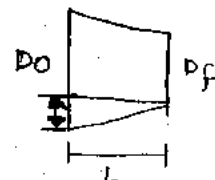
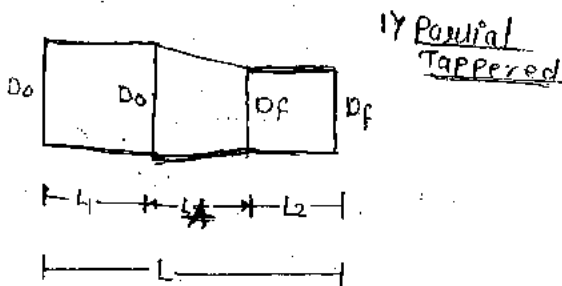
★ TAIL STOCK OFFSET METHOD:



When the Tail stock dead centre is offset by same amount and the work piece is mounted b/w centres. Now as the tool is moving like a plain turning operation it produces tapered components.

Amount of offset to be provided:

2) fully taper



Taper/mm = []

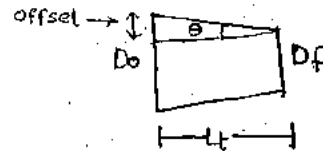
* Taper percent on component

Total Taper = offset

$$= \text{Taper/mm} \times L$$

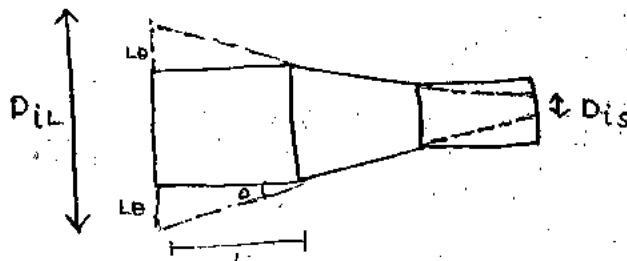
$$\left[\frac{D_o - D_f}{2L_t} \right] \times L$$

$$\text{Taper Angle } \theta = \tan^{-1} \left[\frac{D_o - D_f}{2L_t} \right]$$



*

$$\begin{aligned} \text{Total Taper} &= \text{offset} \\ &= L \times \tan \theta \end{aligned}$$



$$\text{offset} = \frac{D_{iL} - D_{iS}}{2}$$

D_{iL} = imaginary large dia

D_{iS} = imaginary small dia

Features:-

- ① It is used only for external taper turning operations

In std lathes Tail stock can be offsetted by 10 mm

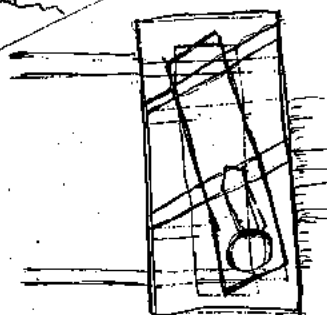
- ② Any job which requires offset more than 10 mm can't be produced by Tail stock offset method.

- ③ The Accuracy of angles produced is upto 0.1 degrees

④ TAPER ATTACHMENT METHOD

In Normal ~~taper~~ turning methods slide ways are kept parallel to guide ways.

But in Taper turning method the slide



Taper angle of component - As the slide ways are tilted the saddle etc also will be tilted automatically. i.e. even though zero of compound Rest is coinciding with fixed mark the tool is getting tilted. when the tool is moving now on slide ways it produces tapered component.

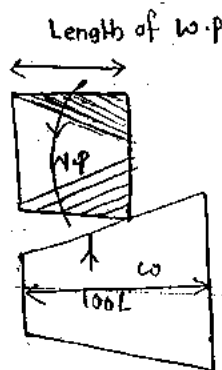
Features:-

- ① It can be used for Both internal and external taper turning.
- ② The maximum taper angle produced is 8 degrees ~~only~~ becoz maximum tilt of slide ways is 8°.

- ③ The Accuracy of taper produced is upto 0.1°
- ④ The Max dist travelled by the saddle is upto 235 mm only.

④ FORM TOOL METHOD

If the shape of tool used is same as that of the component to be produced is called as Form Tool method of Machining operation, for producing the tapered component the shape of tool used must be Taper shape.



For Taper turning

$W > \text{Length of W.P.}$

$W = \text{width}$

Max. $W = 20 \text{ mm}$

Features:-

- ① used only for external taper turning.
- ② The Amount of taper angle produced on the component depends on the amount of taper angle present on the tool.
- ③ Accuracy of Taper angle produced in the component depends on the Accuracy of Angle of taper present on the tool.
- ④ for Every taper ~~separate~~ tool must be used.
- ⑤ No ~~adjustment~~ for angle of taper.

Because the width of Tool is to be greater than length of workpiece, the max width of Tool possible is 20 mm only. $\therefore$ max length of W.P which can be tapered by using form Tool method is 20 mm only.

ex A component having total length 250 mm in which central 100 mm length of component has to be tapered to an included angle of 4 degrees. which of the following methods can be used for this purpose.

$$2\theta = 4^\circ \quad \theta = 2^\circ$$

① compound Rest method ② Tail stock offset ③ Taper attachment

④ Form tool.

a) 1, 2, 3 & 4 b) 1, 2 & 3 c) 1 & 3 d) 1, 3 & 4

$$\text{offset} = L \tan \theta$$

$$= 250 \tan 2^\circ$$

$$= \underline{\underline{8.5}} < 10 \text{ mm}$$

{ external taper }
turning

Feed Gear Box.

Gears each one gear with gear teeth 20 to 120 in steps of 5 teeth and 127 teeth gear is available

20, 25, 30, 35, 40, 45, ... 120 and 127.

To produce required pitch of threads on job using a lead screw in lathe machine; it is reqd to design a gear train in feed gear Box by using available gears in feed Gear Box.

available in feed Gear Box Producing

127 teeth Gear is mainly used for english threads on metric.

Lathe or metric threads on english lathe

If the pitch of threads in job is indicated in terms of mm or 24, mm/cm it is called as metric threads. If the pitch of threads is indicated in terms of inches it is called as English threads. 170

If pitch of Lead screw thread on a Lathe M/c is indicated in terms of mm/cm is called Metric lathe. If the pitch of Lead screw threads on a Lathe is indicated in terms of inches, it is called English lathe.

(If the pitch of thread on lathe m/c is indicated in inches)

$$\text{Train value} = G.R. = \frac{\text{Speed of Follower}}{\text{Speed of Driver}} = \frac{N_{LS}}{N_{Job}}$$

Spindle - Driver

Lead screw - Follower

$$= \frac{T_{\text{driver}}}{T_{\text{follower}}} = \frac{P_{\text{driver}}}{P_{\text{follower}}}$$

$$= \frac{P_{\text{Job}}}{P_{\text{Lead screw}}} = \frac{\text{Lead of Job Threads}}{\text{Lead of Lead screw Threads}}$$

by using G.R. = Gear Ratio

The change gear req. on feed gear box can be calculate

Q. Calculate suitable gear trains for cutting 10 mm pitch 3 start threads on a lathe with lead screw 6.25 mm pitch?

Soln:

$$\text{Train value} = \frac{N_F}{N_D} = \frac{10 \times 3}{6.25} = \frac{30}{6.25}$$

$$\frac{30 \times 4}{6.25 \times 4} = \frac{120}{25} \quad \left[\text{Simple Gear TRAIN} \right]$$

$$\frac{10 \times 4}{6.25 \times 4} \times \frac{3}{1} \times \frac{20}{20}$$

$$\frac{40}{25} \times \frac{60}{20}$$

[Compound Gear Train]

NOTE: It is possible to design Compound Gear Train for every problem.
But simple Gear Train is possible for some cases and others
it is not possible.

Q) Find the Change wheels for cutting 1.75 mm pitch threads
on a Lathe of 6 T.P.I lead screw.

English Lathe

So use 127 teeth

Gear

T.P.I = Threads per Inch

T.P.C = Threads per centimeter

$$\text{TRAIN VALUE} = G.R = \frac{N_F}{N_d} = \frac{1.75 \text{ mm}}{\frac{1}{6} \text{ inch}}$$

$$= \frac{1.75 \text{ mm}}{\frac{1}{6} \times 25.4 \text{ mm}}$$

$$= \frac{1.75}{\frac{1}{6} \times \frac{127}{5}}$$

$$= \frac{1.75 \times 30}{127} = \frac{52.5}{127} \times \frac{2}{2}$$

$$= \frac{105}{254}$$

So this
Simple
Gear Train is
Not possible

$$= \frac{105}{127} \times \frac{1}{2} \times \frac{20}{20}$$

$$\left. \frac{105}{127} \times \frac{20}{40} \right\} \text{Compound Gear Train}$$

Q) Cal Gear Train needed to cut 3 mm pitch on an English
lathe having Lathe Const 8 the Gear progression is 4 and

Gears Available are 24, 28, 32, 100 & 127

Soln:

Gear progression = 4

24, 28, 32, 36 ... 100 & 127

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Lathe Const = T.P.C in case of metric Lathe
= T.P.I in case of English Lathe

$$\text{TRAIN VALUE} = G.P. = \frac{N_f}{N_d} = \frac{P_{\text{Job}}}{P_{\text{C.S}}} = \frac{3 \text{ mm}}{\frac{1}{8} \text{ inch}}$$

$$= \frac{3 \text{ mm}}{\frac{1}{8} \times 25.4}$$

$$= \frac{3}{\frac{1}{8} \times \frac{127}{5}}$$

$$\frac{3 \times 40}{127} = \frac{120}{127}$$

(X)

Not possible

$$\frac{40 \times 3}{127 \times 1}$$

$$= \frac{40}{127} \times \frac{3 \times 24}{1 \times 24}$$

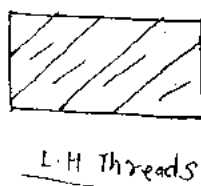
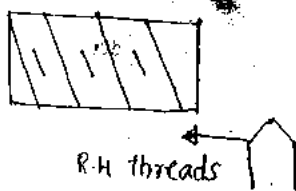
$$= \frac{40 \times 72}{127 \times 24}$$

Compound Gear
TRAIN

R.H. Threads (Right Hand Threads).

During machining operation, direction of Rotation of Job in Lathe is taken as counter clockwise.

* Most commonly used.



L.H threads $\rightarrow$ Jewellery, Mixer Grinder
 as L.H threads
 welding = Acetylene cylinder

Lead screw having R.H threads

* Right Hand Screw Thread principle To produce the R.H threads

By Assuming the direction of Rotation of Job as a counter clockwise direction, to produce R.H threads - the direction of Movement of Tool Req^d is Right to Left direction or Tail stock to Headstock for ^{getting moment} this direction of Rotation of Lead screw Req^d is counter clockwise direction i.e. for producing R.H threads the direction of Rotation of Job and Lead screw must be same. To get this same direction of Rotation

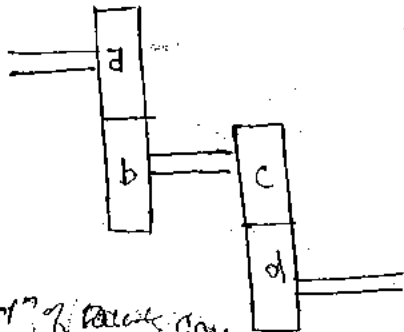
$\Rightarrow$ a) if the designed Gear train is a simple Gear Train use 1, 3, 5... odd no of idle gears.

$\Rightarrow$ b) If designed Gear Train is Compound Gear Train use 0, 2, 4, 6... even no. of idle Gear.

$\frac{a}{b}$ (cw)
 (ccw)

$\frac{a}{b} \times \frac{c}{d}$ (cw) (ccw)
 (ccw) (cw)

condⁿ:



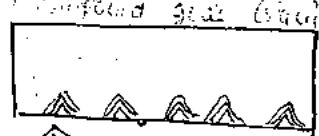
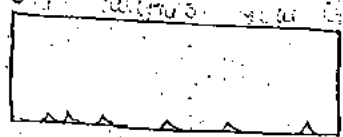
For producing L.H threads with assumption of direction of rotation of Tailstock counter clockwise
 - The direction of Tool Req^d Left $\rightarrow$ Right for this direction of rotation of
 Lead screw is clockwise
 - The direction of rotation of Job and Lead screw must be same

During Producing the threads, path followed by Tool in
 Second and subsequent cuts must Remain Same as
 that of 1st cut

For this if the design gear ratio is a simple gear ratio use:-

0, 2, 4, ... Even no. idle gear. 243

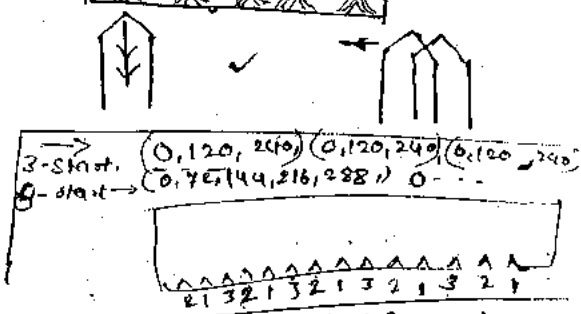
1, 3, 5, 7, ... Odd no. idle gear



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(x)

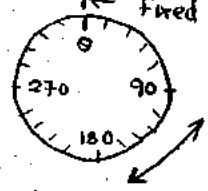
It becomes plain Turning if path followed is Not same.



(Multi-start Thread)

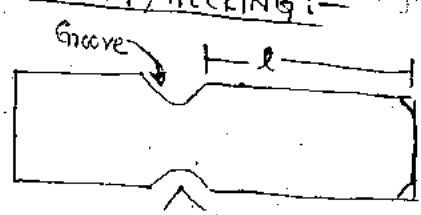
* Thread CHASING DIAL / HALF NUT MECHANISM

During thread cutting opn, the path followed by the tool in 1st & subsequent cut must remain same as that of the first cut only.



For ensuring the above condition the Thread chasing dial available in the lathe machine will be used. i.e. First Bring the Tool away from the work piece. set depth of cut for the first cut and engage the lever of split Nut mechanism. when selected position of T.C.D is coinciding with fixed mark and produce the thread. At the end of first cut disengage the lever of split nut, take the tool Backwards, Bring it ^{away from the W/P} to the front side of work piece. Now again set the depth of cut for 2nd cut and engage the lever of split Nut mechanism when selected position of T.C.D is coinciding with fixed mark. Continue this procedure until the Req'd no of cuts can be produced for multistart thread.

* UNDERCUTTING / GROOVING / NECKING:-



chamfering done for easy assembly of

Bolt of uniform strength. In General thread cutting will be the last operation and sometimes after thread cutting the only operation ~~will be~~ done is chamfering for easy

Assembly of Nut and Bolt

can only cut the groove zone of the farland

Write the operations in sequence

1. Thread cutting - 4
2. Taper Turning - 2
3. Plain Turning - 1
4. Under cutting - 3

instead cutting a groove has
called grooving / necking $\rightarrow$

→ During thread cutting, when ever the tool is coming to the green zone. The operator is feeding certain amount of cut for disengaging the gears without damaging anything.

3 - 2 - 4 - 1

in general thread cutting will be the last ops after thread cutting only chamfering can be done.

Shaping is the operation of Removing a Layer of ^{work} Material from (Flat) surfaces ^{of the w/p} using Reciprocating single point cutting

The diagram illustrates the components and operation of a lathe machine. On the left, the headstock assembly is shown, featuring a RAM (lathe bed) supporting a Chuck. A Taper Shank is mounted on the Chuck. The right side shows the tailstock assembly, which includes a BOX 1 (tailstock cap) and a layer of workpiece (w.p.) material to be turned. The WORK TABLE is positioned below the w.p. material. A Ratchet (Pinion Type) mechanism is used to rotate the w.p. material, with a Pawl and Split Nut mechanism. Arrows indicate the direction of rotation for the Chuck and the Ratchet, and the direction of feed for the tool.

1 Rev of crank = 1 F.S + 1 R.S = 1 Double stroke, 1 C.S + 1 I.S

Forward
stroke

Return
stroke

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In shaping m/c the forward stroke of the tool will be considered as cutting stroke in which material removal is taking place from the work piece and Return stroke will be taken as a idle stroke so that tool is simply moving in Backward direction ^(with max possible vel.) to take the position of tool.

In the forward stroke / cutting stroke the tool has to travel at optimum cutting velocity for removing the material from the work piece whereas in Return stroke becoz it is idle stroke the tool has to travel at Max possible velocity to minimise the production time.

WITHWORTH QUICK RETURN MECHSM

In shaping m/c half Revolution of crank produces forward stroke, another half Revolution of crank produces Return stroke. As per the Requirement of shaping m/c the velocity of forward and Return strokes must be diff. To get this diff velocities of Ram it is not possible to have diff velocities of crank in two diff half revln of crank. To get the variable velocity of Ram even though crank is rotating at uniform velocity, a mechanism is used b/w the Ram and crank called as "Withworth Quick Return Mechanism" which is one of inversion of single slider Crank Mechanism.

In the total Movement of Ram, the "Maximum velocity of Ram" occurs at middle of Return stroke", "Next Maximum possible velocity occurs at end of Return stroke", "Lowest velocity occurs at Beginning of Forward stroke".

During Metal Removal process in shaping operation the Tool should be in position for removing the material from work piece during cutting stroke. But during Return stroke of tool, the Tool has to be lifted upwards bring it back without having contact with work piece and again at Beginning of Forward stroke/cutting stroke the Tool should take position for removing material from work piece. To do this job a Mechanism called as "Clapper Box with Rocker arm" will be used - to maintain tool wear & ensure tool life b/w the time of tool

by feed is given in R.S) The Automatic feed Req'd for shaping operation will be given to the work piece only as a "Intermittent feed" during "Ratchet and Pawl Mechsm" will be used for obtaining the ^{Return stroke} intermittent feed in shaping operation.

in shaping opⁿ, by the machining & taking place intermittently, the feed always given to the work table intermittently - i.e., the intermittent feed given to the W-T is only during R.S of the Ram.

what ever the intermittent feed required for the W-T is obtained by using Ratchet & Pawl mechanism.

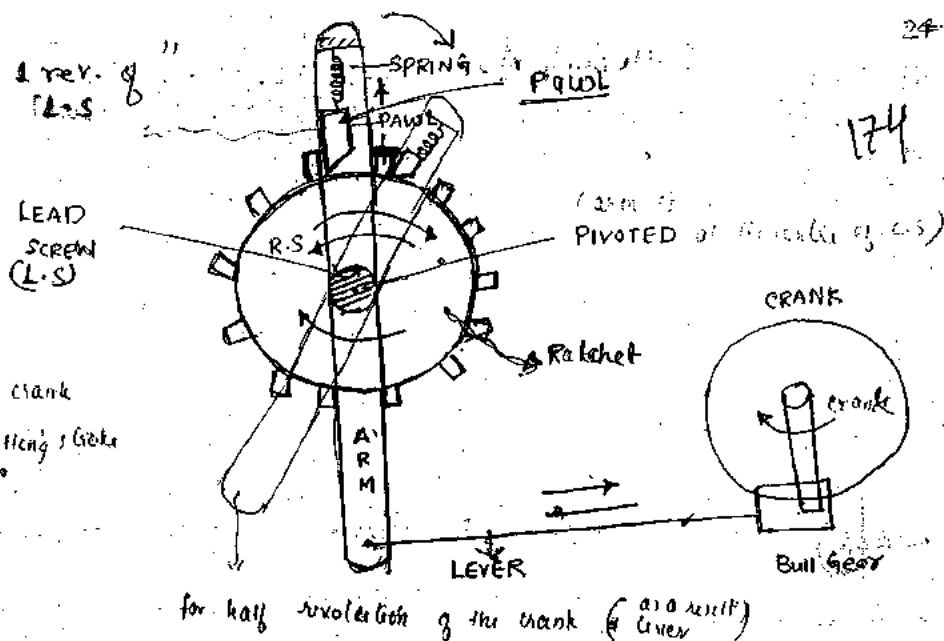
2 Rev ; ratchet - 1 rev of
= 1 pitch (or)
1 lead of LS

"1 rev. of crank = 1 rev. of L.S."

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1st half rev of crank
→ cutting stroke



During 1st half revolution of crank, the lever is moving from right to left direction and it rotates the arm in clockwise direction wrt pivot. During this time becoz of presence of inclination at one side side of Pawl the Pawl is lifted upwards, Rotating without disturbing the Ratchet and whenever the Pawl is finding space b/w the teeth it is again falling downwards. ^{due to the spring force} During and half Revolution of

crank the lever is moving from left to right direction, it rotates the arm in counter clockwise direction wrt pivot. Now becoz there is no inclination is present at other side of Pawl ^{the Pawl} is indexing or Rotating the Ratchet, so that the Lead Screw also rotates and it moves the work piece and work Table by using split Nut Mechsm. If the first half revolution of crank is matched with cutting stroke and 2nd Half Revln is matched with Returnstroke, the intermittent feed is

Shaping operation is obtained only in the Return stroke.

Q.7

$P = 5 \text{ mm}$

No of Teeth on Ratchet = 20 teeth

During every R.S the Pawl is indexing Ratchet by 1 tooth

R & feed obtained = ?

Soln

20 teeth $\Rightarrow$ 1 Rev of Ratchet = 20 R.S

= 20 D.S

$\rightarrow$ 1 rev of L.S

$\rightarrow$ 1 P of L.S

$\rightarrow 5 \text{ mm}$

20 teeth $\Rightarrow 5 \text{ mm} \Rightarrow 20 \text{ R.S}$

$\Rightarrow 20 \text{ D.S} \rightarrow 5 \text{ mm}$

$$1 \text{ D.S} \rightarrow \frac{5}{20} = \frac{1}{4} = \underline{\underline{0.25 \text{ mm}}}$$

if 20 teeth are indexing

1 Rev of Ratchet = 10 R.S

= 10 D.S

$\rightarrow$ 1 rev of L.S

$\rightarrow$ 1 Pitch of L.S

$\rightarrow 5 \text{ mm}$

10 D.S $\rightarrow 5 \text{ mm}$

$$1 \text{ D.S} = \frac{5}{10} = \underline{\underline{0.5 \text{ mm}}}$$

* Machining time in shaping

Let L = stroke length of Ram

V = vel of Ram in forward stroke/cutting stroke / cutting vel.

$$M = \text{QRR} = \frac{V_R}{V_C} = \frac{\text{vel of Ram in cutting stroke}}{\text{vel of Ram in Return stroke}} = \frac{T_{RS}}{T_{CS}} < 1$$

(Quick Return Ratio)
quick return ratio

$$\frac{V_C}{V_R} = \frac{T_R}{T_C} = \frac{1}{2} \text{ (or) } \frac{2}{3}$$

(most commonly used QRR)

T = time taken for...

B = width of w.p

f = ^{table} feed = feed of w.p

T_{CS} = Time taken for cutting stroke = $\frac{L}{V}$

$$T_{RS} = M \times \frac{L}{V} \quad [M \times T_{CS}]$$

Time/D.S

Time per Double stroke = $T_{CS} + T_{RS}$

Time/D.S

$$= \frac{L}{V} + M \frac{L}{V}$$

$$\frac{L}{V} [1+M] = \text{Time/D.S}$$

$$\frac{1}{\text{Time/D.S}}$$

$$= \frac{1}{\text{Time per D.S}}$$

$$= \frac{\text{D.S.}}{\text{Time}}$$

$$\text{RPM of crank (N)} = \frac{1}{\text{Time/D.S}}$$

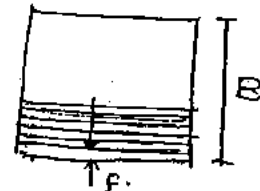
$$= \frac{V}{L[1+M]}$$

$$V = LN(1+M)$$

$$\text{Time/cut} = \text{Time/D.S} \times \text{D.S/cut}$$

$$\frac{L}{V} [1+M] \times \frac{B}{f}$$

$$= \frac{B}{f} \times \frac{1}{\text{RPM of crank}}$$



$$\text{Time/cut} = \frac{B}{f} \times \frac{1}{\text{RPM of crank}}$$

$$\text{Total Time} = \text{Time/cut} \times \text{No of cuts}$$

→ Generally RPM of crank = 5-10 rpm

eg:- If width of work piece is Large

$$\text{Time/cut} = \frac{1}{10} \times \frac{B}{f}$$

if $B = 2m, f = 0.1mm, rpm = 10$
 $\text{no of cut} = \frac{2000}{0.1} = 20000$
 Time Taken is very Large
 $\text{Time/cut} = \frac{20000}{10} = 2000 \text{ min} = 33 \text{ hrs}$

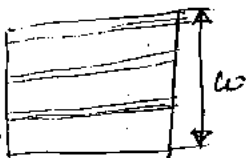
★ Planining operation for one cut 33hrs

To Machine wider work pieces Time Taken ~~for~~ will be very long by using shaping machine. To minimise this time taken more than one cutting tool will be used for Removing the Material simultaneously from one work piece itself. But for mounting more than one tool more than one Ram is Req'd. It is Nothing but more than one shaping m/c will be kept in parallel and it is Not preferable one.

→ More than one cutting tool will be Fixed on to a Beam and allow the w/p to Reciprocate with variable speed.

(like optimum speed in forward stroke and maximum speed in Return stroke). This process is called as planing operation/ planing machine.
 { tool stationary }
 { w/p rotating }

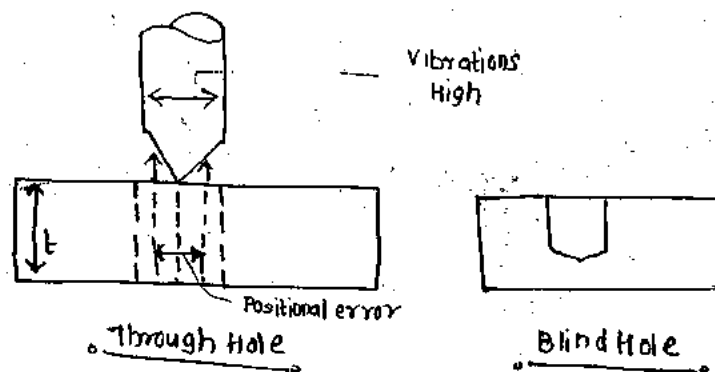
★ Slotting m/c "If the shaping m/c is Rotated by 90°, the work piece will become vertical and tool is also Reciprocating in vertical Axis. This is called as slotting m/c" To get the variable speed of the tool the mechanism used is called as "slotted lever Mechanism"



★ Drilling operation:

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"Drilling is the process of producing Holes by using Multipoint Rotating cutting tool in components."



If the Reqd Large size of Hole is produced directly by using corresponding size of drill bit beoz the forces induced are Higher, vibrations are Higher, and it produces large error in the position of Holes. i.e. the "positional Accuracy" of Hole produced is very poor. To Avoid this problem it is always Recommended to produce the smallest dia hole first, enlarge it slowly by using diff sizes of drill Bits until the Req'd dia of the Hole can be produced.

5, 10, 12, 15, 20, ... 50 mm

By using the above Method in stages maximum size of Hole produced will be 50mm only beoz if Larger Holes are produced by using this method, the Time Taking for Machining is High and cost of manufacturing increases.

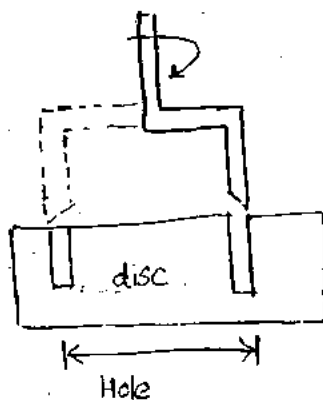
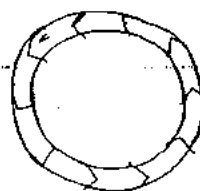
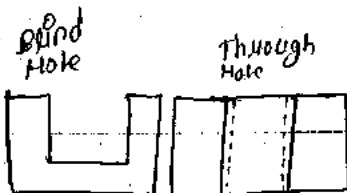
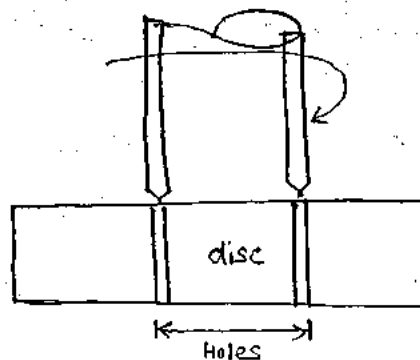
The size of the Hole produced by drilling operation will be Varying by large amount. $\therefore$ To get the exact size and finishing of Hole reaming operation can be used.

"Reaming is the process used for sizing and finishing of holes by removing very small amount of material"

* TREPANING

Trepaning is the operation used for producing large size holes without drilling.

Boring operation uses single point cutting tool. so Time taken for cutting is High.



Limitation :-

By using ~~per~~ Trepaning any size of Holes can be produced. But only Through Holes can be produced Not Blind Holes

★ BORING

24x

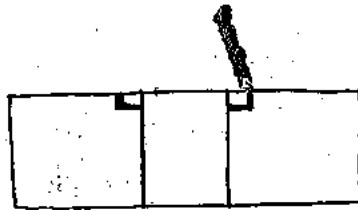
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Boring is a internal turning operation used for enlarging the existing hole by some amount

★ COUNTER BORING

end of component

counter → Related to end of Hole
Not through the Hole



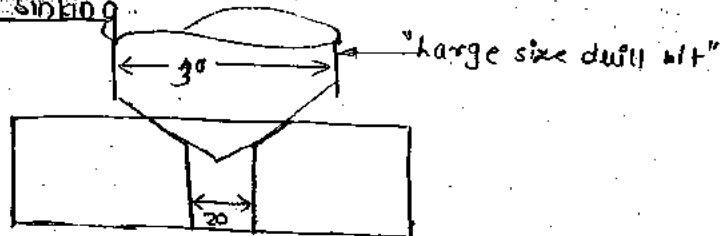
the internal turning operation used for enlarging end of the hole is called as counter Boring.

This is also done by "repet"

★ COUNTER SINKING

Tapering

The conical enlargement of the end of the hole is called counter sinking.



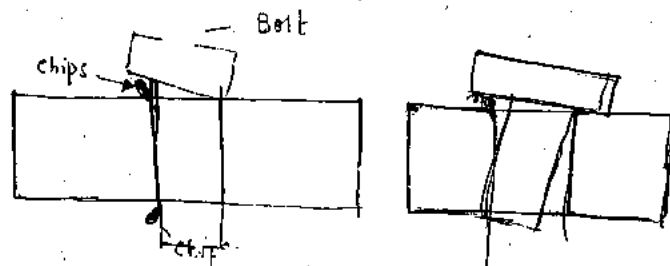
Also
Match the following

Counter Sinking is done by using "large size drill bit than hole"

★ SPOT FACING

Spot facing is the operation of removing the chips present on

surface of hole and making perfectly square hole for proper seating of head heads Nuts etc. It is done by using end mill cutter with drilling machine.



★ HORNING :

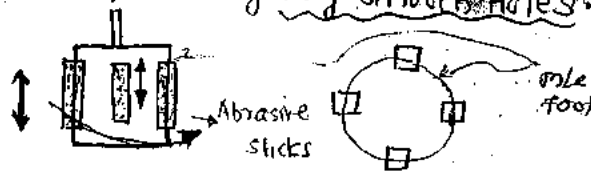
Horning is the operation of producing very smooth Holes. OR Bore Polishing

It is mainly used for finishing

IC engine cylinder. It is

Similar to

★ Lapping operation in external surfaces finishing



Machining Time calculation

Time/Hole =

➡ Even though practically the Required size of Hole can be produced in stages but, for theoretical calculation of Machining Time in drilling, it is always assumed that Required size of Hole can be produced by using corresponding size of drill Bit directly.

$$\text{Time/Hole} = \frac{L}{fN}$$

L = Length of tool Travel

$$L = t_1 + (AP_1) + AP + O.R$$

Approach 1

f = Feed in mm/rev

N = RPM of drill Bit

$$N = \frac{1000 V}{\pi D}$$

D = dia of drill Bit

V = opt cutting velocity

AP₁ = "compulsory Approach"

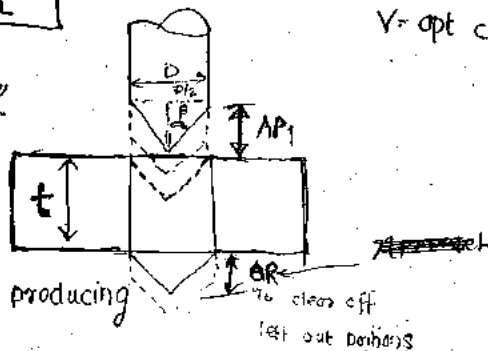
AP₁ = distance to be

Travelled by Tool

for complete dia

of Hole is started

AP₁ = depth of cut



AP_1 = conical Length of drill Bit
 $AP_1 = 0.3$
 $AP_1 = 0.3D$ for Blind Holes
 $0.5D$ for Through Holes

$0.3D$ For Blind Holes
 $0.5D$ for Through Holes



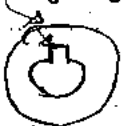
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★ BRACHING ↓

Broaching is always considered as a secondary machining operation because it always needs a hole to be produced before Broaching.

Broaching is mainly used for producing large size non circular Holes but it will not be used for producing small size Non circular Holes because Manufacturing of Broaching Tool for small size non circular Holes is impossible. Hence small size non circular Holes will be produced by using unconventional machining methods like, USM, EDM, etc.

- Fixed
- Square
- Rectangular
- Octagonal
- Semi-circles
- Internal
- Key way



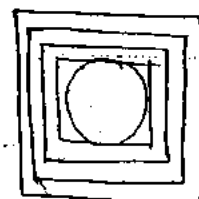
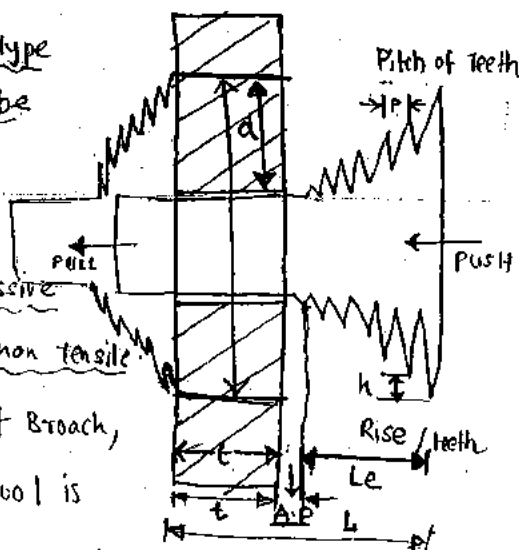
In General Push type of Broaches will be preferred bcoz

every material

will have compressive strength Higher than tensile

With Push Type of Broach, the Broaching Tool is

experiencing Compressive stresses only. 0% chances of failure of Broaching Tool is eliminated.



