6|8|11
Saturday

PRODUCTION

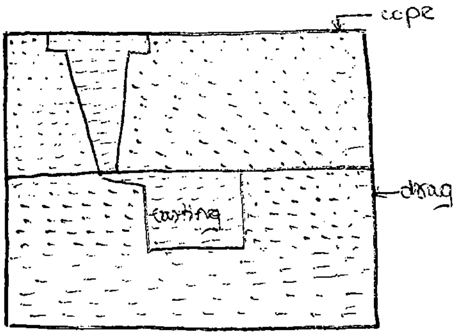
120 hrs

Marks :- 27 to 30.

CASTING

ref:- principles of metal casting by Rofts and Ruzzenthal.
work shop technology by Hajra Choudari.

Casting is a process in which the liquid molten metal is poured into the casting cavity, allow it to solidify and after solidification; the casting can be taken out by breaking the mould.



we pour the liquid molten metal to the casting cavity.

Steps

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

Pattern making

Replica of the casting to be produced is the pattern.

Replica means that shape of the pattern remain same as the shape of the casting to be produced but the dimensions of the pattern is different from the casting.

$$\boxed{\text{pattern size} = \text{Casting Size} \pm \text{Allowances}}$$

Allowances :-

5 diff types of allowances

1. Shrinkage allowance } These two have greater significance in change in size.
2. machining allowance
3. Draft allowance
4. Shake allowance
5. Distortion allowance

① Shrinkage allowance :-

The metals are poured at the pouring temperature

$$\boxed{\text{Pouring temp} = \text{Melting Point} + \underbrace{150-200^\circ C}_{\text{degree of superheat}}}$$

* Always the pouring temperature must be greater than M.P

To avoid the solidification of the molten metal in the passages
[It make use of sensible heat than the latent heat ; thus no phase change occurs]

$$PT(L) \xrightarrow[\text{sensible heat} \; ①]{\text{cool}} FT_{(L)} \xrightarrow[\text{latent heat} \; ②]{\text{cool}} FT_{(S)} \xrightarrow[\text{sensible heat} \; ③]{\text{cool}} RT_{(S)}$$

RT - room temp
FT - freezing temp

3 stages involved in so cooling.

* In all the 3 stages of cooling ; the shrinkage of material will be taking place.
whatever shrinkage taking place in the 1st and 2nd stage is named as liquid shrinkage and whatever shrinkge taking place in 3rd stage is named as solid shrinkage.

The liquid shrinkages are compensated by the riser and solid shrinkage by providing shrinkage allowance on the pattern.

Shrinkage allowance is the allowance provided in pattern for compensating solid shrinkage taking place during casting of the material from freezing temperature as a solid to the room temperature.

Aluminium has the highest liquid shrinkage [6%]

Because the liquids are measures as a form of volume, liquid shrinkages can be specified as a % by volume.

Because the solids are measurable as dimensions, the solid shrinkage will always be specified as a % over dimension.

When a material is heated it expands by

$$\delta L = L \alpha \Delta T$$
$$= L \alpha (T_F - T_r)$$

L - dimension
α - Coeff of thermal expansion
ΔT - change in temp.
FT - fr. temp
RT - room t.

This much will shrink. so this is the shrinkage allowance

$$\boxed{\text{Shrinkage allowance} = L \alpha (T_F - T_r)}$$

It mainly depends of α

strictly speaking S.A should be calculated by this formula but due to unavailability of all

Brass - is having highest solid shrinkage and thus highest shrinka allowance $[\alpha = 23\ \mu m/m^\circ C]$

Admiralty metal - It is having slightly higher $\alpha = 23.5\ \mu m/m^\circ C$

64% Fe
36% Ni

Invar, Platinum-iridium alloy - α = 'almost 0'.

Invar - $\alpha = 0.0000096$

for casting of these 2 metals No shrinkage allowance is provid

Grey cast Iron, Ice - $\boxed{\alpha = -Ve}$

on cooling it expands and contracts on heating.

Taking all shrinkage together is the total shrinkage

Steel - liquid and solid shrinkage taken together would be highest in steel.

* largest riser needed - Aluminium
* largest cast volume - brass
* casting = 200 × 100 × 50, SA = 1%] Grey cast iron.

? $\dfrac{\text{Vol of Patt}}{\text{vol of casting}} = \dfrac{(.99)^3 [200 \times 100 \times 50]}{[200 \times 100 \times 50]} = (.99)^3 = .97$ — since -Ve allowance volume should be reduced.

99%

$200 \frac{99}{100}$

$99 \{2 \times 1 \times \frac{1}{2}\}$

$\frac{99}{2}$

② Machining allowance

The excess material provided on the pattern which will be removed by machining of the casting after the casting process is completed.

It's be provided due to

① As it is the casted components, will have poor surface finish, most of the engineering components require good ~~or excellent~~ surface finish which is possible by machining. ∴ for machin the component excess materials should be provided.

② To accomodate variation in shrinkages taking place due to the variation of room temperature.

$$SA = L\,\alpha\,(T_f - T_r)$$

machining allowance is provided on x mm/side.

eg:- Cylinder D = 20 cm, L = 500 mm

SA = 2 in 100 = $\frac{2}{100}$ or 2:100

∴ MA = 2 mm/side

wt is the dimensions of pattern provided by SA ~~+ MA~~

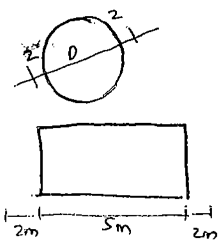
$$D = 200 + \frac{2}{100} \times 200 = 204$$

$$L = 500 + \frac{2}{100} \times 500 = 510$$

dimensions with SA + MA

$$D = 204 + 2 + 2 = 208$$

$$L = 510 + 2 + 2 = 514$$



OR

better :- dimension of pattern size with MA

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

$$L = 500 + 2 + 2 = 504$$

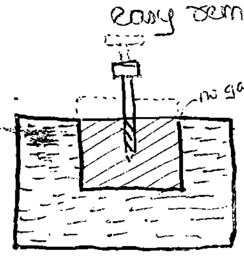
PS with MA + SA

$$D = 204 + \frac{2}{100} \times 204 = 208.08$$

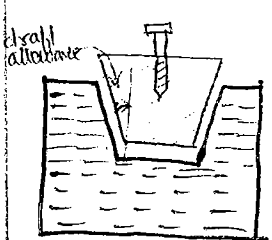
$$L = 504 + \frac{2}{100} \times 504 = 514.08$$

③ Draft allowance

Making the vertical surfaces of the pattern into inclined surfaces for easy removal of the pattern from the mould.



* always the removal of pattern should be with human hand.
No machineries should be encaged.
So if a small shake to our hand – disruption occurs

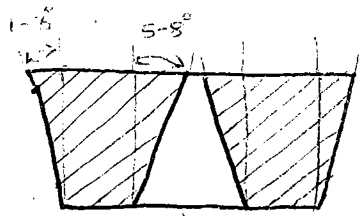


without providing draft allowance – untill the last point of the pattern comes out from the mould, there is a contact b/w the pattern and the mould and any shaking or vibration taken place to the hand ~~make~~ causes to damage the mould walls.

with the provision of draft allowance; as soon as a small amount of pattern is lifted from the mould, immediately the clearance or gap is existing b/w the pattern and the mould. ∴ the pattern can be removed easily without any damages to the mould walls.
∴ the

for external ~~draf~~ surfaces the draft allowances is $1-3^\circ$

~~for~~ internal surfaces the draft allowances $= 5-8^\circ$



NOTE :- In casting process ; if pattern is made by using the materials lik wax, mercury (frozen), and polystyrene as a pattern ; ~~there~~ then no draft allowance is to be provided.

mercury at room temp ⇒ liquid / melting point of Hg is $-39^\circ C$.
Thus mercury when cooled to -70 to $-80^\circ C$; perfect solid Hg is obtained. Then mould is made and when kept in room temp. it changes to liquid. so easily removed.

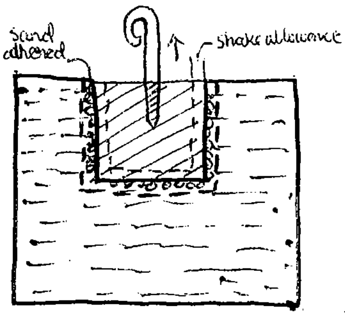
In case of wax when the molten metal is poured ; it's removed in liquid state.

Polystyrene not polystrene (thermosetting plastic) - it can't be converted to liqu
→ (thermo plastic) - it's been used.
without removing ~~mat~~ pattern metal is removed.
M.P of polystyrene - 170-200°C and vapourization temp is 250
The pouring temp would be above it and with in no time the polystyrine is vapourized and escaped by the porousity proper of moulting sand. Also it's escaped through risers.
application → Very large sized casting like machine tool beds.

disadvantages → Not reusable

* large sized pattern could not be removed by humans hand ⇒ so here n need of removal of pattern.

(4) Shake allowance :-



During removal of the pattern from the mould, whatever the moulding sand which has adhered to the pattern also gets removed and it damages the mould walls.

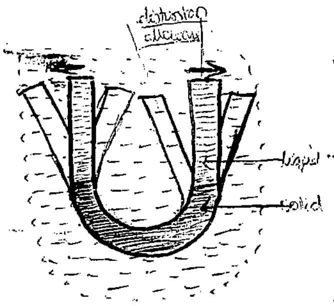
To avoid this, before removal of the pattern from the mould, the pattern will be ~~shaped~~ shaked so that the adhered moulding sand will be separated and no damages would take place to the mould.

But during shaking of the pattern the size of the cavity produced will become greater than the size c the pattern ; which increases the size of the casting.

To maintain the size of the casting as required, originally the pattern size has to be reduced by an amount equal to shake allowance.

The amount of the shake allowance depends on the mold making person.
If the pattern is made of wax or Hg or polystyrene ~~as the~~, no shake allowance is provic

(5) Distortion allowance



It's not required on all the castings but it's required to provide only during the casting of U or V shaped castings to be produced

During casting of U or V shaped castings, because of the differential shrinkage; the vertical legs of U may get bent outwards and produces inclined legs of U

To get vertical legs of U in the original pattern; the legs would be bent inwards so that during casting these legs would be bent outward and produces vertical legs of U.

The amount of bending legs inward is called distortion allowance.

The amount of distorsion allowance depends on $\boxed{\frac{L}{t}}$ ratio where L- length of the leg and t- thickness of leg.

Pattern materials

Properties

1. Low or minimum moisture absorbtion.
   If moisture absorbtion takesplace - pattern increases size → cavity increases → casting size increase
2. Low dencity - for easy handling (placing and removal)
3. Good or excellent surface finish
4. Easiness in fabrication.
5. Cheap

Materials

1. Wood :-
   light weight, low dencity, (0.4-.8g/cc) .... all the properties req for pattern is present except moisture absorbtion.
   whichever wood having low moisture absorbtion; the corresponding wood can be taken as pattern materials.

   eg:- Teak wood, mahagony.

2. Metal :-
   would have a problem of difficulty in manufacturing and dencity would be high.
   Out of all metals lowest δ is possessed by Al (2.7g/cc) but it has dencity almost 5 to 8 times higher than the dencity of ~~too~~ wood.

metal pattern are to be produced again by wood patter
by casting process. [double shrinkage allowance must be pr
in the wood pattern (wood $\xrightarrow{SA}$ metal pat $\xrightarrow{SA}$ casting)

eg:- Al, white metal
(2.7g/cc) (3.2 g/cc)

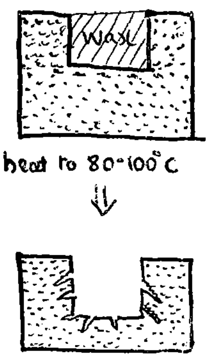
3. Plastic pattern :-

plastics are possessing all good properties which are requir
for pattern material

∴ plastics are the most commonly used pattern materials in the casti
industry toda

eg:- epoxy resin, PVC, cellulose, Nylon, polystyrene etc.

4. Wax :-



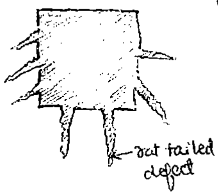
bcz of very high softness, wax could be used as a pattern materi
for producing complex shapes of the patterns very easily.

removal of the wax pattern is also easier in the form of liquid wax

Good or excellent surface finish is possible ⇒ no machining is requir
after the casting proce

Becauz of very high softness; when the pattern is transported from on
place to another place; the pattern may get distorted. To avoid
this max-size of pattern used is 5 kg only.

When wax is used with green sand mould; rapid rat tailed defe
are produced in the casting.



Due to vapourisation of water content in green sand - cracks are develope
when casting this would result in rat tail shaped projections.

used for producing gold and silver ornaments, turbine blades, wave gu
for radar systems etc.

5. Frozen mercury

cooling Hg to −70 to −80°C.

since dencity of Hg is very-very high - its been used for producing
very small sized casting which requires excellent surface finish witho
machining itself.

not used in commercial application. Only in special applications like
in aerospace, its used.

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1-1

MOLD MAKING

Moulding sands are used to manufacture the mold.

basic constituents

① Silica sand particles ⇒ [75 to 80%]

Used for producing required strength of the moulding sand.

② Clay ⇒ [15 to 20%]

To produce the bond b/w the sand particles.

③ Water / Sodium silicate ⇒ [6 to 8%]

To initiate the formation of Bond b/w the sand particle & clay.

Silica sand + clay + water → Green sand

silica sand + clay + Sod. Silicate → Dry sand

Any sand with 50% clay → Loam sand (producing very large casts)

Additives

Added to improve properties of moulding sand

① Wood powder or saw dust — Improves flowabiity of moulding sand

To increase porosity property and collapsibility of the moulding sand.

② Coal powder

Better Surface finish

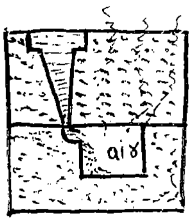
③ Starch / Dextrin

To increase the resistance to deformation or strength of the mould sand.

* upto a maximum of 2% each additive could be added

Properties possesed by moulding sand

① Porosity



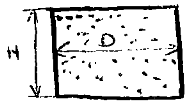
Ability of escaping air or gases through the moulding sand.

determining porosity

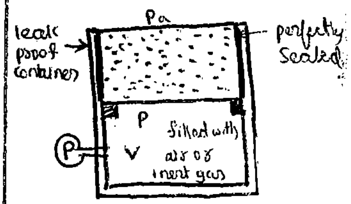
using permiability test. [American Foundry Society] or

* permiability is not a property of moulding sand but it's only a mere test to measure the porosity property of sand.

if not expansed air get trapped & compressed to form defects



$D = H = 5.08\,cm$



V = vol. of container below the sand specimen

$V = 200\,cc$

$P > Pa$

T - time taken in min to reduce volume V from pressure P to Pa

VI $\boxed{\text{Permiability No} = \dfrac{VH}{PAT}}$

P - gauge pressure in kg/cm^2

A → Cross sectional area

T - time

V - volume = 200 cc

H = D = 5.08 cm

$\boxed{P = 10\,kg/cm^2}$

Standard

$\boxed{\text{Perm. No} = \dfrac{50.128}{T}}$

→ prepare the sand specimen of dia D and height H.

→ Then place this specimen in leak proof container where si... are perfectly sealed to avoid the permiability of sand throu... sides.

→ There volume of lower side of the container is V = 200 cc

→ A pressure P > Pa is suppli... by pumping air. The lower side is connected with a pressure gauge.

→ calculate the time taken f... the pressure drop of P to ... in minutes.

How to increase porousity

1. Increasing sand particle size
2. Reducing clay content
3. Adding wood powder
4. Reducing ramming force ⇒ with reduction of ramming force strength of the ... decrease
5. Providing vent holes (venting)

2) STRENGTH

3 types - Tensile strength, Compressive strength, shear strength

All these strength could be measured using UTM

3) Cohesiveness

The ability to form bond b/w particles of same material is called cohesiveness. This can also be indicated by using shear strength.

determination of shear strength

Inter laminar shear strength test (ILSS)

two layers of same material as shown in fig is made

Eccentric loading is applied.

4) Adhesiveness

The ability of formation of bond of sand materials with other material

two layers of different materials are made as shown.

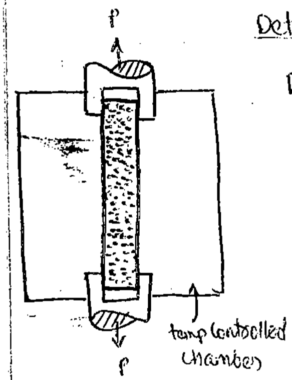
Then bonding strength is calculated or determinated

It can't be called as ILSS. It's not inter laminar.

⑤ Refractoriness

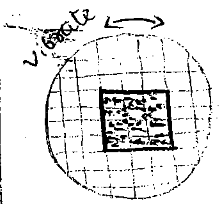
The ability for withstand higher temperature without loosing its strength and hardness.

Determination



Done by using UTM with temperature control chamber.
1st the load can be applied on the specimen upto a required length of the specimen
Then slowly increase the temp of the chamber. ~~slowly~~.
For some temp. the sand specimen will fail

⑥ Collapsability



Ability of breaking the mould with little amount of the force.
measured by using **vibratory mesh**
Sand specimen kept in vibratory mesh and apply vibration.

⑦ Flowability

The ability of moulding sand to flow to each & every corner of the mould.

Flow characteristics of liquid and gases (i.e. fluids) is defined by fluidity.
But flow characteristics of solid is defined by flowability
measured by using orifices.

Mold making

① Hand molding :-

whatever the force required for ramming of the moulding sand ; if obtained by human hand — it is called as hand moulding.

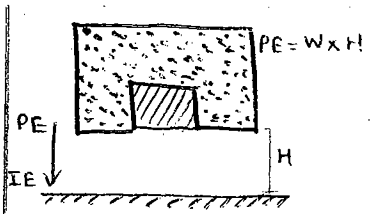
Cheapest method → no equipment is required and no damages will takeplace to pattern because human beings knows that where the projections and extensions are present. For such places he apply lesser amount of force.

limitation :-
The strength & hardness of the mould obtained is non uniform
Production rate is low.

② machine molding :-

Whatever the force required for ramming of the moulding sand; it is obtained by using a machine.

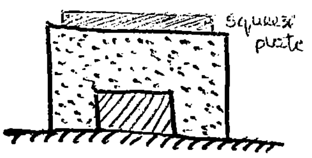
ⓐ Jolting operation



A sand filled mould is radised to certain amount of height so that it is posessing potential energy, when it is allowed to fall freely on the ground, the potential energy is converted into impact energy and impact load which is acting on the ground. The equal and opposite reaction force produced by the groun mould is acting on the mould for compressing the moulding sand.

Bcz of force applied by the ground is not able to transfer upto the top of the mould, the bottom of the mould is attaining higher strength and hardness but the top of the mould is almost like a loose sand.

ⓑ Squeezing operation



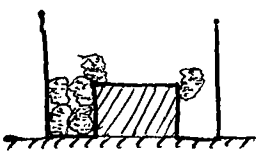
The force is applied by using the press on to the plate it would be transfered on the moulding sand and compressing the sand.

Bcz of the force applied by the plate not transfering up to the bottom, the top of the mold attain higher strength and hardness but bottom will be posessing lower strength

ⓒ Combination By combining jolting & squeezing operation, ~~Higher strength~~ could be obtained on top and bottom.

If the ht of mold < 200 mm - it's possible to get uniform strength and hardness through out the mould but if the ht of mold > 200 mm - the central part of the mould attain the lowest strength.

ⓓ Sand slinging To get the uniform strength throughout with whatever be the height of the mould; the best method of machine moulding is sand slinging



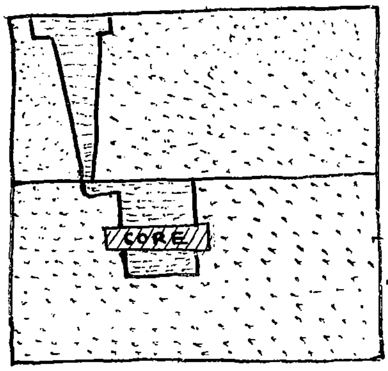
Small small quantities of moulding sand will be thrown into the mould with certain amount of force using machine ⇒ so that localised ramming of molding sand will take place & gives uniform strength through out the mold.

limitation:

Cost of equipment is high and cannot be used for molding pattern having extensions and projections.

Core making process :-

Cores are used for producing hollow castings.

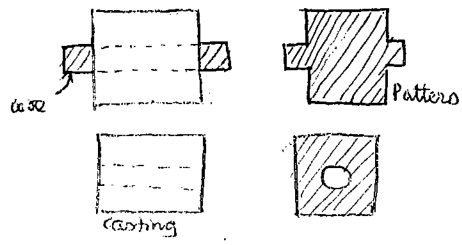


Properties

① Non metallic materials should be used.
(for easy removal and for no-bond formation)

② Free from moisture
(to avoid defects by evaporation of this moisture)

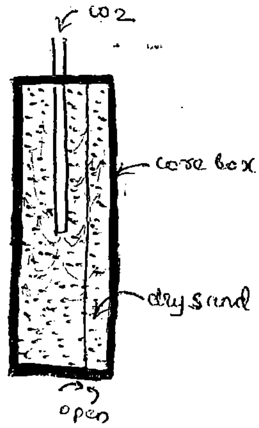
③ Higher strength
(to withstand self wt and wt of molten metal)



④ High collapsability
(for easy removal of core after casting)

* ③ and ④ are contradicting properties

eg:- Dry sand with CO_2 moulding



Dry sand taken in a corebox and then thru a small pipe high pressure CO_2 is passed for 1 - 2 minutes.

$CO_2 + \underset{SiO_2}{\text{Sodium Silicate}} \longrightarrow$ Silica Jel

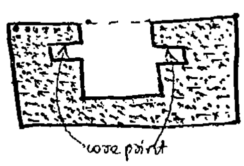
Immediately take the pipe and allow it to dry. with in few minutes (1-2 min) it's dried and open the core box and take out the core (high strength)

Adv :-
whatever the high strength (Silica jel formation) obtained is short lived. After 2-3 hrs duration the strength of the core start deteriorating and after 5 hrs ∴ the strength of core is almost '0'. ie it's found as loose sand. (collapsible)

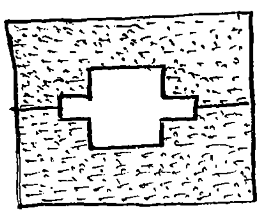
DONT MAKE CORES AND KEEP IN STORE ☺ ⇒ foundry saying.