Always push Broach is preferred

★

$$\text{Broaching Time} = \frac{L}{V}$$

* Broaching velo. = 0.1 to 0.5 m/min. (lowest)
 * Grinding velo. = 18000 m/min. (highest)

V = velocity of B.T = 0.1 to 0.5 m/min



Broaching operation is always done at very low speed because many no. of teeth are in contact with work piece during Broaching. Hence forces induced will be Higher, the power consumption is also Higher if High velocity is used. To minimise this power requirement Broaching is always done at minimum possible velocity.

L = length of Tool Travel

$$L = t + A.P + L_e + O.R$$

* $L_e =$ effective length or
Cutting Length of Broach

In a Broaching Tool in general there are 3 types of teeth will be used.

3 Types of Teeth :-

- ① Rough tooth
- ② Semi finished tooth
- ③ Finished tooth

$$L_e = L_r + L_s + L_f$$

→ L_r = Length of Broaching Tool for Rough Tooth

→ L_s = " " " " " Semifinished Tooth

→ L_f = " " " " " Finished Tooth

Rough Tooth is used for Removing Max amt of material and bringing size of component nearly equal to reqd. No. of rough tooth is taken as, a as many as reqd.

$$\boxed{N_r = \frac{d_r}{h_r} \cdot P_r}$$

P_r = Pitch of Rough Tooth

N_r = no. of Rough teeth

$$N_r = \frac{d_r}{h_r}$$

d_r = depth of material removed by Rough

h_r = rise/Tooth for Rough

Semifinished Teeth are used for Removing Small amount of 250 Material and bringing size of component as Reqd. The No of Semifinished Tooth will be about 4 to 10.

$$L_s = n_s \times P_s = \frac{d_s}{h_s} \times P_s$$

$$n_s = 4 \text{ to } 10$$

P_s = Pitch of Semifinished Tooth

$$n_s = \frac{d_s}{h_s}$$

Finished Tooth is used for removing negligible amount of material and used for producing smooth surface finish on the component. No of finished Tooth will be 2 to 6

$$L_f = n_f \times P_f = \frac{d_f}{h_f} \times P_f$$

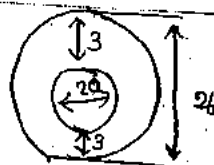
$$n_f = 2 \text{ to } 6$$

$$n_f = \frac{d_f}{h_f}$$

$$d = d_r + d_s + d_f$$

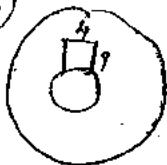
① $D = 20 \text{ to } 26 \text{ mm}$

$$d = \frac{26 - 20}{2} = 3$$



d = Total depth of material Removed

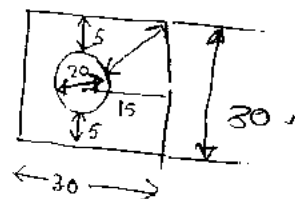
② $D = 20 \text{ mm}$, Square Hole 30 mm Size



$$d = 9 \text{ mm}$$

$$d = \sqrt{15^2 + 15^2} - 10$$

$$d = \frac{30\sqrt{2} - 26}{2}$$



→ Milling operation:-

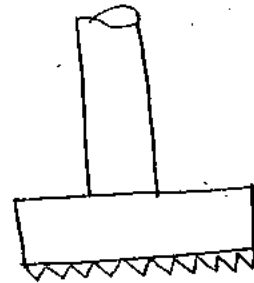
It is the operation used for removing a thin layer of material from the flat surface and also used for producing slots in component.

Types of tools:-

- ① End Mill cutter
- ② peripheral ~~or~~ M.C.

→ If the cutting teeth are provided on the face of the circular disc ^{OR (End)} is called End mill cutter.

The End mill cutter can be used either in vertical milling machine or drilling machine also.

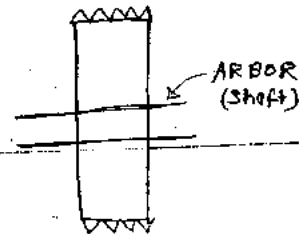
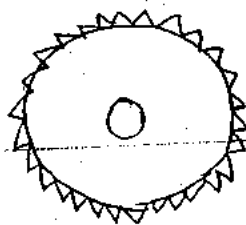


End mill cutter

→ If the cutting teeth are provided on the periphery or circumference of a circular disc it is called as peripheral milling cutter.

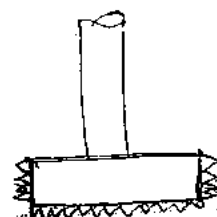
Peripheral milling cutter is used only with horizontal milling

M/C. It is generally mounted on shaft called as ARBOR



② * side milling cutter

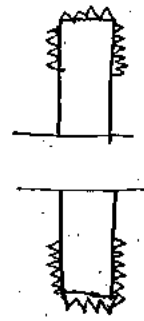
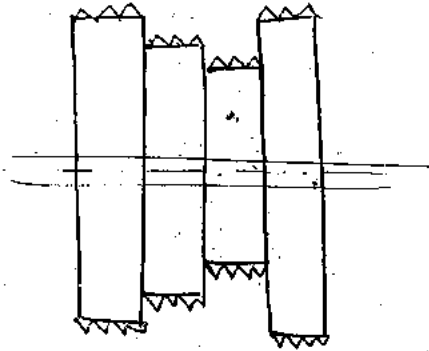
→ In end mill cutter in addition to face of the circular disc if the teeth are provided on periphery also it is called as side milling cutter.



④ ★ Straddle M.C

In addition to periphery if teeth are provided on faces also it is called as straddle milling cutter

⑤ ★ Gang M.C



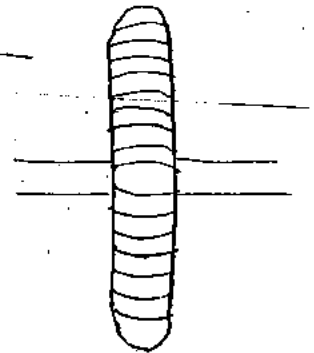
A Gang of diff sizes of peripheral milling cutters are kept together to remove the material simultaneously from one work piece called as a Gang milling cutter

⑥ * Gear milling cutter Form Milling cutter

If shape of milling cutter is like a Gear tooth to be produced, is called as form milling cutter
(Gear)

Types of Milling ↓

- ① FACE MILLING
- ② SLAB OR SLOT MILLING



Milling operation used for removing a layer of material from the complete surface of work piece is called as face milling operation.

If the milling operation used for producing slot in the component is called slab milling or slot milling

Both the types of Milling cutters can be used for performing both the types of Milling operations but preferably the face milling operation is done by using End Mill cutter and slob milling operation is done by using peripheral milling cutter

When peripheral milling is used for performing milling ops, the milling proc. is divided into two types

Machining Time calculation:-

$$\text{Time/cut} = \frac{L}{f_m} = \frac{L}{f_t N} = \frac{L}{f_t Z N}$$

f_m = Table Feed in mm/rot

f_t =

N = RPM of milling cutter

Z = No of Teeth

$$N = \frac{1000 V}{\pi D}$$

f = Table feed in mm/rev

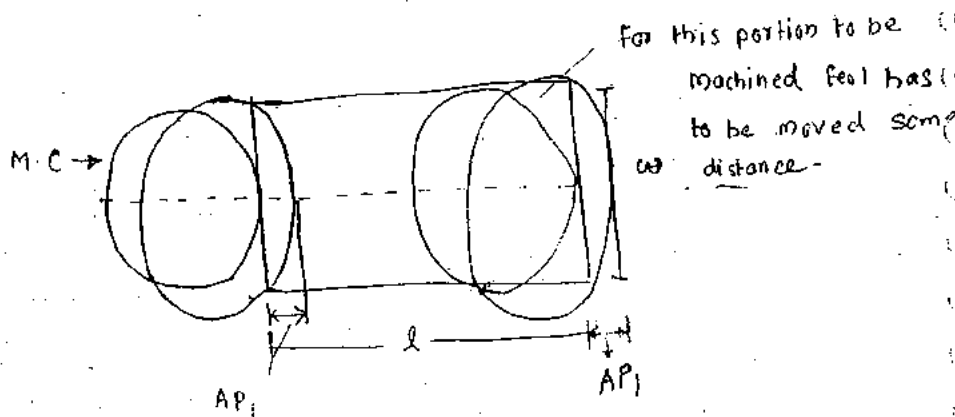
f_t = Table feed in mm/tooth

L = Length of Tool Travel

$$L = l + AP_1 + AP + OR$$

l = length of w.p

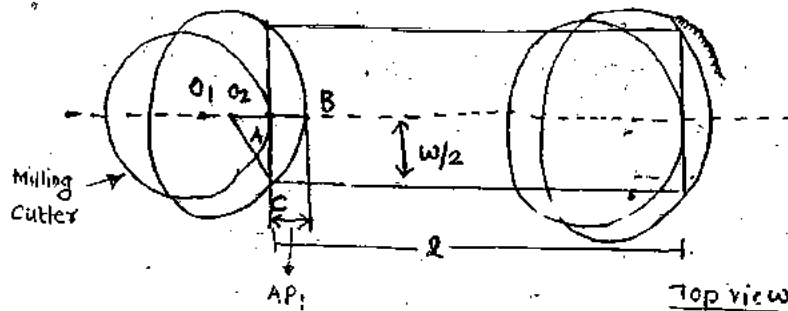
AP_1 = compulsory Approach



AP_1 is the distance to be traveled by Tool for complete width of work piece is to be milled

1. Face Milling cutter
2. Face Milling Peripheral M.C
3. Slab Milling with End M.C
4. " " " Peripheral Milling cutter

FACE MILLING WITH END MILL CUTTER:



$$AP_1 = AB \quad | \quad \begin{aligned} &O_2B - O_2A \\ &\frac{D}{2} - \sqrt{O_2C^2 - AC^2} \\ &\frac{D}{2} - \sqrt{\left(\frac{D}{2}\right)^2 - \left(\frac{w}{2}\right)^2} \end{aligned}$$

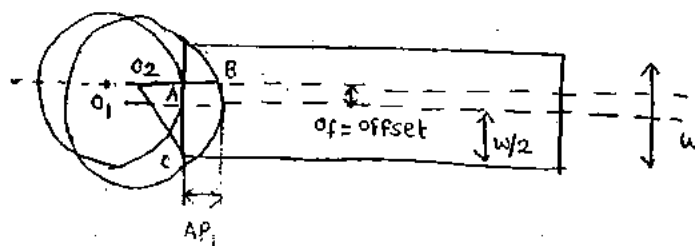
$$AP_1 = \frac{1}{2} \left(D - \sqrt{D^2 - w^2} \right)$$

milling diagram should be drawn such that m.c can be seen like a circle

D = dia of m.c

In Face Milling performed with end mill cutter, when the axis of work piece and axis of milling cutter are coinciding, it is called as Symmetrical Milling operation.

Sometimes Based on Requirement of milling operation, the Axis of Work piece and Axis of milling cutter are offset by some amount called as Asymmetrical milling or Non Axis symmetric milling.



D = dia of work pie
w = width of w.p

$$AP_1 = \frac{1}{2} AB \\ = O_2B - O_2A$$

$$\frac{D}{2} - \sqrt{O_2C^2 - AC^2} = \frac{D}{2} - \sqrt{\left(\frac{D}{2}\right)^2 - \left(\frac{w}{2} + of\right)^2}$$

$$AP_1 = \frac{1}{2} \left(D - \sqrt{D^2 - w_i^2} \right)$$

$$(w_i = w + 2of)$$

{ w_i = imaginary width of w.p
 $w_i = w + 2of$ }

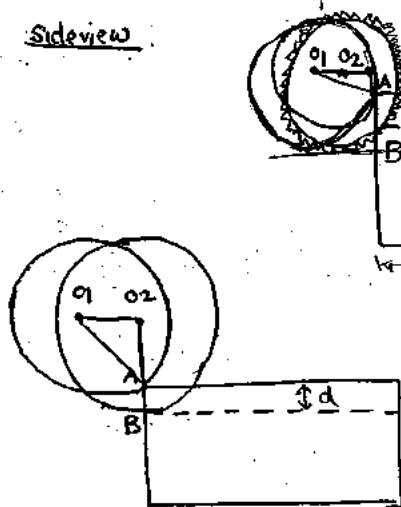
$$W_i = W + 2of$$

★ The Approach 1 for asymmetrical milling operation is > }
 symmetrical milling

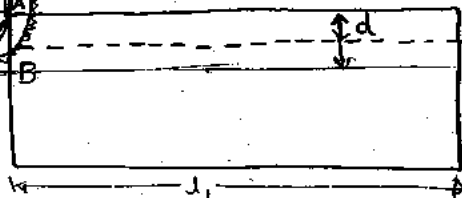
★ ∴ machining time reqd for Asymmetrical Milling > symmetrical Milling
 : whenever the symmetrical milling are not possible for such places only asym. milling will be use

★ FACE MILLING WITH PERIPHERAL MILLING CUTTER

Sidewiew



Side view



D = Diam of milling cutter

$$AP_1 = O_1 O_2$$

$$= \sqrt{O_1 A^2 - O_2 A^2}$$

$$= \sqrt{\left(\frac{D}{2}\right)^2 - (O_2 B - AB)^2}$$

$$AP_1 = \sqrt{\left(\frac{D}{2}\right)^2 - \left[\left(\frac{D}{2}\right)^2 - d^2\right]}$$

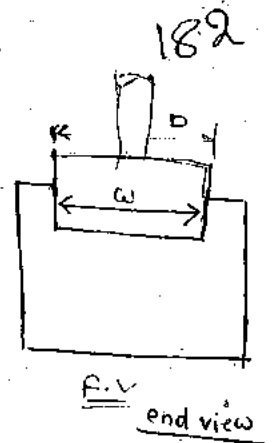
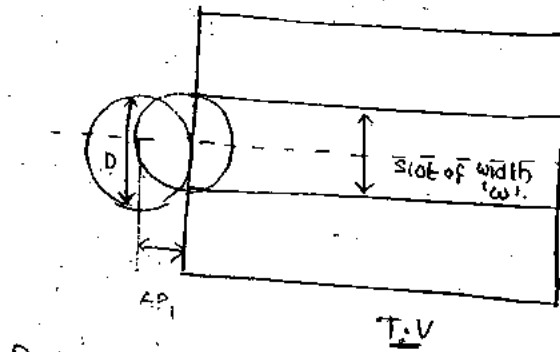
$$= \sqrt{Dd - d^2} = \sqrt{d(D-d)}$$

$$AP_1 = \sqrt{d(D-d)}$$

$$\approx \sqrt{dD}$$

★ SLAB MILLING WITH END M.C :-

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$$D = w$$

$$AP_1 = \frac{D}{2}$$

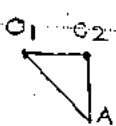
$$= \frac{1}{2} \left[D - \sqrt{D^2 - w^2} \right]$$

$$D = w$$

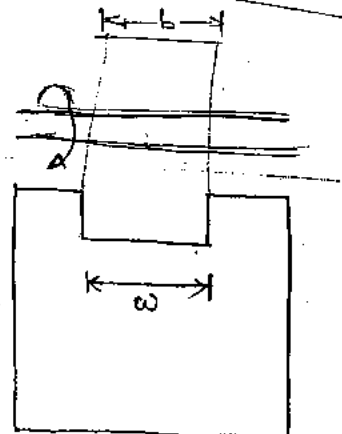
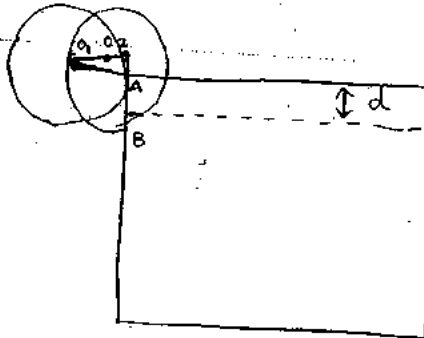
$$AP_1 = \frac{1}{2} \left[D - \sqrt{D^2 - D^2} \right]$$

$$AP_1 = \frac{1}{2} D$$

★ SLAB MILLING WITH PERIPHERAL M.C



Side view



$$AP_1 = \sqrt{d(D-d)}$$

Side view

Front view

End Milling cutter

$$AP_1 = \frac{1}{D^2} [D - \sqrt{D^2 - W^2}]$$

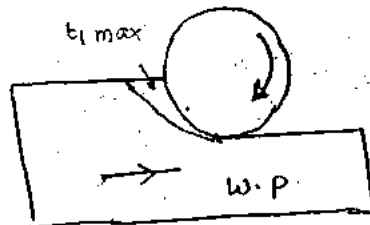
Peripheral Milling cutter

$$AP_1 = \sqrt{d(D-d)}$$

Approach is mainly depend on Milling cutter used.

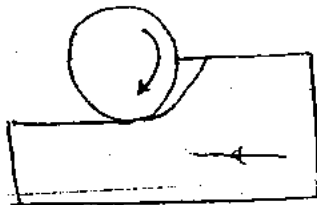
Methods of ~~the~~ Milling using Peripheral cutter:

- ① UP OR CONVENTIONAL MILLING
- ② DOWN OR CLIMB MILLING



(Opposite in direction)

UPMILLING



(Same direction)

DOWN MILLING

In upmilling direction of Rotation of Tool and direction of Movement of work piece are opposite - whereas in downmilling the direction of Rotation of Tool and direction of movement of work piece are same. In case of upmilling becoz of opp direction of movement, the forces acting on Tool Tips is very High, tool wear is higher and tool life is lower. In case of Down Milling becoz of same direction of movement the forces are lower, tool wear is less and tool life is higher.

In upmilling the chip thickness is varying from min. at beginning to max towards at end. $\therefore$ surface finish produced is very poor.

In case of downmilling the chip thickness is varying from max at Beginning to min towards end. $\therefore$ surface finish produced is very good.

Downmilling is Better

{ these things are observed when m/c is new }

As the machine is used continuously for longer periods, the wear and tear is taking place in the transmission parts and Backlash is present b/w the meshing ^{m/c} GEARs. This Backlash will not create any problem in case of upmilling because of opp direction of movement. whereas in case of downmilling the presence of backlash in transmission parts produces fluctuation in work piece. These fluctuations will produce impact loads and tool tips may get failed due to mechanical breakage and surface finish also get damaged due to increased vibrations.

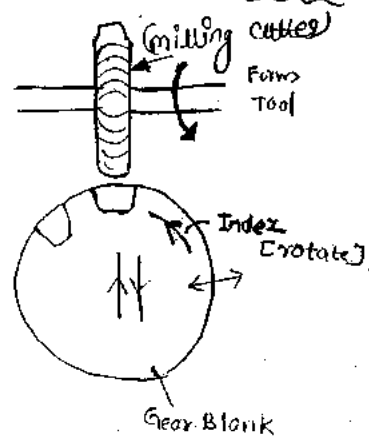
{ $\therefore$ when m/c is new it is preferable to use downmilling. As the m/c becomes old it is preferable to use upmilling }

INDEXING : $\downarrow$ (In milling)

Indexing is the operation of Rotating the Job through Recd. angle in b/w the successive cuts.

$$\text{depth} = \text{Addendum} + \text{dedendum}$$

$$\begin{aligned} & 1p + 1.25m \\ & \underline{2.25m} \end{aligned} \quad [m = \text{module}]$$



For satisfying Indexing Requirements, the "indexing mechanism" should have two basic devices

Two devices:

(1) a device used for Rotating Job through reqd angle

★ "Indexing crank" $\left[\text{L} \rightarrow \text{Lever} = \text{crank} \right]$

(2) a device which is used for ensuring that the given Relations are correct.

★ "Indexing plate" $\left\{ \begin{array}{l} 17 \\ 27 \end{array} \right.$

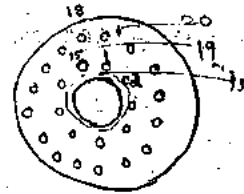
Indexing plate is a circular disc with different varieties of Hole circles present in the plate

★ 1) a) Brown and Sharp Indexing plate

Plate 1: 15, 16, 17, 18, 19 & 20

Plate 2: 21, 23, ~~26~~ 27, 29, 31, 33

Plate 3: 35, 37, 39, 41, 43, 47 & 49



★ 2) b) Parkinson plate:-

Plate 1: 24, 25, 28, 30, 34, 37, 38, 39, 41, 42, & 43

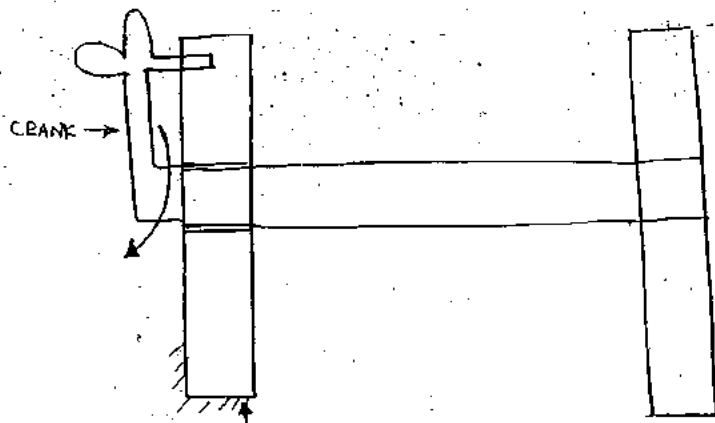
Plate 2: 46, 47, 49, 51, 53, 54, 57, 58, 59, 62, 66

As per Indian standards Brown & Sharp Indexing plate is used.

Methods of Indexing:

- (1) Direct indexing
- (2) plain or simple Indexing
- (3) Angular Indexing
- (4) Compound indexing
- (5) Differential "

In the DIRECT INDEXING the crank and job are directly connected such that one Revolution of crank will produce one Revolution of the job and indexing plate used is a special indexing



DIRECT INDEXING

{ crank and job is directly connected so that 1 rev. of crank will always prod. 1 rev. of job. }

Indexing Plate

Special type

(24 Hole circles)

1 Rev of crank = 1 rev of job.

(N = no. of division; circumference of job is to be divided.)

2, 3, 4, 6, 8, 12, 24

It is a simple and direct method but it can be used for dividing the circumference of a job into 2, 3, 4, 6, 8, 12, 24 divisions only. But other divisions is not possible.

*

2. PLAIN OR SIMPLE INDEXING

No. of division (slot) on job.
(Crank) Tooth. hole

$$N=2, \frac{24}{2} = 12$$

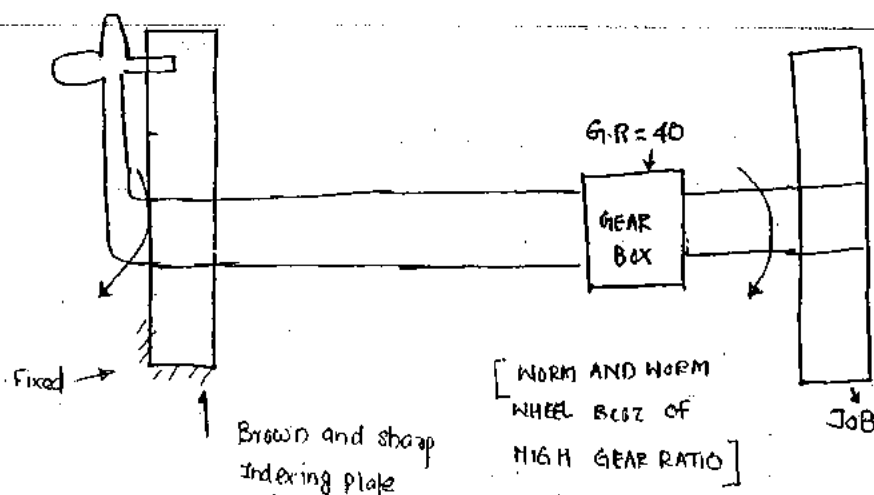
$$N=3, \frac{24}{3} = 8$$

$$N=4, \frac{24}{4} = 6$$

$$N=6, \frac{24}{6} = 4$$

$$N=12, \frac{24}{12} = 2$$

$$N=8, \frac{24}{8} = 3$$



When compared to Direct indexing in Simple Indexing :-

1. Brown and sharp or parkinson indexing plate will be used

- (2) In B/w crank and job a worm and worm wheel type of gear box is used with gear ratio = 40

- (3) the indexing plate used is designed with the Assumption of $G.R = 40$, because indexing plate has been design based on the G.R. 40 only, to get this very high G.R. with smaller size of gearbox. The worm-and-wormwheel type of gear box is preferred.

$$[1 \text{ rev of CRANK} = \frac{1}{40} \text{ REV OF JOB}]$$

Let 'N' be no. of divisions by which circumference of job is to be divided.

CR = Crank Rotation reqd b/w 2 successive cuts

$$= \frac{40}{N} \times \frac{1}{G} \quad \text{Angular indexing}$$

eg:- $N = 24 \text{ divisions} \rightarrow \frac{360^\circ}{24} = 15^\circ = \alpha$

$$C.R: \frac{40}{24} = 1 \frac{16}{24} = 1 \frac{2}{3} \rightarrow \text{must be available as hole circle in plate}$$

$$1 \frac{2 \times 5}{3 \times 5} = 1 \frac{10}{15} \Rightarrow \text{1 complete Rev of crank and 10 holes in a 15 hole circle}$$

$$1 \frac{2 \times 6}{3 \times 6} = 1 \frac{12}{18}$$

$1 \frac{10}{15} \Rightarrow$ After every cut crank has to be rotated through

1 complete revolution and 10 holes in a 15 hole circle.

eg:- $N = 36$

$$C.R: \frac{40}{36} = 1 \frac{4}{36} = 1 \frac{1}{9}$$

$$= 1 \frac{1 \times 2}{9 \times 2} = 1 \frac{2}{18}$$

eg: $N = 46$ division

$$C.R = \frac{40}{46} = \frac{20}{23}$$

256
185
190

Here After every cut crank is Rotated by 20 Holes in 23 Hole circle

3. ANGULAR INDEXING:

If simple indexing is done in terms of Angular values, it is called as Angular indexing

$$C.R = \frac{\theta}{90}$$

$$\text{Rev of crank} = \frac{360}{40} = 90$$

$N = 24$ divisions

$$C.R = \frac{\theta}{90}$$

θ = Angle b/w a consecutive divisions.

$$\theta = \frac{360}{24} = 15^\circ$$

$$C.R = \frac{15}{9} = 1 \frac{6}{9} = 1 \frac{2}{3}$$

Indexing with plain indexing is simple & easier.

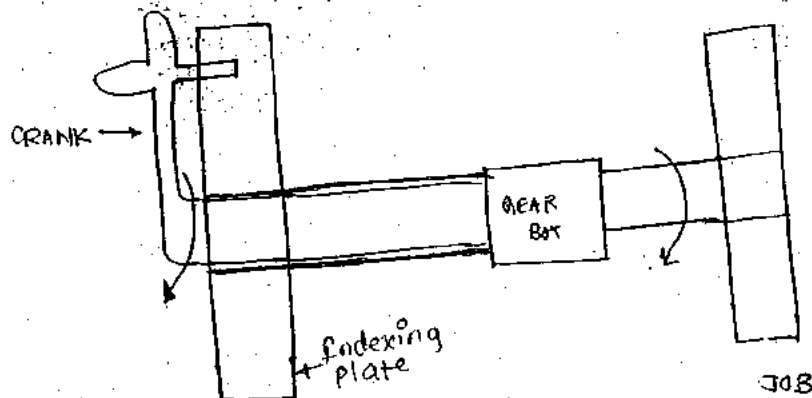
$$1 \frac{2 \times 5}{3 \times 5} = 1 \frac{10}{15}$$

* LIMITATION:-

- ① With Simple indexing upto 40 divisions any no. of divisions are possible but Beyond 40, only some divisions are possible and others are not possible like 53, 79 divisions etc.

4. COMPOUND INDEXING:

To overcome the disadvantage of Simple indexing the Compound indexing is developed.



When compared to simple indexing a new link has been established b/w indexing plate and the gear box so that either by rotating the crank or fixing the plate or by fixing the crank and rotating the plate the job will be rotated with G.R 40.

$$G.R = \frac{40}{N}$$

In compound indexing the Req'd crank Rotation is first divided into two fractions. one fraction can be obtained by fixing the plate and rotating the crank. The other fraction of rotation can be obtained by fixing the crank and rotating the plate.

eg. $N = 27$ divisions

$$G.R = \frac{40}{27} = \frac{2}{3} + \frac{22}{27}$$

$$\frac{2 \times 9}{3 \times 9} = \frac{18}{27}$$

$$\frac{2 \times 6}{3 \times 6} + \frac{22}{27}$$

$$\frac{12}{18} + \frac{22}{27}$$

Both hole circles must be available in single plate. i.e. after every cut plate is rotated.

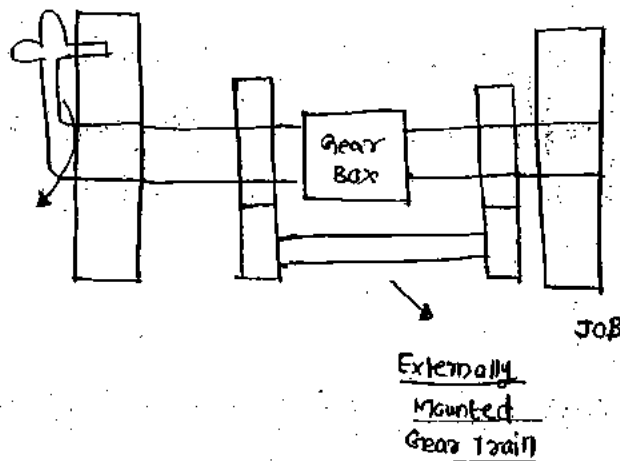
After every cut by fixing the plate the crank can be rotated through 12 holes in 18 circle and by fixing the crank, plate can be rotated through 22 holes in a 27 hole circle.

Adv. By this method any no. of divisions can be produced whether it is below 40 or above 40.

- Limitation of compound indexing is unless one is strong in Mathematics. If it is not possible to divide Revd crank rotation into a ~~frac~~ fraction. Also after dividing it is also Req'd to ensure that the Hdc circle req'd for Both the fractions must be Available in one plate itself. if not find out the fractions one again.

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5. DIFFERENTIAL INDEXING:



When Compared to Compound indexing in differential indexing the link b/w indexing plate and Gear Box has been Removed, a Gear Train is mounted b/w o/p of Gear Box and Indexing plate, so that Crank and indexing plate, both are rotating either in same direction or in opp direction Simultaneously.

Let N = No of divisions, the circumference of job is to be divided by which

n = slightly larger or smaller than N
 a Number

$$C.R = \frac{40}{n}$$

$$\frac{40}{N} \sim \frac{40}{n} = \text{diff}$$

$$G.R \text{ for Gear Train} = (n - N) \cdot \frac{40}{n}$$

40 is of
 Relation
 between
 plate

In differential indexing in addition to calculation of crank Rotation it is also Req'd to design the externally mounted gear

Gear Train

If no. of division less than 40, then preferable to use the simple indexing.
If $> 40 \rightarrow$ differential indexing.

eg:- $N = 53$

$n = 55$

$$C.R = \frac{40}{55} = \frac{8}{11} \cdot \frac{8 \times 3}{11 \times 3} = \frac{24}{33}$$

Gear Ratio for Gear Train

$$(55 - 53) \times \frac{40}{55}$$

$$= 2 \times \frac{8}{11} = \frac{16}{11} = \frac{16 \times 2}{11 \times 2} = \frac{32}{22} \quad \text{simple gear train}$$

$$\frac{2 \times 20}{1 \times 20} \times \frac{8 \times 3}{11 \times 3} = \frac{40}{20} \times \frac{24}{33} \quad \text{Compound Gear Train}$$

* If G.R for Gear Train is +ve then same direction of crank and plate.

* If G.R for G.T is -ve then opp direction of crank and plate rotation.

eg:- ~~$N = 50$~~ $N = 53$

$n = 50$

$$C.R = \frac{40}{50} = \frac{4}{5} \quad \frac{4 \times 3}{5 \times 3} = \frac{12}{15}$$

$$G.R \text{ for Gear Train} = (50 - 53) \times \frac{40}{50}$$

$$= -3 \times \frac{4}{5}$$

$$= -\frac{12}{5} = -\frac{12 \times 5}{5 \times 5} = -\frac{60}{25}$$

$$= -\frac{3 \times 20}{1 \times 20} \times \frac{4 \times 6}{5 \times 6} = -\frac{60}{20} \times \frac{24}{30}$$

Take "n" as multiples of 5 for easy soln.

SIMPLE CRANK

-ve indicate opp dir of Rotation of Crank & plate

Differential indexing can be used for producing any no. of divisions, but ~~bcz~~ bcz of usage of externally mounted Gear Train it is slightly costly process.

GRINDING

It is conventional finish machining operation used for producing the smooth surfaces on components.

Generally it Removes small amt of material only.

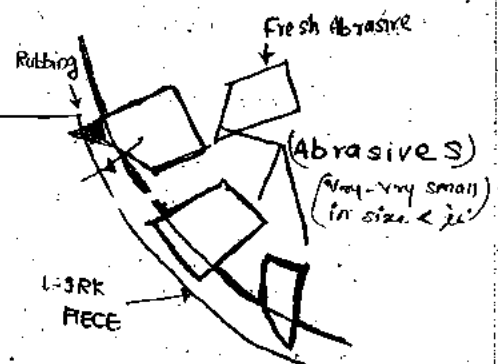
Each and every Abrasive particle present on surface of Grinding wheel is acting

like a single point cutting tool for Removal of material from work piece.

As the Grinding is progressing the Abrasive particles are wearing out slowly.

The worn out particles are started Rubbing on to the work piece producing Rubbing forces. These Rubbing forces are more than sufficient to pull out the blunt Abrasive particles so that fresh and New Abrasive particles present behind will come in contact with work piece and started removing the material. This is called as "self sharpening of Grinding wheel".

Out of all conventional ops. Grinding req. largest cutting Energy. bcz,



→ DRESSING

Sometimes the Grinding wheel may be very Hard such that the Rubbing forces produced is not sufficient to pull out the Blunt Abrasive particles. In such cases the dressing of Grinding wheel will be done called as resharpening of Grinding wheel. For this a thin Layer of material is removed from the surface of the Grinding wheel using Turning operation with diamond single point cutting tool.

BASIC DIFF B/w CONVENTIONAL & NON CONVNTL MACHINING

In Conventional Tool is always Harder than work.



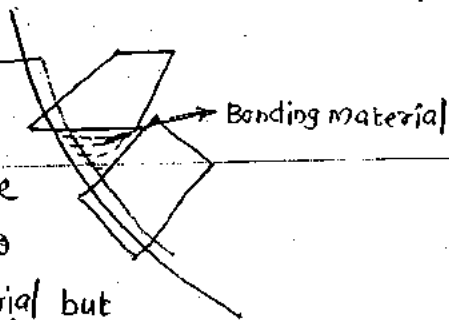
out of all the conventional Methods Grinding is the one which Requires Highest specific cutting energy. This is because of

- ① Random orientation of Abrasive particles. i.e. during Mfg of grinding wheel using powder Metallurgical process; when the mixture of Abrasive particles and Bonding materials are poured into the compacting die, the Abrasive particles are getting oriented Randomly. so only about $\frac{1}{3}rd$ of the Abrasive particles are acting like a single point cutting tool and Remaining are simply rubbing on the workpiece without doing any Machining. Hence the Energy loss due to rubbing tool is higher, and increase in specific E.n.

$$\text{Specific cutting Energy} = \frac{\text{Work done}}{M.R.R \downarrow}$$

Beoz of very small size of Abrasive particles the size of chips produced is also smaller. so material Removal Rate is reducing. Hence specific cutting energy Increases.

Lower ploughing
or
Lower Penetrating Action



Sometimes even though Abrasive particle has higher Capability to penetrate into w.p and remove large amt of material but the Presence of Bonding material ^{bedder} ~~to the~~ the Abrasive particles is Not Allowing the Abrasive particles to penetrate more into the workpiece. so chip size is Reducing, ~~the~~ MRR is Reducing and Specific cutting energy increases. this is called a "size Effect of chip formation"

Shape of Abrasive particle used in Grinding operation.



cubical
with
Rectangle

Shape of chip produced is Triangular

Machining Ratio:-

$$= \frac{\text{Vol of Material Removed on W.P}}{\text{Vol of Tool wear}}$$

Vol of Tool wear

= ~~Grinding Ratio~~ ~~(100 to 1000)~~

In other Conventional M/ching process

Machining Ratio is very Large. ∴ It has

not taken into consideration. But the Machining

Ratio in Grinding operation is called Grinding Ratio

GRINDING RATIO:-

$$= \frac{\text{Vol of M.R on W.P}}{\text{Vol of grinding wheel wear}}$$

Vol of grinding wheel wear

$$= \frac{L \times W \times d}{\frac{\pi}{4} [D_o^2 - D_f^2] \times b} = \underline{0.1 \text{ to } 100}$$

$$\frac{\pi}{4} [D_o^2 - D_f^2] \times b$$

MACHINING TIME CALCULATION:-

$$\text{Time/cut} = \frac{L}{FN}$$

$$L = l + b + AP + OR$$

$$F = \text{Feed mm/rev}$$

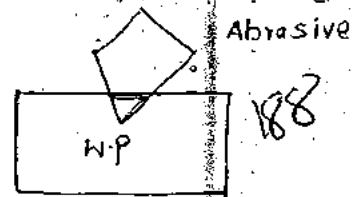
$$N = \frac{1000 V}{\pi D}$$

$$[\text{Cutting velocity } V_c = 18,000 \text{ to } 30,000 \text{ m/min}]$$

→ Note:-

Out of all the conventional M/ching methods Grinding Requires Highest

Cutting velocity

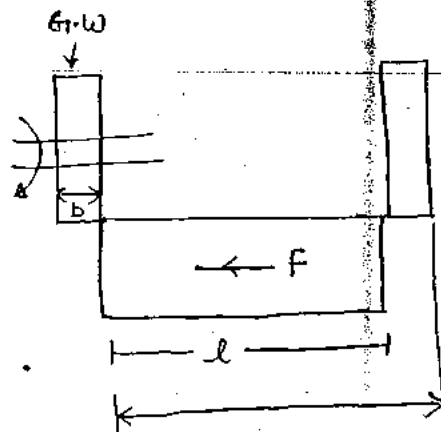


Tool wear
2 to 3mm



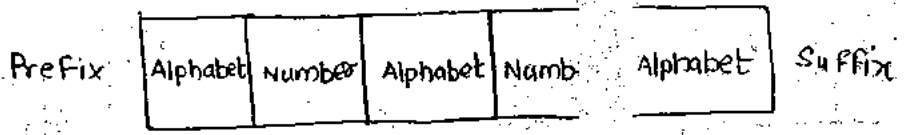
$$\begin{aligned} &\text{Turning} \rightarrow \frac{1 \text{ m}^3}{2 \text{ mm}^3} \\ &= \frac{10^9}{2} \\ &= 0.5 \times 10^8 \text{ mm}^3 \end{aligned}$$

Very Large



SPECIFICATION / DESIGNATION OF GRINDING WHEEL

The standard method of indicating different elements used in manufacturing of grinding wheel is called as specification or designation of grinding wheel.



only Prefix and Suffix are the Non standard codes used by the Manufacturers as secret codes and need not be Revealed to the user of Grinding wheel.

1st Alphabet :- Type of Abrasive

- A : Al_2O_3
- B : Boron carbide (B_4C)
- C : silicon carbide (SiC) (generally available)
- D : Diamond

2nd Number :- Grain size / grid size

- 10 - 24 - coarse
- 30 - 60 - medium
- 80 - 180 - fine
- 220 - 600 - very fine

3rd Alphabet :- Grade of Grinding

- A - H - soft
- I - P - medium
- a - z - hard

4th NUMBER: Structure of Grinding wheel

(79) 87

0-7 - Dense structure

8-16 - open structure

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5th Alphabet: BOND

V - Vitrified

B - Bakelite / Resinoid

S - Silicate

E - Shellac

R - Rubber

The type of Abrasive indicates the Material used for the Manufacturing of Abrasive particles used in Grinding wheel.

Out of the Above Abrasives B_4C is giving very poor performance in Machining and Diamond is costly.

Most commonly used Abrasive particles are Al_2O_3 & SiC .

⇒ Al_2O_3 is softer and Tougher than SiC , whereas SiC

is Harder and Brittle than Al_2O_3 .

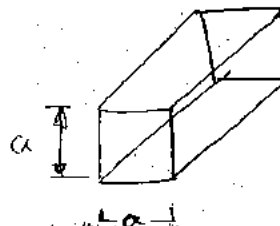
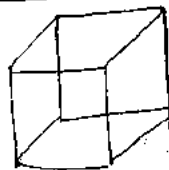
Selection of Type of Abrasive particles is mainly based

on mechanical properties of work material. i.e. for Machining

⇒ of soft and ductile work pieces Al_2O_3 Abrasives are used for

⇒ Machining of hard and Brittle work pieces SiC abrasives are used.

GRAIN SIZE OR GRIND SIZE of Abrasive Particle.



$\left[\frac{1}{\text{Grain size Number}} \right] \text{ inches} = a$ side of size of cubical abrasive particle

10-24 - coarse

30-60 - medium

60-180 - Fine

220-600 - very fine

* App. shape of ab. particles is cubical or sq. etc.

1 inch = 25.4 mm

As the Abrasive particle size is increasing the MRR will be increasing first and then reducing. i.e. when Grain size Number is below 10 the size of abrasive particle becomes very large and it can't act like a tool for removing material.

The Selection of Grain size is done Based on the surface finish Requirements of the Work piece for Rough Grinding operation coarse or medium grain size will be used and finish Grinding operation fine or very fine will be used.

GRADE OF A GRINDING WHEEL

Grade of a Grinding wheel indicates the Hardness of grinding wheel. By combining Abrasive particles and Binding material when the Grinding wheel is produced how the Hardness of Grinding wheel is present, it is indicated by Grade of Grinding wheel. * Grade of Grinding wheel is selected based on Mechanical prop. of W.P.

The Grade of a Grinding wheel is decided Based on compacting pressure applied during compacting stage of a Powder Metallurgical process used in manufacturing of a Grinding wheel. By applying large amount of pressure in the compacting stage of process Hard wheel.

wheel can be obtained.

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A-H → soft Grinding wheel

I-P → Medium " "

Q-Z → Hard Grinding wheel

190' 95'
- Type } of 46 parts.
- Size }
- B.V. }
(Same)

BASIS OF SELECTION OF GRADE

The selection of Grade of Grinding wheel is Based on Mechanical properties of work piece material.

Hard work piece → Hard G.W.
Soft W.P → Soft G.W.

Glazing (Blunting) ^(damage) of Grinding wheel taking place.

Hard work piece → Hard G.W.

Glazing/Blunting of Grinding wheel

During machining of Hard work pieces the forces induced are very High. So tool is becoming Blunt very fast. ^(within 1-2 mins) The Blunt tool/Abrasive particle is started to rubbing on to the work piece and produces

Rubbing forces. If Grinding wheel is a Hard Grinding wheel the Rubbing force produced is not sufficient to pull out the blunt Abrasive particle. So the Blunt Abrasive particle is simply Rubbing on to the W/P without doing any machining. This is called as Glazed Grinding wheel / Blunt Grinding wheel. To

Remove this Glazing of Grinding wheel dressing will be done. During machining of Hard work pieces within 1 to 2 mts

the Grinding wheel will become glazed and for removing

this glazing it needs 15 to 20 mts, which is not a preferable

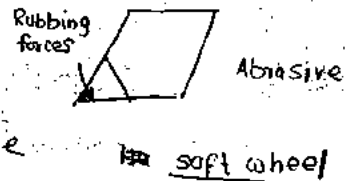
one, if soft wheels are used for Grinding of Hard work piece

^{turning or used for removing layer of mat from surface of G.W. by using pointed cutting tool.}

In soft wheels

When the abrasive particle is becoming Blunt, the Rubbing forces produced is more than sufficient to pull out the blunt Abrasive Particle i.e. self sharpening of grinding wheel will be taking place. Hence soft wheels are used for grinding of Hard Work pieces.

During Grinding of soft workpieces because of smaller amount of forces induced the wear of Abrasive particle is very Low. The same Abrasive particle can be used for 3-5 hrs of



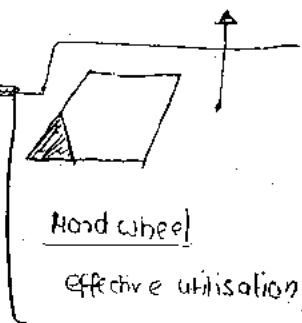
Grinding operation. But if soft wheels are used as and when some amount of wear has been taken place on the Abrasive particle, it induces some amount of Rubbing force which is more than sufficient to pull out the Abrasive particle i.e. without effective utilisation of Abrasive material it is removed from the Grinding wheels. ^{Hence it is not Economical.} If Hard wheels are used for grinding of soft workpieces the Abrasive particles can be effectively utilized. At the end of effective utilization

the dressing of Grinding wheel will be done for sharpening of Grinding wheel. In this case After 3-5 hrs of Grinding operation, spending 15-20 mts of dressing time is very small and negligible.

STRUCTURE :

S.N	Avg Gap b/w 2 consecutive Abrasives particles
0-7	= dense
8-16	= open.

$$= \left[\frac{S.N}{1000} \right] \text{ inches}$$



S.N = Structure No.

eg:-

* The S.N. is choosing by changing the composition of ab. particle and bonding material.

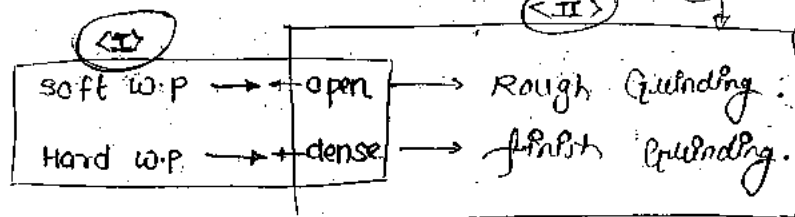
S.N. = 6

$$\text{Avg Gap} = \frac{6 \times 25.4}{1000} \text{ mm}$$

19/10/20

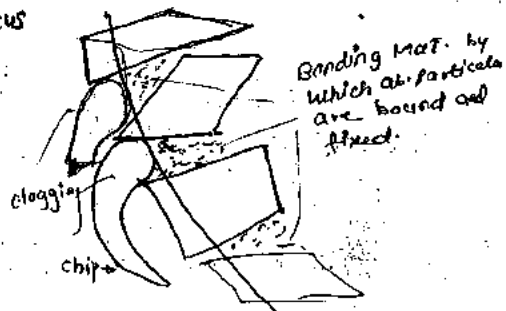
BASIS OF SELECTION OF STRUCTURE

The structure is selected Based on the Mechanical properties (I) of w/p material and Surface Finish Requirements on the work piece.



During machining of soft w.p. continuous and large size chips will be produced.

If dense structure is used for soft w.p. becoz of smaller gap b/w the abrasive particles the large size chips produced will get clogged in b/w the abrasive particles called Loading of Grinding wheel.



LOADING

If open structure is used because of large amount of gap there is no clogging of chips will be taking place.

During machining of Hard w.p. becoz the forces induced are higher if open structure is used becoz of presence of large amount of bonding material in b/w abrasive particles when the force is transmitting from one abrasive to another abrasive chances of breaking the bonding material is very high. But if dense structure is used, the forces can easily be transmitted from one abrasive to another abrasive and grinding wheel can withstand for larger forces.

Rough Grinding $\rightarrow$ open

Finish Grinding $\rightarrow$ dense

* Rough Grinding of ~~open structure~~ soft w.p $\rightarrow$ 12 to 16

* Rough Grinding of Hard w.p = 6, 7, 8

* Finish Grinding of Hard w.p = < 5

* Finish Grinding of soft Workpiece = 7, 8, 9

BONDING:

Bond is indicating Bonding material used for producing Bond b/w Abrasive particles:

Vitrified

Out of the diff Bonding materials Vitrified is the most commonly used Bonding material B/w the Abrasive particle in Grinding wheel. Because it produces Higher Bonding strength, High Temp withstanding capability and High Thermal conductivity.

$\rightarrow$ Rubber and shellac can be used as Bonding material for producing flexible grinding wheel also called as "Buffing wheels" used for super finishing op.

a) Select the Grinding wheel Specification for finish Grinding ab H.S.S cutting tool.

A - 850 - K - 7 - V (A - 270 - K - 8 - V)

b) Select the Specification of Grinding wheel for Rough Grinding of Brass work piece.

A - 20 - S - 12 - V

a) select the Grinding wheel Specification for Finish Grinding of ~~70~~

C1 WP ?

C-250-D-4-V

197
192

P21

$$1) \text{ Time/hole} = \frac{B}{F} \frac{L}{FN}$$

$$= \frac{L + (AP_1 + AP + OR)}{FN}$$

$$= \frac{25}{0.25 \times 300} = \frac{1}{3} \text{ min}$$

$$= 20 \text{ sec}$$

$$2) \text{ Time} = \frac{B}{F} \times \frac{L}{V} (1 + M)$$

$$\left(\frac{\text{double strokes/min}}{\text{RPM}} \right) = \frac{B}{F} \times \frac{1}{\text{RPM of crank}}$$

$$= \frac{300}{0.3} \times \frac{1}{10} = 100 \text{ mm}$$

$$3) \frac{N_{\max}}{N_{\min}} = \frac{D_{\max} \times V_{\max}}{D_{\min} \times V_{\min}}$$

$$= \frac{25 \times 120}{5 \times 40} = 15$$

$$4) \text{ No of High spots/rev} = \frac{360}{30} = 12$$

$$\text{No of High spots/sec} = 12 \times \text{RPS}$$

$$= 12 \times \frac{500}{60} = 100$$

5) Grinding Ratio

vol of material Removed from wp

vol of wheel wear

$$= \frac{200 \times 2.5 \times 5}{4}$$

$$\left[300^2 - (299.46)^2 \right] \times 25$$

$$D_f = D_0 - 2 \times 0.02$$

$$G.R = 5.305$$

$$6) T = 1000 \text{ sec}$$

$$V_c = 0.5 \text{ m/sec}$$

$$L = 80 \text{ mm}$$

$$D = 50$$

$$F = 0.1$$

$$\text{Time/piece} = T_m = \frac{L}{FN}$$

$$= \frac{80}{0.1 \times \frac{1000 \times 0.5}{\pi \times 50}} = 252 \text{ sec}$$

$$\text{No of pieces} = \frac{T}{T_m} = \frac{1000}{252} = 4$$

$$7) \text{ Taper/mm} = \frac{10 - 7.5}{2 \times 80}$$

$$\text{offset} = \text{Total taper}$$

$$= \text{Taper/mm} \times \text{Total length}$$

$$= \frac{10 - 7.5}{2 \times 80} \times 180$$

$$\text{offset} = \frac{D_1 - D_2}{2} \quad (2)$$

$$(11) \quad d = \frac{26 - 20}{2} = 3 \text{ mm}$$

$$\text{cut/tooth} = 0.0075 \text{ mm}$$

$$\text{no. of tooth} = \frac{d}{h} = \frac{3}{0.0075}$$

$$L_e = n \times p = n \times 10$$

$$L = L_e + L_t$$

$$= L_e + 25 = n \times 10 + 25$$

$$= \left[\frac{3}{0.0075} \right] + 25$$

$$(\because v = 0.5 \text{ m/min})$$

$$\text{Boring time} = \frac{L}{v} = \frac{L}{0.5}$$

$$(12) \quad \text{Time/D.S} = \frac{L}{v} [1 + M]$$

$$\text{RPM of crank} = \frac{1}{\text{Time/D.S}}$$

$$= \frac{v}{L(1+M)} = \frac{18000}{200 \left(1 + \frac{2}{3}\right)}$$

$$(13) \quad B = 300 + 5 + 5 = 310$$

$$L = 2000 \text{ mm}$$

$$M = \frac{1}{2}$$

$$\therefore f = 1 \text{ mm/stroke} ; v = 1 \text{ m/sec}$$

$$\text{Time/cut} = \frac{B \times L}{f \times v} [1 + M]$$

$$= \frac{310 \times 2000}{1 \times 1} \left[1 + \frac{1}{2}\right]$$

$$= 930 \text{ sec} \quad \downarrow \quad 2 \text{ w.p}$$

$$\text{Time/Piece} = \frac{930}{2}$$

$$= 465$$

$$(14) \quad L_e = L_r + L_s + L_f$$

$$L_s = 8 \times 20 = 160$$

$$L_f = 4 \times 20 = 80$$

$$d = 45$$

$$= d_o + d_s + d_f$$

$$d_o = d - (d_s + d_f)$$

$$= 45 - [n_s \times h_s + n_f \times h_f]$$

$$= 45 - [8 \times 0.0125 + 4 \times 0]$$

$$= 44$$

$$n_r = \frac{d_r}{h_r} = \frac{44}{0.1} = 44$$

$$L_r = 44 \times 22 = 968$$

$$L_e = 968 + 160 + 80$$

$$= 1208 \text{ mm}$$

$$(15) \quad L = 200 + 5 + 5 + A P_1$$

$$f = f_t \times Z$$

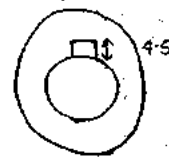
$$= 0.1 \times 12$$

$$N = \frac{1000 \times 50}{\pi \times 100}$$

$$\text{Time/cut} = \frac{L}{f \times N}$$

$$A P_1 = \frac{1}{2} [D - \sqrt{D^2 - w^2}]$$

$$= \frac{1}{2} [100 - \sqrt{100^2 - 80^2}]$$



(16) a

(17) b

$$(18) T_m = \text{Time/Piece} = \frac{L}{FN}$$

$$= \frac{576}{0.2 \times 144} = 20 \text{ min}$$

$$T = \left[\frac{75}{V} \right]^{1/0.75}$$

$$V = \frac{\pi DN}{1000}$$

$$= \frac{\pi \times 1000 \times 144}{1000}$$

$$\text{No of Tools} = \frac{T_m}{T} = \frac{20}{1.96} = 11 \text{ tools}$$

$$\text{No of Tool changes} = 11 - 1 = 10$$

$$\begin{aligned} \text{Total Time} &= T_m + T_{tc} \\ &= 20 + 10 \times 3 \\ &= 50 \text{ mts} \end{aligned}$$

(19) 0.25 mm/D.S

Feed

$$(20) \text{Time/Hole} = \frac{L}{FN} = \frac{45 + 15 \times 0.2}{0.2 \times 1000 \times \frac{\pi \times 20}{\pi \times 15}}$$

$$\begin{aligned} \text{No of Holes/Tool Life} &= \frac{100}{\text{Time/Hole}} \\ &= 161 \end{aligned}$$

$$\text{Avg production time/Hole} =$$

$$\frac{\text{Time} + \text{Idle time} + 300}{\text{No of holes}}$$

(21) 6

193 198

$$\text{Train value} = G.R = \frac{N_f}{N_d} = \frac{P_f}{P_d}$$

$$= \frac{3.175 \times 40}{6 \times 40}$$

$$= \frac{127}{40} \times \frac{1 \times 20}{6 \times 20}$$

$$= \frac{127 \times 20}{40 \times 120}$$

(23)

$$C.R = \frac{40}{28}$$

$$1 \frac{12}{28} = 1 \frac{3}{7}$$

$$1 \frac{3}{7} \times \frac{3}{3}$$

$$1 \frac{9}{21}$$

(24)

(26) b

(27) c

(28)

$$\eta = \eta - 1 \sqrt{\frac{N_{max}}{N_{min}}}$$

$$= 5 \sqrt{\frac{353}{34}}$$

$$\begin{aligned} N_4 &= N_1 r^3 \\ &= 34 \times r^3 \end{aligned}$$

(29)

$$M = 0.6$$

$$\text{Avg speed} = L \times N (1 + M)$$

$$= 250 \times 30 [1 + 0.6] = 12 \text{ m/min}$$

(30)

$$f_m = P_t \times Z \times N$$

$$= 0.05 \times 12 \times 1000 \times 22$$

31) Feed = Lead = no of starts $\times$ pitch
 $= 2 \times 1 = 2.0$

Time = $\frac{L}{V} = \frac{L}{0.05} = \underline{\hspace{2cm}}$

32) b

33) d

34) d

35) $L = d + AP_1$
 $= 200 + AP_1$

$AP_1 = \frac{1}{2} \times [D - \sqrt{D^2 - d^2}]$

$= \frac{1}{2} \times [75 - \sqrt{75^2 - 50^2}]$

36.

$L = 209.55$

offset = $L \tan \theta$

$= 150 \tan 1.5$

39.

~~38~~

offset
 $= 400 \sin 2^\circ$

40.

$1 \frac{3}{17} \left\{ CR = \frac{40}{34} \right\}$

~~37~~

$1 \frac{6}{34}$
 $1 \frac{3}{17}$

41.

CR = $\frac{40}{28}$

44.

Reamer or drill bit

45.

$n = \frac{6}{0.05}$

$L = n \times 5$

07/06/12

ADVANCED MACHINING METHODS

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Difficulties or Limitation of Normal Machining Methods:-

1. The Accuracy of the Components produced depends on the efficiency of operator.
2. Consistency in manufacturing is not present. Hence 100% inspection of component is reqd. *family problem, mood etc.*
3. The personal needs of the operator are Reducing are Reducing the production Rates. Time Req. for producing the component is increased.
4. Bcoz of large amount of man power is involved, the labour law problem will be present. Leads to strikes, lockouts.
5. The complex shapes like the parabolic Curvatures Components, cubical curvatures components, is difficult to manufacture.
6. Frequent design changes in the component can't be incorporated in the existing layout.
7. ~~work in process inventory will be increased.~~
To overcome the above disadvantages the advanced Machining methods like NC, CNC, DNC, ANC, FMS etc has been developed.

NC MACHINE:- (Numerically controlled Machine Tool)

If each and every axis of a Machine tool is controlled by using number or numerals it is called Numerically controlled Machine Tool.

BASIC PARTS:-

1. MCU or CPU (Machine Control Unit @ Central processing unit)
2. Drive unit (O/P)
3. Feed Back device (I/P)
4. Tape Reader system (I/P)
5. Manual controls (I/P)

MCU (Machine control unit or Central Processing unit)

The MCU is working like a brain of a Human being i.e. MCU is taking input information from the I/P device available in NC machine; analysing the data or information, ^{Based on Analysis} taking the decisions and all these decisions will be implemented by using o/p devices available in the NC machine.

The input information given by the Human Being through Tape Reader system or manual controls is in the form of decimal system. But the machine can understand only the Binary system of information (Low level Language). ∴ a device is reqd in MCU to convert the decimal to Binary and vice versa. The device used is ALU (Arithmetic Logic unit)

DRIVE UNIT:-

[o/p device]

Electric motor

- (i) Induction
- (ii) stepper
- (iii) servo

* The Drive unit is usually taking input information from MCU in the form of electrical signals and it is converting electrical energy into mechanical energy. For converting electrical energy into mechanical energy device used is called Electric motor.

In case of Induction motor whenever the power supply is given to motor, it always starts rotating at only one particular RPM i.e. the design RPM. But in case of NC machine it is reqd to rotate the motor at diff rpm for performing machining at diff ~~speed~~ cutting velocities. Hence induction motor can't be used as drive unit in NC machine.

Stepper Motor:-

In case of Stepper Motor when the pulsed electrical energy will be given as input to motor, the motor starts rotating either by changing the no. of pulses of electrical energy input or by changing rate of pulses of electrical energy.

At the time of development of M/C machine servo motor was not developed. out of the stepper motor and induction motor, stepper motor is used as drive unit of M/C machine.

input, the rpm of motor can be changed. In case of stepper motor there is no mechanism available to stop the motor or arms at the reqd destination. ∴ the Accuracies of component produced is poor.

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SERVO MOTOR:

Servo motor is also working similar to stepper motor i.e. it is taking the pulsed electrical energy as input and produces the mechanical energy reqd for travelling the axis at diff rpm. In addition, the servo motor system also consists of quick action Braking system to stop the axis of motor exactly at the position wherever it is reqd. ∴ High positional accuracies of the machine can be obtained. Hence Accurate or close dimensional toleranced component can be produced.

DRIVE UNIT DESIGN:-

150 pulse = 1 rev of motor

- 1 rev of Lead Screw
- 1 pitch or 1 Lead
- 5 mm
- 5 mm

Whenever the Power supply is stopped to the Motor, the quick Action Braking system is activated.

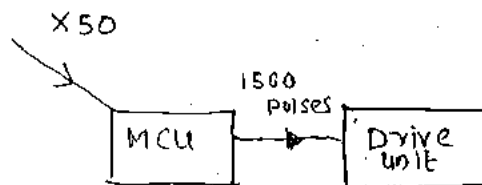
150 pulses → 5 mm

$$1 \text{ pulse} = \frac{5}{150} = 0.033 \text{ mm}$$

= 1 BLU

(Basic Length unit)

Positional Accuracy of M/C



If $x = 50$

For 1 mm $\frac{150}{5} = 30 \text{ pulses}$

For 50 mm $50 \times 30 = 1500$

$1500 \pm 1 \text{ Pulse}$

1499 to 1501

↓

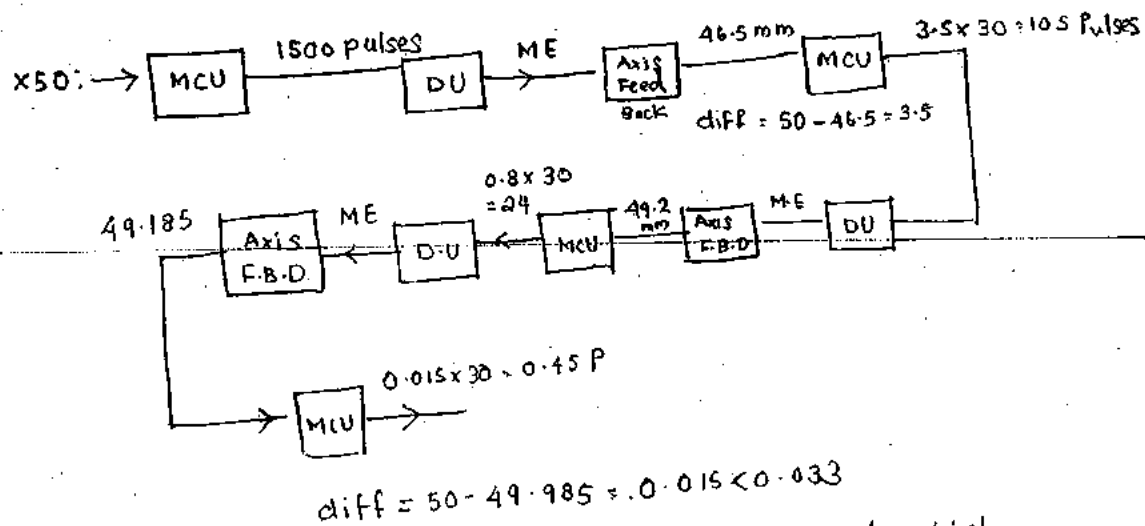
49.967 to 50.033

∴ $50 \pm (0.033)$

Positional Accuracy or Positional Error

Feed Back Device - [FBD]

The feed Back device is a displacement measuring equipment mounted on the axis of a machine for measurement of actual distance travelled by the axis and sending it as a feed Back to the MCU so that the MCU will compare the actual distance travelled by the axis, determines the difference in distance. Corresponding to this diff in distance the MCU will again generate the electrical energy pulses and send it to motor so that motor will generate the mechanical energy reqd for travelling the Remaining distance. once again the feed Back device will measure the actual distance travelled by the axis and send it as feed Back to MCU. this process continues until the diff in distance travelled is less than or equal to 1BLU



→ Whatever the displacement measuring instrument which give displacement o/p in the form of electrical energy/signals can be used as feed Back devices.

1. Potentiometer → millimeters
2. L.V.D.T

↓ Better Accuracy in measurement of displacement

3. Capacitance Transducer
4. Inductance Transducer
5. Synchros
6. Resolvers
7. Inductosyn
8. Tachometer
9. Tachogenerator
10. Encoders - ~~Not~~ (Can measure Nanometers) Most Accurate

115
20,

196

Tape Reader system:-

The punched Tape used in N/C Machine is divided into 8 tracks

Track No: 1 to 4 → Alphabets

1-N → Block No

2-X
 3-Y
 4-Z

} Axis names

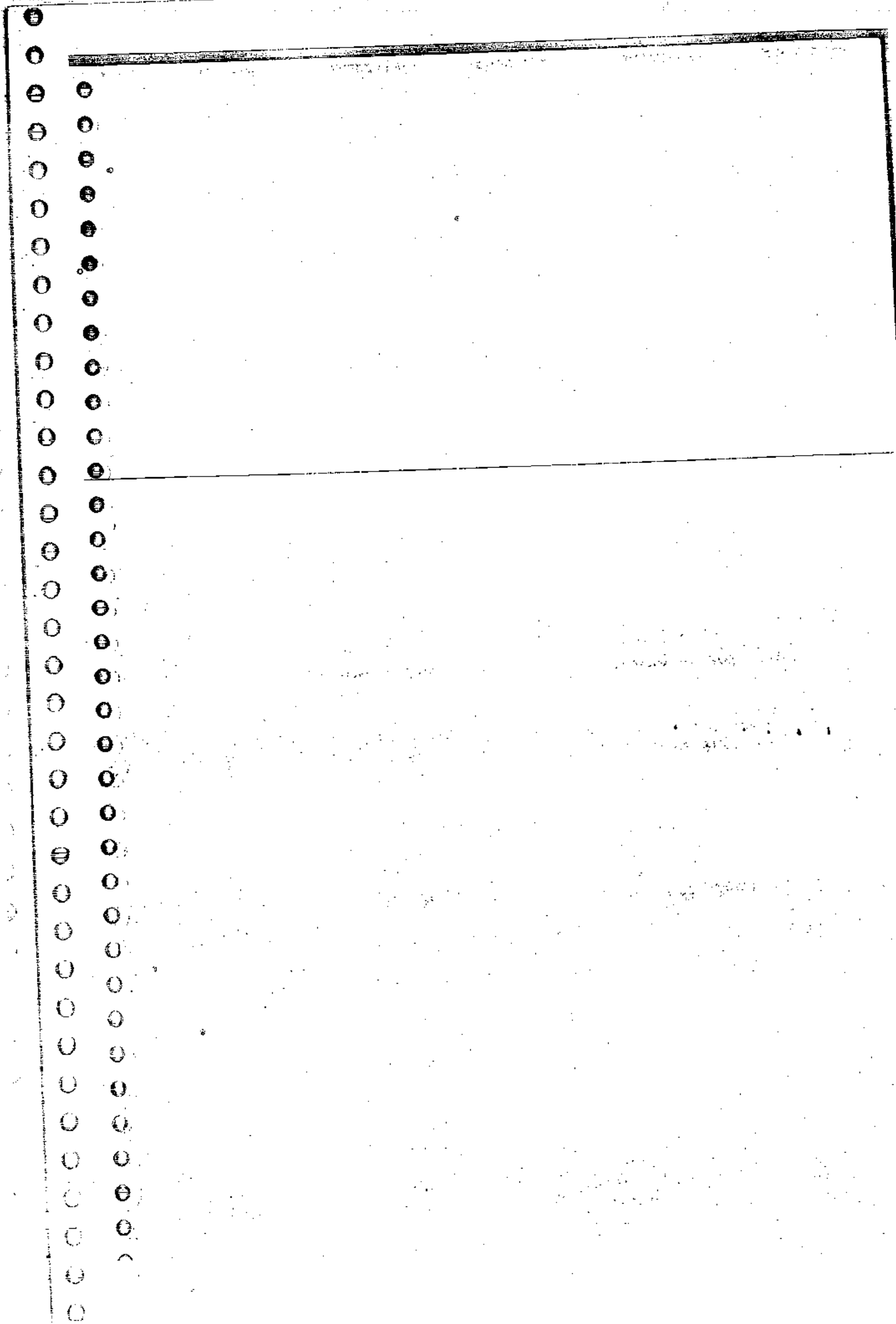
Track No: 5 - parity check (position check)
for proper indexing

6 & 7 - Numbers

8 - End of Block

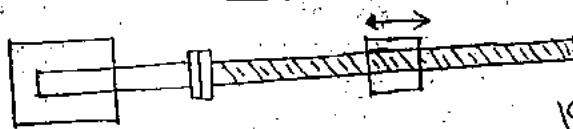
1	2	3	4	5	6	7	8
0	0			0		00	
				0		000	
		0	-	0	-	000	0
				0			
				0			
				0			
				0			
				0			

In NC machine program, one block of information means one complete instruction is given to the machine for travelling the axis from present position to the next position.