Core print :-

The reason for locating, supporting, positioning.

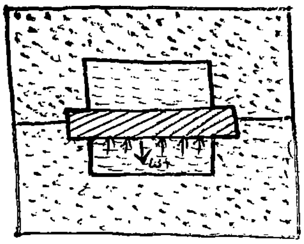


The core prints are produced by providing extension on the pattern



When extensions are provided on the pattern, the removal of pattern from the mould becomes difficult
∴ the pattern will be split into 2 pieces
one piece of the pattern will be kept in the cop and another piece on the drag and the mould is made.
So core-print comes in the junction of cop and drag
This make easy positioning and set of cores

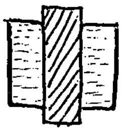
Note: "No two materials are having same density". Here solid core is immersed liquid molten metal. In general the $\rho_{core} < \rho_{molten\ metal}$. Thus an upward buoyant force would be acted upon the core.



Net buoyant force = Wt of liquid displaced − wt of core

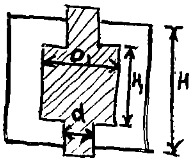
$= V\rho g - Vdg$

$$\boxed{BF = Vg(\rho - d)}$$



(No buoyant force)

but



$\Rightarrow$ BF = Wt of liq displaced by projected volume − wt of core

$= \left[\frac{\pi}{4}(D^2-d^2)H_1\right]\rho g - \left(\frac{\pi}{4}d^2H + \frac{\pi}{4}(D^2-d\right.$

$\boxed{\text{load supported by core print} = 350\ A}$ Newtons

where A = surface area of core print in m^2.

$\boxed{\text{unsupported load} = \text{Net B.F} - 350\ A}$

$\leq 0 \Rightarrow$ no additional supports required

$> 0 \Rightarrow$ additional supports required

whenever the unsupported load is > 0; the additional supports required can be provided by using **chaplets**

Chaplets are used by using same materials as that of the casting. They become an integral part of the casting.

Thus before ~~to~~ placing chaplets — it should be thoroughly cleaned to avoid weak joint formation b/w the chaplets and the solidified metal. and the

<u>chaplet size</u>

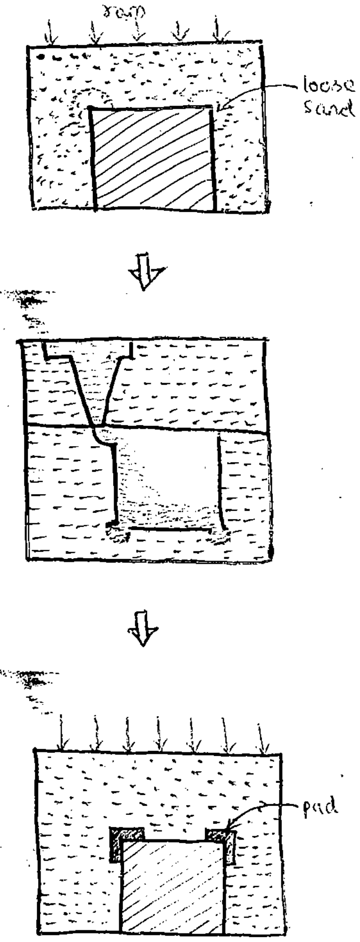
For every 1 N of unsupported load 29 mm^2 c/s area chaplets should be used

[for 10 N → 290 m

Though chaplet is used as an additional support for core; the chaplates also prov the <u>additional functionality</u> as a <u>directional solidification</u>.

Note

Pads :-



During the casting of sharp edged castings, the patterns used will also have sharp edges.

When making mold - this sharp edged patterns, the sand particles present in the corners will get slipped and produces loose sand particles.

During pouring of molten metal to the casting cavity this loose sand particles will get eroded from the mold and entering into the cavity producing sand inclusions in the casting.

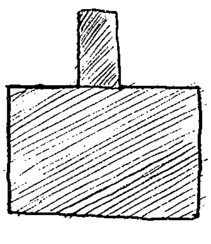
To avoid this during moulding itself L shaped metal or non-metallic pads will be provided so that they will be retaining the mold when pouring of the molten metal and avoids direct contact b/w the loose sand particles and the molten metal.

hence eliminate the sand erosion and sand inclusion defect.

Hence L-shaped pieces are called pads (padding)

Since thermal conductivity of pads is greater than the moulding sand the pads also provides directional solidification.

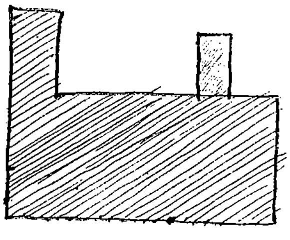
Chills :-



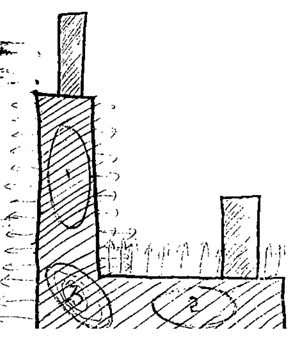
Riser is located based on :-

① During uniform cross sectioned casting the riser is provided on the top most point of casting cavity.

② If the casting is of non-uniform cross section, the riser is provided near to the thickest portion than the thinnest portion.

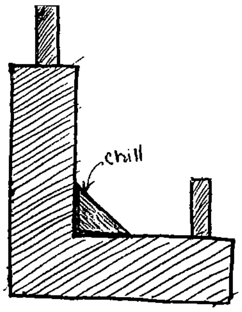


In L shaped uniform casting two risers are shown provided as shown in the figure.



Here due to the presence of risers zone 1 and zone 2 are solidified easily and then only zone 3 cools. This is because as the quantity of molten metal is large in zone 3, so more heat is required also in the corner region, the heat transfer is taking place in 2 directions, ∴ the temperature of mold becomes high and temp diff is reducing. hence reduced heat transfer.

Due to this whatever shrinkages are occuring due to the solidification of zone 3 cannot be compensated by both the risers. Hence produces defect known as void or shrinkage cavity.



To reduce (avoid) this defect we should increase the heat transfer rate and zone 3 molten metal to be solidified before (from) corner portion)

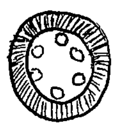
$Q \propto \Delta T$ × temp can't be reduced

$\propto A$ × unable to change the area of cavity

$\propto$ ×

$\propto K$ ✓ by providing high thermal conducti metallic pieces on the corner of mould.

eg:- bullet cover making



in bullet cover, high comprensive strength are provided to inner walls by providing pipes thru which coolents are supplied in the core.

The provision of metallic piece try to tranfer the heat in a specified direction so that the solidif will takeplace according to required methodologi known as directional solidification.

The metallic piece provided in the mould is called **Chills**. So they are used for directional solid. They are materials of higher thermal conductivity. It also have melting point temp. higher than the casting metal.

The chill is getting adherent to the casting in the casting process and its unwanted material. ∴ it have to be removed by maching afterwards.

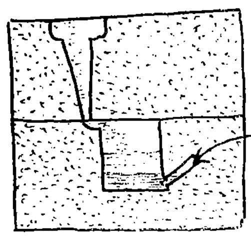
POURING

The molten metal is always poured into the casting cavity by using a system called the gating system. Gating system basically constitutes 4

1. Pouring basin
2. Sprue
3. Runner
4. Ingate

Characteristics of proper gating system (Ideal or Good)

* The gating system should be designed so that the time taken for filling of molten metal to the cavity must be as minimum as possible. This is to ensure that no part of the casting cavity should start to solidify before complete filling of the casting cavity.



$$\text{Pouring Time} = \frac{\text{Vol of cavity}}{\text{flow rate}}$$

flow rate → $A_{min} \times Vel$, or $A_{max} \times Vel$

$$P.T = \frac{V}{\text{Area} \times \text{Velocity}}$$

area & volume can't be changed. So only by increasing velocity

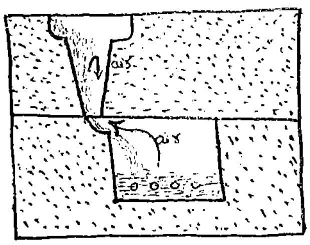
* The velocity of molten metal in the gating system should be as high as possible within the limits of laminar flow.

* As far as possible; the gating system should separate the impurities present in the molten metal.

* It should eliminate the sand erosion.

* It should avoid the aspiration effect

* The flow of molten metal in the gating system should be always full and the partial flow should not be allowed.

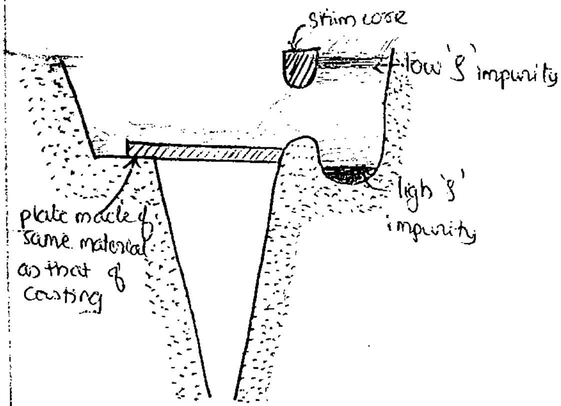


impartial flow

When the cavity is been filled by molten metal; the air get compressed. Instead of moving out through the moulding sand it goes out through the gating system and thus form bubbles entrapped in the molten metal poured.

Pouring basin

It's acting as a reservoir for supplying the molten metal to the casting cavity (basic function)

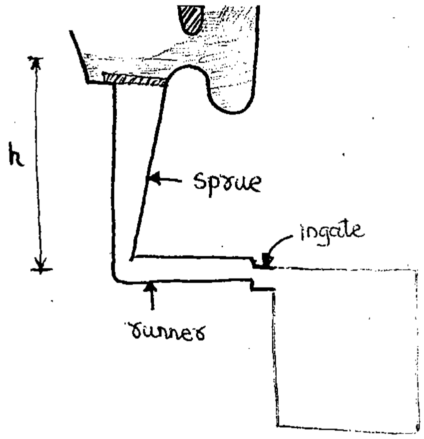


Separates the impurities present in the moltenmetal.

The thin layer provided at the end of pouring basin collects the molten metal over it - so that the excess heat available in the molten metal will be absorbed by the plate and get melted (total plate) at a time.
So that the molten metal produced by the plate and the molten metal collected over the plate are flowing through the gating system simultaneously.

It ensures the full flow of molten metal thru the gating system.

The dimension (shape or size) of pouring basin; will not affect the perfomance of the gating system



Sprue

It's a connecting passage b/w the pouring basin and the runner. It's always vertical with straight tapered circular cross section.
The tapered shape of sprue eliminate the aspiration effect.
The height of the sprue is responsible for producing the velocity of molten metal in the gating system. ∴ The height of the sprue is selected such that the velocity of molten metal at the gating system must be as high as possible within the limits of laminar flow. $V = \sqrt{2gh}$.

let A_s = C·S·A of sprue (bottom)

Runner

Connecting passage b/w the bottom of the sprue and the ingate.
It's always horizontal with uniform trapezoidal cross section.
Out of all the shapes the trapezoidal cross section is the one which is having highest coefficient of discharge. So trapezoidal cross section is used. $Q_{act} = C_d$ Q

When ever the flow is taking place in a passage - bcz of the presence of the datum head, the value of coefficient of discharge remains constant irrespective of the cross section of the passage. ∴ if circular cross section is selected for the sprue - it's easy to manufacture.

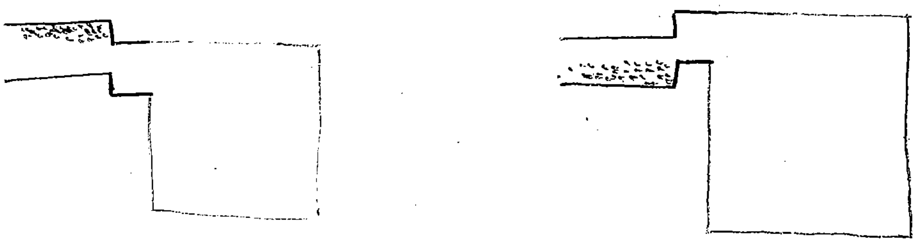
A_r = C·S·A of the runner.

It's necessary to divert the flow from sprue to horizontal to reduce the sand erosion.

INGATE

It's the last point of casting cavity from where the molten metal is floating in the casting cavity from the

It's also horizontal and uniform trapezoidal cross section to



For high 'ρ' metal casting the runner axis is made above the ingate axis so that any low density impurities present in the molten metal will be easily separated and stopped entering the casting cavity.

IIIly During casting of low 'ρ' metals the runner axis is provided below the ingate axis so that any high 'ρ' impurities present in the molten metal will be collected at the bottom and stop entering into the casting cavity

offset ≤ 5mm

A_g – Crosssectional area of the ingate.

Gating ratio

$$\boxed{GR = A_s : A_r : A_g}$$

Accessories used in gating system for increasing the efficiency

Strainer :-

To remove the impurities (top of sprue)

Made by using ceramic material with high porosity

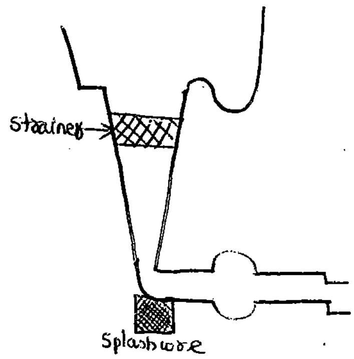
Splash core :-

Provided at bottom of the sprue to avoid the sand erosion from the bottom of the sprue.

... ceramic material with low porosity.

Skim bob

Semicircular cut given in the runner for separating the impurities presen in the molten metal



Classification of Grating system

① Based on pressure above the molten metal in pouring basin

a) Non pressurised Grating System
b) Pressurised Grating system

② Based on position of INGATE

a) Top gating system
b) Bottom gating system
c) Parting gating system
d) Step gating system

a) Non-Pressurised Grating System

If the pressure above the molten metal in the pouring basin = atm pressur It's known as non-pressurised gating system.

It's very easy to maintain just by keeping the pouring basin open to the atmosp

But it cannot be used for casting of highly reactive metals like aluminium and magnesium because of oxidation problem.

optimum Grating ratio for Non-pressurised gating system is

1:4:4 or 1:2:2

b) Pressurised Gating system

If the pressure above molten metal in the pouring basin is greater than atmospheric pressure ; it is called as pressurised gating system.

This is used in

(1) Casting of highly reactive metals ; the top of the pouring basin is simply closed and the space above the molten metal in the pouring basin is filled by using inert gas at a pressure greater than atmospheric pressure. (> atm pres bcz , then chance of air entering the closed pouring basin is less and only inert gas will escape).

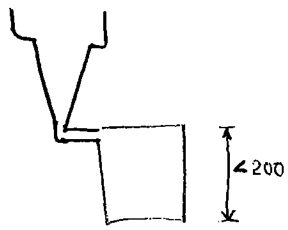
(2) Some time the ~~p~~ top of the pouring basin is closed due to some partial flow of molten metal is allowed in the gating system so that the air which is getting compressing in a casting cavity flowing in a backward direction and may collected on the top molten metal having pressure greater than atmospheric pressure known as back pressure Gating system.

(3) When ever the flow rate is to be increased in a gating system , the velocity of the ~~g~~ molten metal in the gating system has to be increased. But to increase the velocity without increasing the ht of the Sprue (could be increased only upto the ht of cop box) ; the only best method is to increase the pressure above molten metal in the pouring basin.

$$V = \sqrt{2gh + \frac{P - P_a}{\rho g}}$$

ⓐ Top gating system

If ingate provided at the topmost part of the casting cavity ; it's called top gating system.



b Bottom gating system

$$P.T = \frac{Vol}{flow\ rate}$$

$$flow\ rate = A_{min} \times Vel_{max}$$
$$= A_{max} \times Vel_{min}$$

$$A_{min} = \min of (A_s, A_r, A_g)$$
$$A_{max} = \max of (A_s, A_r, A_g)$$

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

$$\text{flow rate} = A_c \times V_{max}$$

$A_c \rightarrow$ chock area
min of (A_s, A_r, A_g)

In case of top gate system — from the beginning to the end of the filling of the casting cavity, the velocity of the molten metal in the gating system is uniform and maximum.

∴ the pouring time or filling time of molten metal into the casting cavity is as minimum as possible.

Preparing or making the top gating system is easier.

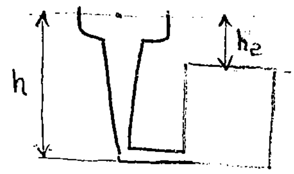
Limitation

Max. ht of cavities upto which the top gating systems can be used is 200mm only; beyond which the sand erosion will takeplace.

It cannot be used for filling the loose sand moulds

(b) Bottom Gating System

If the ingate is provided at the bottom of casting cavity.



$$PT = \frac{Vol}{A_c \times V_{avg}}$$

$$V_{avg} = \frac{V_i + V_f}{2}$$

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

$$V_f = \sqrt{2gh_2}$$

dis adv :-

For same ht. of gating system & same volume of the cavity, the P.T required in the bottom gating system is higher than the top gating syste

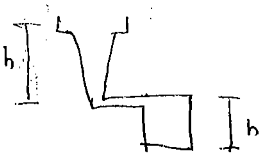
Preparing or making a bottom gating system is difficult.

adv :-

No sand erosion takesplace whatever be the ht. of cavity.

Cavities in the loose sand moulds can be filled very easily without any sand er

Q For ~~the Same~~ pouring height and ~~bo~~ depth of cavity is same $= h$. Then the ratio of P.T for bottom gating system to the P.T of the top gating system is ?



$$\frac{(PT)_b}{(PT)_T} = \frac{\dfrac{Vol}{Area \times (V_{avg})_b}}{\dfrac{Vol}{Area \times (V_{max})_T}}$$

$$= \frac{(V_{max})_T}{(V_{avg})_b}$$

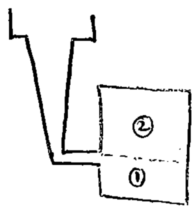
$$= \frac{\sqrt{2gh}}{\dfrac{\sqrt{2gh} + 0}{2}}$$

$h_2 = 0$

$$= \underline{\underline{2:1}}$$

(c) Parting Grating System

If the ingate is somewhere near the middle of the casting cavity.



Pouring time - greater than top gating system
less than bottom gating system

$$P.T = T_{①} + T_{②}$$

$$= \frac{Volume}{Area_c \times V_{max}} + \frac{Volume}{A_c \times V_{avg}}$$

If gating is provided ~~at~~ exactly at middle — middle gating system

(d) Step gating system

To fill large casting cavity using the above gating system, the pouring time is required is very high. ∴ to reduce the pouring time more than one ingate is provided in the given horizontal gating system called as step gating system

If more than ~~ingo~~ one ingate is provided at topmost part of casting cavity is called as top step gating system and so on...

If n ingates are used and the area of ingate is choke area; then multiply each A area with n in the equation. i.e. A_c is replaced by nA_c.

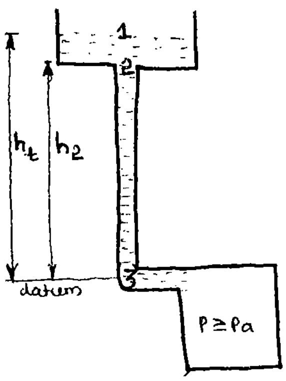
In casting process; during calculation of pouring time — the loss of energy due friction, bent losses, sudden expansion losses and sudden contraction losses etc can be assumed as negligible. Also the time taken for filling of molten metal into the riser is also neglected.

20-8-11
Saturday
9 am - 1 pm

Aspiration effect:-

(Inhalation or breathing effect)

During pouring of molten metal into the casting cavity, somewhere along the gating system; if the pressure falls below atmospheric pressure bcz the out side pressure is atmp pressure, the pressure difference is existing b/w outside and inside of the gating system. Due to this pressure difference; the air start flowing from outside to the inside of gating system through porosity prop of moulding sand called as aspiration or inhalation or breathing effect.



point 1 $P_1 \geq P_a$ - no aspiration effect

applying bernoulli's eqn [when using straight cylindrical sprue]

$$h_2 + \cancel{\frac{V_2^2}{2g}} + \frac{P_2}{\rho g} = h_3 + \cancel{\frac{V_3^2}{2g}} + \frac{P_3}{\rho g}$$

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

$$P_2 = -\rho g h_2 \text{ (gauge)}$$

Thus if straight cylindrical sprue is used pressure at point 2 will become -ve gauge pressure. i.e. < atmp pressure.

Thus aspiration effect occurs at point 2

let $\frac{A_3}{A_2} = R$ [for removing the aspiration effect]

Then $A_2 V_2 = A_3 V_3$

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

$$V_2 = R V_3$$

applying bernoulli's eqn.

$$h_2 + \frac{V_2^2}{2g} + \frac{P_2}{\rho g} = h_3 + \frac{V_3^2}{2g} + \frac{P_3}{\rho g}$$

P_2, P_3 must be ≥ 0 (gauge)

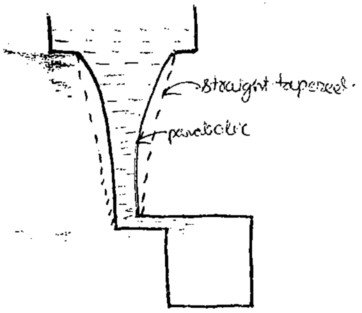
$$h_2 + \frac{V_2^2}{2g} = \frac{V_3^2}{2g}$$

$$\frac{V_3^2 - V_2^2}{2g} = h_2$$

$$V_3^2 - R^2 V_3^2 = 2g h_2$$

$$V_3^2 \left[1 - R^2\right] = 2g h_2$$

$$(1 - R^2) = \frac{2g h_2}{V_3^2}$$



$$R = \sqrt{1 - \frac{2g h_2}{V_3^2}}$$

$$= \sqrt{1 - \frac{2g h_2}{2g h_t}} \qquad V_3 = \sqrt{2g h_1}$$

$$\boxed{R = \sqrt{\frac{h_t - h_2}{h_t}}}$$

<u>equation of parabola</u>

Thus if parabolic tapered sprue is used ; it ensures that the pressure all along the length of the sprue is equal to 'o' gauge pressure or atmospheric pressure and it eliminates the aspiration effect.