Drive unit design

Stepper Motor



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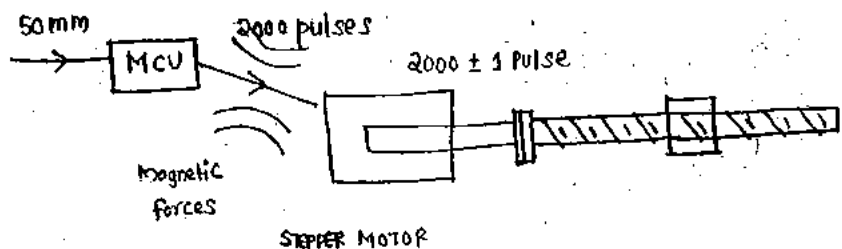
200 pulses $\rightarrow$ 1 rev of motor
 $\rightarrow$ 1 rev of Lead screw
 $\rightarrow$ 1 p. or 1 Lead

200 pulses = 5 mm

$$1 \text{ pulse} = \frac{5}{200} = \frac{1}{40} = 0.025 \text{ mm} \Rightarrow 1 \text{ B.L.U}$$

(Basic Length Unit)

B.L.U is also called as positional error or positional Accuracy of
 M/C Tool



200 pulse = 5 mm

(D.U)

$$\frac{200 \times 50}{5} = 2000 \text{ pulses}$$

-1 pulse $\rightarrow$ due to energy losses

+1 pulse $\rightarrow$ due to the magnetic forces
 1 additional pulse will be formed

$$1999 \text{ pulse} \rightarrow \frac{5}{200} \times 1999 = 49.975$$

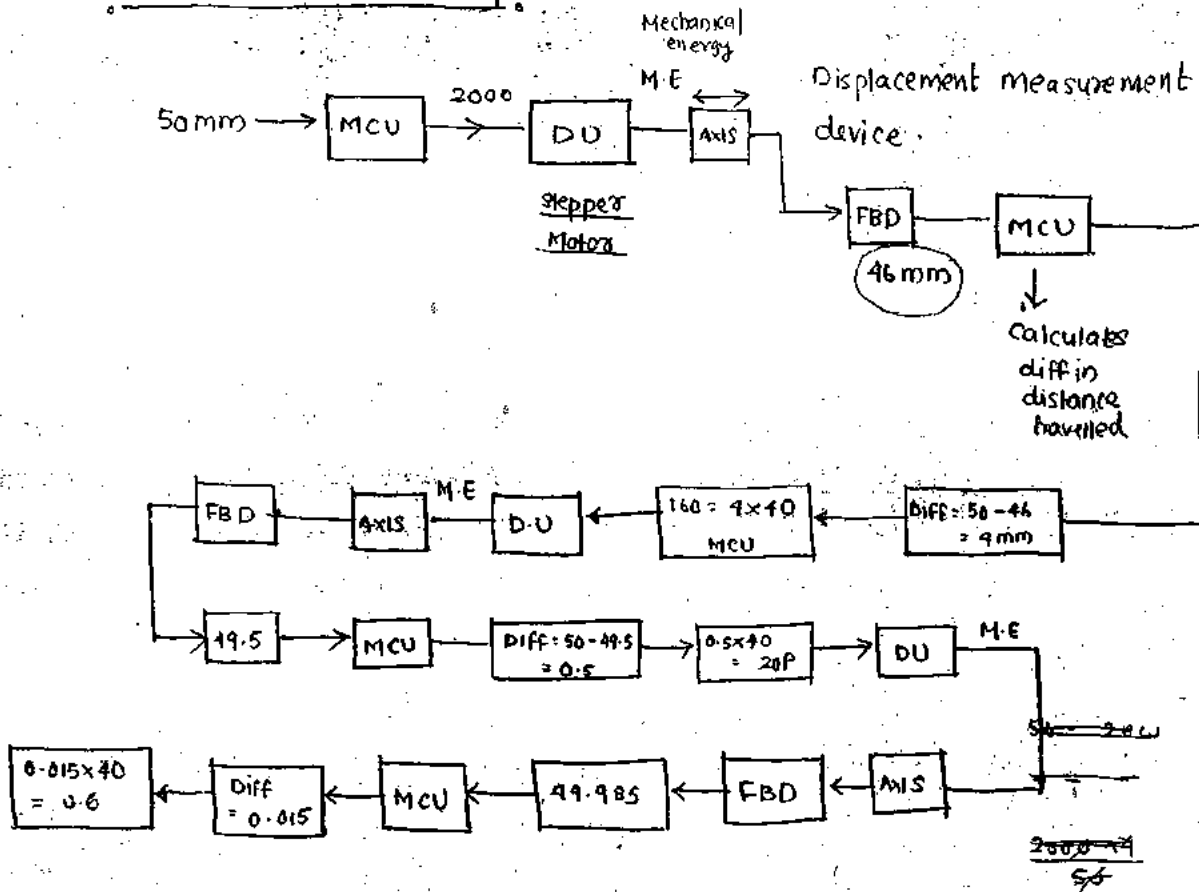
$$2001 \text{ pulses} \rightarrow \frac{5}{200} \times 2001 = 50.025$$

Distance Travelled by axis

Possible Distance = 49.975 to 50.025

Positional Error = $\pm 0.025 \text{ mm}$

FBD [Feed Back Device]



$$5\text{mm} = 2000 \text{ pulse/s}$$

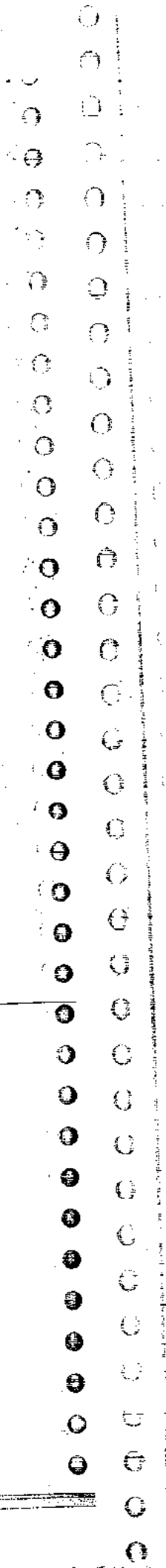
$$1\text{mm} = \frac{2000}{5} = 400 \text{ pulses}$$

TAPE READER SYSTEM

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Bar Number	Circle Position (approx. % of height)
1	95%
2	50%
3	70%
4	0%
5	0%
6	0%
7	0%
8	0%

$$\begin{array}{r|l} 2 & 15 \\ 2 & 7-1 \\ 2 & 3-1 \\ & 1-1 \end{array}$$
$$2^3 \quad 2^2 \quad 2^1 \quad 2^0$$
[illegible]



For Reading the instruction given in the punched paper tape, the ¹⁹⁹ 204
Tape Reader system will be used.

In Tape Reader System one side of tape, light is provided and other side of the Tape, the light Receiving Sensors are provided corresponding to each and every Track - ie in total 21 light Receiving Sensors will be provided. When the Tape is moving and stopping at some location, wherever the Holes are present, the light is passing and incident on light Receiving Sensors. whatever the Sensors which are Receiving the light, they will be generating the electrical energy and this electrical energy will be send to the mcu. When the Mcu is Receiving the electrical energy the corresponding position will be assumed as 1. wherever the Holes are Not present the light is Not passing, the corresponding sensors are Not generating any electrical energy. Hence they are Not sending anything to the mcu. The corresponding positions will be assumed as zero by mcu.

MANUAL CONTROLS

Inspite of Having the above parts NC machine Requires the manual interventions like switching on and off the machine, Loading and unloading of work piece on to the machine, Loading and unloading of Tape on to the Machine etc

classification of NC MACHINES:-

Based on control system :-

- ① PTP control system
- ② straight line control system
- ③ Contour control system

II Based on FBD used

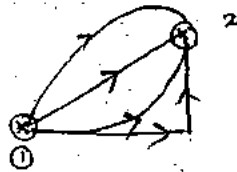
- a) open loop system
- b) closed Loop system

III Based on No of simultaneous axis used :-

2D, 2½ D, 3D, 4D, 5D 11D

Point to Point Control system :-

If end point of movement of Tool is only important and path followed by the Tool in b/w end point is not important it is called point to point control system



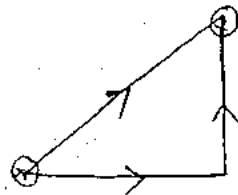
PTP is used during drilling, Reaming, Tapping etc.

For PTP No need to have the simultaneous Axis movements and only one axis movement at a time is sufficient.

Straight Line control system :-

In Addition to end points of Movement of Tool if the path followed by the Tool in b/w end points is a straight line path, the control system used is called as straight line control system

For straight Line control system Atleast 2 axis simultaneous movements are Req'd.



It is used in Turning, Milling, shaping, Grinding, planing etc.

Contour Control system:-

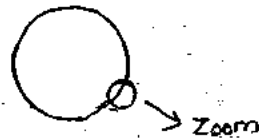
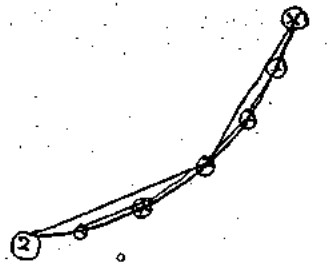
200 119

In Addition to end points of movement of the tool if the path followed by Tool in b/w endpoints is a counter path is called called contour control system.

For Contour control system
Atleast 3 axis simultaneous
Movements are Required. It is
used in Turning, Milling, Grinding
etc.



It is impossible to produce perfect circular Contour. The contour is constructed by many No of straight lines.



If the distance b/w a consecutive points on a contour is smaller and smaller, the smooth and smooth contour can be produced. For this in programming of NC machines Interpolation parameters will be used for indication.

I $\rightarrow$ x Axis
J $\rightarrow$ y Axis
K $\rightarrow$ z Axis

} Interpolation
parameter

0.001 to 999.999

Interpolation parameter means that the maximum distance distance b/w a consecutive points on a contour. If the interpolation parameter is set as a smallest value, no doubt it is producing smooth contour, but Time taken for Manufacturing of Component is Higher. Hence Based on Requirement

is selected and indicated in the program

OPEN LOOP SYSTEM: ↓

NC Machine without the use of Feed Back device is called open Loop system. Because of Non Availability of FBD, the NC M/c system is a unstable system and the dimensional accuracies achieved is poor.

NC machines with the use of FBD is called as closed loop system. It is a fully stable system and produces Accurate components.

2-D Axis system

If two Axis of one Tool are moving simultaneously, it is called as 2D M/c Tool. In this rotation of job is unavailable means it is taken as spindle.

3-D system: -

In Addition to two Axis simultaneous movements of one cutting tool, if the rotation of job is also considered as a axis, called as 3-D M/c Tool.

4-D system: -

If a axis each of two tools can be controlled simultaneously for removing material from one w.p, it is called as 4-D M/c tool. and in this Rotation of job will be considered as a spindle.

$\frac{110}{2 \frac{1}{2} D}$ = is not here please Collect Some where by Ramu

CAD

901 120 206

Design of components using Computer is called Computer Aided Design (CAD).

Shaft $\rightarrow$ 10kW @ 500 rpm

and Having ϕ 5 mm cross hole.

$$\frac{T}{J} = \frac{G \theta}{L}$$

$$\frac{T}{J} = \frac{\tau}{r}$$

Rigidity criteria

Strength criteria

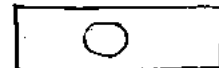
$$d_{max} = \underline{\hspace{2cm}}$$

Biggest of 2 values of dia obtained

SCF - stress conc factor is to be designed

FOS = 2 (min)

Factor of safety.

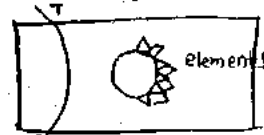


Basic diff b/w Conventional design and Computer Aided design.

In computer design the solid body is divided into no of elements. so it is easier. In conventional design the ^{Body} ~~element~~ is considered as a single element. so In computer design accuracy is very High.

Here SCF = 1

FOS = 1.25 (max).



The Basic diff b/w conventional and Computer Aided design are,

In conventional design, the total Body can be considered as a single element and Analysis will be continued Based on single element only.

In case of CAD the Body can be divided into many no of small size finite elements and analysis is continued as a elemental Analysis. Bcoz of elemental Analysis used in CAD the design of component will be easier and more accurate and bcoz smaller size of elements has been taken near to change in c/s the stress conc factor (SCF) need not be taken. In CAD bcoz of most of the uncertainties has been considered during the

analysis, the Maximum factor of safety to be used is 1.25 whereas in the Conventional design to account for the uncertainties present during the usage of component min factor of safety to be used is 2

Inputs Req'd:-

1. Loading Conditions
2. Approximate Shape
3. Material properties
4. Allowable strains

Process steps:-

1. Generation of 2-D drawing
2. Import into the Analysis package
3. Convert into solid models
4. Divide into no. of finite elements
5. Apply Loading conditions:
6. obtain max stresses and strains
7. Compare with Allowable
8. change the Material and dimensions until the stresses and strains are nearly equal or less than than allowable stresses and strain.
9. Finalise the dimensions.

outputs obtained:-

1. 2-D Production Drawings
2. BOM (Bill of Material)
3. stresses and strains

The o/p obtained is given to CAM

CAM (Computer Aided Manufacturing) : 7

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202

$$FMS + ASRS + CMM = CAM$$

ASRS : Automated Storage and Retrieval system

ASRS :

~~ASRS~~ Automated Material Handling system used in stores for Retrieving the Raw material and storing the finished goods.

• is ASRS :

CMM (Coordinate Measuring Machine)

CMM is used for measuring more than one dimension simultaneously.

Inputs of CAM :

1. 2-D production drawings
2. BOM
3. Raw materials.

PROCESS :-

1. Generate CNC Part Program
2. Retrieving Raw materials from stores
3. Machining
4. Inspection using CMM

[simple parts $\Rightarrow$ computer can generate the code
only for complex parts, manual
Program coding Req.]

OUTPUT :-

Acceptable finished goods

CAD-CAM :-

Input :

Input of CAD

Process :

Process steps of CAD + CAM

output :

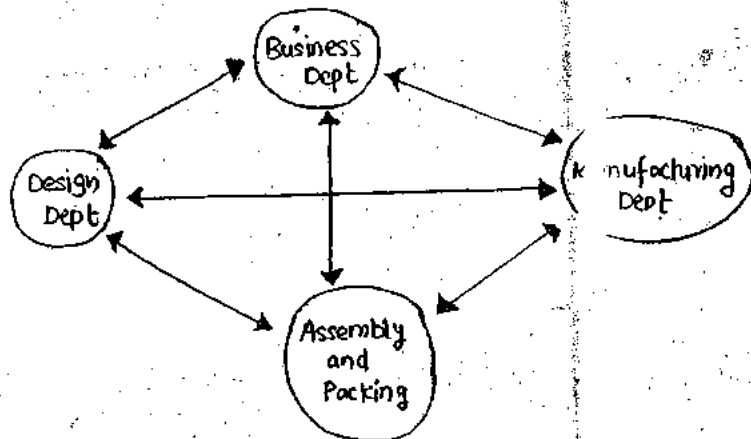
output of CAM

CAD-CAM is an integral approach used for design and manufacturing of components together as a Manless Manufacture.

Extension of CAD-CAM is CIM

CIM (Computer integrated manufacture)

Any industry can be divided into 4 departments:-



Integrating diff departments present in manufacturing industry by using a computer such that manless manufacturing is possible is called as computer integrated manufacturing.

Dell company has implemented CIM system
only one company

Manufacturing of
computers.

In Automobile manufacturing or other parts
taste is diff for everyone so cost becomes very
very high.

PART PROGRAMMING OF CNC MACHINES:

APT was used in earlier days.

203 12

Part Programming is a coded programming written based on the standard codes available in CNC machine. Each code is indicating the name of the program, written for the specified movement of the tool. Whenever the code is used in writing the part program the program corresponding to specified movement of tool will be automatically executed.

G codes (General Purpose) [G00 to G999]

G00 - Rapid Traverse

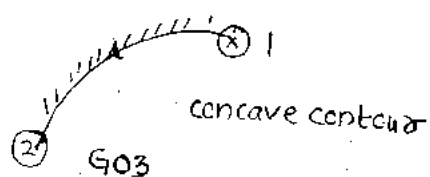
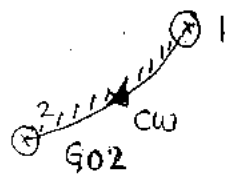
Whenever the tool is travelling in ideal conditions, it is required to travel at max possible speeds. But the M/C programmer can't remember the maximum speeds available in each and every M/C tool of a shop floor. In such cases if the programmer indicates G00 the machine is automatically adapting the optimum max possible velocity present in machine tool so that ideal motion time is minimum and the machine is also ~~safe~~ safe.

G01 - Linear Interpolation

Whenever the tool is required to travel linearly to produce the linear dimensioned components the code used is G01.

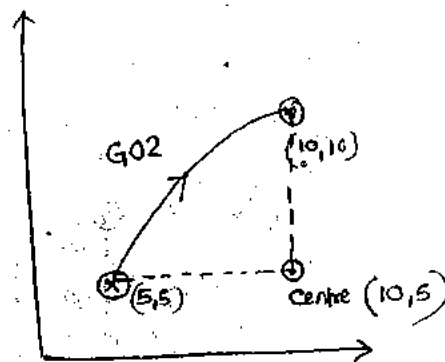
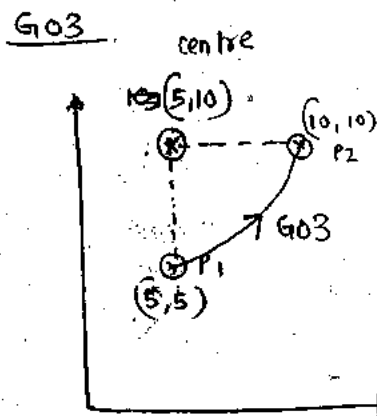
G02 - Circular Interpolation CW }
G03 - " " CCW }

Whenever the contour shaped components are to be manufactured the circular interpolation will be used.



ex: $P_1 = (5, 5)$
 $P_2 = (10, 10)$ } G02

What is the Coordinates of centre of Arc produced



G04 - Dwell

Dwell is temporary stoppage of M/C for specified duration

G04 F50

Specified
duration
in
Sec

Simply

G04

Syntax error

It has to be always followed
by Time.

F followed by No: indicates Temporary stoppage duration in Sec.

G05 - Hold

Temporary stoppage of M/C for unlimited duration.

No need to specify the Time

G05 F50 - Syntax error

G08 - Acceleration

If G08 is indicated, the M/C is started with a lower vel, slowly increasing and



damages taking place in tool and workpiece due to sudden increase in velocity will not take place

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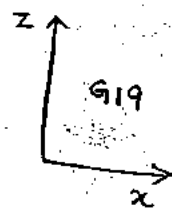
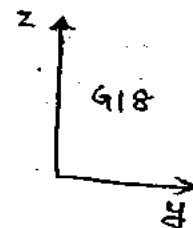
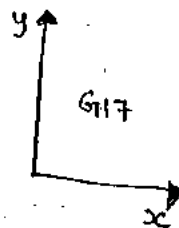
G09 - Retardation:

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By indicating G09 whenever the Tool is nearing to the destination, the velocity of tool will be Reduced so that it is possible to stop the Tool wherever it is Reqd.

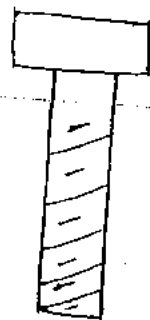
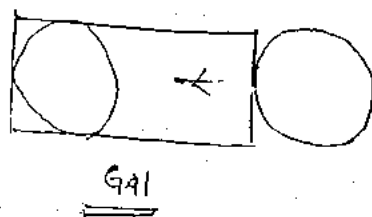
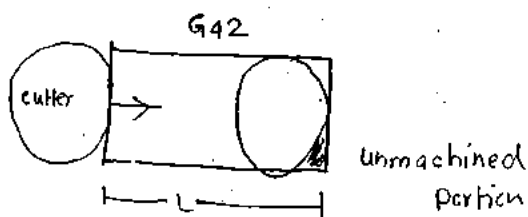
G08 & G09 - Default codes Nowadays.

- { G-17 xy plane
G-18 yz plane
G-19 xz plane } Plane selection



- { G33
G34
G35 } Thread cutting with constant pitch.
Thread cutting with increasing pitch
Thread cutting with decreasing pitch

- { G41 - Tool Radius Compensation Left
G42 - Tool Radius Compensation Right }



Increasing pitch

- G-70 - English Programming [Programming in terms of inches]
- G-71 - Metric programming [Programming in terms of mm]

G70 x 15

x axis to travel by 15 ~~mm~~ inches

G71 x 15

x axis to travel by 15 mm

G71 - Default code used in today's machines

- G90 - Absolute Mode of Programming
- G91 - Incremental Mode

For each and every movement of tool the programming is done with Reference to only one Reference point is called Absolute mode of programming. If the present position of tool can be taken as a Reference point for programming to the next position of tool it is called as Incremental mode of programming.

Most Commonly used in India

Absolute Mode

(Power failure is a major problem) so Absolute Mode

It is easy to write the Incremental program than the Absolute mode. But According to the Indian conditions we prefer to use the Absolute Mode of program only. Bcoz during running of program if power failure occurs it is very easy to locate where the program has got stopped and continue the program from there itself after restoring the power.

M Codes :- (M - M/C or Miscellaneous codes)

(M00 to M99)

M00 - program ~~start~~ stop → G05

Temporary stoppage of M/C for unlimited duration

M01 :- Planned stop = G04

Temporary stoppage of M/C for specified duration

M01 F70

M01 - syntax
error

M02 - End of main Program written without use of
sub programs

{ M17 :- End of sub Program

{ M30 :- End of Main Program written with use of sub Programs

SUB PROGRAM

Whenever there is a repeatable movement of tool is present for the Repeatable movement a program is written called as subprogram. This subprogram will be called whenever the Repeatable movement is Read in the main program.

L100.SPF

The Name of the Subprogram must start with letter 'L' afterwards either only alphabets or only numbers or combination can be used upto a max of 64 characters in total

SPF = sub program function

which is the file name extension for

Subprogram.

L100 SPF

N01 - - - - - LF

N05 - - - - - LF

N10 - - - - - LF

N60 M17 LF

LF → Line Feed → EOB (End of Block)
or
)

Block Numbers are always taken as incremental No! only because in future any design modifications can be incorporated very easily in b/w the Block Numbers.

M17 indicates end of sub Program

MAIN PROGRAM

100 MPF

The Name of Main Program will be upto 64 characters either with only no's or only alphabets or combination of Numbers and alphabets

100 MPF

N01 - - - - - LF

N05 - - - - - LF

N10 - - - - - LF

N15 - - - - - LF

No subprogram

N100 M02 LF

200 MPF

MPF = Main Program file

N01 ----- LF

N05 ----- LF

N10 L100 (P5) LF

N15 ----- LF

N20 ----- LF

⋮

N90 M30 LF

P5 = No of times the sub program
is to be executed
Here 5 times

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If simply L100 then sub program will
be executed only once

ie L100 = L100 P1

{ M03 - spindle start cw
M04 - spindle start ccw
M05 - spindle stop

M03 S 500

Here spindle speed has to
be specified

M04 S 500

S 500

→ spindle speed in Rpm

Here it is 500 rpm

M06 - tool change

useful only in case of Machining centres

M06 T10

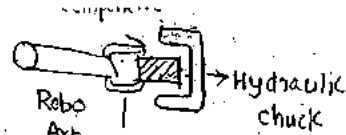
→ indicates tool to be replaced

M07 - coolant Pump 1 ON

M08 - " " 2 ON

M10 - clamping

M11 - Decamping



Hydraulic
chuck
can be used

when the
chuck is engaged
Rebo arm will
release the
load on arm

M01 F70 } Time of stoppage in Sec
G04 F50 }

N35 X50 Y20 F(5000) L1

Feed in mm/min

other than M01 and G04 wherever F followed by Number
is used will indicate the feed in mm/min

I - Interpolation parameter X axis

J - " " Y axis

K - " " Z axis

PROBLEMS

Page 59

Q1 Rev of Lead Screw = $\frac{200}{5} = 40 \text{ rev}$

Angular displacement = 40×360
= 14400

Q2) 1 BLU = distance travelled ^{by Axis} per pulse

No of Pulses = $\frac{9}{\text{BLU}} \times \frac{9}{0.005} = \underline{1800}$

Q3) 360 pulses $\rightarrow 360^\circ$ of L.S.
 $\rightarrow 1 \text{ Rev of L.S.}$
 $\rightarrow 3.6 \text{ mm}^2$

1 pulse $\frac{3.6}{360} = 0.01 \text{ mm}$
= 10 microns

- (4) c
- (5) d
- (6) P = 5 mm
- N = 100 rpm
- V = 10V

126
211
267

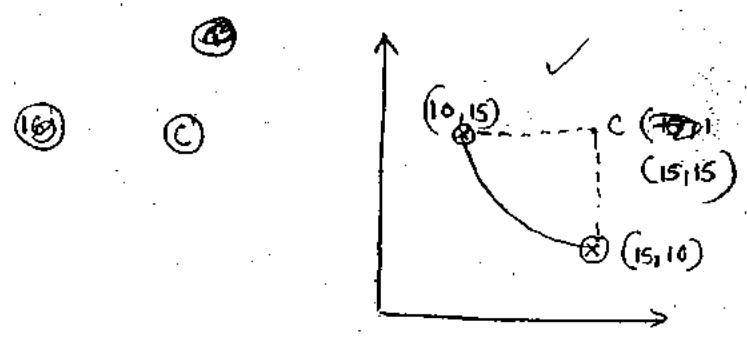
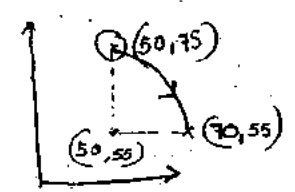
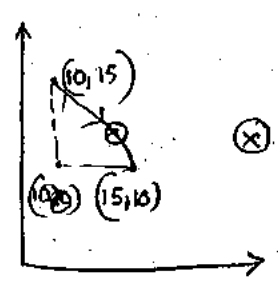
10V → 100 rpm
→ 100 x 5 = 500 mm/min

3000 mm/min = $\frac{10 \times 3000}{500} = 60V$

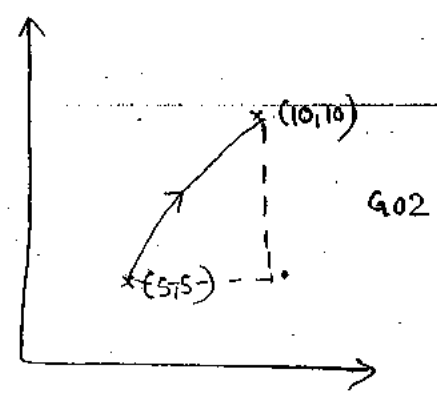
- (7) b
- (8) c
- (9) c
- (10) b
- (11) a
- (12) b

- (13) b
- (14) a
- (15)

10V = 500 mm/min
x = 3000



(16)



N05 X5 Y5
N10 G02 X10 Y10

N05 X5 Y5 X5 Y5 (X) wrong Representation

(17)

(17)

$$1 \text{ pulse} \rightarrow 1.8^\circ$$

$$1 \text{ rev of L.S.} \rightarrow 360^\circ$$

$$\rightarrow \frac{360}{1.8} = 200 \text{ pulses}$$

$$200 \text{ pulses} = 1 \text{ rev L.S.}$$

$$= 1 \text{ pitch}$$

$$200 \text{ pulses} = 2 \text{ mm}$$

$$1 \text{ pulse} = \frac{2}{200} = 0.01 = \underline{\underline{10 \text{ microns}}}$$

(18)

$$200 \text{ pulses} = 1 \text{ rev}$$

$$= 4 \text{ mm}$$

$$G = \frac{O/P}{I/P} = \frac{1}{4}$$

$$4 \times \frac{1}{4} = 1 \text{ mm} \quad \left[\begin{array}{l} \text{Bcoz of gear} \\ \text{drive} \end{array} \right]$$

$$1 \text{ pulse} = \frac{1}{200} = 0.005 \text{ mm} = \underline{\underline{5 \text{ microns}}}$$

BLU.

(19)

no. of table speed dependant on frequency

$$\text{Gear Ratio} = \frac{1}{2} \quad \left. \vphantom{\frac{1}{2}} \right\} \text{critical ch}$$

(v)

(20)

$$150 \text{ pulses per rev} = 1 \text{ rev L.S.}$$

$$= 4 \text{ mm}$$

$$1 \text{ pulse} = \frac{4}{150} = \underline{\quad \quad \text{mm} \quad}$$

$$\text{Frequency} = 200$$

$$\text{Speed} = \frac{4}{150} \times 60$$

$$= \frac{4}{150} \times 200 \times 60 = \underline{\underline{320}}$$

(22) batch / large

(23) d

(24) a

(25) c

(26) d

(27) X

(28) a

(29) a

(48) consistency / hazard

(49) a

(50) a

(51) b c

(52) x

(53) a

(*) (54) c

(55) d

(56) c

(57) a b a

(58) d

(30) b

(31) x

(32) x

(33) a

(34) c

(35) c

(36) c

(37)

(38) a

(39)

A - False

R - True

(40) d

(41) b

(42)

A	B	C	D
4	5	1	3

(42) False

(44) false

(43) no false

(45) a

(46) DNC Host Computer

(47) drilling not MTC

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NTM CONTD :-

Non TRADITIONAL MACHINING

METHODS [NTM]

The Limitations of Traditional Machining Methods:-

1. Tool must be atleast 30-50% harder than workpiece but sometimes the work piece itself is very hard and there is no tool which is harder than w/p.
2. Some Materials will have very poor Machinability. Such materials can't be machined with conventional methods.
3. Small size non circular Holes can't be produced by using conventional methods. But large size small circular Holes can be produced by using Boring operation.
4. Making small size circular Holes is also Not possible.
5. Making Holes in Highly Brittle materials is Not possible with conventional Methods. (eg: Glass)
6. Machining of very soft material like Rubber is Not possible.
7. Manufacturing of complex Curvatures is Not possible.

The unconventional Machining methods are :-

1. USM
2. EDM
3. ECM
4. WJM

5. AWJM
6. EBM
7. LBM

- Mechanism by which Material Removal / chip formation Takes place
- Tool Material
- Medium
- Wear Ratio / Machining Ratio

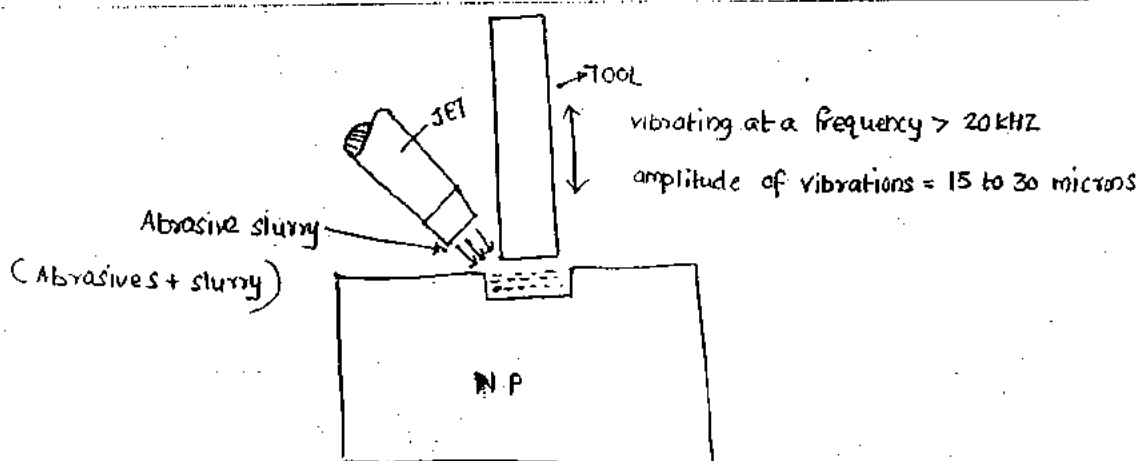
$$\frac{\text{Vol of material removed on work piece}}{\text{Vol of Tool Wear}}$$

- Advantages of Process
- Disadvantages of Process
- Applications

7 PARAMETERS

1. USM (Ultra Sonic Machining)

[MATCH THE FOLLOWING]



When the tool is vibrating at High frequency, the impact loads produced by the Tool will be acting on to the

Abrasive particles which in turn produces impact loads on to the workpiece. When the impact loads are acting on to the w/p, if the w/p material is a highly brittle material, becoz of lower toughness the workpiece is getting fracturing due to Brittle Fracture. The chips produced due to this will be moving along with the Abrasive slurry. From the Above the Mechanism by which chip formation taking place is Brittle fracturing.

Tool Material:-

When the impact loads is acting on to the Abrasive particles, equal and opposite Reaction force produced by the Abrasives will be acting on to the Tool. If the tool is made by using Hard material, the Brittle fracturing will take place on Tool also. Hence the wear of Tool will be Higher. To minimise the wear of the Tool, Tool must be made by using very soft material. The Most commonly used Tool material is Cu, Brass, M.S etc.

The medium used is Abrasive slurry i.e. Abrasives + slurry. The most commonly used Abrasive particles is Al_2O_3 , silicon carbide, Boron Carbide, Diamond etc. As the size of Abrasive particle is increasing, the Material Removal Rate increases first and then Reduces. The most commonly used size of Abrasive particles is 200-600 mm. Boron carbide Abrasives will be used with water as a

as a slurry. The composition of Abrasive slurry is 50-60% by volume is Abrasives.

Wear Ratio of USM will be varying from 1.5 to 100. Generally wear Ratio is dependant on Brittleness of workpiece material. ie Higher the Brittleness, Higher the Wear Ratio.

Tool	W.P	W.R
Cu	glass	100
Cu	ceramic	75
Cu	Tungsten	1.5
Cu	Quartz	50
Cu	H.C.S	1.1

Advantages of USM:-

1. Highly Brittle materials can be Machined very easily.
2. smaller size Non circular Holes can be produced.
3. Electrical conductivity of work piece is not Req'd.
4. It is not a Hazardous process.

3. LIMITATIONS OF USM:-

1. $\frac{L}{D}$ Ratio upto 3 only will be possible

L = ~~Len~~ depth of Hole

D = Dia of Hole

For deeper Holes the Abrasive slurry can't be supplied since gap present b/w w/p and Hole will be less.