But making parabolic curvature sprue is difficult. ∴ the straight tapered sprue can be used.

But if straight tapered screw is used at ends 2 and 3 P = 0 (gauge) but in between the pressure cross sectional area of the straight tapered screw is greater than the parabolic screw. ∴ the velocity is reducing and pressure is increasing. Thus it also eliminate the aspiration effect.

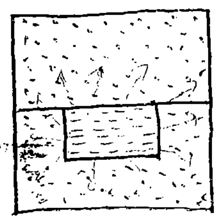
Solidification

PT(L)
cool ↓ SH
FT(L) — solidification
cool ↓ LH
FT(S)
cool ↓ SH
RT

For solidification of the molten metal ; It is required to remove the heat for only 1st two stages of cooling.

∴ Heat to be removed for solidification $= m\,(S\cdot H + L\cdot H)$

$$\boxed{\text{Heat to be removed} = V\rho\left(C_p(T_p - T_f) + L\cdot H\right)} \quad m\text{-mass of casting} \quad (1)$$



For solidification of molten metal in the casting cavity, the heat transfer through the mould is taking place based on unsteady state heat conduction with infinite wall thickness problem.

heat transfer rate

$$\boxed{H.T = \frac{A_s K \Delta T}{\sqrt{\pi \alpha \tau}}} \quad (2)$$

A_s - surface area
K - thermal conductivity
ΔT - temp difference
α - thermal diffusivity
τ - time

solidification time τ $\frac{(1)}{(2)}$

$$\tau = \frac{V\delta(Cp(T_p - T_f) + L)\sqrt{\tau_1 \alpha \pi}}{A_s K \Delta T}$$

$$\sqrt{\tau} = \left(\frac{V}{A_s}\right)\left[\frac{\delta(Cp(T_p - T_f) + L)\sqrt{\pi\alpha}}{K\Delta T}\right]$$

$$\tau = \left(\frac{V}{A_s}\right)^2 \left[\quad\right]^2$$

$$= \left(\frac{V}{A_s}\right)^2 K_1$$

K_1 - mold constant

$$\tau = K_1 M^2$$

$M = \frac{V}{A_s}$

Q:- If casting C_1 of dim $200 \times 100 \times 70$ mm solidifies in 10 minutes. Then casting C_2 of dim. $200 \times 100 \times 10$ mm solidifies in ?

$$\frac{\tau_2}{\tau_1} = \left(\frac{M_2}{M_1}\right)^2$$

At similar condition
$k_1 = k_2$

$$\tau_2 = \tau_1 \times \left(\frac{V_2}{V_1} \times \frac{A_{s1}}{A_{s2}}\right)^2$$

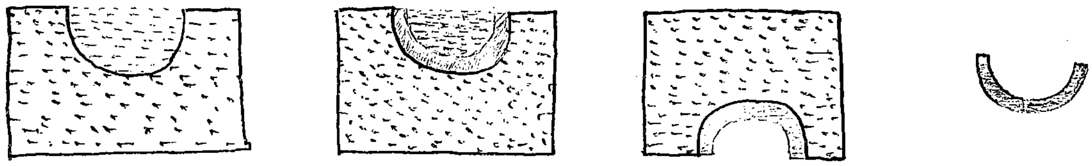
$$= \tau_1 \times \left[\frac{1}{7} \times \frac{2(200\times100 + 100\times70 + 70\times200)}{2(200\times100 + 100\times10 + 10\times200)}\right]$$

$$= 10 \times \frac{1}{7} \times \frac{41}{23}$$

When the solidification process is over. need not required to wait to become room temp. but we could immediately break the mould and take the casting

Slush casting

It's an open casting process in which the liquid molten metal is poured into the casting cavity in open condition, allow it to solidify for some time, invert the mould immediately so that unsolidified molten metal is falling down. leaving the solidified material in side the mould. Now by breaking the mould the casting can be taken out.



① ② ③ ④

Used for producing decorative shapes like lamp shades, christmas tree etc.

Since any oxides produced would float on the surface — it would be removed while inversion.

$$\tau \propto M^2$$

for small thickness $\left(\frac{V}{A_s}\right)_{thin} \approx t$

$$\tau \propto t^2$$

$$t \propto \sqrt{\tau}$$

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

C_1 and C_2 are constant which can be obtained by experimentation.

$\tau_1 = x \rightarrow t_1 = ?$

$\tau_2 = y \rightarrow t_2 = ?$

Then

$t_1 = C_1\sqrt{\tau_1} + C_2$

$t_2 = C_2\sqrt{\tau_2} + C_2$ solve

$C_1 = ?\quad C_2 = ?$

eg:- $\tau_1 = 20 \quad t_1 = 3$

$\tau_2 = 50 \quad t_2 = 4.5$

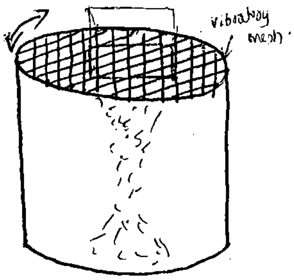
$\tau_3 = 100$ sec $\quad t_3 = ?$

Ans: $t_3 = 6.2$ mm

hint:- 1st find C_1, C_2

Fettling :-

The operation of breaking the mould and taking out the casting is called fettling.



vibratory mesh

The mold which is to be brocken is kept over a vibrator mesh,

Due to the vibrational forces, the mold will be brocken &

The brocken pieces of mould is falling into pit leaving mold boxes and casting over the mesh

Once the complete mould is fond to be brocken, the mould boxes could be send to remoulding and casting to the inspection.

Inspection

① dimensional inspection

only one or two castings would be inspected dimensionally and qualify the pattern. Afterwards dimensional inspection is not req

② Defective inspection

Every casting must be inspected for the presence of defects in the casting.

Non-destructive testing is only used. [destructive testing is only to inspect the mechanical properties]

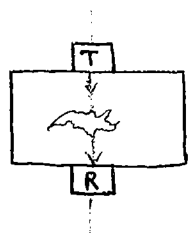
ⓐ Coin testing :-

Take a coin hit, check the sound

simplest easiest and fastest methodology — but needs lot of experience.

ⓑ Ultrasonic Testing :-

① Through transmission technique :-



A transmitter and receiver is present

If the magnitude of the signal received by the receiver is compared with the magnitude of signal transmitted by the transmitted and loss of signal is determined.

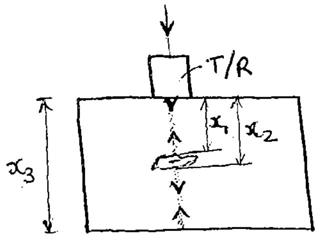
if $\boxed{\text{loss} < 5\%}$ assumed as No defect or presence of defect are smaller in size.

Lim :-

Not give information about the location of the defe

∴ pulse echo technique could be used

(b) Pulse Echo Testing :-



In PET the probe 1st acts as a transmitter so that it produces ultrasonic signal.

Whenever dencity variation is observed in the passage - Some amount of sound signal would be reflected back and the remaining is transmitted.

So that ~~the~~ when the probe is acting as receiver it's measuring the time interval b/w the transmitted signal and 1st received signal, transmitted and 2nd received signal and so on...

$$\therefore V_S = \frac{2x_1}{\tau_1} \Rightarrow \boxed{x_1 = \frac{V_S \times \tau_1}{2}}$$

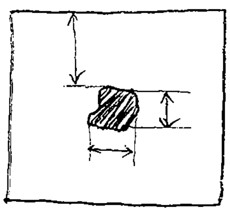
$$x_2 = \frac{V_S \times \tau_2}{2}$$

$$x_3 = \dots\dots$$

Lim :-

Nature of defect could not be obtained

(c) Radiography (x-ray)



x-ray film

During radiography of casting a film is obtained.

By observing the colour variation in the film the presence of defect could be estimated

If pure black coloured patch present in film - high dencity inclusion

pure white coloured patch - blow hole or void

light white coloured patch - low δ inclusion.

By measuring the dimensions of the patch and by dividing by magnification factor will give the size of the defect and its location.

Lim :-

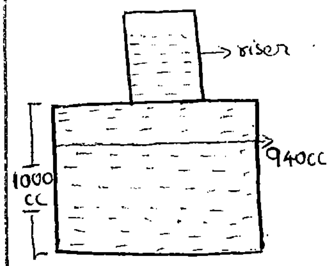
↳ Highly costly

↳ Carcenogenous process. (thick walled (2m) are used)

only critical components (aerospace, aircraft) — its used.

Riser Design :-

Riser is acting as a reservoir for supplying the molten metal to the casting cavity to compensate the liquid shrinkages taking place during solidificat



If 6% shrinkage

To supply additional 40cc riser is used.

conditions

① Volume of riser > Vol. of shrinkage

$V_r \geq 3 V_{sc}$ necessary condition.

② To ensure the molten metal supply from risers to cavity the solidification time of molten metal in the riser must be greater than or equal to solidification time of casting

$$\tau_r \geq \tau_c$$

③. Location of riser

④ Shape of riser

Selected such that surface area of the riser exposed for heat transfer must be as min as possible. so that the solidification time of molten metal in the riser must be as maximum as poss

$$\uparrow \tau_r \propto \left(\frac{V^2}{A_s}\right)\downarrow$$

For a given volume; decrease

the surface area exposed for heat transfer is minimum with cylindrical shape of the riser, the next minimum is the spherical shape of the riser.

∴ best preferable shape of the riser is cylindrical.

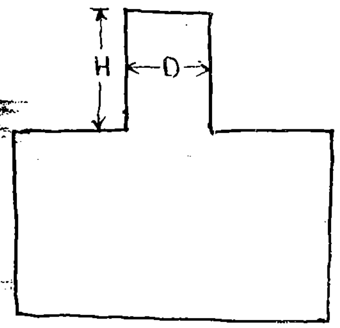
next preferable shape is spherical.

But never prefer the rectangular or cubical shape of the riser.

For given volume of riser – it is possible to determ the dimensions of a spherical riser easily. But for the case of cylindrical riser – to determin the dimensions of a riser, it is required to have the relationship b/w dimensions of the cylinder (

Types of risers

① Top cylindrical riser :-
(top riser)



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

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

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

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

for minimum A_s

$$\frac{d(A_S)}{d(D)} = 0$$

$$\frac{d(A_S)}{d(D)} = \frac{-4V}{D^2} + \frac{\pi}{4} D = 0$$

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

$$4H = 2D$$

$$D = 2H$$

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

modulus

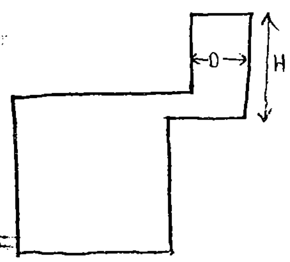
$$M_{top} = \frac{V}{A_S}$$

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

$$= \frac{R}{3}$$

$$M_{top} = \frac{D}{6}$$

② Side cylinder riser :-
(side riser)



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

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

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

for minimum area

$$\frac{dA_S}{d(D)} = 0$$

we get $D = H$

modulus

$$M_{side} = \frac{V}{A_S}$$

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

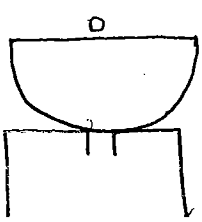
$$M_{side} = \frac{D}{6}$$

③ Spherical Riser

modulus

$$M_{spherical} = \frac{V}{A_S}$$

$$M_{sp} = \frac{D}{6}$$



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

* for all the three types – Top, side and spherical – the modulus are same and = $\frac{D}{6}$

Methods of riser Design

1. Caines method
2. Modulus method
3. Novel Reasearch method
4. shrinkage volume

1. Caines method

freezing ratio $X = \frac{M_r}{M_c}$

$()_r$ - riser

$()_c$ - casting

$$\boxed{X = \frac{(V/A_s)_r}{(V/A_s)_c}} \quad (1)$$

$$\boxed{X = \frac{a}{y-b} - c} \quad (2)$$

a, b, c are constants – can be taken from the casting data corresponding to metal to be casted

y – volumetric ratio $= \frac{V_r}{V_c}$

$(1) = (2)$

$$\frac{\left(\frac{V}{A_s}\right)_r}{\left(\frac{V}{A_s}\right)_c} = \frac{a}{y-b} - c$$

$$\frac{\frac{D}{6}}{\left(\frac{V}{A_s}\right)_c} = \frac{a}{\frac{V_r}{V_c} - b} - c$$

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

$$\frac{(D/6)}{(V/A_c)_c} = \frac{a}{\left(\frac{\pi}{4}\frac{D^2 H}{V_c}\right) - b} - c$$

by knowing the relation b/w D and H – only unknown is D.

Thus find 'D' and then using relation find H.

2. Modulus method

$T_r \geq T_c$

$(M_r)^2 \geq (M_c)^2$

$M_r \geq M_c$ ⇒ 20% extra (assume)

$\frac{D}{6} \geq M_c$

$D \geq 6 M_c$

$D = 6 M_c$

$\boxed{D = 7.2 M_c}$

$M_r = 1.2 M_c$

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

$D = 7.2 M_c$

then find H

③ Novel Research :-

$$\text{Shape factor} \quad SF = \frac{L + W}{t}$$

L - length of casting
ω - width of casting
t - thickness of casting

After calculating the shape factor - by using casting data book corresponding to value of shape factor. The volumetric ratio can be taken from the table

Using the volumetric ratio. The dimensions (D and H) of the riser can be calculated

SF	$y = V_r/V_c$
—	—
—	—
—	—
—	—

$$y = \frac{V_r}{V_s} \Rightarrow V_r = y\,V_s$$

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

find D = __ and H = __

* Here only shape factor is been asked in exams

eg:-

$$SF;\ \text{Rectangular casting} = \frac{L + b}{h} = \frac{L+b}{h}$$

$$SF;\ \text{solid sphere} = \frac{D+D}{D} = 2$$

$$SF;\ \text{solid cylinder} = \frac{L+D}{D} =$$

$$SF;\ \text{Hollow cylinder} = \frac{L+W}{}$$

④ Shrinkage volume :-

Let V_c - volume of casting
a = % shrinkage

V_{sc} = shrinkage volume

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

$$V_r \geq 3\,V_{sc}$$

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

D - __
H - __

check whether $T_r \geq T_c$ → satisfied or not. D, H

If not, $T_r = T_c$

$m_r = m_c \Rightarrow D' = 6\,m_c$ $\quad D' = -$ 3 final dimension of casting.

If the dimensions of a riser is calculated based on sufficient condition, it always automatically satisfies the necessary condition also.

If the dimensions of a riser is calculated directly by using sufficient condition no-doubt it will satisfies the necessary condition also; but it may or may n ensure the optimal size of the riser

Q Casting of 15×15×15 cm cube having % shrinkage 6%, $V_r \geq 3V_{sc}$.
Design the riser by shrinkage volume (top cylindrical)

$$V_c = 15 \times 15 \times 5 \text{ cc}$$

$$V_{sc} = \frac{6}{100} \times 15 \times 15 \times 15 =$$

$$V_r = 3 \; V_{sC}$$
$$= 3 \times \frac{6}{100} 15 \times 15 \times 15$$

$$\frac{\pi}{4} D^2 H = 3 \times \frac{6}{100} \; 15 \times 15 \times 15$$

Top cylindrical so $H = \frac{D}{2}$

$$\frac{\pi}{8} D^3 = \frac{3 \times 6 \times 15 \times 15 \times 15}{100}$$

$$D^3 = (15 \times 15 \times 15) \times 2^3 \times \frac{3^2 \times 2}{\pi \times 100}$$

$$D = 30 \sqrt[3]{\frac{3^2 \times 2}{\pi \times 100}}$$

$$= \underline{\underline{11.56}}$$

$$T_r \geq T_c \Rightarrow m_r \geq m_c \Rightarrow \frac{D}{6} \geq m_c$$

$$\frac{11.56}{6} \geq \frac{15}{6} \Rightarrow \text{not satisfied.}$$

$$T_r = T_c \Rightarrow m_r = m_c$$
$$D = 6 \, m_c$$
$$= 6 \times \frac{15}{6} = \underline{\underline{15}}$$

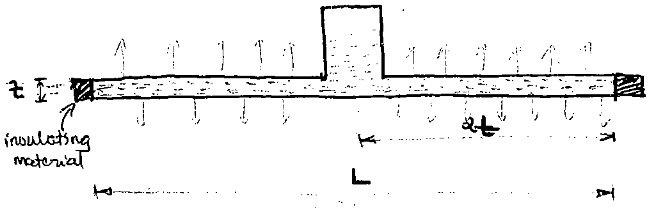
Note :-

only in the last shrinkage volume method both necessary & sufficient conditions a checked (cotellar satisfied)

In all the 3 other methods it's not necessary as the constants or tables from the data book ensure the satisfication of both necessary and sufficient condition

Q what is the maximum length of casting which could be produced by using a single top riser. (only for thin and platelike design)

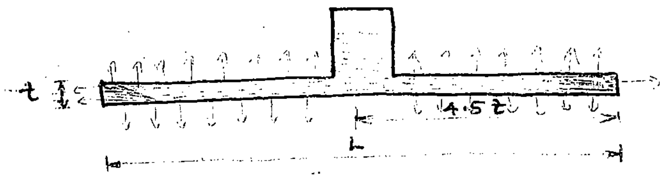
(1) with out end wall effect



$L = 4t$

$2t \Rightarrow$ Riser gradient

(2) with end wall effect

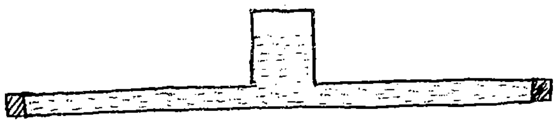


$L = 9t$

$2t \Rightarrow$ Riser Gradient

$2.5t \Rightarrow$ End wall effect Gradient (extra)

(3) with chills



$L = 9t + 100mm$

$2t \Rightarrow$ Riser gradient

$2.5t \Rightarrow$ End wall effect gradient

$50mm \Rightarrow$ chill gradient (extra)

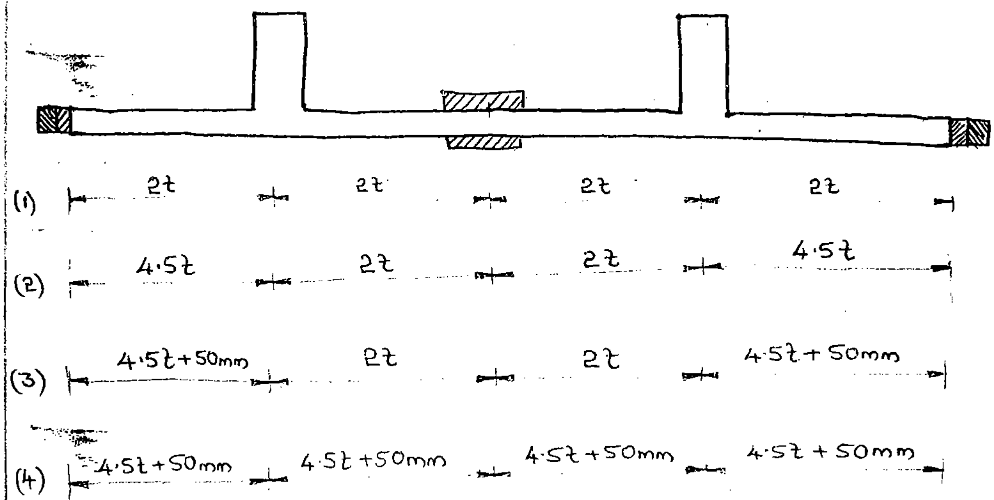
TWO RISERS

(1) with out endwall effect — $L = 8t$

(2) with end wall effect — $L = 13t$

(3) with end chills — $L = 13t + 100mm$

(4) with end and central chill — $L = 18t + 200mm$



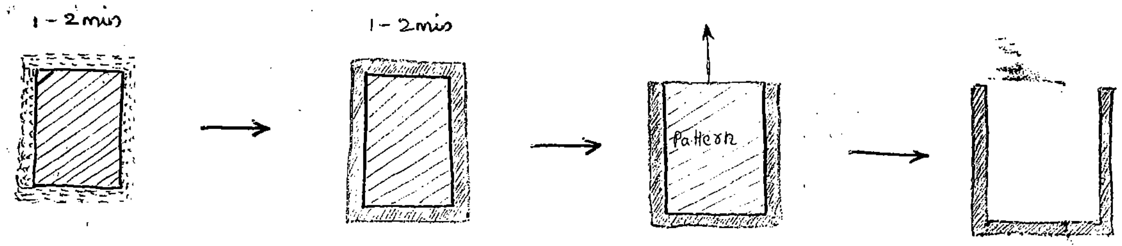
23/8/11
Tuesday
6-9 am

Special Casting Process

① Slush Casting

② Shell Mold Casting

In this the mould is made like a shell i.e. a thin or hollow mold can be made.



Phenolic resin — liquid — $\mu = 1500$ to 2000 cp

Dip the pattern in phenolic resin and keep it for 1-2 minutes

Take out the pattern and keep it in furnace @ 300°C for 1-2 minutes

Take out the pattern and remove the top layer of phenolic resin

Remove the pattern.

Features

Handling of the mould is easier

Production rate is high (only 1-2 min dip, 1-2 min)

Time taken to produce 1 mold is about 5 minutes

The process can be completely automated or mechanised

No reusability of the mold material

Used for producing circular and symmetrical shape of the mould.

Components produced

cylinder and cylinder heads of IC engine, automobile transmission part, ~~bearing~~ crank shaft, bevel gear, gear blank.

③ Investment casting

Wax can be used as a pattern material.

Complex and intricate shape of the castings can be easily produced

Removal of pattern would be easier in the form of a liquid.

Surface finish produced in casting would be very good.

Only upto 5 kg casting could be produced.

~~It is the length of the casting which could be produced with a single~~

The mould is made by using cement concrete as a mould material.

Bcz of cement concrete mould – same mold can be used for producing more than one casting ∴ it's called semi-permanent mould casting

cement concrete is having high thermal conductivity than sand mould. head transfer rate will be higher and surface hardening heat treatment effect would be taking place in casting. ∴ the castings produced by investment casting process would always have hard surface and soft interior.

eg:- Gold & Silver ornaments, Turbine blades, wave guides for radar system, shuttle eye for weaving technology, Surgical instruments etc.