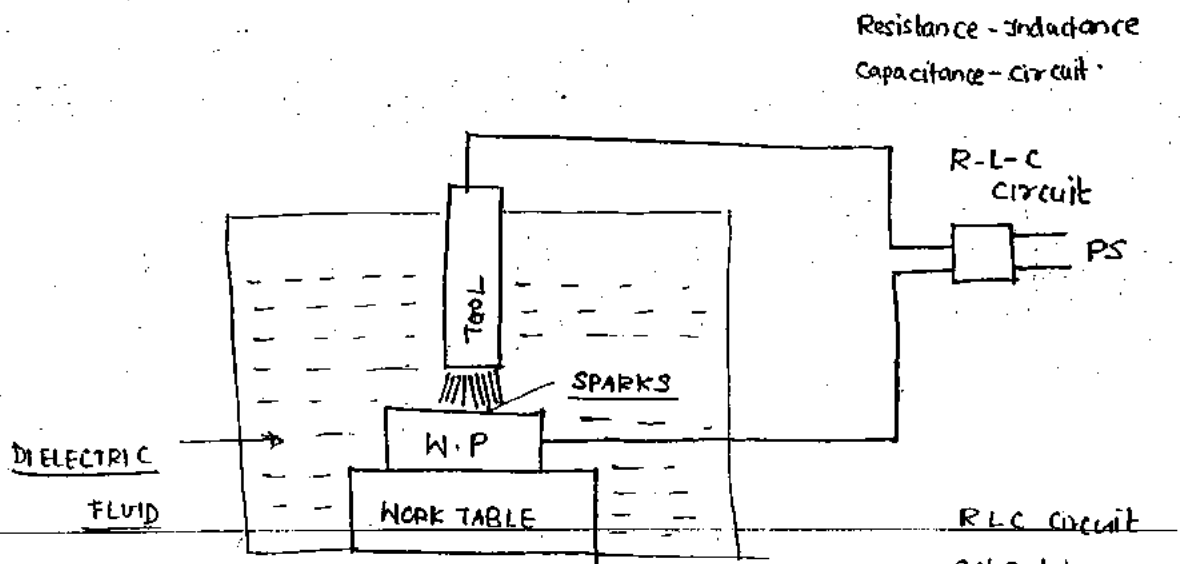
2. Bcoz of Brittle fracture surface finish is very poor.

1. Specific cutting Energy Requirements are Higher

Applications:-

1. It is used for producing circular / Non-circular Holes in Highly Brittle Materials like Glass, ceramic, Tungsten carbide etc.
2. Dental Doctor uses USM for producing Holes in Human Teeth bcoz it is a painless drilling methodology.
3. Holes of size upto 0.1mm can be produced by using USM.

2. EDM (Electric Discharge Machining)



When the Power supply is given to the R-L-C circuit Nearly 75-85% of cycle time Duration, the energy supplied by the power supply unit will be stored in the R-L-C circuit bcoz R-L-C circuit in electrical Technology is working like a flywheel in mechanical systems. During remaining 20-25% of cycle time duration, the energy stored in R-L-C circuit and energy supplied by Power supply unit will be released.

Spontaneously ~~set~~ so that wherever gap is present in the work piece such place sparks are produced i.e. the tip of tool and work piece

Bcoz of sparking Heat is generated at the interface of tool and work piece. By using this Heat the work piece material is melting and evaporating. To increase the evaporation efficiency of the metals the sparking zone will be immersed in a dielectric fluid. Bcoz the evaporation is taking place inside the liquid and vapours are continuously coming out, At the ~~pre~~ sparking zone pressure falls below partial pressure of water vapour in atmosphere and hence cavitation is occurring.

From the Above the mechanism by which chip formation occurs is by melting and Vapourisation associated with cavitation also called as SPARK EROSION & CAVITATION.

To Avoid the Heat generation within the tool, the tool material must be made by using High electrical conductivity material to minimize the melting of tool, the M.P of tool must be as High as possible. The tool will be made by using cu / Tungsten / cu-Tungsten alloy etc will be used. The medium used is Dielectric fluid, the most commonly used is kerosene and Sometimes mineral oil also can be used.

[No catching of fire to kerosene Bcoz O₂ is

Wear Ratio induced is varying from 0.1 to 10. The wear Ratio mainly depends on the difference b/w the M.P of Tool and Work piece material. 2/2

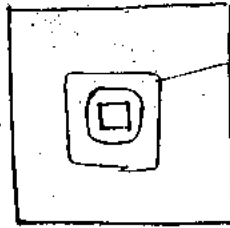
When ~~for ex~~ M.P of Tool is very much Higher than work piece, the high wear Ratio's can be obtained for ex during machining of Al as WC as Tool the wear Ratio obtained will be 10. During machining of steel work pieces using Cu as Tool the wear Ratio obtained is 0.1.

Advantages:

1. $\frac{L}{D}$ Ratios as high as 20 is possible.
 2. There is no physical contact b/w Tool and Work piece so no forces are acting in machining so no residual stresses are generated in machining.
 3. out of all the unconventional machining methods, EDM is the one which gives Highest MRR, and EBM will give the lowest MRR.
-
4. Beoz melting and evaporation is the Mechanism of chip formation, the Mechanical properties of W.P material will not affect the Material Removal Rate (MRR).
 5. surface finish produced will be Better.

Disadvantages :-

1. Work piece material must be electrically conductive.
2. perfect square cornered Holes can't be produced.



Hardening effect-

(Heating will be taking place near to hole) since it is immersed in fluid, heating and quenching takes place i.e. Hardening

Hardening effect will be taking place i.e. near to the hole

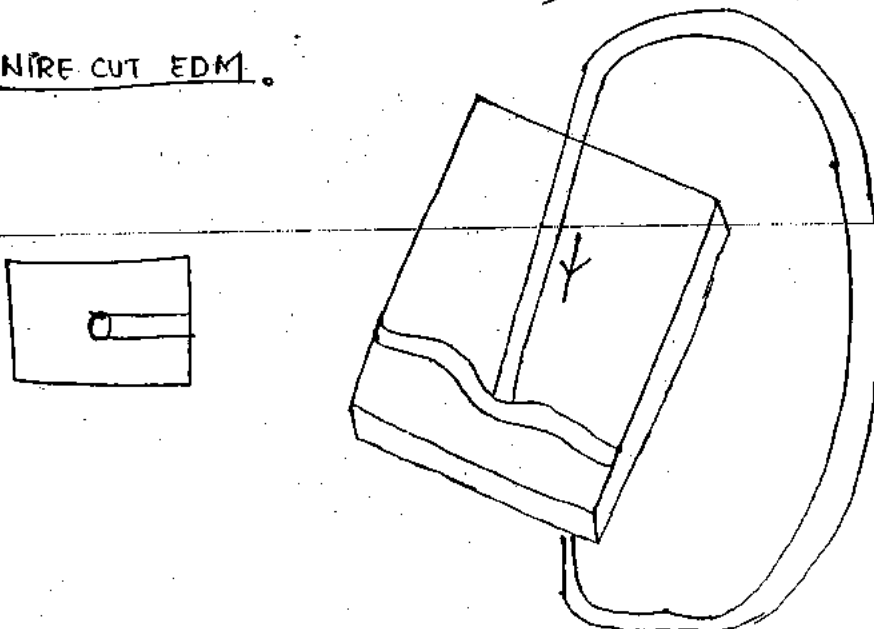
Hardness of work piece is increased.

Applications:-

1. used for producing very small size holes like holes in diesel injection nozzle
2. used for producing holes in air brakes
3. used for Die Sinking etc.

* ECM (Electrochemical Machining)

WIRE CUT EDM.



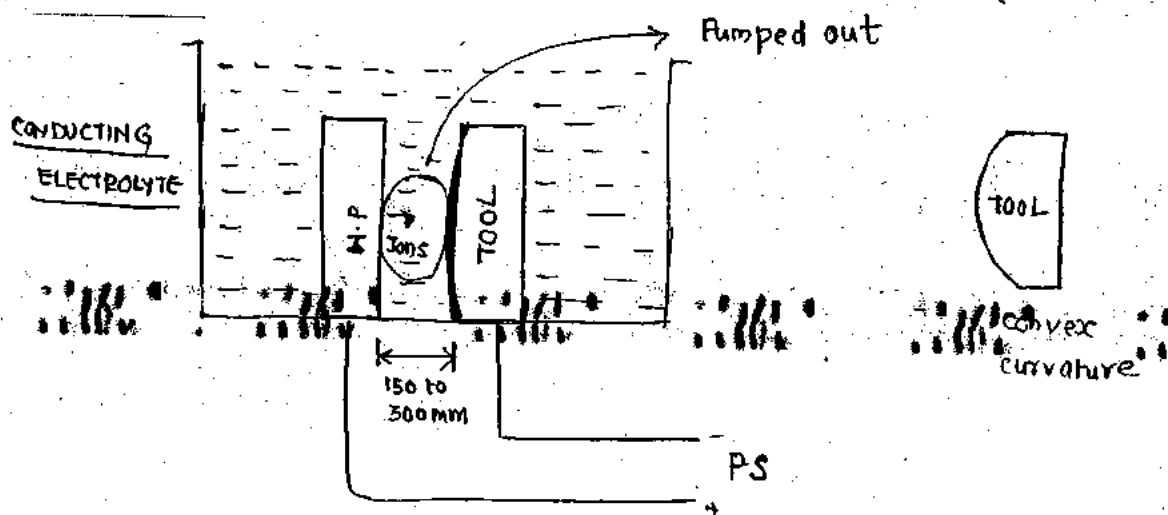
Wire cut EDM is similar to EDM but used for cutting sheets into complex shapes. In this process a continuously moving wire will be used as tool so that the sparks are produced b/w circumference of the

progressing, in case of EDM length of tool will be reducing.
But in case of wire cut EDM the diameter of wire will be reducing.

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Mainly used for cutting of sheets into complex shapes.

3. ECM (Electro chemical Machining operation) :-



When the power supply is given to the work piece and the tool, because of Faraday's Law of electricity, the ions are displacing from the work piece and trying to deposit over the tool. Before that depositing, when the electrolyte present below the tool and work piece ~~will~~ will be pumped out continuously so that ions displaced from the work piece are also moving along with the electrolyte. Hence there is no disturbance taken place to the tool. The same tool can be used for producing infinite no. of components. From this the mechanism by which the chip formation taking place is due to ion displacement.

The Material Removal Rate or No of ions displaced is directly proportional to the gram atomic weight of work piece material.

② directly proportional to current density of ECM process.

③ Inversely proportional to the distance b/w the tool and work piece.

④ directly proportional to the electrical conductivity of electrolyte. i.e. for Rough machining process, High electrical conducting electrolyte is used also called as passivating electrolyte. and for finish machining operations Low electrical conductivity electrolytes is used. i.e. it is also called as Non passivating electrolyte.

⑤ In Addition to above the electrolyte must be chemically stable, low viscous and High Specific Heat.

Tool Material:-

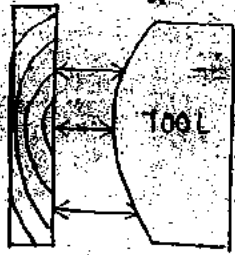
If the tool and workpiece are made by using same material and work piece is connected to +ve terminal of power supply more no: of ions are displacing from the work piece. ∴ Tool must be made by using same material as that of work piece.

Medium:-

The medium used is Conducting electrolyte preferably Salt solution.

Wear Ratio:-

Wear Ratio is infinite since Tool is Not wearing out i.e. Tool wear is zero.



Advantages:-

1. Complex, concave curvature components can be produced easily by using convex, concave curvature tools.
2. Bcz tool wear is zero, same tool can be used for producing infinite no. of components.
3. Bcz there is no direct contact b/w tool and work piece, no forces, no residual stresses.
4. Bcz ion displacement is the mechanism by which material removal is taking place, the surface finish produced is excellent.

LIMITATIONS:-

1. Out of all the unconventional machining methods ECM requires highest specific cutting energy.
2. Workpiece material must be electrically conducting.
3. Generally preferable for producing contours only.
4. Sharp corners is not possible to produce.

Applications:-

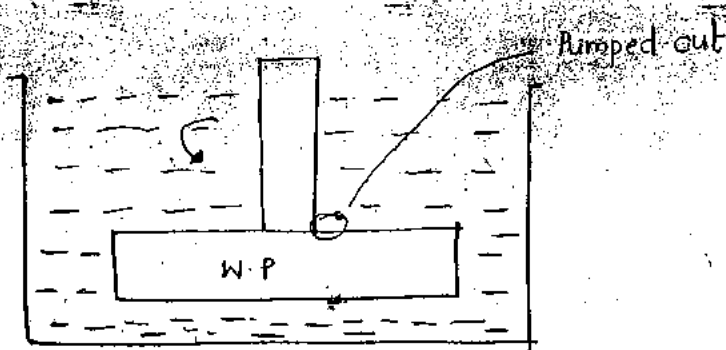
Mainly used for producing complex shape of components like Turbine Blades.

$$MRR = \frac{AI}{ZF}$$

F = Faraday's
Const

A - Atomic wt of w/p
I = Current in

ECG (Electro chemical Grinding)



$$\text{Material Removal} = \text{Electro chemical} + \text{Mechanical}$$

In ECG the Rotating Grinding wheel will be used as a Tool

So that the Material Removal is Taking place due to electrochemical process and Mechanical process as 90:10 %.

The Gap b/w Tool and Work piece is mainly controlled by

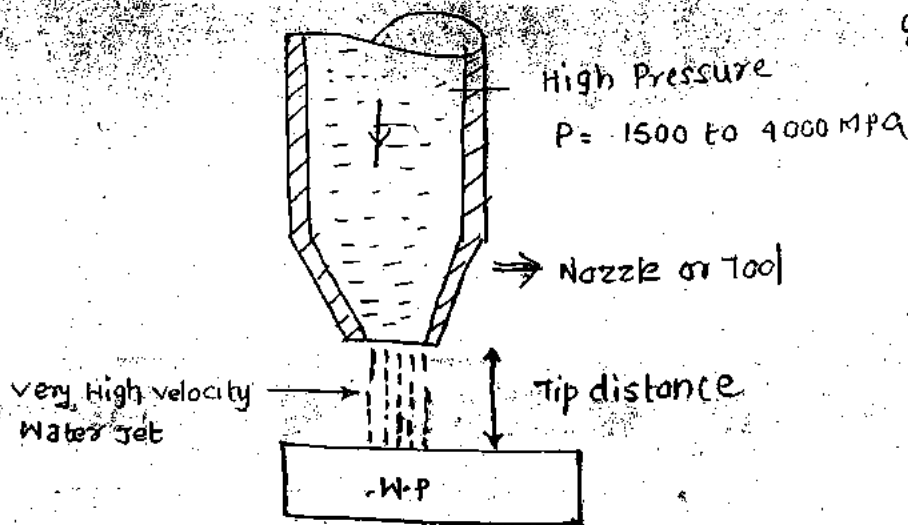
using the Abrasive particles present in the Grinding wheel.

Applications:-

used for Grinding of very Hard work pieces like Grinding of carbide cutting tools.

Even though carbide cutting tools are ReGrindable by using ECG it is Not preferable because the cost of ECG is much Higher than New cutting Tool itself.

4. WATER JET MACHINING [WJM]



When the Very High Pressure water is passing through the convergent nozzle the pressure energy is converted into velocity energy. ∴ Water is coming out from nozzle at very high velocity. When this high velocity water jet is impinging on to the workpiece continuous impact load will be produced on the workpiece so that the workpiece material is plastically deforming and fracturing will be taking place i.e. mechanism by which material removal takes place is plastic deformation and fracturing. It is also called as Etching process.

To withstand for high pressures of water, nozzle or tool is made by using Tungsten carbide (WC) is infinity since nozzle wear is almost zero.

Adv.:-

used for machining of very soft materials like Rubber.

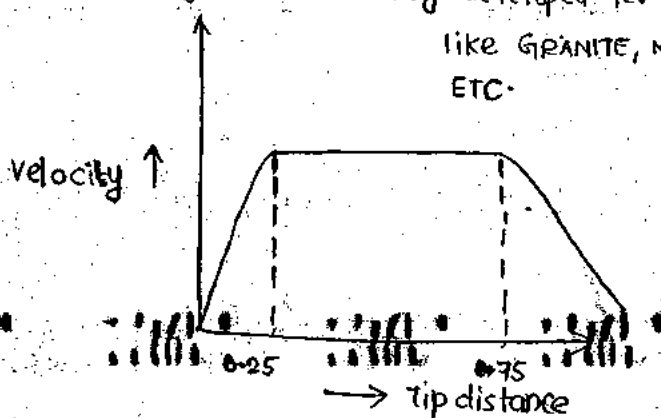
Disadv.:-

Pressurizing water to very high

It can't be used for Machining of Hard Materials

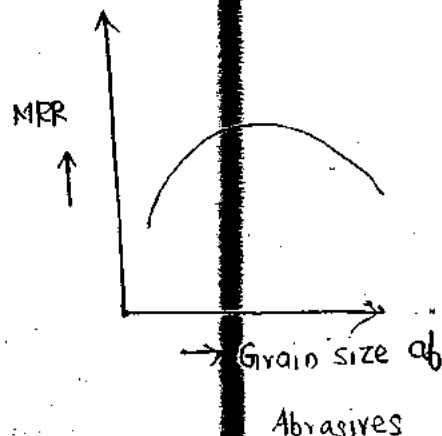
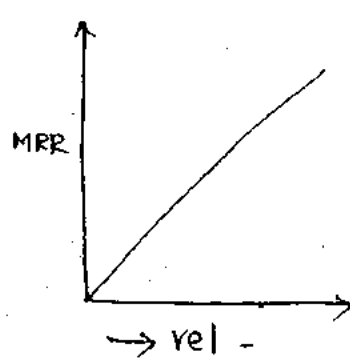
To overcome the disadvantage of Machining of Hard Work pieces by water jet Machining, Abrasive particles are added into the water so that Abrasive particles also will be coming out from Nozzle tip at very High velocity. When this High velocity Abrasives are impinging on to Hard work piece it is possible to produce plastic deformation in Hard work pieces also. Hence the fracturing and chip formation is taking place. This is called Abrasive water Jet Machining (AWJM) or Abrasive Jet Machining. It is mainly developed for cutting of Hard Materials

like GRANITE, MARBLE, COMPOSITE MATERIALS ETC.



At High Tip distances the Air Resistance also comes into play. Hence vel Reduces

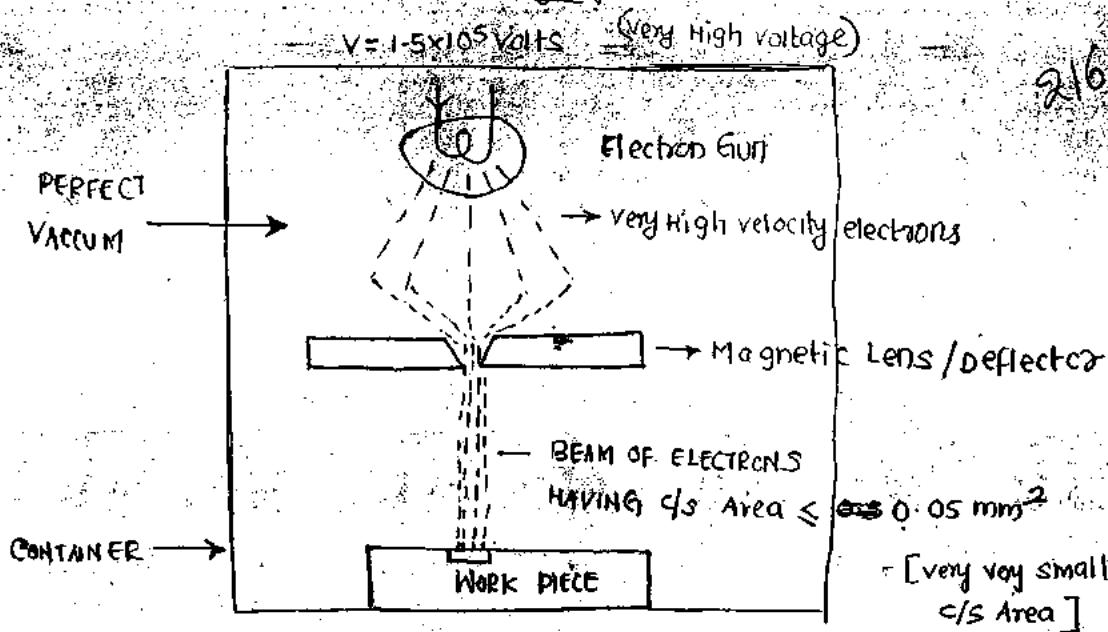
Optimum Tip distance = 0.25 to 0.75mm



REASON why water particles can't be used for Machining Hard work pieces

[Because water particles are soft, when high velocity water particles are impinging on Hard work piece, without producing any plastic deformation, water particles are simply reflected away.]

EBM (Electron Beam Machining)



When very High voltage power supply is given to the electron gun, it produces very High velocity electrons in all the directions.

By providing a Magnetic lens or deflector all the High velocity electrons will be collected and formed into a Beam of

electrons which is having c/s Area $\leq 0.05 \text{ mm}^2$. When this High velocity electron Beam is impinging on to the work piece, the K.E of e^- is converted into Heat energy.

∴ the Heat is getting generated at work piece. This Heat will be used for melting and vaporisation of the work piece material. From the Above mechanisms of material removal is by melting and vaporisation. After the Magnetic deflector bcoz of presence of Air Resistance the e^- may get dispersed again. To Avoid this the total setup will be kept in the container and perfect vacuum is maintained inside the container. Bcoz of perfect vacuum Highly Reactive metals can be machined very easily without any oxidation.

[Work piece is fully protected from atmospheric

In this electron gun is used as tool. The medium is perfect vacuum. Wear Ratio is infinite.

Advantages:-

1. Very very small size Holes can be produced.
2. Surface Finish Produced is Good.
3. Highly Reactive Metals like Al and Mg can be machined very easily.

Limitations:-

- ① Maintaining Perfect vacuum is very difficult.
- ② Material Removal Rate is very low.
- ③ Beccz the total equipment is kept inside the container the Machining process can't be seen by operator.

Applications:

Used for producing very very small size Holes like Holes in diesel injection Nozzles, Air Brakes etc.

④ Work Piece Material is Should be electrically conducting.

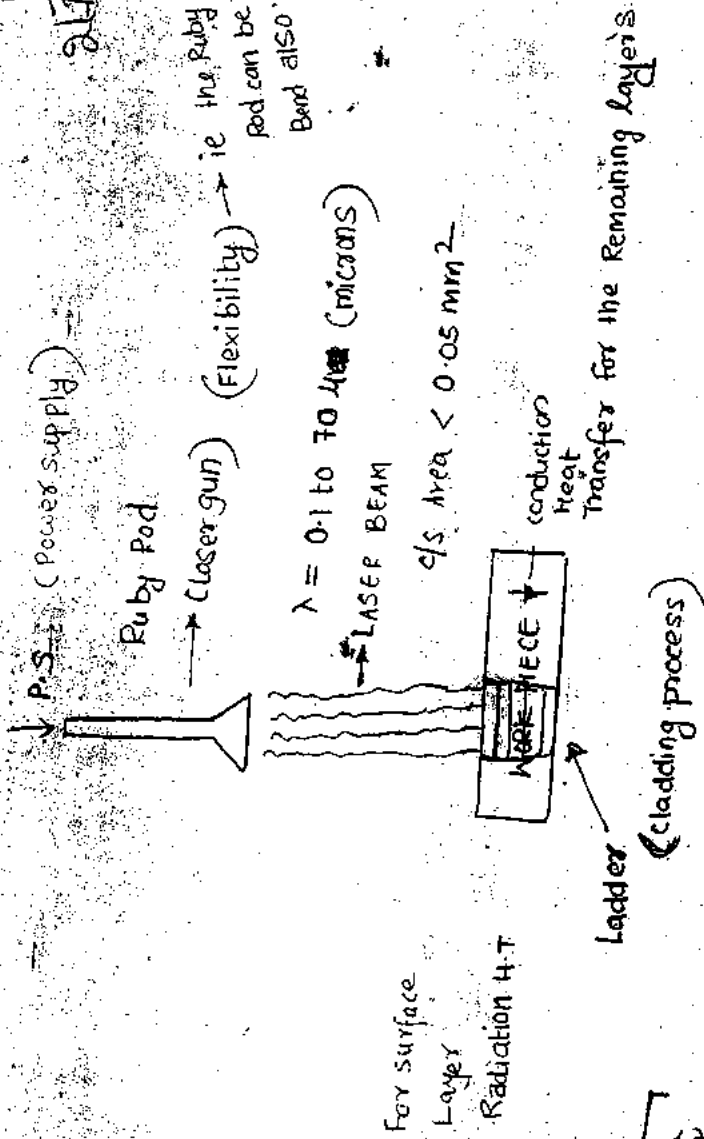
⑤ out of the unconventional Methods ERM will give the Lowest MRR

⑥ used only for circular Holes

Electron Beam Welding:-

If voltage of power supply to electron gun is Reduced to about 70-80,000 volts the vel of e^- is Reducing, the Heat generated at workpiece is Reducing. $\therefore$ workpiece is only melting and No evaporation is taking place. This Melting of work piece can be used for

7. LASER BEAM MACHINING



When power supply is given to laser gun, it produces high intensity EM waves having wavelength 0.1 to 70 μm , the laser beam has cross sectional area of $< 0.05 \text{ mm}^2$ when this laser beam

is impinging on to the workpiece the electromagnetic wave energy is converted into heat energy onto surface of workpiece. So surface layer of w/p is melting and evaporating. But for further layers heat is transferring by conduction process when the first layer is evaporating the 2nd layer of material is exposing for EM waves and this also will get melted and evaporated. Like this layer by layer of workpiece material is getting exposing EM waves melting and evaporating. Hence this process is looking like a ladder called as cladding process from the above mechanism of metal removal is by melting

[Since most of metals are opaque in nature, the heat transfer by radiation can be taken as a surface phenomena]



Ladder

Tool material

Ruby Rod

Medium

Air

Wear Ratio is ∞ since there is almost no wear of the tool.

Advantages:-

1. No vacuum is reqd. Hence process will be easier.
2. The size of Hole and slots produced is same as that of EBM.
3. Bcoz the Ruby Rod is flexible, to some extent the zig zag Holes can be produced by using LBM.
4. No need to have electrical conductivity of work piece material.

Disadvantage:-

Energy or Power Reqd. for LBM is very high.

$$\lambda = 0.1 \text{ to } 70 \mu\text{m} \text{ (microns)}$$

Practically we use $(0.4 \text{ to } 0.6 \mu\text{m}) \rightarrow P = 5000 \text{ to } 6000 \text{ MW}_{\text{reqd}}$

usually they are located near Nuclear Power plants.

If less amount of power supply is used then it becomes Laser Beam welding.

→ Bcoz of presence of flexibility of Ruby Rods the Zig-Zag Holes can also be produced by using LBM.

→ Applications of LBM are same as EBM.



JIGS AND FIXTURES

- JAMES

Jig is a device used for holding and positioning of work piece, locating and guiding of tool. Normally the Jigs are light in construction. These are commonly used in drilling, Reaming, Tapping operations.

Fixture:- is a device used for Holding and Positioning of work piece, Locating and setting of tool. But does not guide the tool. Fixtures are generally Heavy in construction. These are used in turning, Milling, shaping, Grinding etc operations.

Advantages of using Jigs and Fixtures :

1. With Jigs and Fixtures Loading and setting of work piece and tool is easier and even unskilled person can do this.
2. With use of Jigs and Fixtures, Time taken for loading and setting of work piece and tool will be minimum.
3. The Accuracy of components produced is very good.
4. Due to usage of Jigs and fixtures Repeatability / consistency in manufacturing is very High. $\approx 100\%$ inspection of Component is Not Req'd.
5. LeadTime in manufacturing is reducing.
6. Production Rate is increasing.
7. Safety in Manufacturing conditions is achieved.

Limitations:

Unless sufficient qty of components are manufactured by using Jigs and Fixtures the usage of Jigs and Fixtures cannot be economically justifiable.

BASIC ELEMENTS

1. Body of a Jig or a Fixture ~~shall~~ is Rigid ~~enough~~ enough to withstand for forces acting during Machining and can able to absorb vibrations included during M/ching. For this Jig/Fixture is always made by using Grey cast Iron as material and manufactured by casting as a manufacturing process.

2. Locating element

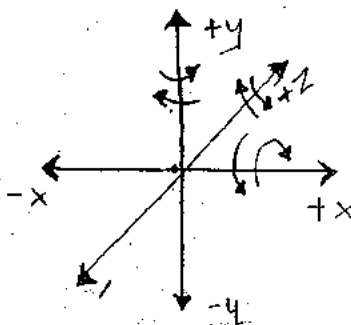
3. clamping element

4. Tool Guiding element in case of Jig → Bush

Tool setting element in case of Fixture → Reference points marked on Fixtures

A Component in space consisting of 12 degrees of freedom

6 LINEAR
 $\begin{cases} +x, -x \\ +y, -y \\ +z, -z \end{cases}$



6 LINEAR
6 Rotational

The Max DoF which is allowed to Arrested by using Locating elements in Jigs and Fixtures is 9 D o F

that remaining 3 D.O.F will be left over out of 12 D.O.F. 138 224

2. D.O.F will be used for loading and unloading of component and the remaining one degree of freedom is used for Tool movement. 214

During actual M/cing process the 2 D.O.F left for Loading and unloading is arrested by using clamping element. The one D.O.F left for Tool movement is arrested by cutting forces acting during M/cing. so that During M/cing all the 12 D.O.F will be arrested.

PRINCIPLES USED IN DESIGN OF LOCATING ELEMENTS IN JIGS/FIXTURES

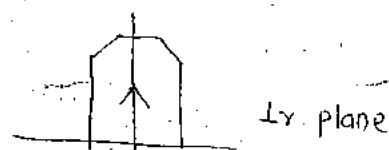
1. Principle of Min No. of Locations:-

In Any given plane it is always Recommended to use as min no of locating elements as it is possible to use for arresting Max no of degrees of freedom.

{ space Available b/w pins is more so }
Easy to Remove chips

2. Principle of Perpendicular planes :-

whenever the Locating elements used in Jigs and fixtures for locating work piece must be provided only in $\perp$ r Planes.



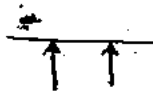
Here No additional pins reqd



Inclined plane

3. PRINCIPLE OF EXTREME LOCATION

Whenever more than one Loc. Mark is used in a given plane provide them only at extreme positions. Don't provide at the centre.



Here also slipping occurs

if only one location is used. No alternative. Provide it at centre.



slipping occurs unsafe

No slipping occurs. more safe



METHODS OF LOCATIONS:-

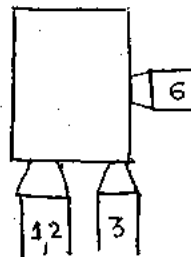
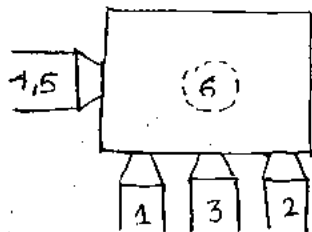
1. 3-2-1 method of location

This method is used for locating cartesian coordinate system of a component

3, 2, 1 indicates no of pins used for

Arresting the Req'd no of D.O.F in 3 mutually $\perp$ directions.

eg:-



Diff views

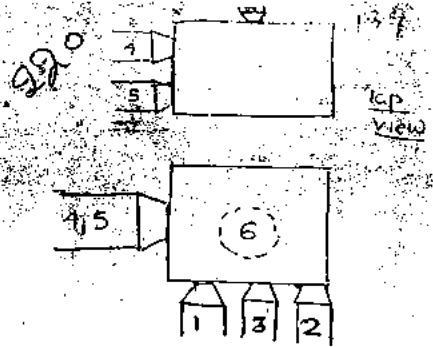
3 pins used in one plane $\rightarrow$ 5 DOF (arrested)

if one pin added to 3 pins, no change will occur. But if one pin is reduced,

ie if 2 pins are used $\rightarrow$ DOF arrested

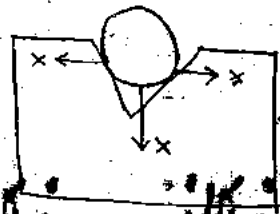
1 linear + 4 Rotations

1 PIN $\rightarrow$ 4 DOF (1 LINEAR)



2. V-Location :-

It is used for locating cylindrical coordinate system of a component.



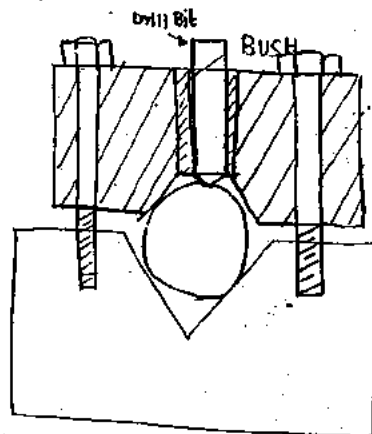
7 DOF arrested

(3L + 4 ~~Rotational~~)

3. Bush Location cum CLAMPING :-

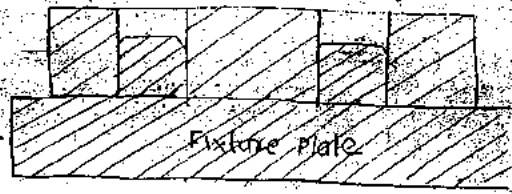
Mainly used for locating spherical coordinate system of a component.

By using Bush Location cum clamping all 12 D.O.F of a spherical component can be arrested.



PIN LOCATION / RADIAL / DIAMOND LOCATION :-

This method is used for locating thin plates with atleast 2 holes present in the plates.



With Radial Location/ diamond location total of 11 D.O.F will be arrested and 1 D.O.F will be left over. The same 1 D.O.F will be used for loading, unloading, Tool movement. The shape of the pins used in pin location is diamond shape $\therefore$ the Name called as Radial/diamond location.

eg:- Hole size

$$20 \pm 0.5$$



Pin $\geq$ Max Size of Hole

$$20.05$$

Circular pin

Removal becomes

Very difficult

Interference fit

Hole

DIAMOND PIN



contact only at certain locations so easy Removal

clamping elements :-

Whatever the two degrees of freedom left over for loading and unloading of components will be arrested by using

clamping elements. The clamping elements are temporary elements

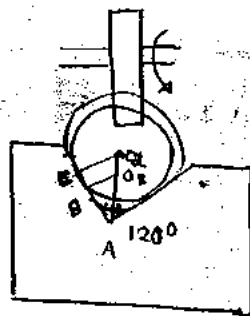
safety in citing surfaces. Design should be such that the operator can be able to see the Machining Zone just by standing away from the m/c without Bending his Body/Head.

ii. Design of Jig/Fixture should be such that it should be simple and cheaper.