(4) Die Casting Process

Mould is made by using metal – so mould is also called as die

Die steel or tool steel can be used

Excellent surface finish is possible since we use metal moulds as metal moulds itself would have excellent surface finish. So no-machining is required after casting.

Bcz of melting of mould when high temp molten metals are poured into the cavity, This process could be used for casting of only low MP materials ~~kit~~ like Pb, tin, Al, cadmium etc.

To avoid adhering of solidified molten metal to the mould or casting cavity, the silicon powder must be sprinkled on the surface of the cavity before pouring the molten metal into the cavity.

Becz of no porosity property of mould – The ~~se~~ air present in the casting cavity could be removed by using 'through risers' instead of blind risers

(a) Gravity Die Casting

If the flow of molten metal into the casting cavity is due to the gravitational force – then it's called as gravity die casting

Bcz the molten metal cannot flow into each and every corner of the complex shape of the cavity, the gravity die casting cannot be used for casting of complex shapes of the casting and can be used only for simple eg:- IC engine piston made by using Al alloy

ⓑ Pressure die Casting

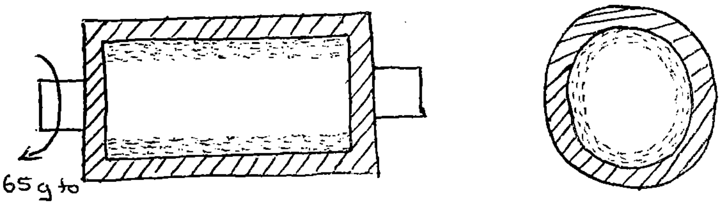
If external pressure is used for the flow of molten metal into the casting cavity - it's called as pressure die casting

Bcz of the ext. pressure the flow of molten metal into each & every corner of a complex shape of a casting can be easily possible ∴ pressure die casting can be used for producing complex shape of casting.

eg:- Carburetor body made of Al alloy.

⑤ Centrifugal Casting Process

The centrifugal force produced due to the rotation of the mould can be used for distributing the molten metal around the circumference of the mould. the rotation of the mould would be continued until the molten metal get solidified. Now break the mould and takeout the casting.



Mainly used for producing large sized hollow casting without using the core.

For sound casting the acc. used is 65 - 75g.

$$F_c = ma = mr\omega^2 = m\frac{D}{2}\left(\frac{2\pi N}{60}\right)^2$$

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

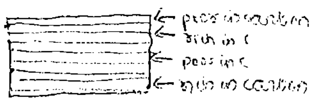
$$N^2D = \frac{a \times 2 \times 60^2}{4\pi^2} = \text{Constant}$$

$$\boxed{N^2D = \text{const}}$$

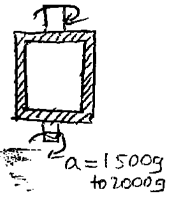
$$N = \sqrt{\frac{\text{const}}{D}}$$

since centrifugal force $\propto \rho$ - any low density impurities present in the molten metal will be collected at the center of the casting, which can be removed after the casting process

In general the centrifugally casted components would have poor machinability This is bcz of segregation or separation due to density variation ($\rho_{Fe} = 8g/cc$, $\rho_c = 1.4g/cc$ in steel) more centrifugal force is on iron and thus iron gets moved to outward producing layered structure.



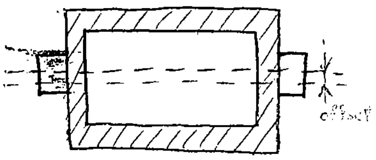
It's not homogeneous. Thus not machinable.



If the mould is vertical - to produce sound casting 1500 to 2000g is req.

So in general centrifugal casting is done only with horizontal axis of rotation.

If the axis of rotation and axis of the mould are coinciding - it's called as true centrifugal casting process. and it produce uniform thickness of casting around the circumference.



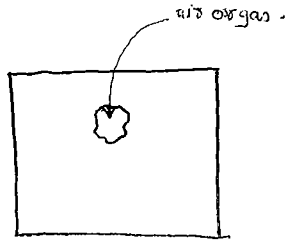
eccentric or semi-centrifugal casting are also used to produce non-uniform thickness of casting.

Uses of centrifugal casting

To produce large sized pipes without using the core (city water pipes)

Casting Defects

① Blow or blow hole



The air or gas bubble (large sized) present inside the casting is called blow or ~~flow~~ blow hole.

Reasons :-

low porosity property of the moulding sand.

following partial flow of molten metal in gating system

Allowing aspiration effect in the casting process (etc)

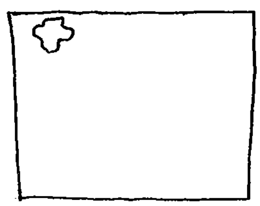
② Scar

The presence of air or gas bubbles on the surface of the casting.

It's not dat much problem and may even not considered as a defect bcz it would be removed by machining

Reasons are same as that of blow hole.

③ Blister



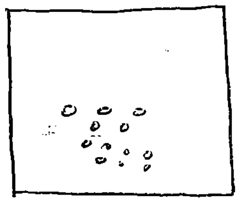
The presence of air or gas bubbles near to the surface of casting

Reasons are same as blow hole.

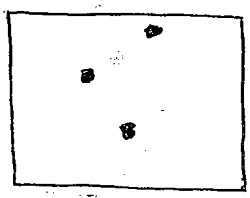
④ **Porosity :-**

Small sized air or gas particles present inside the casting

Reasons same as that of blow hole.



⑤ **Dross**



Presence of impurities inside the casting

Mainly caused due to improper separation of impurities present in the molten metal.

Avoided by using strainer, skim bob, offsetting the axis of runner and ingate etc.

⑥ **Inclusion or Sand Inclusion :-**

The presence of sand particles inside the casting

Mainly bcz of sand erosion taking placed during casting.

This is due to the turbulent flow in gating system.

- Using top gating system for the cavities having ht. >200mm
- Using top gating system for filling loose sand moulds etc.

⑦ **Voids or Shrinkage Cavity**

The open space produced in the casting due to the non availability of molten metal for compensating the liquid shrinkages taking place during solidification.

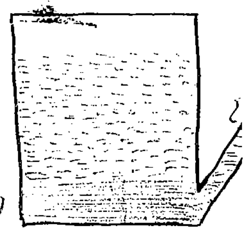
Could be eliminated by using chills.

⑧ **Misrun :-**

Non filling of the projected portion of a casting cavity using the molten metal.

bcz of solidification before complete filling of the casting cavity.

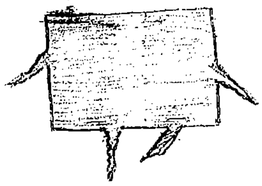
This can be eliminated either by reducing pouring time of molten metal into the cavity or increasing degree of Superheat of molten metal.



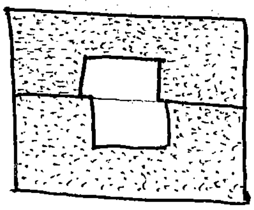
⑨ **Rat tail :-**

Tail like elements produced on the surface of a casting.

produced when wax pattern used with green sand mould.



(10) Shift :-

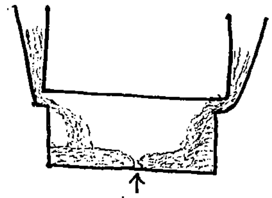


when multi-piece patterns are used there may be a mismatch between the cavities of cope and drag boxes which produces the shift defect.

It can be reduced by using dowel pins

(11) Cold Shut

The discontinuity produced in the casting due to indirect contraction ; ~~its~~



WELDING

Books :-

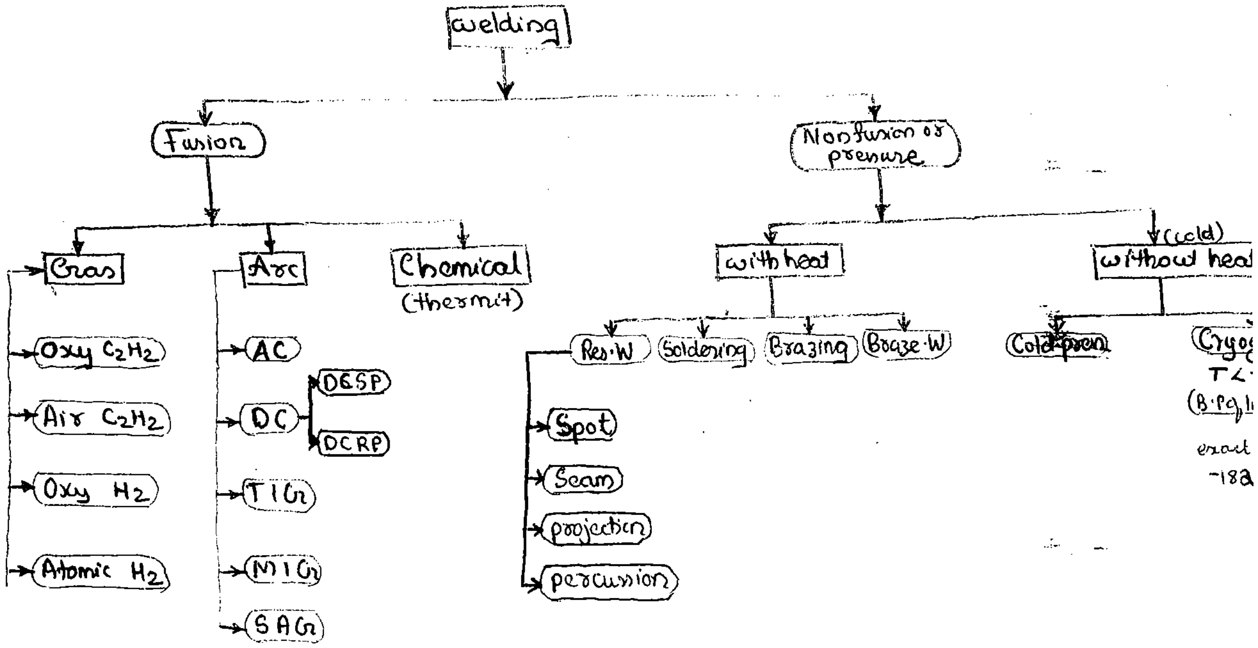
Welding Technology by Little [gas,

Welding Technology by Parm [electrode and resistance welding]

Welding Technology by Quanishburg

Welding definition :-

The process of joining two or more similar or dissimilar metals with ~~and~~ without the application of heat, with or without the application of filler material and with or without the application of pressure.



preheating & post heating

weldability of metals

welding metals.

Fusion welding Process

With the melting of parent material, the joint is produced

Non fusion or Pressure welding Process

With out the melting of parent material ~~or~~ or with application of pressure-joints are produ.

~~Gas~~ welding

By burning of gas - if the heat rq: for melting of metal is obtained.

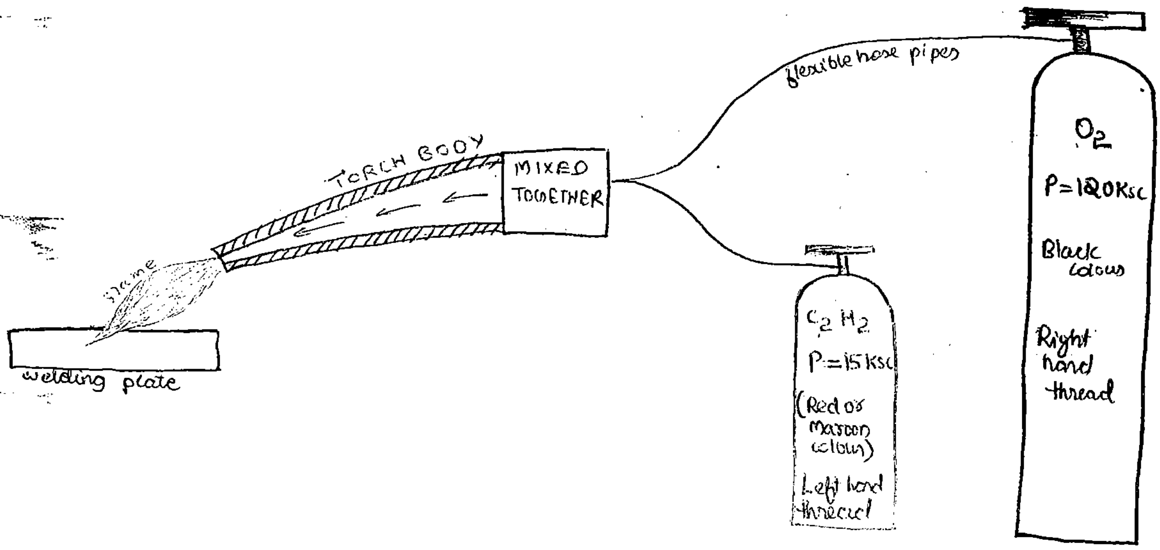
Arc welding

Due to the electrical arc - the heat is obtained

Chemical ~~welding~~

Due to exothermic chemical reaction ~~the~~ heat for melting of plates is obtained.

Oxy-Acetelene Gas welding :-



The oxygen and C_2H_2 will be drawn from their respective cylinders into the torch body, mixed them together in the torch body.

The mixture is posessing certain higher pressure, when this high pressure mixture is passing through the convergent nozzle the pressure energy is converted into velocity energy.

∴ the mixture is coming out at high velocity

When this mixture is given initiation or burning — the continuous flame will be produced so that the heat available in the flame can be used for melting of plates and joining

$$C_2H_2 + O_2 \longrightarrow 2CO + H_2 + heat$$

$$2CO + O_2 \longrightarrow 2CO_2 + heat$$

$$H_2 + \frac{1}{2}O_2 \longrightarrow H_2O + heat$$

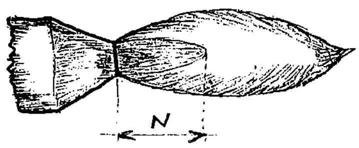
for complete combustion of 1 unit Vol of acetelene, 2·5 units of vol of O_2 is req

out of which 1 unit vol of O_2 is obtained from O_2 cylinder and 1·5 unit vol of O_2 is obtained from atmosphere.

Based on the amount of O_2 consumed from the O_2 cylinder, the flame produced is divided into three types.

① Neutral flame

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



$N = 10$ to 15 mm

Inner and outer core would be distinguished by their coller.

Inner core – red or yellow – incomplete combustion
Outer core – blue colour – complete combustion

Maximum temp is at the intersection of inner and outer core [inside incomplete combus / outside radiation, convet los

Maximum temp at intersection $= 3260°C$

Average temp reduced in flame $= 2000 - 2100°C$

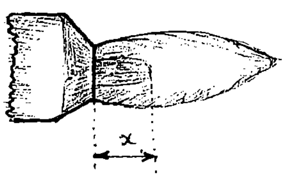
[during burning large qnty of H_2 produced. To evaporate the water large amount of heat is carried ~~away~~ by the water hence temp is reduced by 1/3rd.

Application :-

Used for cutting and joining of all ferrous and nonferrous materials except Brass (during welding of brass, the zinc present in the brass get evaporated. hence neutral flames shouldnot be used)

② Oxydising flame

$$\frac{O_2}{C_2H_2} = 1{\cdot}15 \text{ to } 1{\cdot}5$$



$x = \frac{N}{3}$ to $\frac{N}{2}$

Bcz of excess amount of O_2 drawn from the O_2 cylinder. The distance to be travelled by the flame for complete combustion is less. ∴ length of the inner cone will be small.

Slightly lean mixtures would be having maximum η (so in IC engine)

$T_{max} = 3380°C$

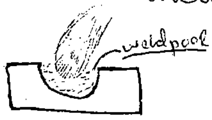
$T_{avg} = 2100$ to $2200°C$

Application :-
Bcz of excess amount of oxygen of O_2 is supplied from O_2 cylinder, there is a possibili free oxygen in the flame. This produces metal oxides during joining of highly reactiv

metals like aluminium, Mg etc.

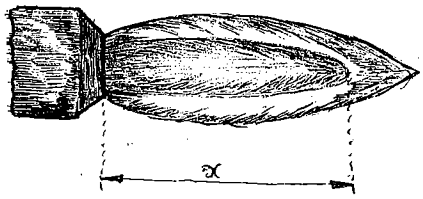
bcz of higher average Temp of flame - high M.P materials could also be joined by using this process.

This can be used for joining of all ferrous & nonferrous metals including brass. (using oxidising flame, - bcz of presence of excess amount of O_2 in the flame, this O_2 pre combines with some Quantity of Zn present in the brass and produces Zn oxides. which floats over the weld pool & not allow (ferrous oxide) rem. Zn to evaporate)



③ Carburizing or Reducing flame

$$\frac{O_2}{C_2H_2} = 0.85 \text{ to } 0.95$$



$x = 2N$ to $3N$

Bcz of short supply of O_2 from the O_2 cylinder, for complete combustion of the acetelene, the flame has to travel for a longer distance and length of the inner cone is $2N$ to $3N$

Bcz of longer length of the cone; the heat energy lost by convection and radiation is very high. ∴ the maximum and avg temp. are reduced.

$T_{max} = 3040^\circ C$

$T_{avg} = 1800 - 1900^\circ C$

Bcz of lower average temp of flame very high M.P materials cannot be joined.

Application :-

Bcz of short supply of oxygen; the free carbon may present in the flame so that if this flame is used for joining of ferrous materials, the carbon may be absorbed by the iron and produces rich in carbon. and changes the mechanical properties.

∴ Carburizing flame shouldnot be used for joining of ferrous materials.

It's most commonly used for joining of highcarbon steel.

In case of steel - with increase of Carbon content - M.P reduces.
∴ high carbon steels will have low MP. and the high carbon steel ~~will be~~ already saturated with carbon. Thus eventhough free carbon is present in the flame - it cannot be absorbed by the high carbon steel

So highcarbon In case of cast Iron - ↑C → MP↓

24-8-2011
6-9 am

Hose :-

For connecting O_2 cylinder to the torch body; Copper hose can be used. It has a capability to withstand high pressure and also has flexibility.

If Cu hose pipes is used for connecting acetylene cylinder, Cu can chemically react with acetelene and produce paste like material and pipe will fail. Hence cu pipes cannot be used for connecting acetelene cylinder. Thus no interchangability of hose pipe is possible. ∴ for

∴ for withstanding low pressure (15 kg/cm²), cheaper materials can be selected for connecting acetelene cylinder. So we used rubber or plastic materials.

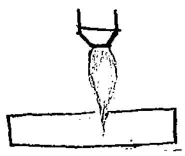
To avoid the interchangability of the hose pipe; the size, colour and the type of thread distribution can be used

Torch angle :-

The angle b/w the axis of the torch and axis of workpiece is called as torch angle.

$$TA = 0-90^{\circ}$$

TA =



TA =

With increase of Torch angle; the area to which the flame is exposed to the weld bit is reduced
∴ the flame dencity will increase

$$\boxed{\text{flame dencity} = \frac{\text{heat supplied}}{\text{Area}}}$$

Factors affecting torch angle

① Thickness of plate

As thickness increases, amount of heat to be supplied per unit area of the weld bit is increasing. Hence the torch angle is to be increased.

② MP of plates to be joined :-

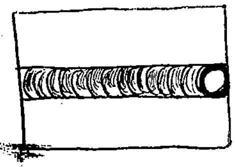
As M.P of plates is increasing - heat supplied for unit area has to be increased ∴ the torch angle has to be increased.

③ Thermal conductivity of plates :-

As the thermal conductivity of plates is increasing, the heat transfer by conduction is increased and net heat available at the joint is reducing. ∴ To compensate this loss of heat the higher torch angle is to be used.

④ Place of welding

Irrespective of the above factors; Use large torch angle at the beginning of the welding and small torch angle at the end of the welding. In the beginning the temp of plate is at room temp; to raise the plate to M large amount of heat is to be supplied. for this large torch angle should be used.



At the end of the welding if small torch angles are used, the force of flame is obstructing the overflow molten metal and eliminates the **crater** defect at the end of the welding.

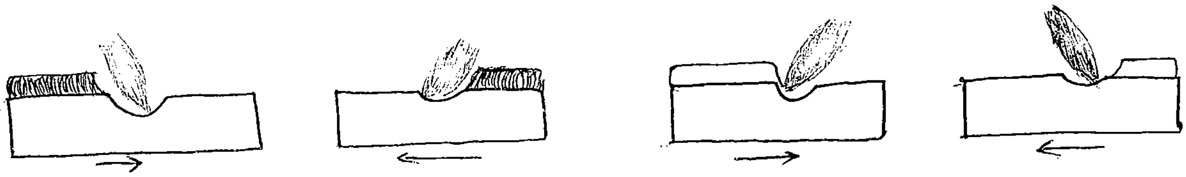
WELDING TECHNIQUES (gas welding)

2 types
1. Foreband or Left hand welding technology (LHWT)
2. Back hand or Right hand welding technology (RHWT)

- method of focussing of flame on to the weld plate can be used as a basis for dividing the type of weld technique

- If the flame is focussed towards the non-welded portion it's foreband welding technique.

- If the flame is focused towards the already welded portion is called backhand welding technique.



foreband welding Technique (irrespective of direction)

back hand welding technique

- In practice most of the welders found that the foreband welding technique is more efficient and effective if it is done from right to left direction

- and backhand welding is found to be more effective & efficient is done from left to right direction.

- In foreband welding technique bcz of the flame focused towards non-welded portion, the preheating of the welding edges will take place where as in case of backhand welding technique bcz the flame is focused towards the already welded portion, the forced heating of the weld bead takeplace.

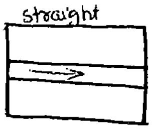
- In forehand w.r.t the force of flame is pushing back the molten slag particles into the weld pool. ∴ Some of the molten slag particles may retain inside the weld bead which reduces the strength of the weld bead and it also

produces non uniform slag layer over the weld ~~bead~~ which promotes atmospheric contamination of the weld bead.
In case of bhwt the force of flame is pushing out the molten slag particle from the weld pool. ∴ No slag particles are present in the weld bit and uniform slag layer is formed over the weld bead.

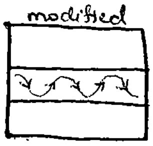
Application

forehand

straight



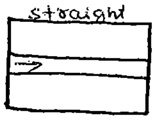
modified



Joining of plates upto 4mm thickness in single pass welding using straight movement of the torch and upto 6mm thickness can be welded by single pass by modified movement of the torch.

back hand

straight



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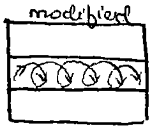


The back hand welding techniques could be used by joining plates upto 6mm thickness in single pass welding with straight movement of the torch. and upto 15mm thickness plates is single pass welding using modified movement of torch.

Welding Positions:

① Horizontal or flat W.P
② Vertical welding position
③ Horizontal Vertical
④ Overhead

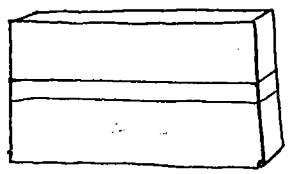
① Horizontal or flat plate weldng Positn

$t \le 4$ mm Forehand or Back hand with

$t = 4-6$ mm

$t = 6-15$ mm Back hand with

$t > 15$ Multipass

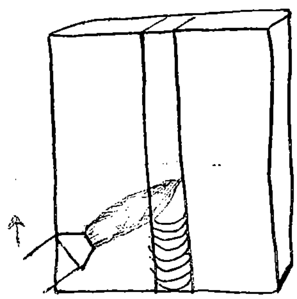


② Vertical welding position

Always from bottom to top

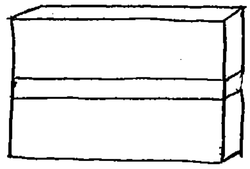
Always

If forehand welding Tech is used, the force of flame act as an additional force for holding the molten metal particles without falling.



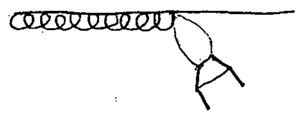
(3) Horizontal Vertical

In horizontal vertical position since plates are vertical; molten metal try to fall down; the force of flame acting by the back hand welding technique can act as an additional for holding the molten metal particles in position.
So backhand is used

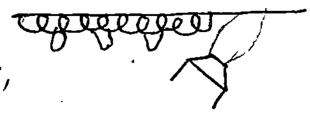


(4) Over head

Bcz of surface tension; b/w the solid body and molten metal, the molten metal is kept in position without falling. If back hand welding technique is used; the force of flame is acting as an additional force. ∴ uniform weld bead can be produced.



whereas with forehand welding technique some of the molten metal particle try to fall down, but before they fall, they get solidified. ∴ non uniform weld bead is produced.



backhand W T is preferred.

Flux used in gas welding

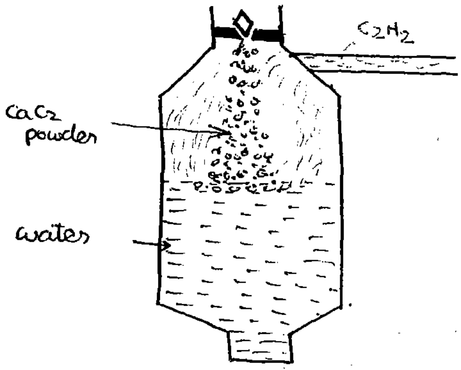
During gas welding operation; the welder is frequently taking out the filler rod from the welding zone and dipping in a powder - called as flux powder.

Functions :-

1. To deoxidize the melt.
2. To observe gases present in the weld pool.
3. To form slag layer over weld bead and avoid atmospheric contamination.

Properties :-

1. It should deoxidize the melt
2. It should absorb gases
3. It should be able to form slag layer.
4. M.P should be < mp of parent and filler rod material
5. S should be as low as possible for easy separation from the molten metal.
6. Viscosity should be low for slag produced, for easy spreading.
7. Sulphur should not be present in the flux powder (sulphur is best deoxidant bcz it react with O_2 to form SO_2 which is highly poisonous)



CaC_2 powder is used.

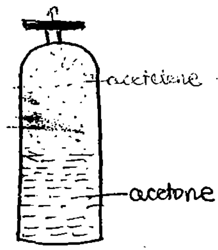
low pressure acetelene is produced

but production rate is high (area of powder exposed chemical reaction is increased)

The equipment is larger bcz; it always needs a rolling mill besides the carbide to water type equipment.

Acetelene is always stored as acetone.

when we add acetelene to acetone; It would absorb the acetelene added and no separate mechanism is needed.



1 ltr acetone $\Longrightarrow$ 25 lts of C_2H_2 @ 1 ksc

$\Longrightarrow$ $15 \times 25 = 375$ ltr of C_2H_2 @ 15 ksc

$\Longrightarrow$ $25 \times 25 = 625$ ltr of C_2H_2 @ 25 ksc

15 ksc is the safe storage pressure of acetone - beyond which acetone may get exploded at any time.

AIR Acetelene Gas Welding :-

If whatever the total oxygen required for complete combustion of the acetelene is obtained only from the atmospheric air; it's called as air-acetelene gas welding.

$C_2H_2 + O_2 \longrightarrow 2CO + H_2 + \text{heat}$

$2CO + O_2 \longrightarrow 2CO_2 + \text{heat}$

$H_2 + \frac{1}{2}O_2 \longrightarrow H_2O + \text{heat}$

↳ atmp.

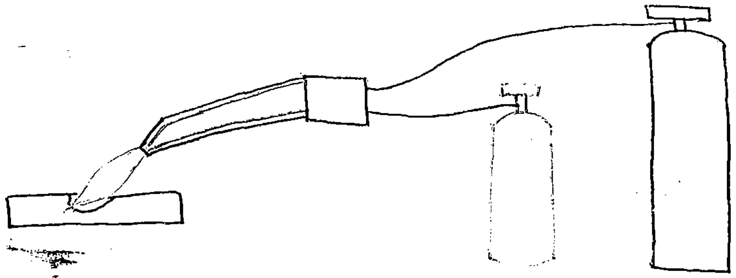
long flame

Here flame is to travel for a longer distance for complete combustion to take the total oxygen from the atmosphere; - the convection and radiation heat energy losses are very high. ∴ the average temp of flame is about 500-700

Bcz of very low average temp of the flame, only very low M.P materials can be joined, like lead, tin, zinc, cadmium etc.

This also can be used as a heat source for soldering operation.

Oxy-Hydrogen Gas Welding



$2H_2 + O_2 \longrightarrow 2H_2O + \text{heat}$

$\frac{H_2}{O_2} = 2$ (Theoretical)

$= 2.5$ to 6

Theoretically the ratio of $H_2 : O_2$ ratio is 2. But practically; this ratio is 2.5 – 6 can be used. So that during welding the excess hydrogen present in the flame is simply moving away from the welding torch and acting as a shielding gas for protecting weld pool from atmospheric contamination. ∴ this method can be used for joining of highly reactive metals like aluminium, Mg etc.

Max. Temp in flame = 2880°C

Average Temp = 700 - 900°C

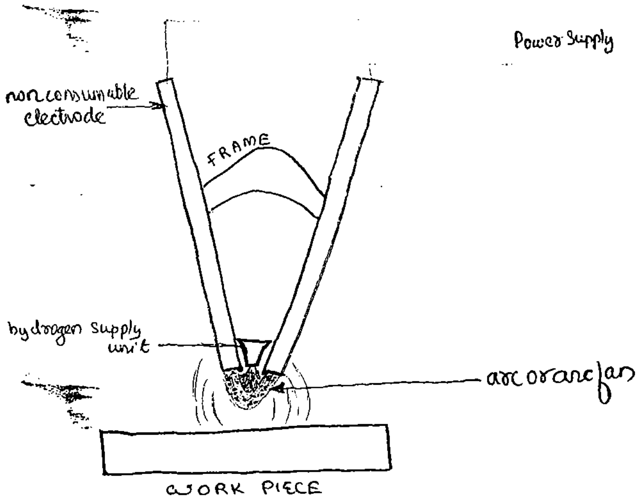
This lower avg. temp is due to the formation of water.

Bcz of this low avg temp of flame; this method can be used for joining of Low MP materials including aluminium.

This method was developed for joining of highly reactive metals.

ATOMIC HYDROGEN GAS WELDING (Special Gas welding process)

It's also called as special gas welding process bcz; its a combination of gas and arc welding operations.



When the power supply is given and optimum gas is maintained b/w the electrode tips, the arc is produced ~~with~~ b/w the electrode tips.

When the hydrogen is supplied into the arc, the molecular hydrogen will be desintegrated into atomic hydrogen which is endothermic reaction and the heat required for this is obtained from the arc fan.

The atomic hydrogen produced in the arc fan when it comes out becomes an unstable gas at atmospheric condition. ∴ it's reunited to form the molecular hydrogen which is exothermic reaction.

The heat generated melts the plates.

examples

1. During gas welding of carbon alloys or nickel alloys - # NO flux is to be used.

The presence of carbon or nickel, the material itself act as deoxidizer.

2. Borax - commonly used flux during gas welding of all other metals.

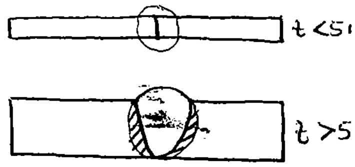
Filler rod :-

It is used to supply additional molten metal to the weld bead.

When ever edge preparation or joint preparation is done for joining of the plates - additional molten metal is required to fill the gap.

· If thickness of plates to be joined $t > 5mm$ - edge preparation is done

If $t < 5mm$ - square joint can be used (no - edge preparation) without supplying any additional metal - such a welding operation is called Puddling operation (no filler rods)



properties to be possessed

1. density (ρ) of filler rod material should be nearly equal to that of parent material so that the mixed molten metal of filler and parent metal would retain sometime without separation.

2. MP of filler rod material $\leq$ M.P of the parent material. (to avoid the excess of melting of parent material)

3. The molten metal of filler rod material is readily mixed with the molten metal of parent material.

filler rod materials

Low carbon steel, medium carbon steel, brass etc are commonly used.

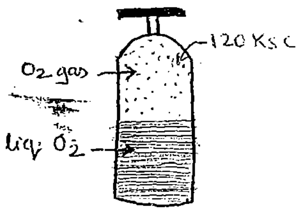
Production of Oxygen

Producing O_2 from atmp. air is the cheapest & safest methodology

air			B.P
	N_2	78.7%	$-195.8^\circ C$
	O_2	21%	$-183^\circ C$
	Org elements	0.3%	$-185.7^\circ C$

$$\underset{(gas)}{Air} \xrightarrow{cool} \underset{\text{liquid air}}{-220^\circ C} \xrightarrow{\text{heat gently}} \underset{liq(O_2+org)}{-195^\circ C} \xrightarrow{\text{heat gently}} \underset{liq\ O_2}{-185^\circ C}$$

Oxygen is always preferable to store in the form of liquid oxygen only. To avoid the usage of refrigeration system – presence of liq O_2 can be increased to 120 KSC. Then the B.P of O_2 would be 40-50°C. Thus this can be stored in the atmospheric temperature easily.



Production of acetelene

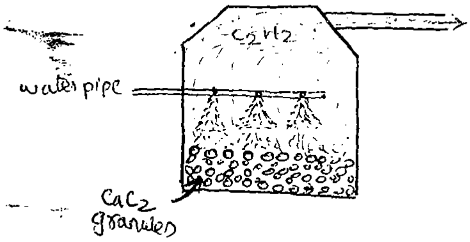
C_2H_2 is always produced by mixing calcium carbide with water

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

based on this principle 2 method of production is there:.

1) Water to carbide type:

If water is allowed to fall on the Calcium carbonate granule for producing the acetelene. ~~is cattle~~



low pressure acetelene is only produced.
Small production rate
It's a portable equipment.
always granule is used instead of powder bcz if we used powder after a top layer reaction – No further reaction occurs.

2) Carbide to Water type

In addition - out of the molecular hydrogen produced, nearly $\frac{1}{3}$rd of the hydrogen is burning by taking the oxygen from the atmosphere and remaining $\frac{2}{3}$rd hydrogen simply moving away from the welding tool acting as a shielding gas for protecting the weld pool from atmospheric contamination.

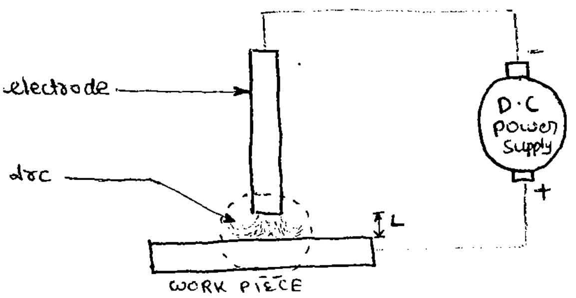
The heat req. for melting of plate can be obtained due to exothermic chemical reaction and also by burning of $\frac{1}{3}$rd of molecular H_2.

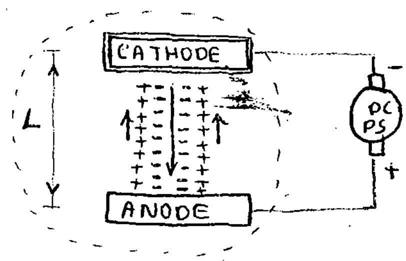
This method gives better protection to weld pool than the oxy-hydrogen weld

∴ They are used for joining of highly reactive metals like aluminium, also used for joining of stainless steel.

Arc Welding:-

The heat required for the melting of the plate is obtained due to electric arc; it's called as arc welding.





When the power supply is given and optimum gap is maintained b/w tip of electrode and work piece; the high velocity electrons will be generated at the cathode which are attracted by the anode ~~and~~ move towards anode. When they are impinching on to the anode; the KE of electrons will be converted into heat energy. ∴ the heat is generated at the anode. Simultaneously the high velocity positively charged ions will be generated at the anode which are attracted by the cathode and moves towards cathode. When this high velocity ions are impinging on the cathod; the K.E of the ions is converted into heat energy.

∴ the heat is generated at the cathode also. But the velocity of the electrons is much higher than the velocity of ions. ∴ the heat generated at the anode is higher than that of cathode.

The heat generated at anode to heat generated at cathode = 2:1

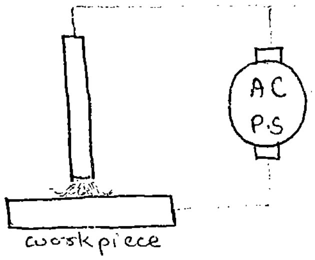
During the process some of the -vly charged electrodes and +vly charged ions will collide in the passage so that the K.E of both the elements will be spontaneously converted into heat energy which is observed as a spark b/w th

Due to this sparking; the temp induced in the arc is around 5000 to 6000 °C. From the zone ultraviolet rays are generated and spreads around the arc. ∴ If the arc is directly seen with human eye; after few minutes of time, the eyes will be started paining. ∴ To avoid this the arc must be seen only through safety goggles or safety glasses.

Direct Current Straight Polarity (DCSP) OR Direct Current Electrode Negative (DCEN) — electrode −Ve, workpiece +Ve

Direct Current Reverse Polarity (DCRP) OR Direct Current Electrode Positive (DCEP) — electrode +Ve, workpiece −Ve

AC arc welding OR ACHF (Alternating Current High frequency)



AC power supply is used

50%-50% heat generated at anode and cathode.

If $f = 50\ Hz$ cycle time $T = 0.02$ sec
each 0.02 sec the polarity changes.

Features of arc welding operations:-

DCSP

Bcz of high heat generation at the workpiece; high M.P materials and higher thickness plates could be joined easily.

Higher depth of penetration is also possible.

Bcz of lower heat generated at the electrode, ~~only~~ the melting rate of electrode is low, deposition rate is low and ∴ only low welding speeds are possible.

DCRP

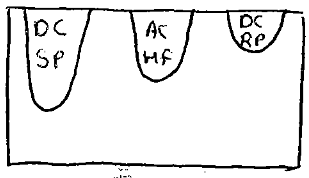
Bcz of lower heat generated at the work piece – only low M.P materials and lower thickness plates can be joined.

low depth of penetration.

Bcz of higher heat generation of at electrode – melting rate of electrode is high; deposition rate is high and ∴ higher welding speeds are possible.

ACHF :-

Medium thickness plates
medium depth of



Arc recovery time :-

The time required to establish the arc b/w the ~~electrode~~ electrode and work piece. 'Establishing arc' refers to establishing the flow of electrons and ions in their respective directions.

In D.C arc welding whatever may be the arc recovery time ; it won't influence the welding process.

In AC arc welding bcz the terminals are continuously changing. The arc recovery time must be less than ½ of the cycle time. for effective utilisation of arc.

$$\boxed{ART < \frac{1}{2} CT}$$

In general the C.T will be fixed (since we req. high frequency) and arc recovery time is reduced.

By increasing Voltage of power supply the ART could be reduced

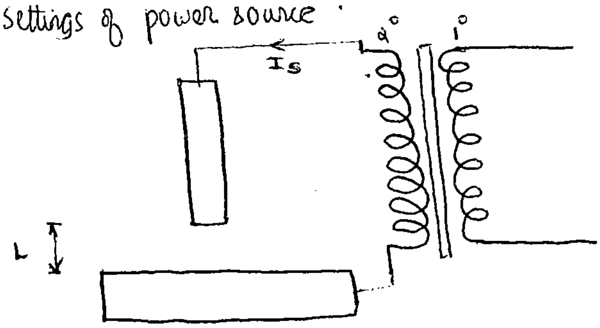
For effective welding operation ; the range of ~~welding~~ voltage used in the arc welding operation is 30 – 70 V

max. voltage human can withstand. (considering the risk of danger)

If 50 Hz freq C.T = 0.02
If ART = 0.03 sec
No arc could be struck since polarity changes every 0.02 S.
If ART = 0.018 S
arc set up by 0.018 sec thus arc will be struck only for 0.0002 sec = 2 millisec. So not effective &
ART < ½ C.T

Optimum Settings

For the system to be in equilibrium conditions ; whatever the energy supplied by using power supply unit is only has to be utilized at the arc point. For this it is required to determine the optimum arc length using the welding process and optimum settings of power source.



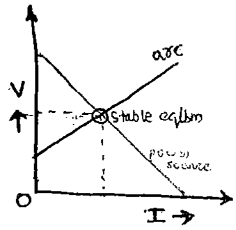
V_0 – open circuit voltage – Max Voltage

I_s – Short Circuited current (max. current)

I – current passing thru 2° when load is connected to a load

V – Voltage of secondary when load is connected

L – arc length.



$V = V_0 - V_{drop}$

$= V_0 - R_s I$

$$\boxed{V_p = V_0 - \frac{V_0 I}{I_s}}$$

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

At $L = 0$, $I = I_s$
$L = \text{large}$, $I = 0$ } as L increases I reduces
R increases (air gap increases)

$V = I R$

Increase of R > decrease of I

thus V - increases

$$\boxed{V_a = a + bL}$$

At eqlbm point.

Voltage at arc = voltage at powersource

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

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

$$I = \frac{I_s}{V_0}(V_0 - a - bL)$$

$$\text{power} = VI$$

$$P = (a+bL)\frac{I_s}{V_0}(V_0 - a - bL)$$

for optimum arc length

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

Q $V_0 = 80V$, $I_s = 2000A$, $V = 20 + 40L$, L-arc length. calculate optimum arc length & setting of a power source

$V_p = V_a$

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

$$80 - \frac{\cancel{2000}\,80 \times I}{2000} = 20 + 40L$$

$$\frac{80 I}{2000} = 60 - 40L$$

$$4I = 1000(6 - 4L)$$

$$I = 250(6 - 4L)$$

$P = VI$

$= (20+40L)(250(6-4L))$

$= 250(20+40L)(6-4L)$

$= 250(120 - 80L + 240L - 160L^2)$

$P = 250(120 - 160L - 160L^2)$

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

$0 = 250(-160 - 320L)$

$L = \frac{160}{320} = \underline{\underline{0.5}}$

$I = 250(6-4L)$

$= 250(6-\frac{4}{2}) = \underline{\underline{1000\,A}}$

$P = (20+40L)(250(6-4L))$

$= (20+20)(250)(6-2)$

$= 1000 \times 40$

$= \underline{\underline{40\,kWatt}}$

Q $V = 60V$, $I = 1000A$. Then the optimal setting for welding is ?

(A) 60V, 400A (B) 50V, 1000A (C) 60V, 1000A (D) 50V, 400A

Ans 'D'

Since $V < V_0$
$I < I_s$

Duty Cycle (D)

The % of time during which the arc is on without overheating of vital eq elements of welding equipments.

$$\boxed{\text{Duty Cycle} = \frac{\text{Arc 'ON' time}}{\text{Total Welding Time}}}$$

Arc ON TIME is the actual welding time during which the arc is on for generating the heat required for melting of the plate.

$$\boxed{\text{Total welding time} = \text{Arc ON Time} + \text{Rest time}}$$

→ No welding done.

R_S - resistance of the secondary. I the current.

heat generated (in ac) $\Rightarrow Q_g = I^2 R_S$. here R_s remains constant but I varies from 0 welding to welding.

heat dissipated $\Rightarrow Q_d = h A \Delta T$ [constant]

$Q_d \geq Q_g$ Rest Time $= 0$ Duty cycle $D = 100\%$

$Q_g > Q_d$ $\underset{\text{accumulation}}{Q_a} = Q_g - Q_d$

after some time the accumulated heat become very high and temp of transformer becomes very high and the transformer may fail.
To avoid this; after every certain period of time; the rest time must be given to the welding equipment so that during this time only heat dissipation will occur and no-generation of heat.

Q $I = 1500\,A$ $Q_g = 10\,kw$, $Q_d = 6\,kw$, $(Q_a)_{max} = 2000\,KJ$. Duty Cycle ?

$$Q_a = Q_g - Q_d = 10 - 6 = \underline{\underline{4\,kw}}$$

$$AOT = \frac{(Q_a)_{max}}{(Q_a)} = \frac{2000}{4}\,sec = \underline{\underline{500\,sec}}$$

$$RT = \frac{2000}{6} = \underline{\underline{333\,Sec}}$$

$$D = \frac{500}{500+333} = 0.6 = \underline{\underline{60\%}}$$

Q If same welding equipment with $I = 2000A$ - Duty cycle.
Thus for every change in I we should calculate the 'D'.

$$Q_g \propto I^2$$

$$D \propto \frac{1}{Q_g}$$

so $$D \propto \frac{1}{I^2}$$

$$I^2 D = \text{constant}$$

$$\boxed{I_r^2 D_r^2 = \text{constant}}$$

I_r - rated current, D_r - rated Duty cycle } obtained from name plate

$$\boxed{I_r^2 D_r = I_d^2 D_d}$$

I_d - desired current
D_d - desired duty cycle.