P74.

① b

②



$$D = 60 \pm 0.1$$

$$59.9 \text{ to } 60.1$$

$$\sin 60^\circ = \frac{O_1 B}{O_1 A}$$

$$O_1 A$$

$$A O_1 = O_1 B \times \operatorname{cosec} 60^\circ$$

$$O_1 B = \frac{60.1}{2} \operatorname{cosec} 60^\circ$$

$$O_2 A = \frac{60.1}{2} \operatorname{cosec} 60^\circ$$



$$O_1 O_2 = \text{shaft in centre}$$

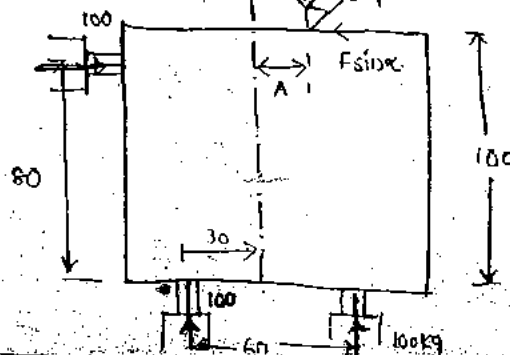
$$= O_2 A - O_1 A$$

$$\text{error} = 2 \times 0.02$$

$$0.22$$

3.) c

1.)



$$\frac{F \sin \alpha}{F \cos \alpha} = \frac{100}{100 + 100}$$

$$\tan \alpha = \frac{100}{200}$$

$$\alpha = \tan^{-1} \left(\frac{1}{2} \right)$$

$$F = \frac{100}{\sin \alpha}$$

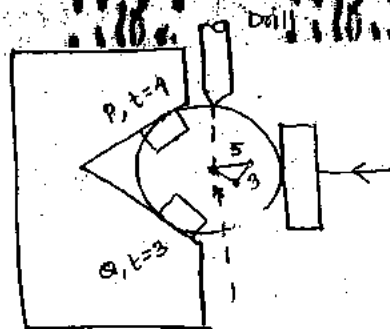
$$F \cos \alpha \times A + 100 \times 30 = 100 \times 30 + 100 \times 20$$

$$F \cos \alpha \times A = 100 \times 20$$

$$A = \frac{100 \times 20}{F \cos \alpha}$$

$$= \underline{\underline{100 \text{ mm}}}$$

⑥



$$e = \sqrt{3^2 + 4^2} = \underline{\underline{5 \text{ mm}}}$$

eccentricity = 5 mm

$$\textcircled{b} \quad 5 = \sqrt{x^2 + x^2}$$

$$5 = \sqrt{2x^2}$$

$$5 = \sqrt{2} x$$

$$x = \frac{5}{\sqrt{2}} = \underline{\underline{3.5 \text{ mm}}}$$

Some block
thickness

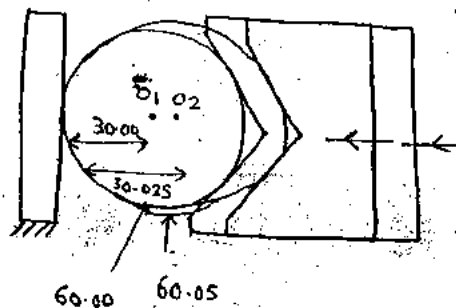
and method is more suitable since it is a more stable system

Some thickness Block method is preferable bcoz it gives stable system of measurement.

(7)

Case I

Fixed Rectangular Block

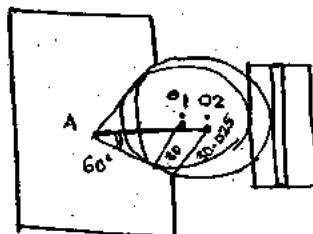


$$\text{error} = 0.02 = 30.025 - 30.00$$

$$\underline{0.025}$$

Case 2

Fixed V Block



$$O_1 A = 30 \operatorname{cosec} 60$$

$$O_2 A = 30.025 \operatorname{cosec} 60$$

$$\underline{O_1 O_2 = 0.029}$$

$$\sin 60 = \frac{30}{O_1 A}$$

$$O_1 A = 30 \operatorname{cosec} 60$$

errors depending
on fixed members

3rd case same as 2nd case

1st one is preferable

81 84

METROLOGY

ENG6 METROLOGY BY SHARP

" " " MILLER

— ENG6 METROLOGY BY I-C GUPTA

METROLOGY

Metrology is defined as a science of measurements. Metrology is also defined as precision of measurements. Metrology is also defined as Accuracy of measurements.

Precision

Repeatability / Reproducibility of measurements

Accuracy

Nearness to the True value.

Whatever the No. of times a given dimension is measured by using a given measuring equipment, if same dimension is obtained everytime it is called Repeatability / Reproducibility.

Precise measurements made by using standard measuring equipments is called as nearness to true value.

Standard measuring equipments $\Rightarrow$ doesn't have any error.

Accuracy is reqd when more than one measuring equipment is involved in measurement of dimensions.

standards used for measurement of Linear dimensions :

1. Imperial standard yard $\rightarrow$ Name of master piece of yard

1 yard = 3 feet

1 foot = 12 inches

MASTER PIECE (1)

$\downarrow$
Supplementary or
Parliamentary (1)

$\downarrow$
Working Level

Master piece of yard must be made by using material which has

New High Tensile Steel

Bailey metal (82% Cu, 13% Sn, 5% Zn)

It is used as standard material for manufacture of yard.

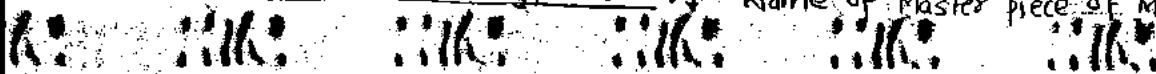
→ It is stored at 62°F

It is in custody of Board of Trade of U.K.

4 supplementary pieces are in custody of

- Royal society
- Royal Mint
- Royal observation
- House of commons

2. International Prototype Meter : Name of master piece of meter



$1\text{m} = 100\text{cm} = 1000\text{mm}$

Masterpiece → only one

- made by using platinum-iridium alloy

(90%) (10%)

- stored at 0°C .

- It is in custody of International Bureau of Heights and Measurements at Sevres in Paris.

supplementary pieces are made like a each and every country is having at least one supplementary piece. The supplementary piece corresponding to indian Requirements is in custody of statistical measuring instruments, kolkata.

As on today Based on ISO standards the meter is a

Linear dimension: The physical standards used for measurements are susceptible due to damages by natural calamities. In such situations to manufacture another master piece of meter, next standard is used called as wave length standard.

According to wave length standard

$1\text{m} = 1650763.73$ light waves of Red orange lines of krypton-86.

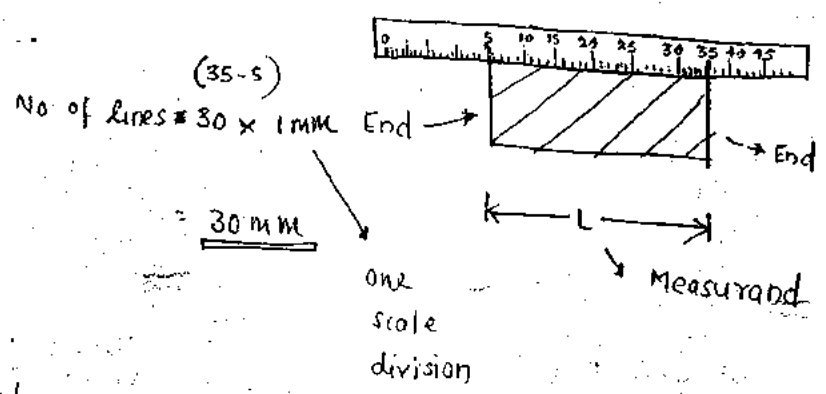
Red orange lines of krypton 86 is selected because it produces sharp edged fringes.

Methods of Linear Measurements:

1. Line standard Method
2. End standard Method

Line and End standard Method

LINE STANDARD: If lines of measuring equipment are coincided with the ends of the Measurand by counting the No of lines in b/w the coincidence lines and multiplying with one scale division, the dimension of component will be obtained.



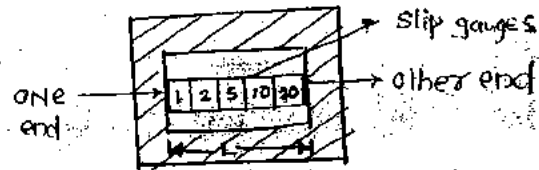
ex: scale, Tape etc

END STANDARD

If ends of measuring equipment are coincided with ends of Measurand and by adding the individual dimensions of end standard used for measurement, the dimension of component can be obtained.

eg: Slip Gauges

End Bars etc



LINE AND END STANDARD

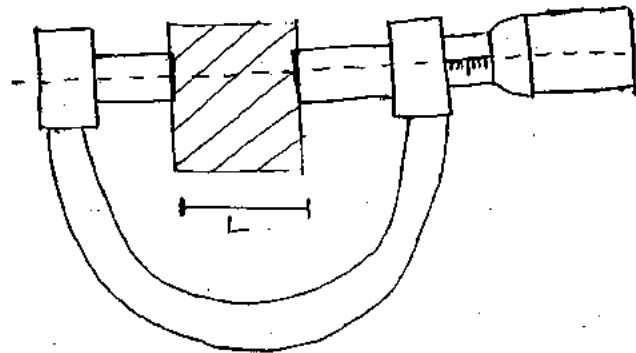
In this the ends of measuring equipment are coincided with the ends of Measurand and by counting the No of Lines the dimension of the

Measurand

$$L = 20 + 10 + 5 + 2 + 1$$

$$L = 38 \text{ mm}$$

Component can be obtained called as Line and End Standard method of measurement.

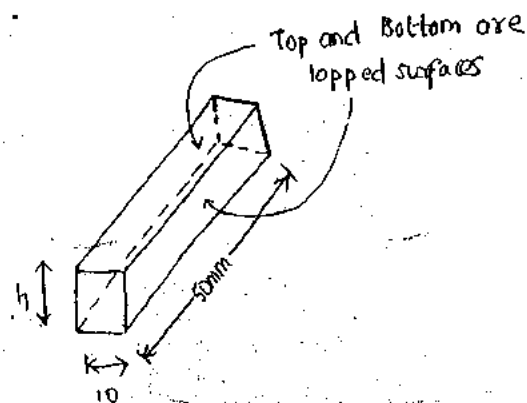


ex: vernier

micrometers,
screw gauge etc

SLIP GAUGES :-

Lapping is the machining operation used during manufacture of slip gauges.



Slip Gauges will be specified by using its Height only

(*) Standard sets

<u>Ranges</u>	<u>In steps off</u>	<u>No of Gauges</u>
1.001 - 1.009	0.001	9
1.01 - 1.49	0.01	49
0.5 - 9.5	0.5	19
10 - 90	10	9
		<u>Total = 86</u>

eg: 42.386

Points to be considered during Building of Given dimension using

Slip Gauge

1. Every slip gage used for the Building must be Available in the Standard set.
2. Donot use same dimension slip gauge more than once in one setting.
3. use as min no of slip Gauges as it is possible to built a given dimension.

42.386

1.006

last digit +1

1.08

1 + 0.006

1.30

1 + 0.08

9.00

1 + 0.3

30.00

+ 1.0 = 10 } 40.00

$$\begin{array}{r}
 1.006 \\
 1.38 \\
 \hline
 40.000 \\
 \hline
 42.386
 \end{array}$$

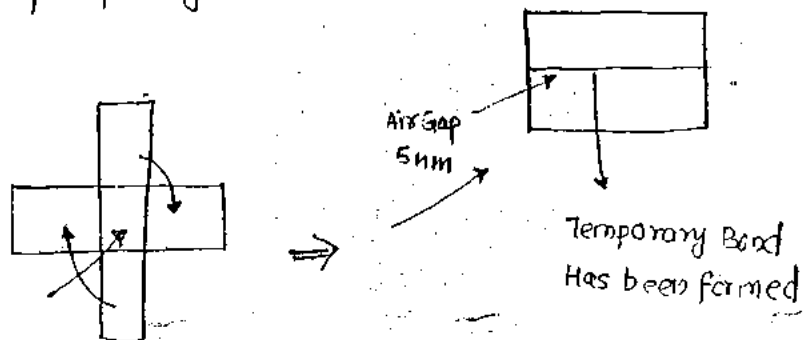
73.849

$$\begin{array}{r}
 1.009 \\
 1.040 \\
 \hline
 1.30 \\
 1.50 \\
 \hline
 9.00 + 1.00 \\
 60.00
 \end{array}$$

$$\begin{array}{r}
 1.009 \\
 1.34 \\
 1.50 \\
 70.00
 \end{array}$$

WRINGING

The Process used for Building a given dimension using more than 1 slip Gauge. The process of making a single slip Gauge by using many No of slip Gauges by producing temporary Bond b/w the slip Gauge surfaces is called wringing of slip Gauges.



How Bond Formation is Taking place ?

The atoms

• More active to share the energy with other atoms. Bcoz At

Slip Gauge surfaces are lapped surfaces, atoms present on both slip gauge surfaces are trying to share the energy and produces Temporary Bond b/w two slip Gauge surfaces. Do not leave the wrunged slip Gauges for longer periods because the Temporary Bond will become permanent.

possible Air Gap b/w slip Gauges = 5 nm

6 slip Gauges $\rightarrow$ 5 Air Gaps = $5 \times 5 = 25$ nm

4 slip Gauges $\rightarrow$ 3 Air Gaps = $3 \times 5 = 15$ nm

error
decreases
as No of
slip Gauges
decreases

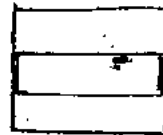
∴ Min No of slip Gauges will be used for Building a given dimension so that error introduced due to presence of Air Gap is minimised.

FEATURES OF LINE AND END STANDARDS

1. Measurements of dimensions by using Line standard method is simple easier and faster becoz only one measuring eqpmt is sufficient for measurement of many dimensions. whereas for the case end standard method to measure one dimension itself many no: of slip Gauges are Reqd. ∴ measurement will be difficult and Time consuming.
2. The Accuracy of the measurements made by using line standards is upto 0.5 mm only whereas in case of end standards the Accuracy of measurements is upto 0.001 mm.
3. Line standards are experencing parallax error problem whereas end standards doesnot have any parallax error.

4. End standard method is experiencing wear of the measuring equipment. But in line standard method absolutely there is no wear problem.

5. Built in datum is Always existing at Both the ends of the measurement using End standard. whereas No Built in datum is existing using Line standard method of measurement.



② LIMITS, FITS AND TOLERANCES

Limit:- The variation permitted on the given dimension is called Limit.

Tolerance:- The total variation permitted on given dimension is called Tolerance.

For eg:- Design an
IC engine

$P = 10 \text{ kW @ } 700 \text{ rpm}$

Design:-

$D_{\text{cyl}} = D_{\text{piston}} = 50 \text{ mm}$

Manufacture:-

Cyl = 50 mm

Piston = 49.95 mm

Lower Limit

L. Limit

Upper Limit

H. Limit

Tolerance

50.00 to 50.05

Total Variation = 0.05

49.85 to 49.95
L Limit H Limit

$T = 0.1$

Beoz it is difficult to manufacture the components to the exact dimension it is always permitted to vary the dimension of the component. Whenever the dimension of a component is permitted to vary, it always gives a range of dimensions b/w which whatever the dimension of a component is coming will be taken as acceptable. In the range of dimension, the lower side

dimension is called Lower Limit and upper side dimension is called H Limit

$$\text{Tolerance} = \text{H Limit} - \text{L Limit}$$

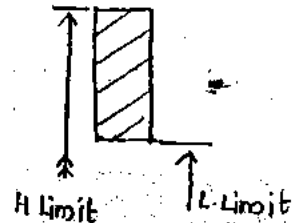
What is the difficulty in manufacturing components to exact dimension :-

3 M's

Material

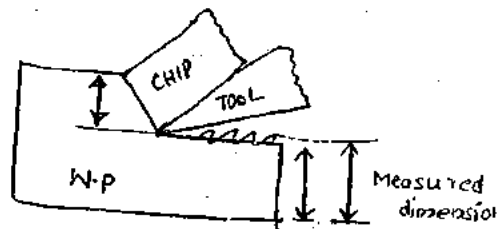
Man

Machine



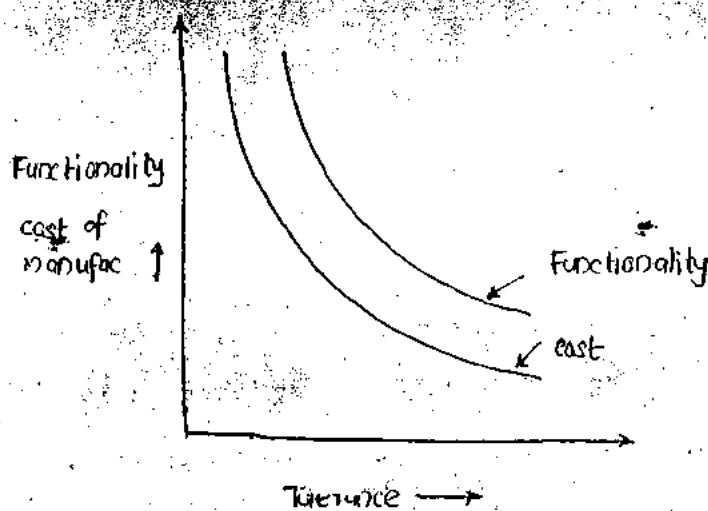
During Manufacturing of a component 3 M's are involved i.e. material, Man and Machine. These three are making it difficult to manufacture the components to the exact dimension.

- The Method of Rupturing of the material during Machining operation is making it diff to manufacture the components to exact dimension.
- The efficiency in Setting of Work piece and tool during Machining by the operator is influencing the dimensions of component obtained during machining.



- The presence of errors in the m/c tool like straightness and flatness errors of guide ways, Run out error of spindle etc will be transferred on to the workpiece and making it difficult to manufacture the components to exact dimension.

The amount of tolerance to be provided on the dimension of component is Based on Compromise b/w cost and functionality.



As Tolerance ↑ cost of manufacturing ↓

As Tolerance ↑ Functionality/Performance ↓

The ideal Conditions of manufacturing requires manufacturing of component with Highest functionality and lowest cost of manufacture. It is impossible. The idealistic manufacturing of components is almost impossible because Highest functionality needs to be provided with smaller amount of tolerance and lowest cost of manufacturing needs to be provided with large amount of tolerance. ∴ it is necessary to make a compromise b/w cost and functionality. i.e. whenever cost of Manufacturing of a ~~part~~ Product is more important provide large amt of Tolerance. whenever functionality of component is imp, provide small amt of tolerance. If cost and functionality Both are important provide Medium amt of Tolerance.

1. Piston and cylinder of Hydraulic Press → Functionality is imp. so Pressure in Range of 500 kg/cm²
2. shaft in Journal Bearing. → Provide very small amount of tolerance otherwise.

Shaft in Journal Bearing $\rightarrow$ Cast is imp $\rightarrow$ Provide large Tolerance

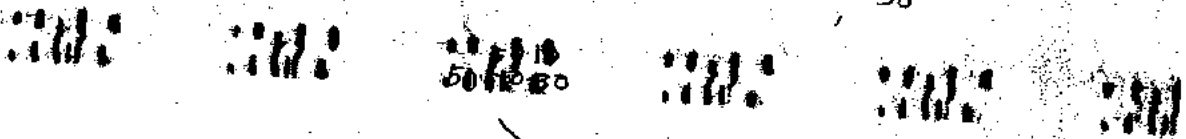
Piston and cylinder of I.C engine $\rightarrow$ Both cast & Functionality is imp $\rightarrow$ Provide Medium amt of Tolerance.

Types of Tolerances :-

1. Unilateral Tolerance
2. Bilateral Tolerance

If the total variation permitted on the given dimension is on only one side of given dimension it is called as unilateral Tolerance.

eg:- $50^{+0.1}_{+0.0}$, $50^{+0.2}_{+0.05}$, $50^{+0.00}_{-0.15}$



49.70 to 49.90

Manufacturing of the components with unilateral Tolerance is difficult and costly. Generally They can be provided on Both mating and Non mating parts. But of which it is Generally preferable on mating parts only.

Bilateral:- If the Variation permitted on the given dimension is at Both the sides of given dimension it is called as Bilateral Tolerance.

50 ± 0.1 ; $50^{+0.2}_{-0.05}$, $50^{+0.1}_{-0.3}$

Manufacturing of Bilateral Tolerance components are easier

Non mating parts.

Mating Parts :- After the Assembly if one part is moving inside another part, the assembly is called as mating Assembly and Parts are called as mating parts.

ex: Piston and cylinder of IC engine, shaft in Journal Bearing, Ball in Ball point pen.

Nonmating Parts :- After Assembly if one part is Not moving inside another part it is called non mating Assembly and parts are called Non Mating parts.

ex: Dia of Flywheel, Thickness of flange of coupling.

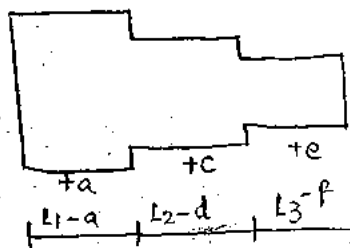
Tolerance Accumulation :-

When a Component is Having more than one dimension or an assembly is Having more than one Component so that the total tolerance on the Component/assembly is equal to the sum of the individual tolerances. called as Tolerance Accumulation.

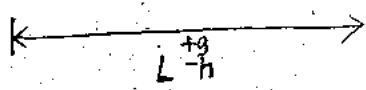
$$\begin{matrix} +a & +0.1 \\ L_1 - b & = 50 - 0.05 \end{matrix} \} 0.15$$

$$\begin{matrix} +c \\ L_2 - d & = 80 \pm 0.1 \end{matrix} \} 0.2$$

$$\begin{matrix} +e & +0.2 \\ L_3 - f & = 40 - 0.1 \end{matrix} \} 0.3$$



$$0.15 + 0.2 + 0.3 = 0.65$$



If each and every dimension of a component or each and every component dimension in assembly is specified with reference to only one

Progressive dimensioning

large Tolerance Accumulation will be eliminated by using total Tolerance on component or Assembly will be very even though individual Tolerances are very small, but the ie. Tolerance Accumulation is a dangerous situation because

$$\text{overall Tolerance} = 0.1 \times 10000 = 1000 \text{ mm}$$

10000 parts
tol = 0.1 per part

For ex on Aircraft

$$\left[\begin{array}{c} \text{Overall} \\ \text{Tolerance} \end{array} \right] = 0.65$$

$$170.4 - 169.75$$

$$\begin{array}{r} 170.4 \\ - 169.75 \\ \hline 0.65 \end{array}$$

$$+0.4 \quad +0.25 \quad -0.25 \quad -0.65 \quad = \quad 170.4$$

$$49.95 + 39.90 + 39.90 = 169.75$$

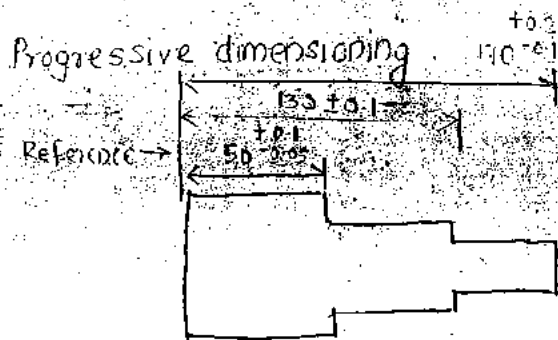
$$L_{min} = L_{1min} + L_{2min} + L_{3min}$$

$$50.1 + 80.1 + 90.2 = 170.4$$

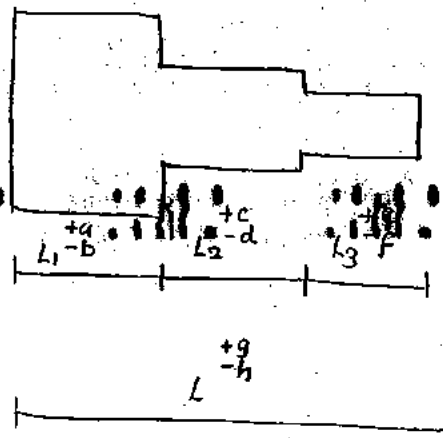
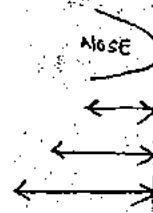
$$L_{max} = L_{1max} + L_{2max} + L_{3max}$$

230

147



for ex: in Aircraft nose tip is used as Reference



4 dimensions
3 individual dim
1 total dimension

The dimensions specified in above diagram are the dependant dimensions because if any of 3 dimensions are given the 4th dimension can be calculated.

$$\text{So } L \begin{smallmatrix} +g \\ -h \end{smallmatrix} = 200 \pm 0.2 \text{ mm}$$

Mixed dimension calculation.

$$L_1 \begin{smallmatrix} +a \\ -b \end{smallmatrix} = 70 \pm 0.1$$

$$L_2 \begin{smallmatrix} +c \\ -d \end{smallmatrix} = 80 \pm 0.2$$

$$L_3 \begin{smallmatrix} +e \\ -f \end{smallmatrix} = ?$$

$$L_1 = 200.2 - 70.1 = 80.1$$

$$\frac{200.2}{70.1} = 80.1$$

Q3

$L_{3 \max}$

$$L_{3 \max} = L_{\max} - (L_{1 \min} + L_{2 \min})$$

$$= 200.2 - (69.9 + 79.8)$$

$$= 50.5$$

$$L_{3 \min} = L_{\min} - [L_{1 \max} + L_{2 \max}]$$

$$= 199.8 - [70.1 + 80.1]$$

$$= 49.6$$

$$L_3 = \begin{matrix} +9 \\ f \end{matrix} \begin{matrix} +0.5 \\ 50 \end{matrix} \begin{matrix} -0.4 \end{matrix}$$

[Reverse calculation Need]
not be true

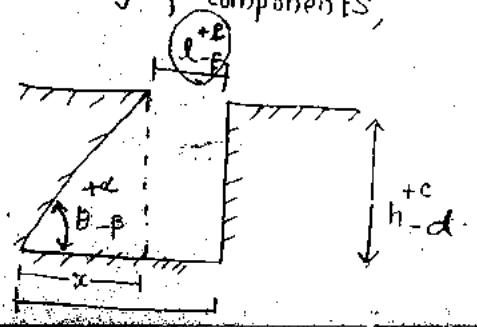
Compound Tolerancing :-

In the Tolerance Accumulation and missed dimension calculation only addition and Subtraction of Tolerances are only used. In addition if multiplication and division of Tolerances are also used in calculation of Tolerances of Assembly of components, it is called compound Tolerancing.

$$l = L - x$$

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

$$\therefore x = h$$



$$l = L - \frac{h}{\tan \theta}$$

$$l_{\max} = L_{\max} - x_{\min}$$

$$l_{\max} = L_{\max} - \frac{h_{\min}}{\tan \theta_{\max}}$$

$$l^{+e} = L^{+a} - \frac{h^{-d}}{\tan \theta^{+x}}$$

$$l^{+e} = F(L^{+a}, h^{-d}, \theta^{+x})$$

$$iii) l_{\min} = L_{\min} - x_{\max}$$

$$= L_{\min} - \frac{h_{\max}}{\tan \theta_{\min}}$$

$$= L^{-b} - \frac{h^{+c}}{\tan \theta^{-p}}$$

$$l_{\min} = F(L^{-b}, h^{+c}, \theta^{-p})$$

2) If h^{+c} is to be determined

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

$$h = x \cdot \tan \theta$$

$$= (L - l) \tan \theta$$

$$h_{\max} = x_{\max} \cdot \tan \theta_{\max}$$

$$= (L_{\max} - l_{\min}) \cdot \tan \theta_{\max}$$

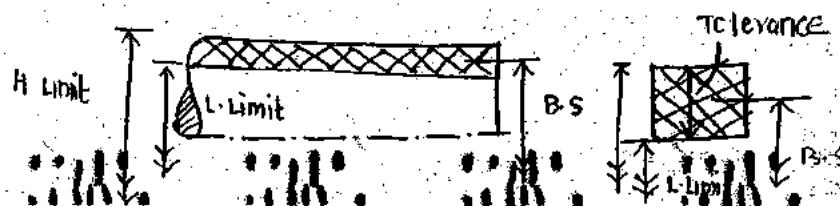
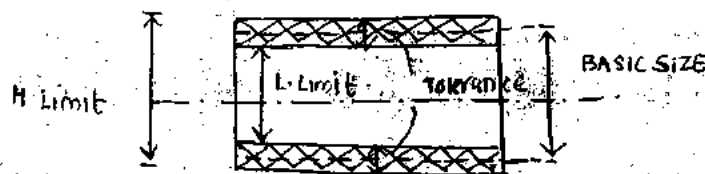
$$h^{+e} = (L^{+a} - l^{-f}) \tan \theta^{+a}$$

$$h^{-d} = (L^{-b} - l^{+e}) \tan \theta^{-b}$$

151
939

DIAGRAMATIC REPRESENTATION OF HOLES AND SHAFTS

Shaft:-



↓ indicates that similar dimension of minor image exists in other side

Max. Material Limit = M.M.L

The Limit of the shaft at which the material Present on shaft is maximum is called maximum material Limit

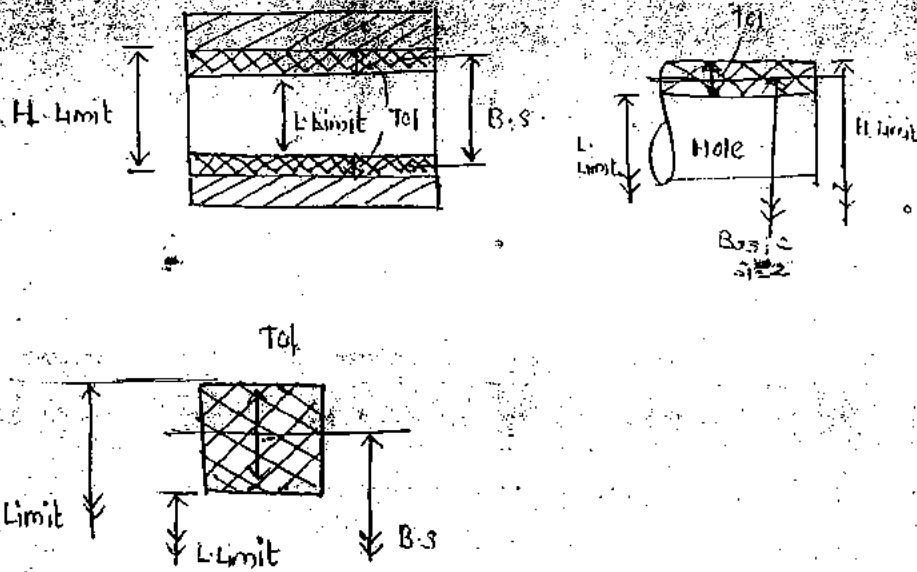
$$M.M.L \text{ of Shaft} = H. \text{ Limit}$$

Min Material Limit

The Limit of shaft at which the material Present on shaft is minimum is called min material Limit

$$Min \text{ M.L of Shaft} = L \text{ Limit}$$

HOLE :-



Max. Material Limit = L. Limit of Hole

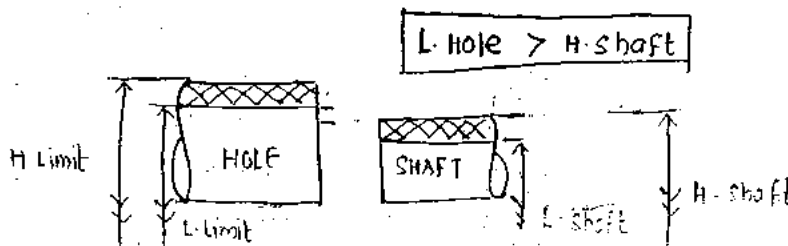
Min Material Limit = H. Limit of Hole

FITS :-

The Relationship b/w Hole and shaft during the Assembly is called Fit. There are 3 Types of fits.

1. Clearance Fit :-

The Dimensions of Hole and shaft are such that the clearance / Gap is always existing b/w the two called as clearance fit. Here No additional effort is Reqd.



L-Hole & L-shaft $\rightarrow H > S$

H-Hole & H-shaft $\rightarrow H > S$

L-Hole & H-shaft $\rightarrow H > S$

* Max clearance = $H_{\text{Hole}} - L_{\text{shaft}}$

= Diff b/w minimum Material Limits

* Min clearance = $L_{\text{Hole}} - H_{\text{shaft}}$

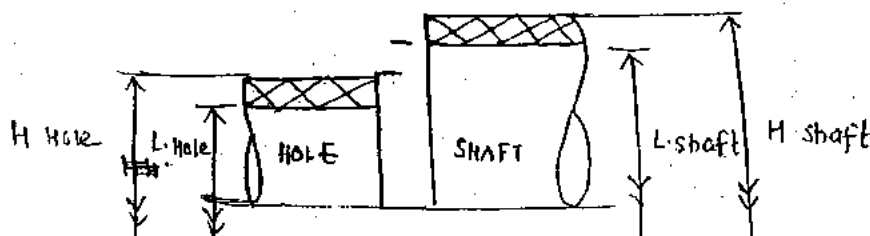
= Diff b/w Max Material Limits

Applications:-

- In all the mating assemblies like Piston and cylinder of IC engine, shaft in Journal Bearing etc.

2. Interference fit :-

The dimensions of Hole and shaft are such that, without the interference of external agency the assembly of Hole shaft pair is not possible is called as Interference fit.



$L_{\text{Hole}} \& L_{\text{shaft}} \rightarrow S > H$

$L_{\text{Hole}} \& H_{\text{shaft}} \rightarrow S > H$

$H_{\text{Hole}} \& L_{\text{shaft}} \rightarrow S > H$

$H_{\text{Hole}} \& H_{\text{shaft}} \rightarrow S > H$

If diff. b/w
Hole & shaft
> 0.5 mm, it
is not possible
to assemble

If $L_{\text{SHAFT}} > H_{\text{HOLE}}$

It always produces interference fit.

$$\text{Max interference} = H_{\text{shaft}} - L_{\text{hole}}$$

Diff b/w max material limits

$$\text{Min interference} = L_{\text{shaft}} - H_{\text{hole}}$$

Diff b/w min M-L of hole and shaft.