$(1500)^2 \times 60 = 2000^2 \; D_d$

$$D_d = \frac{\cancel{1500}^{3} \times \cancel{1500}^{3} \times \cancel{60}^{15}}{\cancel{2000}_{4} \times \cancel{2000}_{4}}$$

$$= \frac{45 \times 3}{4} = \underline{\underline{33\%}}$$

If I = 1000A = I_d

$$D_d = \frac{1500^2 \times 60}{1000^2} = 135\%$$

$\hookrightarrow D_d = \underline{\underline{100\%}}$

So No rest time is there = continuous welding can be done.

Electrodes

Functions

① Acts as an electrical element for closing the electrical circuit

② Sometimes it melts and supplies the additional molten metal to weld bead

If electrode only satisfies the 1st functionality → then it's nonconsumable electrode
If electrode satisfies both the above functionality → then it's consumable electrode.

nonconsumable electrode

- Should have high M.P and higher electrical conductivity.
- Graphite, tungsten, carbon etc

  C, Graphite - have lower M.P - so used only with DCSP
  Tungsten - have higher M.P - DCSP, DCRP, ACHF.
- Always used as 'bare wire' electrodes - No coatings would be provided on electro

consumable electrode

- Same qualities as that of filler rod in gas arc welding.
- 2 types :-

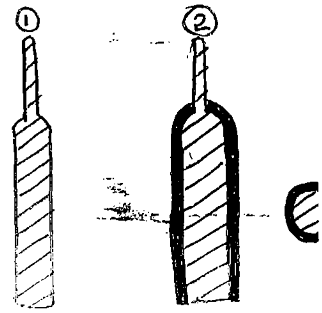
  ① Bare wire electrode

  ② Coated electrode

  adv of coating

  1) Act as deoxidizer during welding
  2) It can absorb gases present in the molten metal.
  3) It can form as a slag layer over weld bead and

①　②



4. It can stabilize the arc

5. It can produce shielding gases for protecting weld pool from atmospheric contamination.

6. It can supply alloying elements for improving the mechanical properties of weld bead.

Imp
* Type of coatings given

1) for deoxidization and absorbing gases –
   Ferrosilicon or ferromanganese coatings
2) for slag formation
   Titanium Oxide (Rutile) – TiO_2
3) For Arc stabilization
   Pottasium compound
4) for shielding gases
   cellulose coatings.
5) for adding alloying elements
   Small quantities of Vanadium, cobalt, Nickel, Manganese, Cu, Al etc is added in coatings

Electrode designation

By a 6 digit code

1st 3 digits – indicates performance of coating in w

last 3 digits – indicates mechanical properties of electrode material

X X X   X X X

Type of coating (0–9)

welding position

Current condition

% elongation.

Strength of welding
11 – (110 → 210 MPa)
21 – (210 – 310 MPa)
31 – (310 – 410 MPa)
⋮
91 – (910 – 1010 MPa)

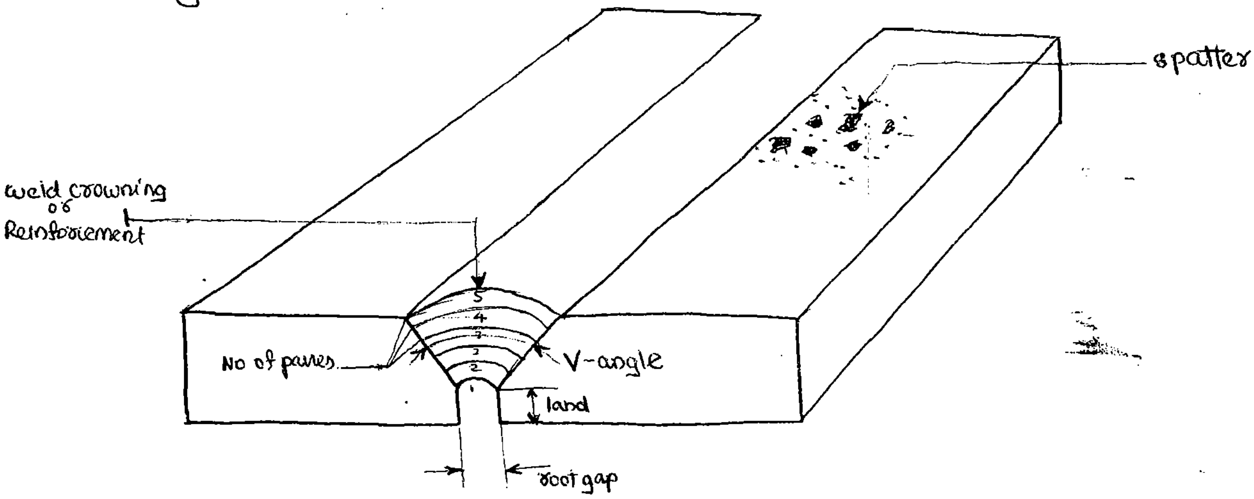
15 CDV6 Steel having 980 MPa is material with highest strength.

Titanium also there higher but its not used in welding.

Design of weld bead :-

1. No of electrodes required
2. Welding speed
3. No: of panes
4. Total welding time

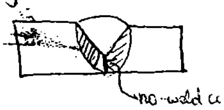
Terminologies



Root Gap.

The gap provided b/w the 2 plates at the bottom most point of weld bead

If the complete thickness of the plate is not melted atleast the molten metal of electrode should flow upto the bottom most point of the plate and produce the joint. For this the root gap is required. Upto 5mm root gap can be given.

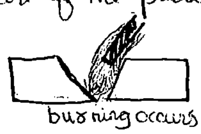


Land

The straight portion of the plates provided at the bottommost part of the plate during welding.

The land is provided to avoid the burning through of edges.

Maximum land used is 5mm.



V-angle

Whenever the thickness of plates to be joined is greater than 5mm; it's necessary to prepare some types of joints like V or U or I joint. Out of which the V joint is the most efficient joint bcz it gives the highest surface area and lower amount of filler additional molten metal

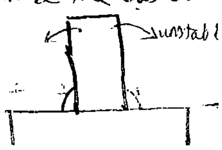
Most commonly used V-angles are - 60° or 90° or 120°

No: of passes

Whenever the thickness of plates is higher and higher - it's not possible to join the plate using single pass welding. So it could be done well by using multi pass welding operation

In most of the welding process, it's always preferable to weld in single pass welding if not use as minimum number of passes as possible to minimize the distortion except in T fillet ~~melting~~ welding operation.

In T fillet use as minimum passes as possible to ...



Weld Crowning or Reinforcement

The excess material provided over and above the surface of the plates

Crowning is provided to ensure that the resistance area available at the joint is atleast equal to the resistance area of the plates to be joined. (Common consideration or assumption in design of welded joints)

10-15% Volume of weld bead can be provided as crowning.

Spatter :-

During welding operation, some of the molten metal particles are jumping from the weld pool and fall on other areas of the plate due to the force of arc or flame - called as spatter.

It's the loss of molten metal from the weld pool and affect the surface finish of plate

Spatter loss will be about 5-10% Volume of weld bead.

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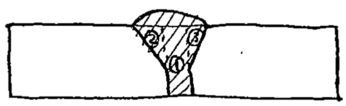
Design

(1)

$$\text{No of electrodes required} = \frac{\text{Total Vol. of weld bead}}{\text{Vol. of one electrode}}$$

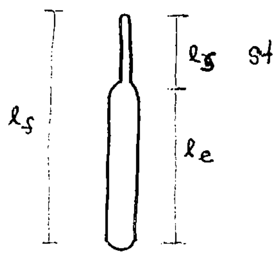


Vol of w.B $= (A_1 + 2A_2) \times \ell$

Total volume of weld bead = Vol. of w.B + Crowning + Spatter

$= (1.15 \text{ to } 1.25) \times$ Vol of w.B

$$\text{Volume of electrode} = \frac{\pi}{4} d^2 \ell_e$$



(2) heat supplied to weld bead

Q = heat utilized for melting + heat lost by conduction

$$= \frac{5}{4} \pi K \theta_m w \left[\frac{2}{5} + \frac{Vw}{4\alpha}\right]$$

K - thermal conductivity of plates
θ_m - M.P of plates to be joined
w - width of the weld bead
V - welding speed
α - thermal diffusivity

During joining of very long plates, the heat transfer by conduction along the length direction is becoming very small and negligible. ∴ the heat transfer along

Then, by considering 2-Dimensional heat loss The heat supplied

$$Q = 8 K \theta_m t \left[\frac{1}{5} + \frac{v\omega}{4\alpha} \right]$$

t - thickness of plates

④

welding time/pass $= \frac{\text{length of W.B}}{V}$

AOT = Welding Time (WT)

$= W \cdot T/\text{pass} \times$ No: of passes

Total welding time $= \frac{AOT}{\text{Duty Cycle}}$

③

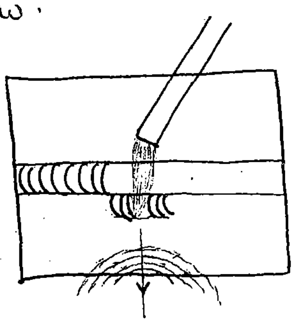
Let x = length of the weldbead welded by using one electrode (obtained from the welding data book; corresponding to the dia. of electrode and thickness of plates to be joined) $x = 200-500$ mm/electrode

No: of electrodes/pass $= \frac{\text{length of weld bead}}{x}$

No: of passes $= \frac{\text{No: of electrodes req}}{\text{No: of electrodes/pass}}$

Magnetic arc blow or Arc blow :-

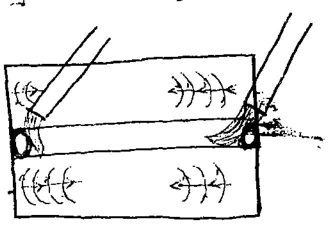
The magnetic forces created by the electric current will tend to draw the arc in the shortest line of action and making the welding taking place in different plane than required. This is called magnetic arc blow or arc blow.



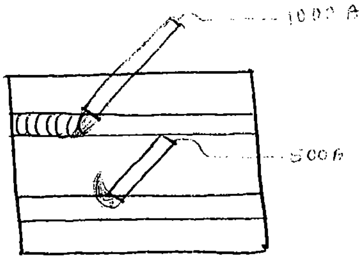
It's mainly occuring in DC arc welding and not in AC arc welding

Reasons

- welding near to the earth connection
2. Starting and ending arc blow.



3. Simultaneous welding at more than one place which are nearby and using different current condition



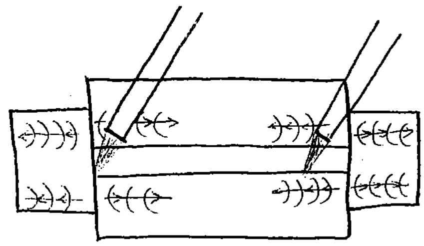
Remedies for magnetic arc blow

1 welding away from the earth connection :-

when the welding is done from one end of the plate ; the earth connection would be given on the other end. After half of the welding is been completed ; stop the welding and shift the earth connection towards the already weld side.

2 Starting and ending arc blow could be eliminated by using the start on plate & run out plate respectively.

They also get adhered to the plates after weld. which could be removed by simple hammer blows.



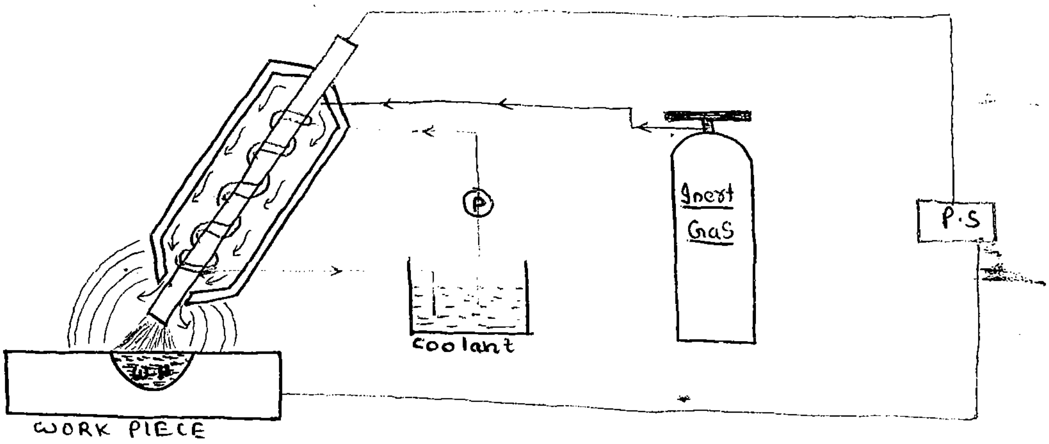
3. whenever simultaneous welding at more than one place is done, use same current conditions for all the electrodes.

4. The best solution for eliminating the arc blow is using AC power supply instead of DC power supply

The most commonly used power supply in the arc welding operation is — DC power supply.
Bcz the heat generation of the work piece and electrode can be controlled by changing the polarity.

Tungston Inert Gas Welding or Gas Tungston Arc Welding or Argon Arc Welding

(TIG) or (GTAW) or (AAW)



The tungston is used as an electrode material ∴ it's considered as a non-consumable electrode welding operation.

To protect the weld pool from atmospheric contamination, the inert gas would be supplied to the welding pool continuously using inert gas cylinders.

The most commonly used inert gas is Argon ∴ name argon arc welding.

To avoid the melting of electrode, the coolant will be suppled through a small pipe which is wrapped around the electrode so that the temp of electrode is kept as low as possible.

Bcz of continuous supply of inert gas is taking place in the weld pool; it could be better protected from atmospheric contamination. Hence after the invention of TIG welding; Atomic hydrogen became obsolete and TIG is popularly used for joining of highly reactive metals like Al, Mg etc.

Limitations :-

1) Cost is very high due to usage of inert gas and coolent.

2) Bcz of non-consumable electrode welding – only upto 5mm thickness plates can be joi

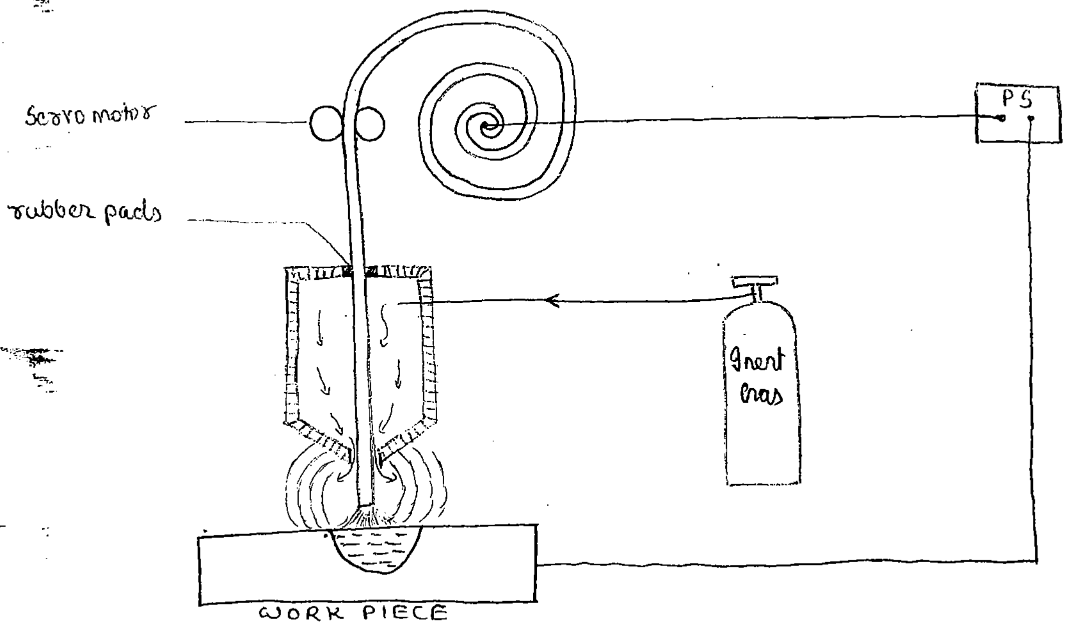
3) For using the TIG welding operations to join the plates of thickness more than 5mm additional filler rodes must be used.

* with filler rodes; the air particles may stick to the surface of filler rod and enter into the weld pool; which may contaminate the weld pool again.

4) Eventhough tungston electrode is not melting; at high temperature; the atoms of tungston may diffuse from the tip of the electrode and enters into the weld pool which increases the brittleness of the weld pool.

Metal Inert Gas Welding or Gas Metal Arc welding

MIG or GMAW



Bcz of consumable electrodes; the electrode neednot be cooled. ∴ no coolent is to be supplied.

Hence the cost of welding reduces.

Due to consumable electrodes - It's possible to join more than 5mm thickness rods without using any additional filler rods.

when the electrode is passing through the rubber pads, any air particles which are sticking to the surface can be squeezed out.

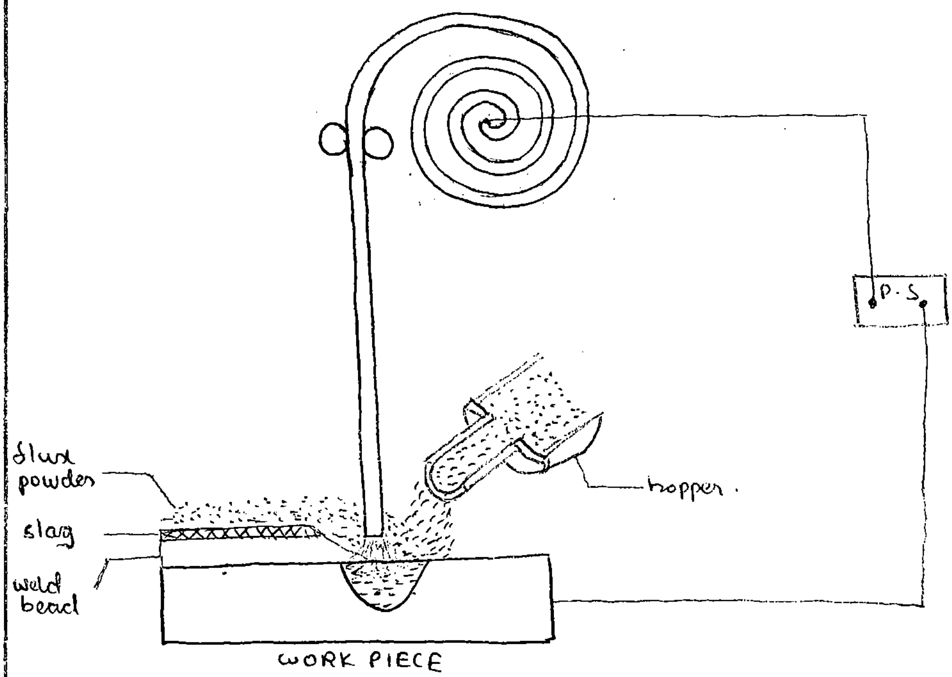
Bcz electrode itself is consumable, no-tungsten diffusion.

Continuously consumable electrode which is wound on the spool and fed by using servomotor.

Limitation :-

Bcz the electrode is to be wound on to the spool, the maximum size of the electrode would be 3-4mm. During joining of large thickness plates; in single pass welding with mig-welding bcz of smaller size of electrode; the welding speeds lost must be low. After low welding speeds; the size of the weld pool produced in front of the arc is very large and due to the force of arc the molten metal particles then easily jump from the weld pool and the spatter loss would become very high. To avoid this max-thickness of plate which can be welded by using single pass welding is 30mm only.

Submerged Arc Welding



In this the arc is completely submerged in the flux powder. ∴ name - Submerged arc welding

Continuously consumable electrode wound on the spool and fed by using servo control

In this inplace of inert gas, large quantity of flux powder will be supplied through the hopper, out of which some amount of flux powder is melting and converting into the slag - remaining flux powder is simply floating on the top called unused flux. It is collected and reused through the hopper.

In this also during welding of large thickness plates in single pass welding; bcz of smaller size of the electrodes; the welding speed used is low. and size of the weldpool produced in front of the arc is larger. Due to the force of arc the molten metal particles are trying to jump from the weld pool. But bcz of presence of large quantity of flux powder over the weld pool; its obstructing the jumping of molten metal particles. Hence the spatter loss is minimized.

It's limited to use upto 75mm thickness plates economically using single pass welding, i.e beyond 75mm conception of flux powder is very high.

Electro Slag Welding:-

It's a special welding process which can be used for joining plates of above 75mm thickness economically in single pass.

It's only been used in vertical welding position.

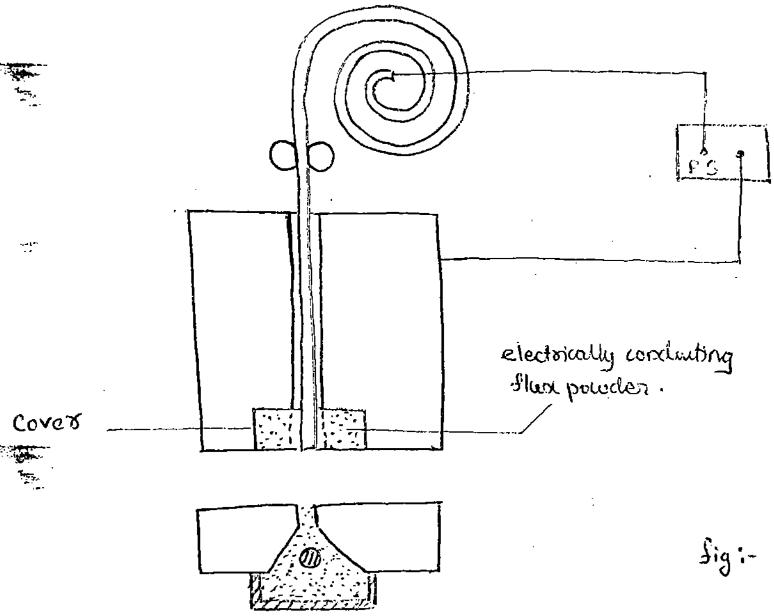


fig :-

when the power supply is given, the arc is produced b/w the tip of the electrode and work piece; The heat generated due to the arc can be used only for melting of the electrically conducting flux powder and ~~foaming~~ as a molten slag; so that the tip of the electrode will be immersed inside the molten slag. and the arc is put off.