Applications:-

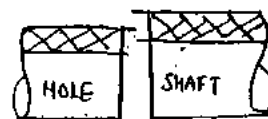
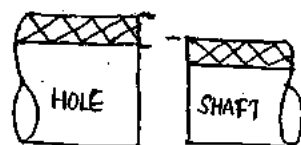
In all the mating Assemblies interference fit can be used.

eg: Bearing Bushes fitted into Bearing housing.

key in keyway.

3. TRANSITION FIT :

The dimensions of hole and shaft are such that sometimes the clearance fit and sometimes interference fits produced is called as Transition fit.



$$L.H \ \& \ L.S \rightarrow H > S \rightarrow C$$

$$L.H \ \& \ H.S \rightarrow H < S \rightarrow I$$

$$H.H \ \& \ L.S \rightarrow H > S \rightarrow C$$

$$H.H \ \& \ H.S \rightarrow H > S \rightarrow C$$

$$L.H \ \& \ L.S \rightarrow H < S \rightarrow I$$

$$L.H \ \& \ H.S \rightarrow H < S \rightarrow I$$

$$H.H \ \& \ L.S \rightarrow H > S \rightarrow C$$

$$H.H \ \& \ H.S \rightarrow H < S \rightarrow I$$

If H Limit of one of components is lying b/w the L and H Limits of other components is called as Transition fits.

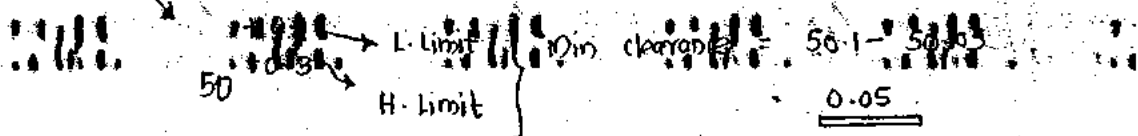
Allowance — Diff b/w Max material limits.

Applications:-

used for Non mating Assemblies like fit b/w piston and piston rings, shafts and couplings etc.

eg:- Hole = $20^{+0.10}_{+0.00}$
Shaft = $20^{+0.05}_{-0.05}$ } Transition fit
Allowance = $20.05 - 20.00$
 0.05mm

Hole = $50^{+0.03}_{+0.1}$
Shaft = $50^{+0.05}_{-0.02}$ } clearance fit
max clearance = $50.3 - 49.8$
 0.5



TYPES OF ASSEMBLIES USED IN MANUFACTURING INDUSTRY:-

1. Make to suit:-

In this one of the component will be made nearly equal to the Req'd dimension and other component is made slowly such that it can be assembled on to the first component according to the Req'd Assembly conditions.

Advantages:-

1. Lack of No Limits and Tolerances, Absolutely No rejection of the components.

7c engine

$$D_p = D_c = 50\text{mm}$$

Disadvantage:

During the usage of assembly by customer if one of the component in assembly fails the total assembly has to be brought to one of the manufacturing industry and get it manufactured the failed component which is suitable for the existing component. Sometimes it is becoming very difficult to bring the total assembly. To avoid this the interchangeable assembly is developed.

INTERCHANGABLE ASSEMBLY:

The parts manufactured under similar conditions in any corner of the world can be interchangeable.

SELECTIVE ASSEMBLY:

It is a type of interchangeable assembly.

In selective assembly only selected group of components can be interchangeable.

The interchangeability point of view selective assembly is inferior than interchangeable assembly but still selective assembly has been developed in manufacturing industry because selective assembly is used for producing components having very small amount of tolerance on a machine which has poor process capability.

Min toleranced components which can be produced on a machine with more than 99% of acceptability is called as process capability of m/c.

2418 5787 810

$$A = (8.14 \times 10^{-1}) \times 10^4 = 8.14 \times 10^3$$

$$L^2 : P = \gamma_{+X} = 0.0$$

$$7H^2\psi - 2\psi^3 = 4\psi$$

$$1'0 \neq p = 1 + y'0 + 1 = 0$$

$$5.08 \times \frac{100}{100} = 5.08 =$$

$$9541 - 6.0 =$$

MSA-OSW = 0.7 1.5

$$\% 88 = \frac{01}{01 - 110.01} = 88.08$$

$$\omega_{\text{eff}} = \omega_0 + \gamma = 14$$

$$1 \text{ auf } S \in R \quad S/R = 1 \text{ auf}$$

$$\frac{d}{dt} \left(\frac{x}{Q_1} \right) = k$$

014-115-492

0.4 - 120-55 = 65

$$G_L = G_T + 0.6 =$$

$$0.1A = \sqrt{0.07^2 + 0.2A^2}$$

$$r_1 + v_1' + t_1 = d$$

$$D = 50 + 0.4 + 25$$

$$Q_1 = Q_4 + Q_2$$

$$SS = 0.591 - 0.18$$

$$\left(\frac{99.8}{3} \right) \text{ mg/l} = 0$$

998 $\frac{2}{3}$

77.8 =

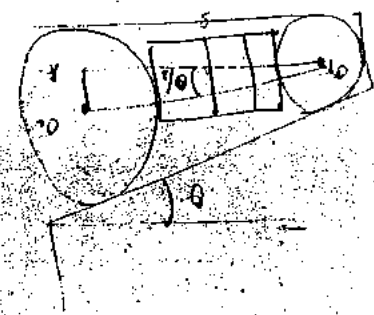
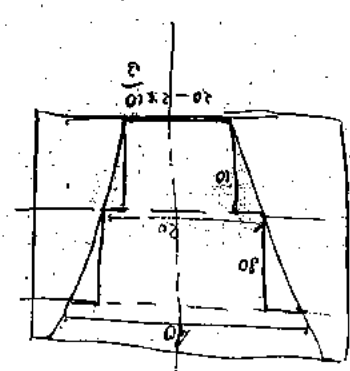
54-
6-21-60

$$\frac{1}{2} = \frac{1}{2} \cdot \frac{2}{2} = \frac{2}{4}$$

935 246

THE THE THE THE THE THE

$$\begin{aligned}
 &= 0 \\
 &\frac{45.86}{8} = \frac{0.1}{0.1} = \frac{2}{0} \text{ may} \\
 &45.86 = \\
 &45.86 + 8 = \\
 &0.1 + 1 = 1.1 \\
 &8.4 - 8 = 0.4
 \end{aligned}$$



eg - $D = 100 \text{ mm}$

1000 parts

$$100 \pm 0.1 \rightarrow \frac{650}{1000}$$

$$100 \pm 0.2 \rightarrow \frac{680}{1000}$$

$$100 \pm 0.3 \rightarrow \frac{992}{1000} \rightarrow T_{ol} = 0.6$$

$$100 \pm 0.4 \rightarrow \frac{996}{1000}$$

$$100 \pm 1 \rightarrow \frac{1000}{1000}$$

$T \geq 0.6$ then % Acceptance $> 99\%$

Process Capability of a m/c.

Higher the min Amt of Tolerance Poor is the Process Capability of m/c

	A	B
P.C	0.4	0.7

m/c is Better

Selective Assembly is adopted for m/c with Poor Process Capability.

In selective Assembly first enhance the Tolerance on the Components such that the Tolerance on the Components is $>$ Process capability of the m/c, Manufacture the Component Accordingly, After Manufacturing, inspect the component and divide the component into no: of groups. When corresponding lettered group of components are Assembled, the Assembly conditions will be better than or Same as the original Assembly conditions.

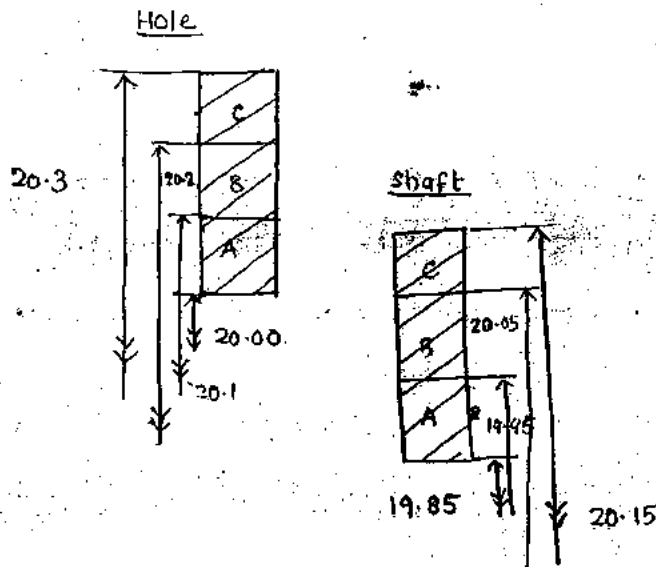
$$\left. \begin{array}{l} \text{Hole} = \begin{array}{l} +0.10 \\ 20 +0.00 \end{array} \\ \text{Shaft} = \begin{array}{l} -0.05 \\ 20 -0.15 \end{array} \end{array} \right\} P.C = 0.3 \text{ mm}$$

Hole Tolerance = 0.1

Type of fit = clearance

Maximum clearance = 0.25

Min clearance = 0.05



Hole c and shaft c

+0.3

20 +0.2

20 +0.05

Hole Tol = 0.1

Shaft Tol = 0.1

Type of fit = clearance

Max clearance = 0.25

Min clearance = 0.05

Limitations

1. Beoz of Random No of components in each group, in some Groups the components will get Accumulated without the usage.
2. During usage /assembly if one part fails in Assembly, first Refer the Manual of the Assembly and identify the failure Component belongs to which b group and then search in diff

Applications:-

In spite of the Above Limitations Selective Assembly is used for Manufacturing of Ball Bearing Assembly.

1. Inner Race : Small, Medium, Large
2. Outer Race :
3. Ball :

- (a) Small Inner Race, Large Outer Race with Large Balls
- (b) Small " " , Small " " , " Medium Balls
- (c) Large Inner Race, " " " , Small "
- (d) " " " , Large OR " " Medium Balls.
- (e) Medium IR, Med Outer Race with Medium Balls.

In the Ball Bearing Assembly by using different Permutations

and combinations accumulation of one group of components can be eliminated completely. During usage of Assembly if one component fails in assembly it immediately produces scratches in other two components. So other two Components also will become useless and total assembly has to be Replaced. When total Assembly is Replacing whether it belongs to small group or medium group doesnot have any problem.

SYSTEM OF LIMITS, FITS AND TOLERANCES:-

The standard method of designation of Hole-shaft pair in Assembly is called as system of limits, fits and tolerances.

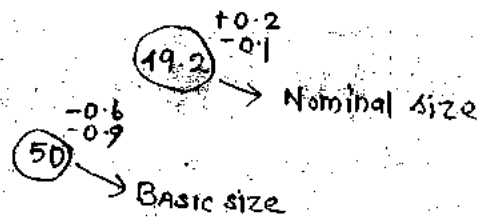
$$\begin{array}{l} \text{Hole : } 30 \begin{array}{l} +0.025 \\ +0.000 \\ -0.08 \end{array} \end{array} \quad \left. \vphantom{\begin{array}{l} \text{Hole : } 30 \end{array}} \right\} 30 \text{ H7/g8}$$

NOMINAL SIZE

Nominal size is the size decided based on the design considerations of a component.

$P = 20 \text{ kW @ } 800 \text{ rpm}$

Dia of shaft = 49.2 mm



BASIC SIZE

It is the size based on which limits and tolerances of a component can be specified conveniently. Sometimes the Basic size and Nominal size will be equal.

DEVIATION

The amount by which the limit of a component is deviated from Basic size is called as deviation.

Upper deviation: - The amount by which the upper limit is deviating from Basic size is called upper deviation. It is also taken as diff b/w H. Limit and Basic size.

Lower deviation (L.D): -

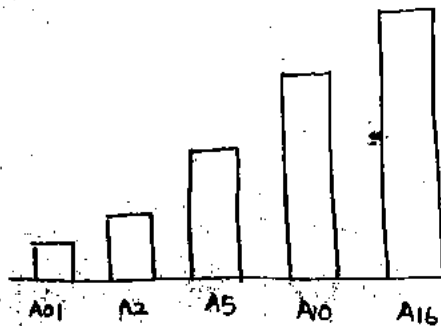
The amount by which lower limit is deviating from Basic size is called as lower deviation. It is also taken as diff b/w Lower Limit and Basic size.

Fundamental deviation (FD): -

It is one of the deviations, either upper or lower.

only J and JS are Bilateral Toleranced Components and all others are taken as unilateral Toleranced Components.

238



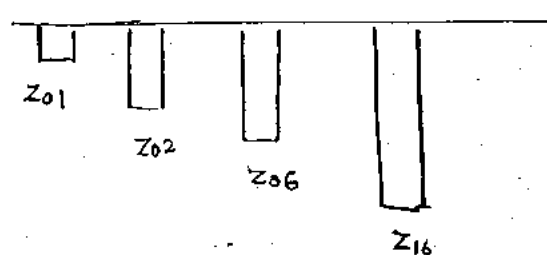
L.D is fixed one

HOLE A

The straight line indicates that the corresponding limit of a component remains constant irrespective of Grade of Tolerance and variable line indicates that the corresponding limit of component is varying as the Grade of Tolerance is varying.



Hole Zc



Upper Limit const.

U.D is fixed one.

From the above diagram Holes A to H will have Fundamental deviation equal to Lower deviation.

For Hole H $\rightarrow F.D = 0$

For J and JS $\rightarrow$ No Fundamental deviation

because the F.D. of Hole H is equal to zero it is named as Basic Hole and if it is used in assembly, it is called as Hole Based system.

for shafts

A to h $\rightarrow$ F.D is upper deviation

h $\rightarrow$ F.D = 0

J and js $\rightarrow$ No F.D

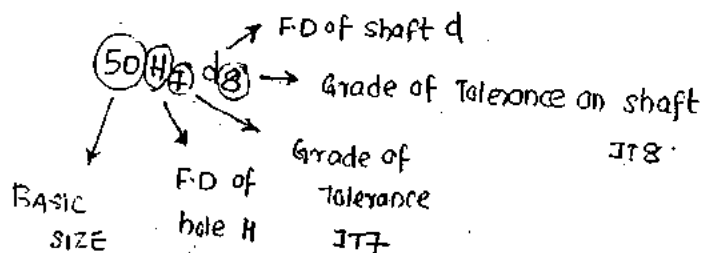
k to zc $\rightarrow$ F.D is Lower deviation

shaft h is called Basic shaft since F.D = 0

When Hole Based system is the most commonly used system,

only 18 varieties of Hole Heads can be used for producing the Assemblies with 450 varieties of shafts.

18 holes $\rightarrow$ 450 shafts



F.D - Fundamental deviation

1 Hole $\gg$ 18 shafts

so clearance fit

deviation for specifying the limit and Tolerances.

HOLE BASED SYSTEM

In the make to suit Assembly if the Hole is made first approximately near to the Reqd dimension and shaft is made slowly such that it can be Assembled into Hole according to the Reqd Assembly conditions.

SHAFT BASED SYSTEM

If the shaft is made first approximately near to the Reqd dimension and enlarge the Hole such that it can be assembled on the ~~shaft~~ ^{shaft} Hole according to reqd assembly conditions.

→ In case of Hole Based system, Reducing the dia of shaft slowly Requires one single point cutting Tool and Lathe m/c.

whereas in shaft Based system To enlarge the Hole, many no. of Reamers are Reqd; which is costly and difficult. ∴ Hole Based system is the most commonly used System.

According to Latest definition if Hole "H" is used in Assembly; called as Hole Based System and if shaft "h" is used in Assembly, it is called as shaft Based system.

INDIAN SYSTEM OF LIMITS, FITS AND TOLERANCES

* Holes → capital Letters

Holes will be specified by capital Letters

* shafts → small letters

Holes $\rightarrow$ A, B, C, D, E, F, G, H, J, Js, K Z_A, Z_B, Z_C

shafts $\rightarrow$ a, b, c, d, e, f, g, h, js, k Z_a, Z_b, Z_c

* 18 Grades of Tolerances can be Taken.

IT01, IT0, IT1, IT2, ..., IT16

$\rightarrow$ Increasing order of tolerance

IT01 - Lowest amt. of tolerance

IT16 - Has Highest amount of tolerance

Hole A - A01, A0, A1, A2, A3, ..., A16

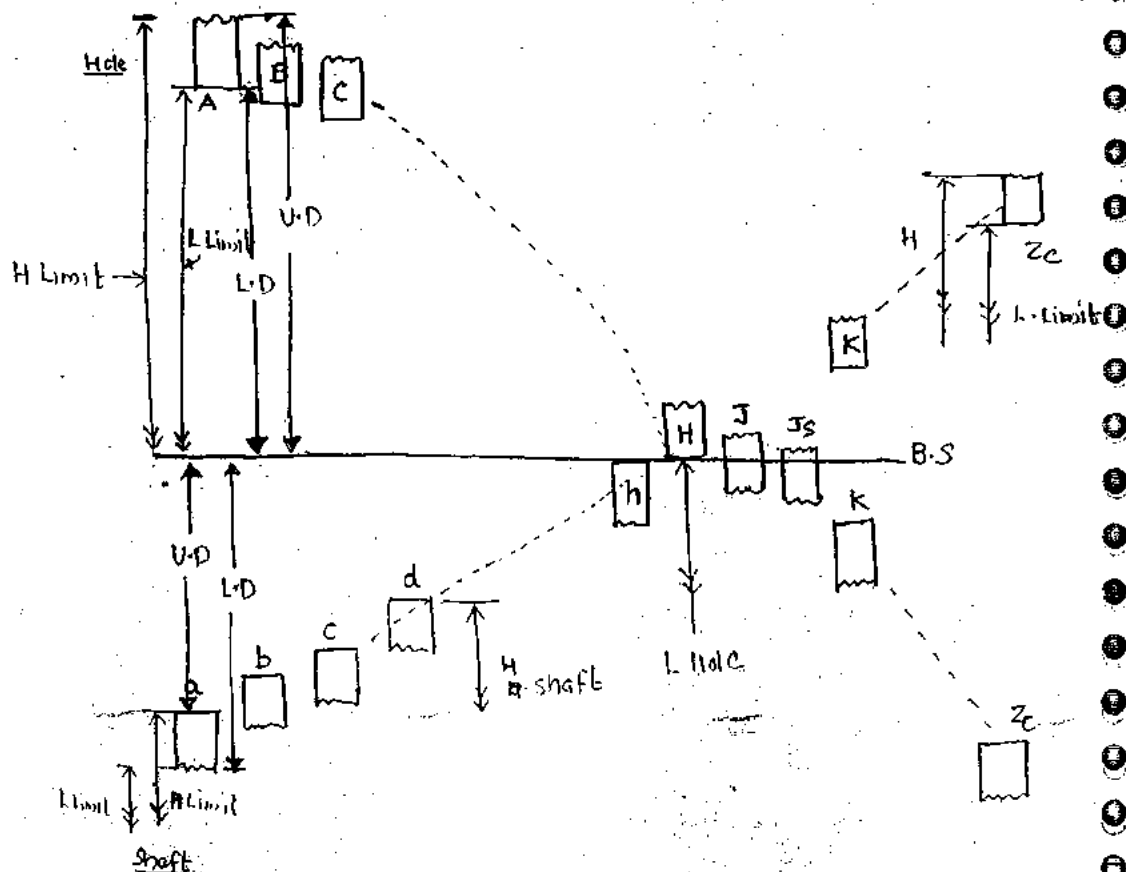
Hole B - B01, B0, B1, B2, B3, ..., B16

Shaft a - a01, a0, a1, a2, a3, ..., a16

Shaft b - b01, b0, b1, b2, b3, ..., b16

Holes $\rightarrow$ 18x25
450

Shafts $\rightarrow$ 18x25
450



Hole H with shafts a to g $\rightarrow$ clearance

Hole H with shafts p to zc $\rightarrow$ interference

Hole H with shafts h to h $\rightarrow$ Transition

Hole H with shafts a to c $\rightarrow$ Large clearance fits

Hole H with shafts d and e $\rightarrow$ Medium " "

Hole H with shafts f and g $\rightarrow$ Small clearance fits

GRADES OF TOLERANCES

IT5 to IT10 $\rightarrow$ General Purpose Application

IT11 to IT16 $\rightarrow$ Very Less important / Non mating Application

IT2 to IT4 $\rightarrow$ Highly important / mating Assemblies

IT01 to IT1 $\rightarrow$ Measuring equipment

ex: Dia of piston = cylinder of IC engine

50 mm

Select a Hole shaft Pair

~~50 H₁₀ / f₆~~ 50 H₆ d₈

or

50 H₆ d₅

ex: Hydraulic press having 1000 tonne Capacity - select the

Hole shaft pair

(a) 200 H₁₀ F₁₂

(b) 200 H₆ g₇

✓ (c) 200 H₃ F₄

CONVERSION OF STD designation into Limits and Tolerances

Let $D = \sqrt{30 \times 50} = 38.7 \text{ mm}$

$50 H7 g8$

$i = \text{std} \cdot \text{tol unit}$

$= 0.45 \sqrt[3]{D} + 0.001 D \text{ } \mu\text{m}$

$= 1.56 = 1.6 \text{ } \mu\text{m}$

F.D of hole $H = 0$

F.D of shaft $d = -16 D^{0.41} \text{ } \mu\text{m}$

$-ve \text{ indicate}$
F.D is upper
 $= 16 (38.7)^{0.41}$
 $= \underline{80 \text{ } \mu\text{m}}$

Hole Tol = IT7 = $16 i \cdot 16 \times 1.6 = \underline{26 \text{ } \mu\text{m}}$

Shaft Tol = IT8 = $25 i \cdot 16 \times 1.6$

$= \underline{40 \text{ } \mu\text{m}}$

L.Hole = B.S = 50.00

H.Hole = L.Hole = tol

L.Hole = H.Hole - tol

$= 50 - 0.026$

Hole = $50 H7 = 50 \begin{matrix} +0.026 \\ +0.000 \end{matrix}$

H-shaft = $50 - 0.08 = 49.92$

H-shaft - L-shaft = Tol

L-shaft = H-shaft - Tol

$= 49.92 - 0.04$

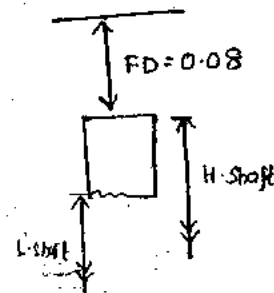
$= \underline{49.88}$

i = Geometric mean dimension of dimension step b/w which given Basic size is lying

DIM STEP TABLE

above	upto and including
0	3
3	6
6	10
10	18
18	30
30	50
50	80
80	120
120	180
180	250

11.5	- 71
6	- 10 i
7	- 16 i
8	- 25 i
9	- 40 i
10	- 64 i
11	- 100 i
12	- 160 i
13	- 250 i
14	- 400 i
15	- 640 i
16	- 1000 i



-0.08

Limit Gauges used for Inspection of component

The Gauges used for inspecting the limits of a component by using a method called ~~was~~ inspection by attributes

Methodology is called as Limit Gauges.

Methods of Inspection:

1. Inspection by variables.
2. Inspection by Attributes.

If each and every dimension of a Component is measured physically by some equipment, Based on the dimension obtained if it is falling within the limits of a component specified, the component is said to be Acceptable and if it is falling out of the limits of a Component, The component is said to be Rejectable. This is

called as inspection by variables method. Without measuring the

dimensions of a Component physically the Component can be inspected by using Go and NO Go Gauges. If the Go Gauge is entering into the component and NO Go Gauge is Not entering into the component, the Component is said to be Acceptable.

If Both the Gauges are entering or both the Gauges are Not entering the component is said to be Rejected.

Today's industry uses combination of inspection by variables and attributes methodology.

Limit Gauge :-

Go Gauge

NO Go Gauge

If Go and No Go Gauges are used for inspection of component it is called Limit Gauges.

During manufacturing if the material present on the component is greater than the min material limit and less than maximum material limit, the component is said to be acceptable.

GO GAUGE: — max material limit of comp.

Go Gauge is made for maximum material limit of component such that it always enters into the component which has material less than the max material limit. The length of the Go Gauge is at least equal to the length of the component to be inspected so that uniformity in dimension of the component can be checked.

NO GAUGE:

It is made for the min material limit of comp such that it will not enter into the component which has material $>$ than min material limit. The length of No Go Gauge may be any length.

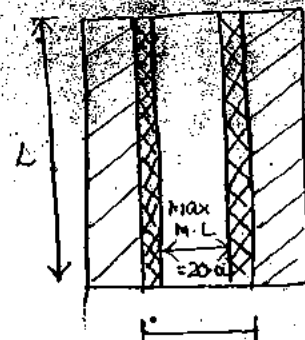
If the Go Gauge is entering and No Go Gauge is not entering means that material present in the component is $>$ min material limit. Hence the component is said to be acceptable.

The shape of the Gauges must be always taken as opposite to that of shape of component to be inspected.

Hole: - $+0.10$
 20 ± 0.00

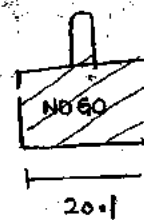
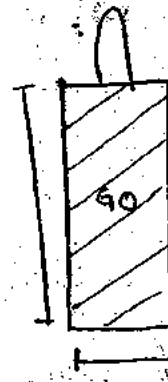
$$M-M-L = 20.00 = GO$$

$$\text{Min } M-L = 20.10 = NOGO$$



Min ML
 $= 20.1$

If the dimensions of GO & NOGO
 Gauges are interchanged only rejectable
 Components will be accepted and
 all acceptable components will be
 Rejected. Hence it is always Read
 to make GO gauge for Max material
 Limit and NOGO Gauge for Min



Single end
 Solid type

INSPECTION OF HOLES

Holes will be inspected by using gauges having shaft
 shape. % Named as plug gauges.

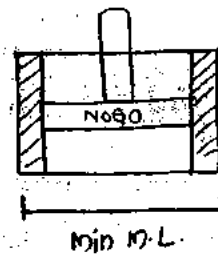
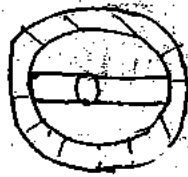
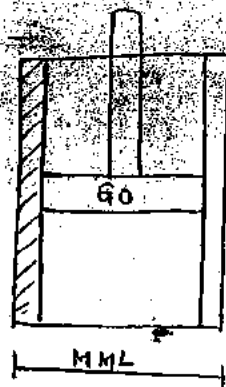
They are mainly of 3 types

1. solid type {
 - single ended
 - double ended
2. Renewable Type
3. progressive Type

Double ended
 Solid Type

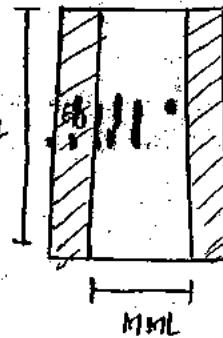


As the size of Hole to be inspected is
 increasing the plug gauge size also increases
 % it is becoming difficult to handle solid type
 of Plug gauges. Hence the Hollow type of Gauges will be
 used called as Renewable Type of plug gauges.

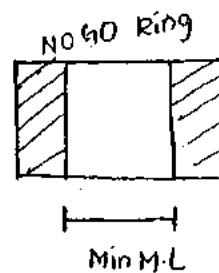
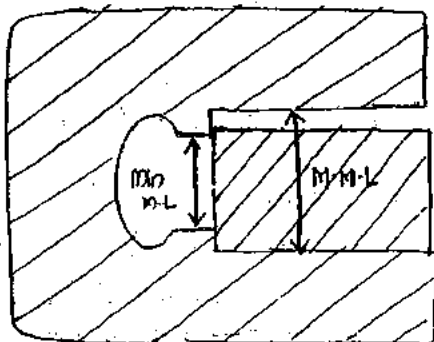


Shafts

1. Ring Gauges
2. Snap Gauges
3. Gap Gauges



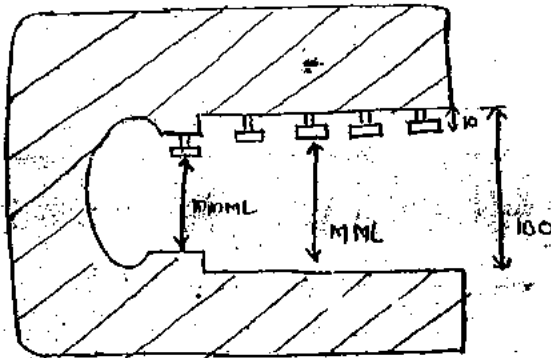
Gap Gauges:-



Limitations:-

Gap Gauge is Heavy in construction & if it is used for

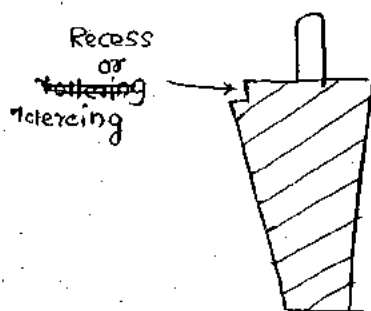
Justifiable. If the Gap Gauge is modified for inspecting more than one type of dimension then it can be economically justified. Pins will be provided in the Gap Gauge, either at one side or both the sides to inspect diff dimensions of components.



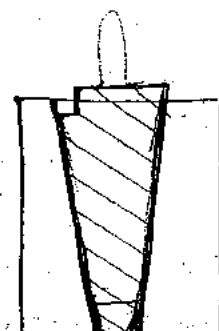
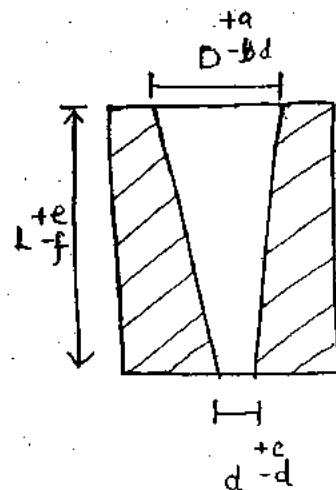
With the provision of pins on Gap Gauge and by varying length of pins, same gap gauge can be used for inspecting different dimensions of component. Gap Gauge with provision of pins is called SNIP GAUGE.

TAPERED HOLE:-

For inspecting tapered hole only one gauge is sufficient called as Taper plug Gauge.



TAPER PLUG GAUGE



Taper plug gauges are always tapered at big end side only.

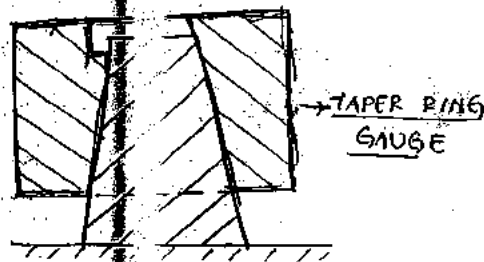
If Top surface of Component is lies in low limit of Recess. The Component is said to be acceptable.

TAPERED SHAFT

Taper Ring Gauge

acceptable

Taper Ring Gauges are always Toleranced at the small end side.



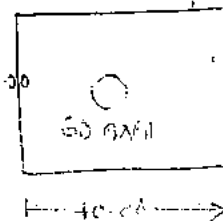
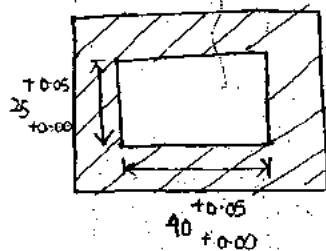
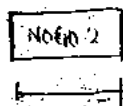
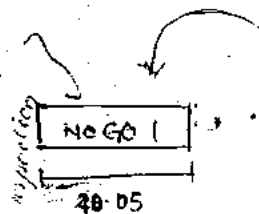
Principles of used in design of Limit gauges

1. Basic principle

According to Basic principle No rejectable component is allowed to Accept. But there is no problem in rejecting the Acceptable components. This is to ensure that the Good will of company should not be Lost.

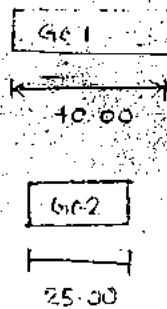
2. TAYLOR'S PRINCIPLE

According to Taylor's principle, Go gauge is made to the limit of component and it has to incorporate as many dimensions as possible to inspect in one stroke. But No GO GAUGE is made for min. of component and separate NO GO Gauges must be used for each and every dimension.

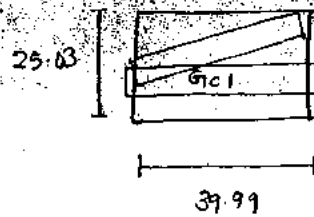


means that this has single gauge of same dimension.

Violation of
Taylor's principle

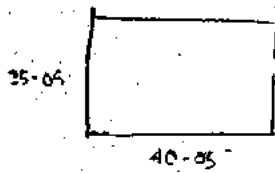


Multiple Go Gauges

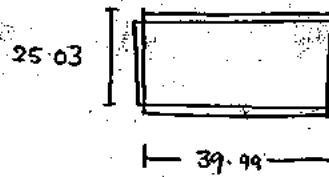


rejectable
component

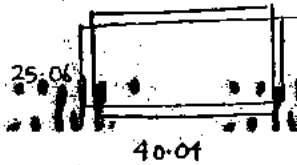
to accept a hole, all the dimensions must be
in the acceptable limit



Single NO GO
Gauge



Single Go
Gauge



If Taylor's principle is violated during designing of limit gauges, it
may accept the rejectable components and so violate the Basic
principle in designing of limit gauges.

3.

PRINCIPLE OF PROVISION OF LIMITS AND TOLERANCES:

Because the limit gauges also has to be manufactured by us in the industry, it is reqd to provide some amount of Limits and Tolerances on limit gauges, also such that the Basic principle in designing of limit gauges should not be violated.