Now the electricity is flowing from electrode to the work piece; through electrical conductivity of the molten slag.

when the current is passing through the molten slag, bcz of electrical resistance of the slag, the heat is getting generated and this heat will be used for melting of the plates and electrodes. ie the heat req. for melting of plates ~~can~~ be is ~~ae~~ obtained due to the electrical resistance of the molten slag.

name as electro-slag welding operation.

As the electrode is getting melted; It occupies space at the bottom of the weld bead, which pushes the molten slag in the upward direction so that the cover will be moving slowly in the upward direction.

The commonly used electrically conducting flux powder is silicon based flux powder.

Any thickness could be welded economically.

but for thickness < 75mm - it's not much economic.

All the above 3 methods are the pure. Non fusion welding operations.

Soldering Brazing and Braze welding

1 mechanism

In all the non fusion welding processes ; when the liquid molten metal is poured at the joints, it is wets the solid surfaces and form the surface alloy joi... ∴ the mechanism by which the joint formation taking place is wetting and surface allowing .

Reasons for devloping Non-fusion welding

① When ever two metals are to be joined which has large difference in melting ... so that before melting one material ; - the other material may be evaporated

for steel 1400°C - melts but aluminium evaporates at 950°C

② Some metals can never produce liquid molten metal.

Tungston (MP - 3400°C - at this temp ; Wb is disintegrated to powder form)

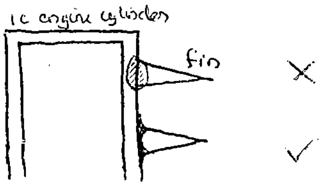
even when we heat it to 10,000°C we can't form molten tungston.

③ When ever a very thin components is to be joined to the very thick components. before joining of ~~thick met~~ components ; thin components will melt

eg:- joining of electric wires to PCB

④ Melting and solidification of parent materials causes change in mechanical properties of parent material in fusion welding. In case we are not allowed to change the mechanical properties of parent material. In such cases non-fusion welding will be used.

eg:- IC engine cylinder & fin.



For any non-fusion welding 5 points should be kept in mind

1. mechanism
2. Temperature
3. Heat source
4. filling rod
5. Applications

Soldering

mechanism → wetting and surface allowing

Temperature → Tem < MP of plates

$< 427°C$ [since tin & lead alloy will evaporate at 427°C] (tin present in alloy actually evaporate)

Heat source → Air-acetelene flame (cold age) / electrical resistance heating (now)

If metal A − 350°C B − 500°C Then take T < 350°C

If A − 460°C B − 620°C T < 427°C

which ever is less.

Filler rod → lead-Tin-alloy (50 : 50) ⇒ called Soft soldering

lead-Tin-Silver (30 : 30 : 40) ⇒ called hard soldering :- bcz of additional silver. Strength of joint produced is very high. (expensive)

↓

only used in space application (aircraft, missiles, space shuttle) (vibration is high - so it is used)

A small quantity of bismuth is added to filler rod to increase the wettability of molten metal to solid body and to reduce the MP of filler rod materials.

Application → mainly used for joining electric and electronic wires to the PCB hard soldering in space application,

Brazing

– if without joint preparation - 2 plates are joined.

brazing Cu+Zn

mechanism → wetting and surface allowing

Temperature → < M.P of plates

$> 427°C$ [lowest M.P of Cu alloy is 420°C ≈ 420. So for easy rem. we take 427]

A − 350°C, B − 500°C] X not possible

A − 460°C, B − 620°C] 427 < T < 460°C

* metals having M.P < 427°C cannot be brazed or braze welded

Heat source → Oxy-hydrogen
furnace brazing
resistance brazing

Filler rod → copper-Zn alloy – having high capillary among copper alloys

[since molten metal of filler rod are flowing in the joint due to capillary action]

Application - whenever joint preparation are not possible.
closing hole of a pipe.

Braze welding :- if 2 plates joined with end preparation.

All properties are same except the foll.

filler rod :- molten metal from filler rod move in b/w the plates by gravity.
Cu - Tin - alloy is having high gravitational force among the Cu alloys.
so it's been used.
Cu - won't allow tin to get evaporated even above 427°c (may get doubt)

Application :- whenever joint preparation are possible.
Joining of pipes.

order of priority.

Braze welding < brazing < soldering.

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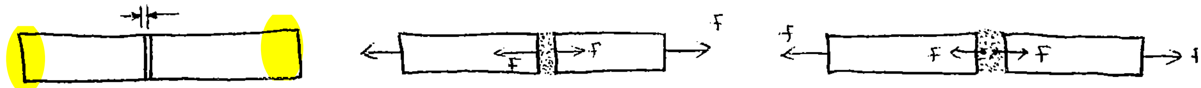
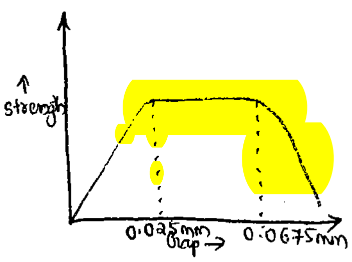
In brazing operation as the joint thickness (or) joint gap is increasing the strength of the joint is increases first and then reduces.





As joint gap increases the flow of molten metal into the joint increases; as the flow become easier.
∴ wetting area and the surface alloying area increases.
Hence the joint strength increases.
after some gap the quantity of filler rod materials present the joint becomes considerable. ∴ during usage of the component; the force will be transmitted into the filler rod material also and the filler rod materials fail before the surface alloy joints fails.
Hence the strength of the joint reduces.

Resistance welding

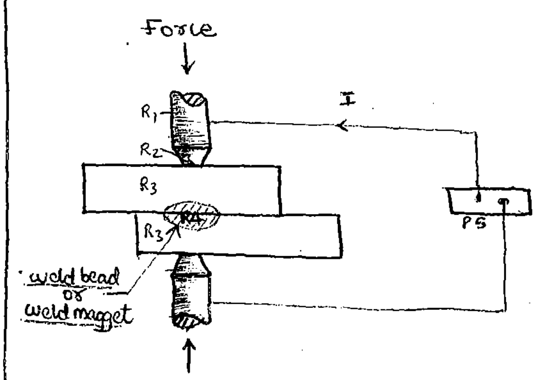
Resistance spot welding :-

- The heat req; for melting of plates and joining is produced b/c of electrical resistance.
- ∴ name given as resistance welding.

The shape of the weld bead produced is approximately like a spark. ∴ called as spark welding.

It's a fusion pressure welding process

Fig :- Resistance Spot welding



Heat generated (H.G)

$$\boxed{Q_g = I^2RT}$$

I - current passing thru the circuit
R - resistance of ~~electrode mat~~ plate
T - time for which current flows.
R_1 - resistance of electrode material.

non-consumable electrode material should have

- → low electrical resistance
- → high M.P
- → higher strength

preferable materials for manufacturing of electrodes are

Cu or Tungsten or Cu-Tungsten alloy

Current

$I = 10000$ A, $t_1 = 1.5$ mm, M.P $= 1400°$C } Steel plate

$\boxed{t_2 = 10\text{mm} \quad I_2 = ? \text{ — steel}}$

$Hg \propto I^2$, $\propto t$ } $t \propto I^2 \Rightarrow \frac{t_1}{t_2} = \frac{I_1^2}{I_2^2}$

$I_2 = I_1\sqrt{\frac{t_2}{t_1}} = 10000\sqrt{\frac{10}{1.5}} =$

$\boxed{t_2 = 1.5\text{mm}, \rightarrow \text{Al plate}, I_2 = ?}$

$Hg \propto I^2$, $\propto m.p$ } $M.P \propto I^2$

$I_2 = I_1\sqrt{\frac{mP_2}{mP_1}} = 10000\sqrt{\frac{660}{1400}} =$

$\boxed{t_2 = 5\text{mm} \rightarrow \text{Cu plate} \quad I_2 = ?}$

$I_2 = I_1\sqrt{\frac{t_2\, mP_2}{t_1\, mP_1}} = 10000\sqrt{\frac{5 \times 1100}{1.5 \times 1400}}$

Resistance

(R_1) - should be as minimum as possible

(R_2) - contact resistance b/w tip of electrode and work piece.
- it also should be as minimum as possible

Generally R_2 depends on
→ surface roughness & cleanliness of surfaces

To minimize R_2 - contacting surfaces must be smooth and clean

(R_3) - electrical resistance of plates to be joined
- It should also be as minimum as possible to avoid melting of complete thickness of the plates and joining of electrodes to the plates.

R_3 cannot be changed.

(R_4) - Faying surface resistance - Contact resistance of joining surfaces or
it should be as maximum as possible. → by making contact surface clean and rough

Limitation :-

1. Highly electrically resistant materials cannot be resistance welded.

$$\boxed{R = 2(R_1 + R_2 + R_3) + R_4}$$

$= 200 + 500\ \mu\Omega$ or $200\ \mu\Omega$

$D\Omega \rightarrow$ nano

T - time during which the current is passing through the resistance welding circuit.

usually $\tau < 0.2$ sec] - current is passed only 4 a short duration.

Bcz: maximum temp in spot resistance welding is $T_{max} = 9000 - 1200°c$

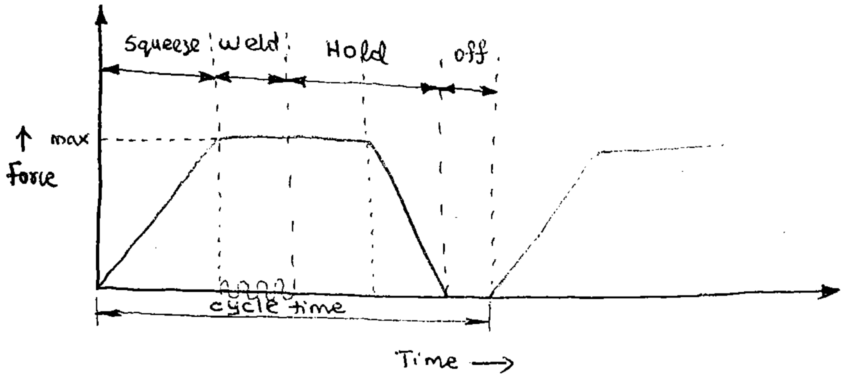
If this much temp is been passed for a bit long time it may leads to burning of plates or entire melting of the plates.

The time is been controlled in such small fraction by using AC current with a relay.

P.S → Relay →
50 Hz eg: (5 cycle)

$\tau = \frac{5 \text{ cycle}}{50 Hz} = \frac{1}{10} = 0.1$ Sec

Whenever the power supply is given, relay will allow only a set number of cycles of power only.



Time during which the air present in the joint would be squeezed out or driven out is called squeeze time.

Time during which the current is passing through the circuit is called weld time (τ)

$$H G = I^2 R (\omega \cdot \tau)$$

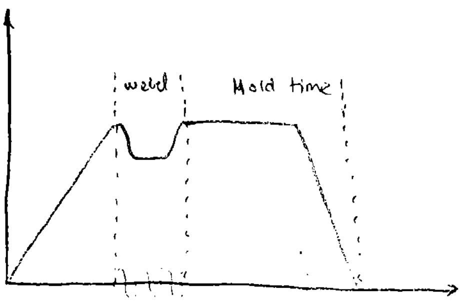
Time during which the force is continued to hold until the molten metal produced will get solidified is called hold time. (otherwise expansion occurs)

Time during which the complete resistance welding equipment is switched off is called off time.

This is to account for

- time taken for shifting of electrodes from present position to the next position
- To account for the rest time in duty cycle.

modification to increase efficiency of resistance weld cycle

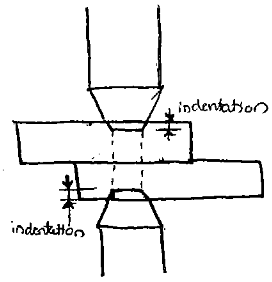


1. During weld time, the force applied on the plates can be reduced slightly so that the roughness of the surfaces will be trying to regain and it increases resistance of which intern increases the heat generation and size of the weld bead.

2. Just b/se reducing force in hold time; 1 or 2 cycles of pa...

of weld bead, to reduce the brittleness & increase the toughness.

Efficiency of resistance welding



$$\eta_{EU} = \frac{\text{Heat Utilized}}{\text{Heat Supplied}} = \frac{H \cdot U}{H \cdot G}$$

$$HG = m(SH + LH)$$
$$= m\left(C_p(T_m - T_r) + LH\right)$$
$$= \rho V\left[C_p(T_m - T_r) + LH\right]$$

actual nugget is eliptical but it's difficult to obtain the dimensions of it. ∴ for theoretical calculation of volume of weld bead - the approx. shape of the weld bead produced is cylindrical with dia equal to dia of the electrode tip and ht is equal to the distance b/w 2 electrode tips.

$D = 6\sqrt{t}$ t - avg thickness of plates to be joined.

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

$$\boxed{HG = \rho\left(\frac{\pi}{4}D^2 h\right)\left[C_p(T_m - T_r) + LH\right]}$$

$$\eta_{EU} = \frac{HU}{HG}$$

$= 85 - 95\%$ for resistance welding (highest *)

If $\eta_{eu} = 100\%$ ⇒ $HU = HG = m(SH + LH)$

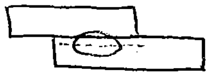
$$\boxed{I^2 R t = m(SH + LH)}$$

$\eta_{eu} = 45 - 55\%$ - Arc welding

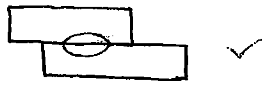
$\eta_{eu} = 55 - 65\%$ - Gas welding

methods of improving the strength or load bearing capacity of the resistance welded joint

① To increase the strength; the major axis of eliptical magget must coins with the axis of the joint

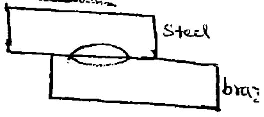


The chances of ~~act~~ shifting of major axis of eliptical maggot may happen due to the total resistance above the joint is different from below the joint



This mainly happen due to the change in R_3 at top and bottom.

Change in R_3 will happen during joining of diff thicknes plates of same m[aterial] or by joining diff material plates of same thicknes. or different thicknes plates ~~and~~ made of different materials.



To ensure that the major axis of the eliptical magget is coinciding with the axis of the joint, the total resistance above the joint must be made equal to total resistance of the joint below.

This is possible by changing the electrode material or by changing the dimensions of the electrode.

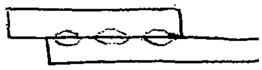
If higher resistance is needed on any side use Tungston.
(if the magget produced is low)

If lower resistance is needed on any side use Cu
(if weld bead is very large

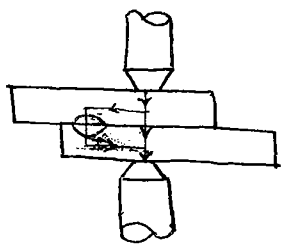
Mainly the diameter of the electrode is been changed (not the length)

$$R = \frac{\rho L}{A}$$

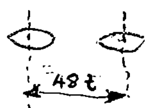
② By increasing the over lap of the plates, many number of maggets will be produced in the plates.



when producing multiple maggets; during making of 2nd and subsequent maggets; the shunting of or bipassing of electricity may take place. The shunting is the property of electricity that which always try to pass through the continuous material rather than discontinuous material; if it's available nearby

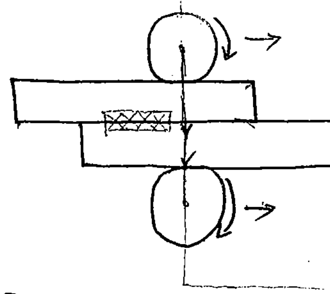


Shunting can be eliminated by maintaining optimum spot spacing.
minimum spot space to avoid shunting is $\geq 48t$



③ By using continuous resistance welding or resistance seam welding.

Resistance Seam Welding



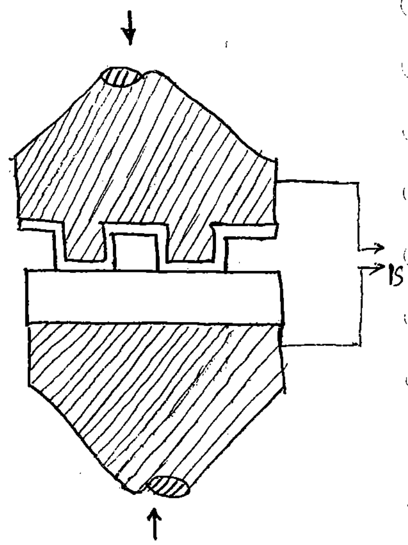
The continuous resistance welding b/w the two plates to be joined

disc shaped electrodes are used

The problem of shunting of electricity is very severe and it cannot be eliminated.

∴ To get the req. amt. of current at joint whatever the amount of current which is bipassing, the corresponding amount of current has to be increased at the supply conditions itself.

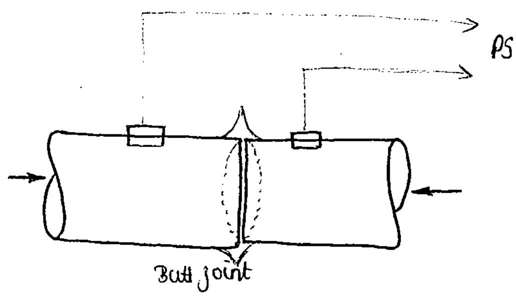
Resistance Projection Welding Operation :-



The method of joining a projectioned component by using resistance spot welding operation is called the resistance projection welding.

The shape of the electrode will be same as the shape of the component to be joined

Percussion Welding Operation



This is a non-fusion pressure welding

end-to end joining is done - so butt joints are produced

No separate electrodes are used - the components to be joined acts as electrode

In this the power supply will be given first so that the joint can be heated to a temperature nearly equal to the M.P temp. of the material. So that the material of the joint will become very soft and atoms present in the surfaces will more active to share the energy.

Now stop the power supply and apply the force percussively (suddenly).

Thus a surface alloy joint would be forming b/w materials

During the process some amount of materials projects from the joint as a flash.

∴ its also called as Flash butt welding.

It gives lower joint strength and are used for joining of shafts from end to end

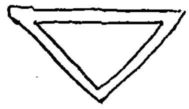
Common application of Resistance welding

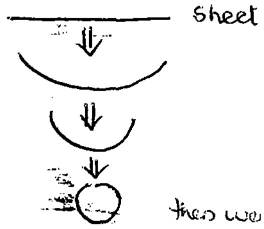
① Where ever leak proof joints is to be produced

eg:- pressure vessels, fuel tanks of automobiles.

② where ever the increase in weight of the system is not allowed.

eg:- Aircraft construction, manufacturing of structural tubes of a cycle, space craft.



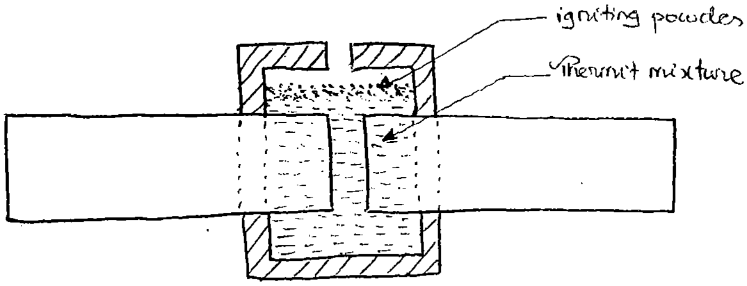


③ Joining of throw away type of tip of tools to the tool bodies.

Thermit welding

Thermit mixture $\xrightarrow{\text{chem. reaction}}$ $\boxed{\text{heat}}$ + residues

$$\underbrace{Fe_3O_4 + Al}_{\substack{\text{Thermit Mixture} \\ \text{(powder)}}} \longrightarrow \underset{\text{filler rod}}{\underset{\downarrow}{Fe}} + \underset{\text{Slag}}{\underset{\downarrow}{Al_2O_3}} + \underset{\text{melting of plates}}{\underset{\downarrow}{heat}}$$



$T_{max} = 3750 - 4000°C$

The initiation for burning of igniting powder will be given by using a ~~bat~~ match box.

The most commonly used igniting powders are <u>barium Peroxide</u> or <u>Magnesium</u>

When igniting powder is burned ; the heat generated will be used for initiating the exothermic chemical reaction of thermit mixture ~~and~~ and produce iron, Al_2O_3 and heat.

Mainly developed for joining of rails in remote areas like hilly, forest areas etc where electricity is not available for joining.

also be used for joining of thick components.

Pre heating.

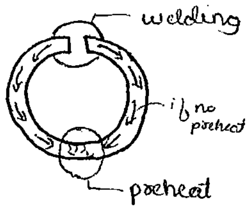
Heating the joint before welding

→ It remove the dirtiness present in plates like for evaporating grease, oil, H_2O etc

→ Whenever high thermal conductivity and high M.P materials are to be joined.
Bcz- during welding of such materials; the heat lost by conduction is very high ∴ it's to difficult to raise the plate to Melting Point.
By doing the preheating - the heat lost by conduction can be reduced (by maintaining less temp difference)

→ During joining of high expansion materials - when the plates are preheated, the weld bead will be cooled slowly and cracking tendency can be eliminated.

→ During joining of ring like structures; the ring should be preheated at a place exactly opposite to that of the weld bead. so that the cracking tendency of the ring will be eliminated



→ whenever the welding speed is to be increased. Instead of raising the temp from room temp; only from an intermediate temp.

Post heating:-

Heating the weld bead after the welding

→ To relieve internal residual stresses present in the weld bead

→ To reduce the brittleness and increase the toughness of weld bead

→ To convert martensite structure present in weld bead into troostite or sorbite

Weldability

The ease with which the welding of given metal can be done with out producing defects in the weld bead.

Factors :-

① M.P of the metals to be joined

Both very high MP and Very low M.P materials are taken as a difficult weld materials

Medium MP materials are taken as 'easy to weld' materials.

② Thermal conductivity of metals to be joined

High thermal conductivity materials are taken as difficult to weld materials
bz - the heat lost by conduction is very high and it is difficult to raise the plates to M.P.