Gauge Tolerance = 5 to 10% work Tolerance = wear ~~tolerance~~ Allowance

Hole = 20 ± 0.06 19.96 to 20.06

W.T. = 20.06

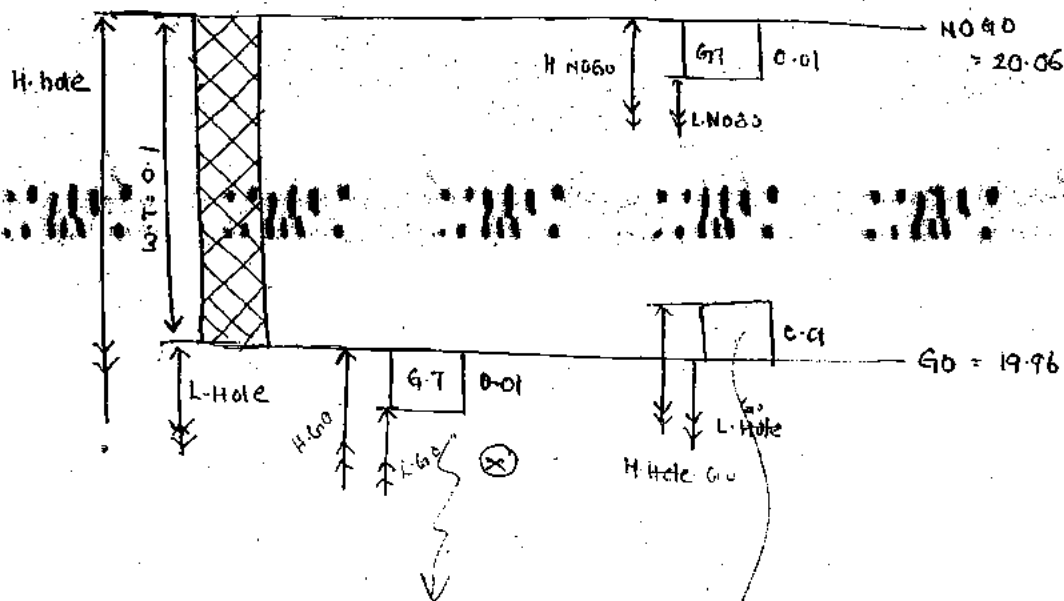
G.T - Gauge Tolerance

W A = Week Allowance

0.01mm

Tolerances During inspection by the gages on entering into & coming out of the component, the component & gage is

Tolerances:- During inspection by the gauges on entering into & coming out of the component, the component & gauge is Hole considered as a mating assembly & in the limit gauges, it is recommended to provide only the unilateral tolerance.



$$90 = 19.95 \text{ to } 19.96$$

Just Rejectable Hdd

= 19.952. Acceptable

Parte de mension d

19.959

Above the line

Mo. - 1996 to 1997

60 - 19.96

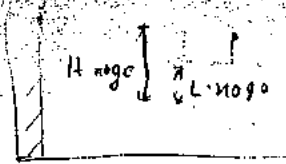
19465

B Acceptable component

NO GO - 20.05 to 20.06

NO GO - 20.061 ~~Reject~~

NO GO: 20.05



During inspection 20.06

(In case of) Go Gauges (As it is) entering into and coming out

from components. Some amt of wear is experienced by the

Go Gauge and it may accept the Rejectable components. To

Avoid this, some amount of wear allowance must be provided

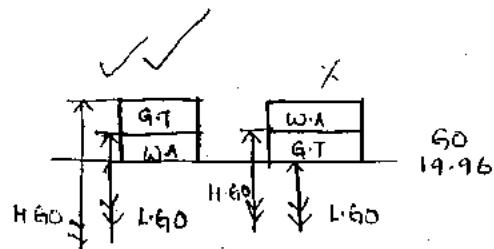
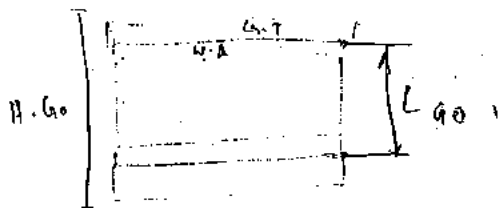
on the Go Gauge such that even though the wear has been

taken place on the Go Gauge it should not accept the

Rejectable components.

Wear Allowance = 5 to 10% ~~W.T~~

= 0.01 mm



GO = 19.97 to

19.98

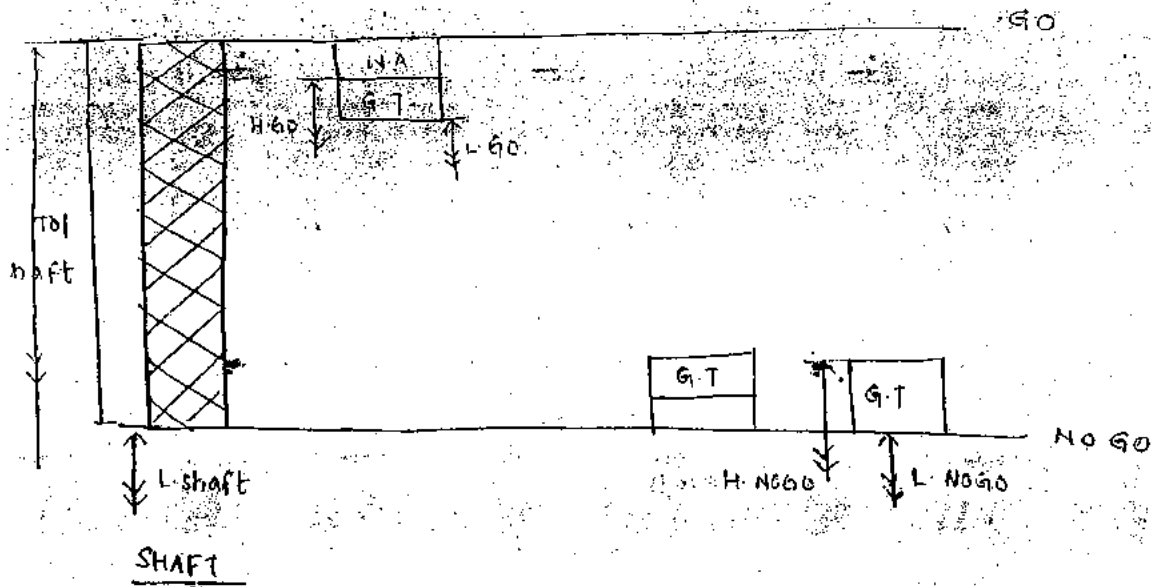
correct methodology

GO = 19.96 to 19.97

(X)

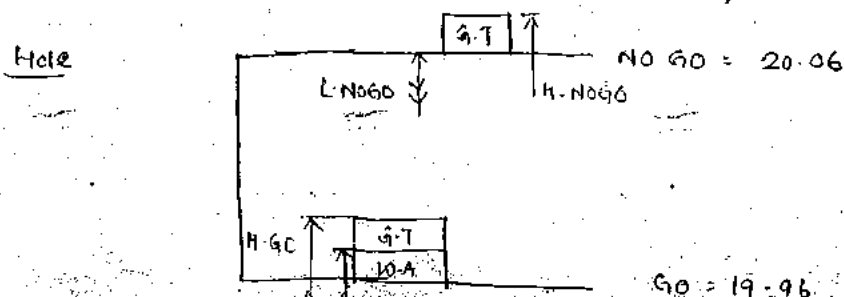
by wear

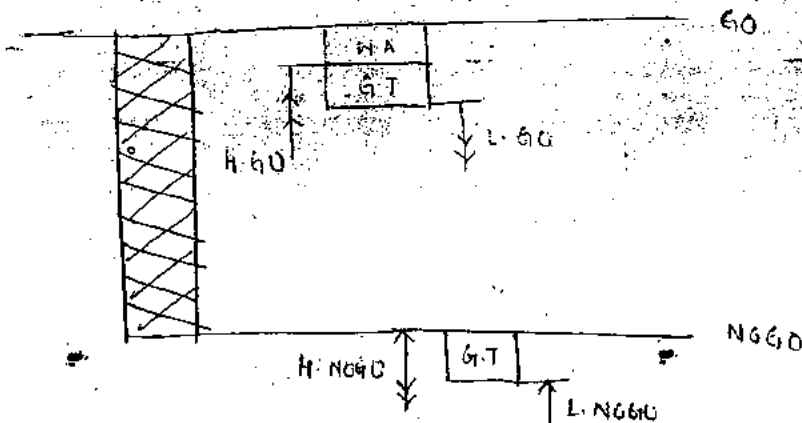
allowance



The above method of providing Limits and Tolerances on limit gauges is considered on limit gauges used for inspection of component in workshop or shop floor where basic principle in designing of ~~proper~~ limit gauges must be strictly followed.

But for ~~in~~ Limit Gauges used in inspection of component in quality control rooms and limit gauges used for general purpose application, on the GO gauge we are strictly following the Basic principle but on the $NOGO$ Gauge we are giving some relaxation so that gauge tolerance on NO gauge is outside limit of work tolerances, it will accept some qty of rejectable component.





In the case of Inspection and General purpose Gauges only on No Go Gauges we are giving some relaxation. But on Go Gauges absolutely No relaxation is given. This is bcoz of

at the gauges at the

① If a component is Rejected (bcoz) of Non entry of Go gauge means that material present on the component is greater than the max ^{or machining} m/L limit. It can be sent for Reworking, Reinspecting and Reaccepting. Hence it is not a loss to the company.

② If a component is Rejected bcoz of entry of NOGO gauge means that material present on component is less than the min material limit of component. No alterations is possible and it has to be scrapped. When it is Scrapped some amount of loss is incurred to the company. To reduce this loss some Rejectable Components will be Acceptable.

③ If a Rejectable Component is Accepted to Go gauge side and sending it to the customer ^(assembly), At the Assembly period type of fit will get changed i.e. clearance fit will become interference fit, so customer will easily come to a conclusion that

company has sent a rejected company. But
at the assembly point in Chicago, a lot of it is sent to the assembly
plant where it will become more clean and let the customer will want go
about on the new component.

For measurement of surface finish of a given surface we pre-fer not measuring surface finish of total surface and we always select some portion of component and measure the surface finish which is indicating surface finish of total Body called as Sample Length.

$$L = 0.025, 0.08, 0.25, 0.8, 2.5, 8, 25 \text{ mm}$$

Generally 0.8 and 2.5 are most commonly used Sample Lengths

$$R_a = \frac{1}{L} \int_0^L h_x dx$$

3. R_{rms} / h_{rms}

Root mean square value of surface finish

$$R_{rms} = h_{rms} = \sqrt{\frac{\sum h^2}{n}} \text{ or } \frac{1}{L} \sqrt{\frac{1}{L} \int_0^L h_x^2 dx}$$

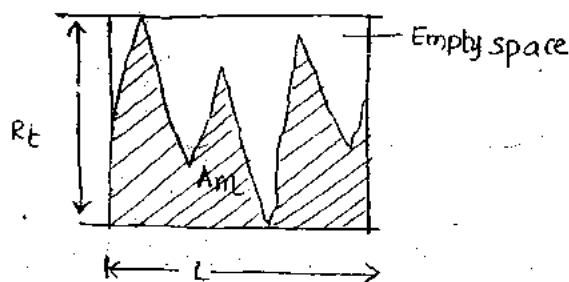
4. R_z = Avg over definite ordinates

$$= \frac{\sum \text{Peaks} - \sum \text{valleys}}{\text{No of Peaks or valleys}}$$

No of Peaks or valleys

$$= \frac{(h_1 + h_3 + h_5 + h_7) - (h_2 + h_4 + h_6 + h_8)}{4}$$

5. Form factor (K) = degree of fullness



The Form factor is nothing but percentage of Area of Rectangle occupied by Metal

$$K = \frac{A_m}{R_t \times L}$$

Area of Metal can be measured by using Planimeter.

* If Form Factor (K) is more than 0.8 will indicate that the surface finish of surface is good.

If two or more surfaces are having same values of R_a , R_t & R_z it is assumed that the surfaces will have the nearly same type of surface Texture.

$$R_{t1} = R_{t1} \neq R_{t2} \neq R_{t3}$$

$$R_{t1} = R_{t2} = R_{t3} \checkmark$$

$$R_{a1} = R_{a1} \neq R_{a2} \neq R_{a3}$$

$$R_{a1} = R_{a2} = R_{a3}$$

$$R_{z1} = R_{z2} = R_{z3}$$

$$R_{z1} = R_{z2} = R_{z3}$$

R_t will be Largest

Generally $R_t > R_{rms} > R_a > R_z$

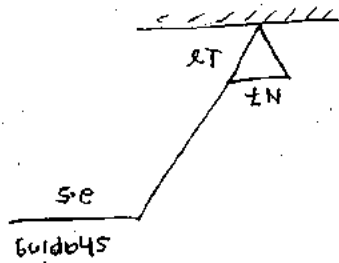
Designation of surface Finish values:

Mainly 2 methods are used.

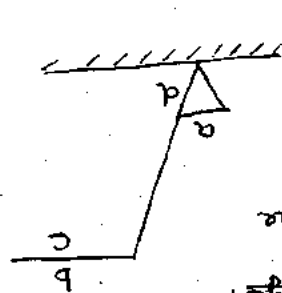
1. International or I.S.O Method

Symbol	R_a value	Range of $R_a = R_a \begin{matrix} +50\% \\ -25\% \end{matrix}$
N_1	0.025 (μm)	0.02 to 0.04
N_2	0.05	0.04 to 0.08
N_3	0.1	0.08 to 0.15
N_4	0.2	0.15 to 0.3
N_5	0.4	0.3 to 0.6

This symbol indicates the given surface is to be machined by using shaping as machining operation to get surface finish

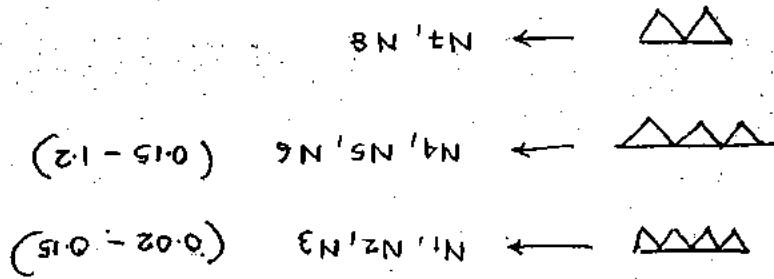


ex:



a = surface finish symbol or Ra value
b = machining method
c = sample length in mm
d → Direction of lay

Representation of surface finish in drawings:-



Equivalent ISO symbol

2. Indigo method:-

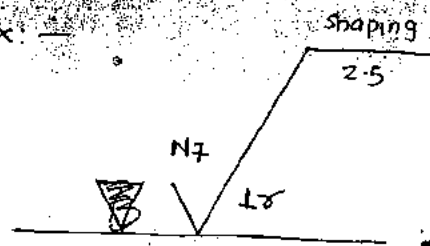
Symbol	Equivalent ISO symbol
N1	3.2
N2	2.4 to 4.8
N3	6.3
N4	12.5
N5	25
N6	50
N7	31.5 - 75

849

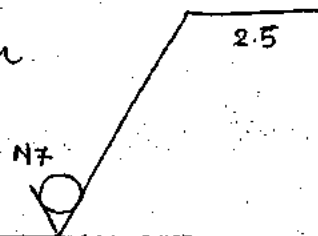
piece After Machining for Measurement of surface finish sample length to be used is 2.5 mm.

This symbol indicates that the machining is optional, i.e. the Req'd surface finish can be obtained / without M/ching directly by using Metal forming / casting etc.

If M/ching is used, use only shaping operation with direction of Lay $\perp$ to the surface.



This symbol indicates No M/ching is Allowed on the surface. i.e. the Req'd surface finish has to be obtained directly by using casting / Metal Forming process etc.



Methods of Surface Finish Measurement:-

1. Visual Inspection $\rightarrow$ Qualitative method
2. Touch Inspection $\rightarrow$ By using equipment
quantitative method

(a) Talminson surface meter

(b) surface profile graph

(c) Talysurf

(d) Abards profilometer

(e) Piezoelectric crystal

(f) Perthometer

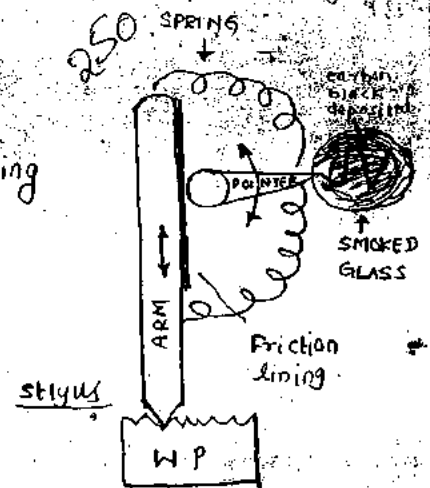
(g) Plastic Replica Technique

None of those equipments will give the value of R_a , R_z , R_t directly.

TAMMISON SURFACE METER:-

As the work piece is moving the stylus is finding the peaks and valleys, the stylus is moving up and down and due to this the pointer is

- Rotating. As the pointer is rotating it is removing smoke from the glass producing magnified version of surface texture. using this magnified surface texture heights of irregularities like h_1, h_2, h_3 etc can be measured by taking the datum line and using this the values of ~~R_a, R_t~~ R_a, R_t & R_z can be found out.



Limitations:-

1. The Magnification is limited because of limited length of Pointer.
2. The smoked glass has to be handled carefully.

Plastic replica technique:

Due to the limited size of the platform, the above equipments cannot be used for measurement of surface finish of very large surfaces like measurement of surface finish of the guideways of a machine tool. Also the above equipments cannot be used for measurement of surface finish of internal surfaces like surface finish of a hole, because the R_a arm & stylus are not accessible to move inside the hole.

For the above cases, the surface finish can be measured by using plastic replica technique.

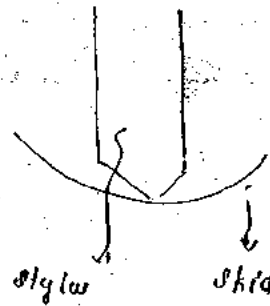
the same. Now for plastic piece the surface finish is measured on the plastic piece is same as that of the actual surface. Hence the plastic piece is kept on the platform of any one of the above surface finishing measuring equipment & measure the surface finish. The only difference is the peak & the actual component will become the valley on the plastic piece & vice versa.

Wavelength $\lambda = 8\lambda$ to 50λ .

Pr: 56

Q1: $R_L = 47-18$

$$R_L = \frac{E_k}{10} R_L = \frac{(35+40+35+42+35) - (25+22+18+25)}{10} = \frac{160 - 90}{10} = 7$$



used for measurement

roughness $R_a \times 1.1 = 1.1 R_a$

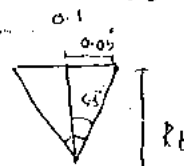
$R_{12} \Rightarrow R_a = 50 = 37.5$ to $75 \rightarrow$ not

$N_{11} \Rightarrow R_a = 25 = 18.75$ to 37.5 ✓

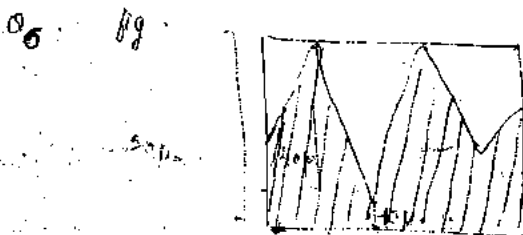
international grade of roughness

used for measurement of microscopic irregularities

Q2: $R_a = \frac{2A}{L} \times \frac{1}{H.m} \times \frac{1000}{V.m} = \frac{480+480}{0.8} \times \frac{1}{100} \times \frac{1000}{15000} = 0.8$

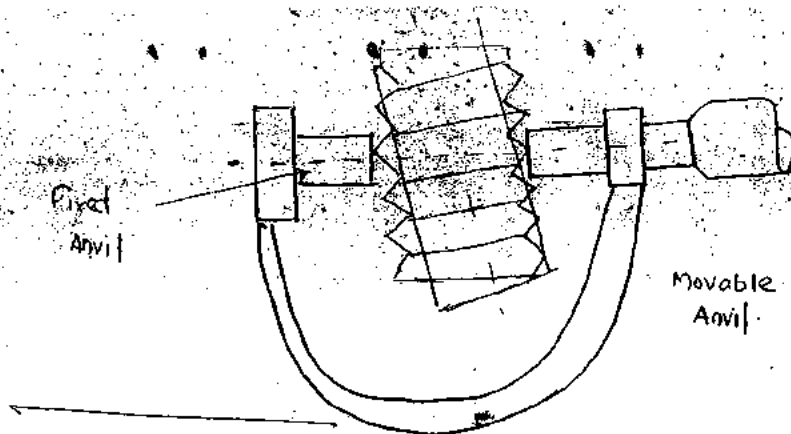


$\tan 45 = \frac{0.05}{R_L} \Rightarrow R_L = \frac{0.05}{\tan 45} = 0.05$



$A_m = 0.0105 = 0.01 \times 2.5$

$k = \frac{A_m}{R_L} = 0.8$



- Q₁ - c Q₂ - 4-3-2-1 c Q₃ - b 10 - c 11 - c 12 - c 13 - D acety (inverted 26)
 14 - b 15 - c 16 - A (not for gate) 17 - $R_L = \frac{f}{\tan \alpha \cot \alpha} = \frac{1}{\tan 30 + \cot 10}$
 18 - it's not spindle, it's mandrel A.

P_{NO: 54}

1- major dia = $d + (r_2 - r_1) = 35.5 + (11.8708 - 9.8768) =$

min dia = $30.5 + (13.530 - 15.3168) =$

2- $M = \frac{20.54}{11.2428 - 13.8768} \Rightarrow$ micrometer reading

3- $d = \frac{P}{2} \sec \frac{\alpha}{2} = \frac{2}{2} \sec \frac{60}{2} = 2 \text{ mm}$

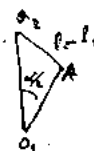
$D_e = M - \left(d + \frac{P}{2} \tan \frac{\alpha}{2} \right)$

4- $VED = D_e + \left(\delta p \cot \frac{\alpha}{2} + 0.0131 p (\delta \theta_1 + \delta \theta_2) \right) =$ 5-A

6- $d_1 = 0.866, d_2 = 1.4434$

$m_1 = 20.032, m_2 = 22.06$

$\sin \frac{\alpha}{2} = \frac{d_2 - d_1}{m_2 - m_1} = \frac{d_2 - d_1}{(m_2 - m_1) - (d_2 - d_1)}$



7- $D_e = M - \left(d + \frac{P}{2} \tan \frac{\alpha}{2} \right)$

$M = D_e + d + \frac{P}{2} \tan \frac{\alpha}{2} = 14.701 + 1.155 + \frac{2}{2} \tan \frac{60}{2}$

8- $d = \frac{P}{2} \sec \frac{\alpha}{2} = \frac{2.5}{2} \sec \frac{60}{2} = 2 \text{ mm}$ 9- $D = \frac{2}{2} = 1.5$

10- very imp. 11- $d = \frac{P}{2} \sec \frac{\alpha}{2} = \frac{2}{2} \sec \frac{60}{2} = 1.155$ 12-C

13- $VED = D_e + \left(\delta p \cot \frac{\alpha}{2} + 0.0131 p (\delta \theta_1 + \delta \theta_2) \right) = D_e + V_L$

$V_L = \text{vertical change}$

14- $P = 2, m = 16.455, d = \frac{P}{2} \sec \frac{\alpha}{2} = \frac{2}{2} \sec 30 = 1.155$

$D_e = M - \left(d + \frac{P}{2} \tan \frac{\alpha}{2} \right) = 14.723$

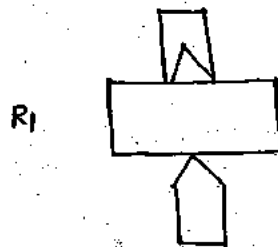
$V_L = d p \tan \frac{\alpha}{2} = 0.2 \cot 30$

$$\text{Major dia of screw thread} = S + (R_2 - R_1)$$

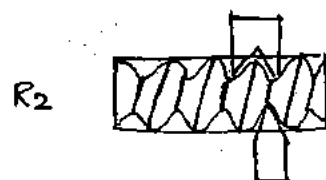
For measurement of minor dia V and conical anvils are used

For measurement of major dia using Bench micrometer flat faced anvils are used. But for measurement of minor diameter the V and conical anvils will be used with V anvil having the angle 90° and conical anvil will have angle 45° .

Let s = dia of std cylinder



$$\text{Major dia} = S + (R_2 - R_1)$$

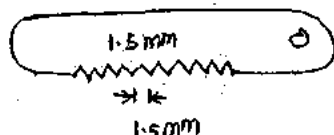


Pitch of SCREW THREADS.

The distance b/w two consecutive points on a screw thread is called pitch of screw threads.

1. Screw pitch Gauges:-

From the bunch of screw pitch Gauges select one screw pitch Gage randomly and move it over the component. If it is moving loosely on to the component, will indicate that



Bunch = 18 S.P.G's

(Screw Pitch Gauges)

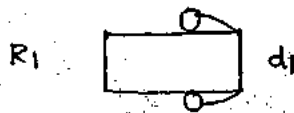
Flank Angle or Thread Angle :-

Two wires or Rollers of dia d_1

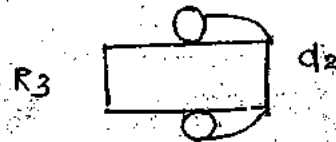
Two wires or Rollers of dia d_2

Bench micrometer

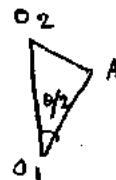
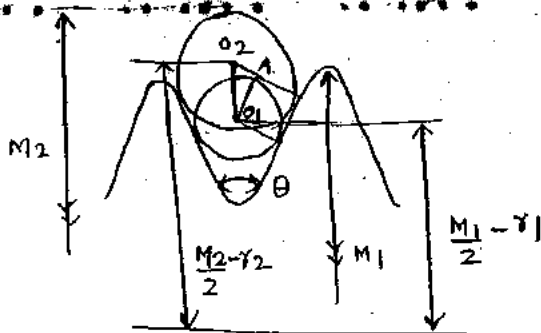
Let S = Dia of standard cylinder



$$M_1 = S + (R_2 - R_1)$$



$$M_2 = S + (R_4 - R_3)$$



$$O_1O_2 = \left[\frac{M_2 - \gamma_2}{2} \right] - \left[\frac{M_1 - \gamma_1}{2} \right]$$

$$O_1O_2 = \left[\frac{M_2 - M_1}{2} \right] - \left[\gamma_2 - \gamma_1 \right]$$

$$\sin \frac{\theta}{2} = \frac{O_2A}{O_1O_2}$$

$$= \frac{\gamma_2 - \gamma_1}{\left(\frac{M_2 - M_1}{2} \right) - (\gamma_2 - \gamma_1)}$$

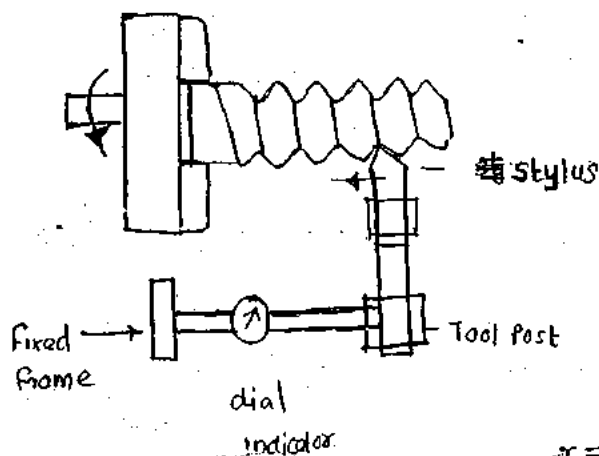
$$= \frac{d_2 - d_1}{(M_2 - M_1) - (d_2 - d_1)}$$

The pitch of the threads on screw pitch gage is less than pitch of threads on component. Hence select Higher pitch screw pitch gage. Again move it over component. If it is moving tightly on to the component indicates that pitch of threads on screw pitch gage is greater than pitch of threads on component. Hence select lower pitch again. Like this check the component with screw pitch gages until screw pitch gage is moving on to the component exactly. Now Take out the screw pitch gage and see the No printed on the gage which indicates the pitch of threads on component.

Limitations:-

- It needs experience of the inspector for exact movement of screw pitch gage on to the component.
- These gages can measure only standard pitch of screw threads.

Pitch measuring machine



α = distance travelled for 1 rev. of spindle

= Lead = $p \times \text{no. of starts}$

$$\therefore p = \frac{\alpha}{\text{no. of starts}}$$

Effective Diameter

It is the imaginary diameter at which the thickness of the screw thread and gap b/w the 2 threads will be equal.

and is equal to half of the pitch

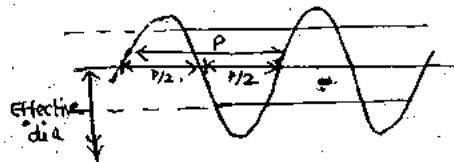
Because the location of

effective dia line itself is very

difficult, the measurement of effective diameter directly is

Not possible. Hence the effective dia is always measured

indirectly

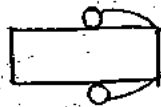


Two wire method of measurement

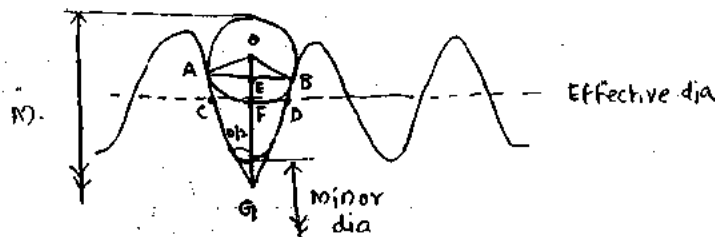
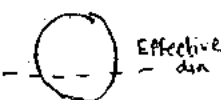
Two wires of dia "d"

Let S = dia of std cylinder

R_1 = M-n Reading over std cylinder with 2 wires



R_2 = M-n Reading over screw thread with 2 wires



$$D_e = \text{Effective dia} = M - (2r + 2 \times OF)$$

$$= M - (d + 2 \times OF)$$

Δle OAG

$$\sin \frac{\theta}{2} = \frac{OA}{OG} \Rightarrow OG = \frac{d}{2} \times \operatorname{cosec} \frac{\theta}{2}$$

From Δle CFG

$$\tan \frac{\theta}{2} = \frac{CF}{FG}$$

$$\Rightarrow FG = CF \cot \frac{\theta}{2} = \left(\frac{P}{2} \right) \times \cot \frac{\theta}{2}$$

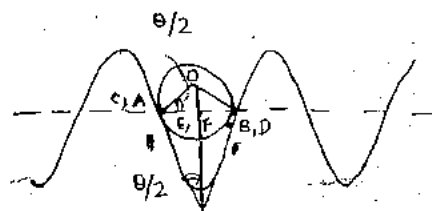
$$= \frac{P \cot \frac{\theta}{2}}{4}$$

$$OF = \frac{d}{2} \operatorname{cosec} \frac{\theta}{2} - \frac{P \cot \frac{\theta}{2}}{4}$$

$$De = M - \left[d + d \operatorname{cosec} \frac{\theta}{2} - \frac{P \cot \frac{\theta}{2}}{2} \right]$$

In the Above diagram as the diameter of wire is reduced slowly, the contacting points of A and B will be moving downwards slowly. At some diameter, points A and B will coincide with points C and D. The corresponding dia of wire is called the Best wire size.

From the Above the Best wire is the one which touches the flanges of screw thread at pitch line or effective diameter line itself.



$$\cos \frac{\theta}{2} = \frac{AE}{AO}$$

$$OA = \frac{P \sec \frac{\theta}{2}}{2} = \gamma$$

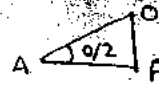
$$d = \frac{P \sec \frac{\theta}{2}}{2} \quad \text{Best wire size}$$

$$D_e = M - (2x + 2 \times OF)$$

$$M = (d + 2 \times OF)$$

$$\frac{\Delta l}{2} = OF$$

$$\tan \frac{\theta}{2} = \frac{OF}{AF}$$



$$OF = AF \times \tan \frac{\theta}{2}$$

$$AF = \frac{P}{2} \times \tan \frac{\theta}{2}$$

$$D_e = M - \left[d + \frac{P}{2} \tan \frac{\theta}{2} \right]$$

effective dia with the Best wire size

Limitations/Errors present in a wire method

1. Becoz of presence of Helix



angle of screw thread. Both the wires are not in one line. $\therefore$ they are slipping and measurement is becoming unstable. Due to this wire is not contacting both of the flanks and produces error in the measurement called as Rake error.

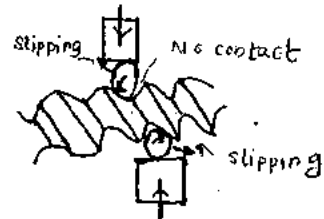
2. Becoz of wire is not in contact with

Both the sides of flanks the force

applied for measurement will be acting like a concentrated load on screw thread which induces compression in screw thread and produces error in measurement called as

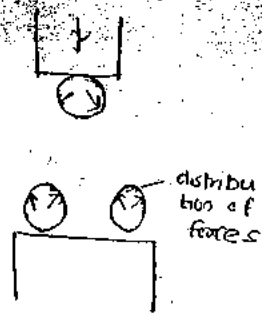
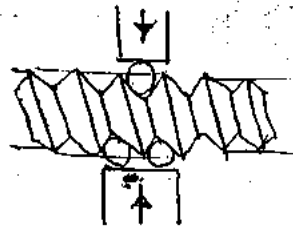
Compression error. To avoid the above errors next method

called as three wire method of measurement of effective dia



and third wire will be kept at the centre of first two wires.

By using 3 wire
Method of measurement
is perfectly stable
and No slippage of wires
is present. $\therefore$ Rate error



will be completely eliminated. Because the wire is in contact with both the sides of the flanks the force applied for the measurement is distributed into many no of force forces. $\therefore$ Amount of compression and compression error will be minimized.

To Assemble Nut and Bolt the Following conditions must be satisfied:—

1. Type of threads is same.

$\frac{P}{2}$ is same

2. Pitch is same
3. Major dia of Bolt $\leq$ Major dia of Nut
4. Min dia of Bolt $\leq$ Min dia of Nut
5. Eff dia of Bolt $\leq$ Effective dia of Nut

For a given Bolt & Nut it is found that all the five parameters are exactly equal. But on microscopic observation it is also found that Nut is Having perfect thread whereas Bolt is having some pitch & Flange angle errors. due to this when Nut is assembled on to the Bolt it is Not possible to assemble the Nut.

To make them Assemble

- Effective dia of Nut Threads can be increased
- Effective dia of Bolt threads can be Reduced

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out of the two it is preferable to increase the effective dia of Nut threads only becoz bolt is already having the errored threads. when we are modifying the Bolt threads it may get spoiled completely. this increased effective dia of Nut threads is called virtual effective dia of Bolt Thread.

$$V.E.D = d_e \pm (V.C)$$

$V.C$ = virtual change in dia

$$= \delta P \cot \frac{\theta}{2} + 0.013 P (\delta \theta_1 + \delta \theta_2)$$

δP = Pitch error

in degrees

$\delta \theta_1, \delta \theta_2$ = flank angle errors for L.H and R.H

Flanks

[If $\delta \theta_1, \delta \theta_2$ not given take it as zero]

$+$ $\rightarrow$ V.E.D of Bolt

$-$ $\rightarrow$ V.E.D of Nut

—————x

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1970 1971 1972 1973 1974 1975