If a material is having high MP and high thermal conductivity it is treated as
Cast iron - but could be welded by pre-heating

③ Coefficient of thermal expansion of materials

High expansion materials are taken as difficult to weld material bcz. it produces crack very easily in the weld bead

④ Reactivity of the metal

Highly reactive metals - very difficult to weld. eg:- Al, Mg

⑤ Electrical resistance

highly electrically resistance materials - very difficult to resistance w

⑥ Surface condition

Dirty surfaces are difficult to weld

Q write Cu Al MS CI in decreasing order of its weldability

MS → Cu → CI → Al

29/8/11
8-9am

Defects in welding

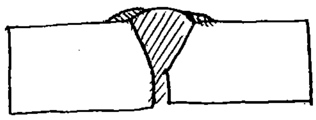
1 External defects (seen from outside
2 Internal defects

1	2
1 Over lap	1. Internal porosity
2 Under cut	2. Internal cracks
3 Spatter	3. Slag inclusion
4 Crater	4. Incompletely filled groove
5 Excessive convexity	5. Lack of fusion
6 Excessive concavity	
7 Surface porosity	
8 Surface cracks	

① Overlap

If the excess of metal is provided at one side or both the sides of weld bead.

Reasons



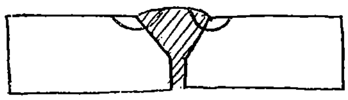
Magnetic arc blow with DCRP

Manipulation of torch movement in gas welding

Excessive current condition

② Undercut

Reasons



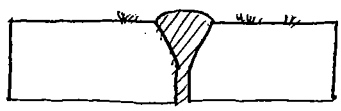
Use of DCSP with magnetic arc blow

Excessive arc length ⇒ force of arc is high

Insufficient size of the electrode

③ Spatter

During welding due to force of arc or flame, some of the molten metal particles are jumping from the weld pool and falling on the other areas of plate.



Reasons

Lower welding speed if used for welding large thickness plate.

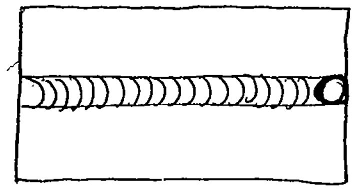
Excessive arc length

Magnetic arc blow

Manipulation of the torch movement.

④ Crater

Shallow spherical depression produced at the end of the welding

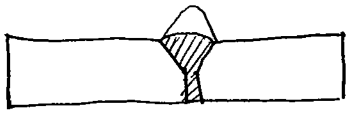


Reasons

Incorrect torch angle or electrode angle at the end of the welding.

⑤ Excessive convexity

Reasons



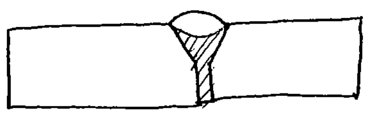
Lower welding speed with DCRP

Excessive size of the electrode

Excessive current conditions

⑥ Excessive concavity

Reasons

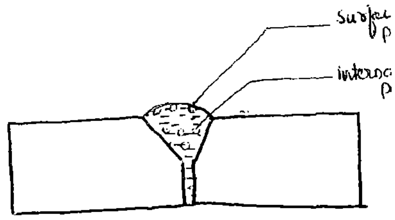


Use of DCSP with high welding speed

Insufficient size of the electrode

Insufficient or incorrect current conditions

① Internal porosity



Small size air particles or gas particle present on the surface of weld bead is called surface porosity and if it is present at the inside it is called internal porosity.

Reasons

Gas welding with out the use of flux

Arc welding with the use of bare wire electrodes

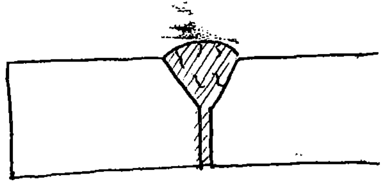
Use of damp electrodes (excessive cellulose coated electrode)

Use of shielding gases during welding.

⊛ No blow holes would produced in welding

② Internal Cracks

If cracks are present in the surface of the weld bead it's called surface crack and if found inside ; it's called internal cracks



Reasons

Presence of residual stresses in the weld bead bcz of arresting the distortion taking place in the joining plates.

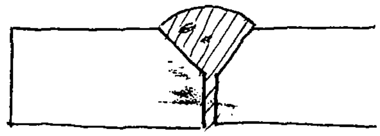
Joining of high expansion materials without preheating.

Use of hydrogen as a shielding gas during welding of ferrous materials (absorb H_2 and become brittle)

Allowing the tungsten diffusion in TIG welding.

③ Slag inclusions

The presence of slag particles inside the weld bead.



Reasons

Use of forehand welding technique in gas welding

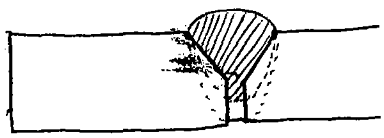
Incorrect selection of fluxes in gas welding or flux coatings in the arc welding.
(flux 3 near to parent material)

Improper cleaning of the weld bead in multipass welding.
Excessive used of flux in welding

④ Incompletely filled pool

Reasons

Joining of high thermal conductivity high M.P materials without preheating.



Joining of dirty surfaces without preheating.

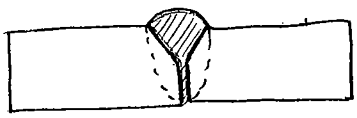
welding of high MP ~~and~~ higher thickness plates using small torch angle.

joining of high MP materials or higher thickness plates using dcRP

lower amount of the root cap.

⑤ Lack of fusion :-

No melting of parent material is taking place



Reasons are same as incompletely filled pool

Welding classroom booklet (chapter 2)

1 $P = 0.4 + 0.8L - 0.1L^2$, Loss $= 20\%$, $\rho = 8\,g/cc$, Heat req per g/cc $= 1400\,J$, $l = 1000$, $t = 5m$

No: k given ; - so

Speed ~~velocity~~ $\Rightarrow V = \dfrac{\text{length}}{\text{~~Arc~~ on time}} =$

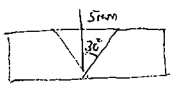
$\dfrac{dP}{dL} = 0.8 - 0.2L = 0$

$L = \underline{4mm}$

$P = 4 + 0.8 \times 4 + 0.1 \times 4^2$

$= \underline{5.6\,KW}$

Welding speed $= \dfrac{l}{AOT}$



$= \dfrac{l \times \text{heat supp} \times \eta}{\text{Het req}}$

$=$

Heat req $=$ mass of w.B $\times$ H.R/g

$= (A \times l \times \rho) \times 1400$

$= \left(2 \times \frac{1}{2} \times 5 \tan 30 \times 5\right) \times 100\,0 \times 10^{-3} \times l \times 1400$

AOT $= \dfrac{\text{Head req}}{\text{heat supplied} \times \eta}$

$= \dfrac{HR}{P \times 0.8}$

2 $V_a = 20 + 40\,l$

$V_p = V_0 - \dfrac{V_0}{I_S} I$

$V_a = V_p$

when $L = 3mm \rightarrow I = 500A$ (he has not given respectively so for less arc len high curr)

$V_a = 20 + 400 \times 0.3 = 32 = V_0 - \dfrac{V_0}{I_0} \times 500$

when $L = 5mm \xrightarrow{V_a} I = 400A$

$V_a = 20 + 40 \times 0.5 = 40 = V_0 - \dfrac{V_0}{I_0} \times 400$

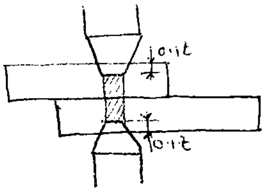
$V_0 = \underline{\underline{72\,V}}$

$I_S = \dfrac{V_0 \times 100}{8} = \underline{\underline{900A}}$

(3). $H \cdot G = I^2 R t$

$= (10000)^2 \times 200 \times 10^{-6} \times \frac{5}{50} =$

(4)



$H \cdot R = \text{mass} \times HR/g$

$= \left(\frac{\pi}{4} D^2 \times h\right) \rho \times 1380$

$=$

$D = 6\sqrt{t} = 6\sqrt{5}$

$h = 2t - 2 \times \text{indentation}$

$= 2t - 2 \times 0.1t = 1.8t$

(5) $P_r = 50\ \text{KVA}$ $V_r = 25\ \text{V}$

so $I_r = \frac{P_r}{V_r} = \frac{50 \times 10^3}{25} = \underline{\underline{2000A}}$

$D_r = 50\%$

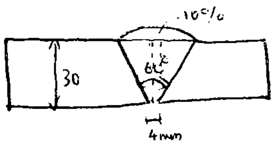
$I_d = 1500A$

$D_d = \frac{I_r^2 D_r}{I_d^2} =$

$D_d = \frac{AOT}{TWT}$

$AOT = Q \times T \cdot W \cdot T$

(6)



No of electrodes $= \frac{\text{Total vol of weld bead}}{\text{volume of electrode}}$

$= \frac{1.1 \times \left[(30 \times \tan 30) \times 30 \times 2 + 4 \times 30\right] \times 1000}{\left[\frac{\pi}{4} \times 4^2 \times (450-50)\right]}$

$= \underline{\underline{140}}$

(7) $x = 200$

No of electrode/pan $= \frac{1000}{200} = 5$ electrode

No of panes $= \frac{140}{5} = 28$ panes.

(8). AOT/pan $= \frac{1000}{100} = 10\text{min}$

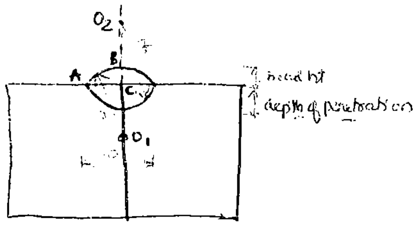
$AOT = 28 \times 10 = 28\text{min}$

$TWT = \frac{AOT}{DC} = \frac{280}{0.6} = 467.67\text{min}$

(9) $H \cdot I = I^2 R \lambda \eta$

$= (150)^2 \times 36 \times 10^{-6} \times \frac{900}{300} \times 60 \times 0.8$

(10)



Bead ht $= BC = O_1C - O_1B$

$= 20 - \sqrt{O_1A^2 - AD^2}$

$= 20 - \sqrt{20^2 - 5^2} =$

Depth $= BD = O_2D - O_2B$

$= 7 - \sqrt{O_2A^2 - AB^2}$

$= 7 - \sqrt{7^2 - 5^2}$

$=$

(11)

$Q_{g_1} = I^2 R$

$= \frac{V^2}{R} = \frac{V^2}{R_{c_1}}$

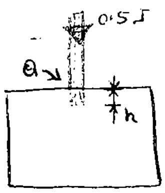
$R_{c_1} = 0.85 \times \frac{\rho}{\alpha \pi a}$

$= \frac{0.85 \times 2 \times 10^{-5}}{25 \times \pi \times 0.01} =$

$Q_{g_1} = \frac{V^2}{R_{c_1}} = \frac{5^2}{R_{c_1}} =$

$Q_{g_2} = \frac{V^2}{R_c^2}$

(12)



$H \cdot S = H \cdot U$

$0.5 = m(SH + LH)$

$= \text{Vol} \times \rho\,(C_p(T_m - T_0) + L)$

$0.5 = a \times h \times \rho\left[(896(933-303) + 398 \times 10^3)\right]$

$h = 3.85\text{mm}$

(13) C

(14) $HI = \frac{V I \eta}{\text{Speed}}$

$= \frac{25 \times 200 \times 0.65}{\frac{18}{60}} = \underline{\underline{10.83}}$

(15) filling area = filled rate

$\frac{\pi}{4} d^2 \times f = A \times \text{Speed}$

$A = \frac{\frac{\pi}{4} \times 1.2^2 \times 4000}{180} = 25$

(16)

$H.S = H.U$

$I^2 R \tau = m \cdot H.R/kg$

$= Vol \cdot \delta \times 1400$

$= \frac{\pi}{4} \times 5^2 \times 1.5 \times 10^{-9} \times 8000 \times 1400 \times 10^3$

$I = \sqrt{\frac{(\quad)}{200 \times 10^{-4} \times 0.1}} =$

(17)

$HI = Q_g = VI = 150 \times 30$

H.R for melting of electrode $= \frac{\pi}{4} d^2 f \delta [C_p(T_m - T_s)]$

$\eta = \frac{H.R}{Q_g \times 2/3} =$

(18)

(19) $\eta = \frac{H.R}{H_g}$

$\left[\begin{array}{l} HR = Vol \times \delta \times 2.9 \\ HG = I^2 R \tau \end{array} \right.$

$= 6000 \times 7.5 \times 10^{-6} \times 1.5$

(20) $V_0 = 80$ $I_s = 800$, $I_1 = 500$, $L_1 = 5$ $I_2 = 460$ $L_2 = 7$

$V_a = V_p$

$V_a = E = a + bL$

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

$V_a = V_p$

$a + b \times 5 = 80 - \frac{80}{800} \times 500$

$a + b \times 7 = 80 - \frac{80}{800} \times 460$

$a =$ $b =$

(21) C

(22) $3V + I = 240$

At eqlbm condition

$V_a = V_p$; $I_a = I_p$

$I = 240 - 3V$

$P = VI = V(240 - 3V)$

$= 240V - 3V^2$

for optimum power

$\frac{dP}{dV} = 0$; $240 - 6V = 0$

$V = \frac{240}{6} = \underline{\underline{40V}}$

(23) Ans: 27 (not given in choice)

(24) 344 (c)

(25)

$H.G = I^2 R \tau$

$= 360$

$H.D = HG - HR$

$= 360 - 344$

$= \underline{\underline{16}}$

(26)

$H.R = Vol \times H.R/m^3$

$= \frac{\pi}{4} (D_0^2 - d^2) \times 1 \times 2 \times 64.4 \times 10^6 \times 10^{-9}$

$H.S = P = VI = \frac{V^2}{R}$

$\frac{H.R}{H.S} =$

(27) B (28) B

(29) $Q_g \propto I^2$

$\propto t$

$t \propto I^2$

$I_2 = I_1\sqrt{\frac{K_2}{K_1}} = 160\sqrt{\frac{5}{10}}$

=

(30)

(31) B

(32) A

(33)

$F = P \times A \times U$

$T = F \times \frac{2}{3} \times R$

$P = \frac{2\pi NT}{60 \times 1000}$

(34) A true R false

C

(35) 'B'

METAL CUTTING

Ref:- Metal Cutting by Redford and Booth Royd
Metal Cutting by Sen and bhattacharya
Metal cutting tool by Nag pal
Experimental investigation in metal cutting by VC Venkatesh.

Metal cutting is a process of analysing machining or metal removal process for determining the forces in machining operation, power consumption in machining operation, the temp. induced in machining operation, tool life etc.

<u>Hot hardness temperature</u>: the minimum temp. above which increase in temperature causes considerable reduction in the hardness of a tool material.

H.C steel tool

	Temp	hardness
	30°C	Rc 65
	100°C	Rc 64
	200°C	Rc 63
hot hardness temp of High Carbon steel →	250°C	Rc 62
	260°C	Rc 61

By knowing the <u>forces</u> in machining the <u>rigidity</u> requirement of the machine <u>tool</u> can be estimated. By knowing the <u>power consumption</u> in machining, the <u>capacity</u> of the <u>prime mover</u> required can be estimated. By knowing the temperatures induced during machining; cutting tool material is selected, Such that the hot hardness temp of metal > the temp induced during machining. By knowing the tool life;- the process parameters can be adjusted & the tool life ≥ tool changing time.

TYPES OF TOOLS

The machining operation is generally done by using 2 types of tool

① <u>Single point cutting tool</u>

If only one cutting edge is available from removing materials from the workpiece

eg:- Turning tools, shaping tools, facing tools, chisels etc

In general; Material removal rate with single point cutting tools is lower.

② <u>Multi Point cutting tool</u>:-

If more than one cutting edge is available for removing the material from the workpiece.

eg:- Drill bits, Milling cutters, broaching tools, grinding wheels etc.

Factors influencing Machining Operation [broadly]

① Properties of work piece materials :-

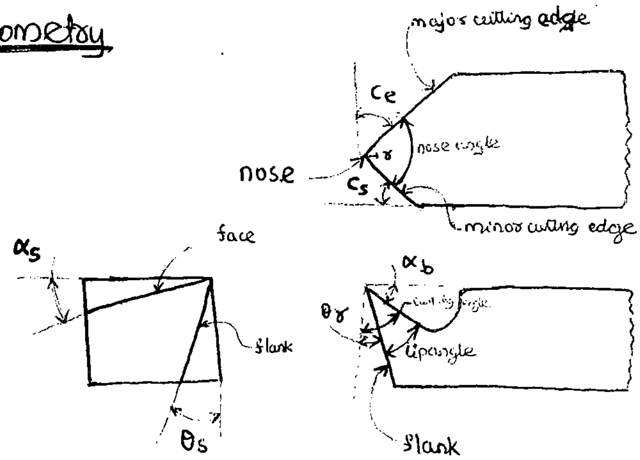
when hardness ↑ → forces increases → Power consp ↑ — tool life ↓

② Tool Geometry

③ Use of cutting fluids or coolants

④ Process parameters – interaction b/w tool & workpiece (speed, feed, depth of cut)

Tool Geometry



α_b - Back rake
α_s - Side rake
θ_e - End relief
θ_s - Side relief
C_e - End Cutting Edge angle
C_s - Side Cutting Edge angle
γ - Nose radius

standard method of specifying geometric properties of a single point cutting tool on a tool itself is known as tool designation or tool signature.

① ASA system (American standards Association system)

$$\alpha_b - \alpha_s - \theta_e - \theta_s - C_e - C_s - r$$

whatever 6 angles indicated in the ASA system are measured w.r.t to 3 mutually ⊥ planes.

Bcz of this understanding of angles of ASA system is easier and measurement of angles also will be easier.

In the machining operation ; the formation of chip, formation of shear plane and chip flow behaviour are mainly taking place w.reference to the major cutting edge of the tool. ∴ If different properties of a single point cutting tool are known with reference to the cutting edge, the analysis of machining operation would be easier. but in ASA system the analysis of machining operation is difficult.

② ORS system (Orthogonal Rake System)

$$i - \alpha - \theta_s - \theta_e - C_e - \lambda - r$$

inclination angle
orthogonal (effective) side rake angle
side relief
end relief angle
End cutting edge angle
Approach or Entering or principal angle
nose radius

The angles specified in ORS are measured w.r.t cutting edge of the tool.

Bcz of this it's very easy to analyse the machining operation.

But the understanding of angles and measurement of the angles is very difficult.

→ The most commonly used method of designation of single point cutting tool is ASA system.

→ If nothing is mentioned in the problem, the given designation is always assumed as a ASA system of designation.

A given tool can be designated by using both of the methods.
∴ there must be a relationship b/w the angles of ASA and ORS.

Relation ship

$$\begin{bmatrix} \tan i \\ \tan \alpha \end{bmatrix} = \begin{bmatrix} \sin\lambda & -\cos\lambda \\ \cos\lambda & \sin\lambda \end{bmatrix} \begin{bmatrix} \tan\alpha_b \\ \tan\alpha_s \end{bmatrix}$$

$|||^{rly}$

$$\begin{bmatrix} \tan\alpha_b \\ \tan\alpha_s \end{bmatrix} = \begin{bmatrix} \sin\lambda & \cos\lambda \\ -\cos\lambda & \sin\lambda \end{bmatrix} \begin{bmatrix} \tan i \\ \tan\alpha \end{bmatrix}.$$

$$\begin{bmatrix} \cot\theta_s \\ \cot\theta_e \end{bmatrix} = \begin{bmatrix} \sin\lambda & -\cos\lambda \\ \cos\lambda & \sin\lambda \end{bmatrix} \begin{bmatrix} \cot\theta'_s \\ \cot\theta'_e \end{bmatrix}$$

$|||^{rly}$

$$\begin{bmatrix} \cot\theta'_s \\ \cot\theta'_e \end{bmatrix} = \begin{bmatrix} \sin\lambda & \cos\lambda \\ -\cos\lambda & \sin\lambda \end{bmatrix} \begin{bmatrix} \cot\theta_s \\ \cot\theta_e \end{bmatrix}$$

$C_e \Rightarrow$ remains same

$|||^{rly}$

$C_s = 90 - \lambda$

$\lambda = 90 - C_s$

$\gamma \Rightarrow$ remains same

③ Normal Rake System (NRS)

Used before the invention of ASA and ORS.

Only 2 parameters are used.

α_n = normal rake angle.

θ_n = normal relief angle.

ORS to NRS

$\alpha_n = \tan^{-1}(\tan\alpha \cos i)$ • $\alpha_b(=ASA) = \alpha(ORS) = \alpha_n(NRS)$

$\theta_n = \tan^{-1}\left(\dfrac{\tan\theta'_s}{\cos i}\right)$

Effect of Tool Geometry

① Back rake angle (α_b)

When back rake angle increases ↑

Resisting area available for resisting load decreases ↓

Strength ↓

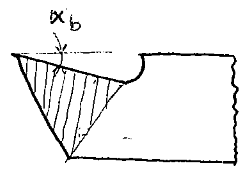
Force required for machining ↓

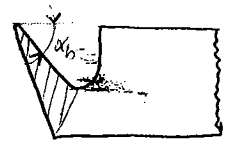
Power consumption ↓

Friction ↓

Tool wear ↓

* Tool life ↑ – If tool fails due to lack of strength; it's considered as abnormal failure and it's not considered in tool life calculation.





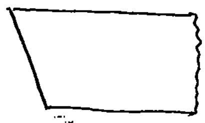
+ve back rake angle

+ve back rake angle

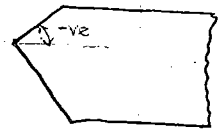
Most commonly used rake angle in the machining operation bcz the chip flow in the rake face would be easier.

The max. possible +ve back rake angle used is 45°

bcz beyond 45°; the reduction in the strength of the tool is very high. ∴ the tool will fail easily.



'0' back rake angle



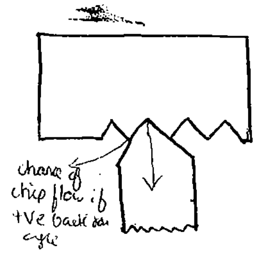
'-ve' back rake angle

'0' rake angle

Used during → machining of brass work pieces
→ Thread cutting operation.

During machining of brass with '0' rake angle, the surface finish produced is better due to the crystallographic structure of brass.

To avoid the weakening of threads during thread cutting operation. The '0' rake angle must be used. So that no-sideward flow of the chip be taking place.



-ve back rake angle

The usage of -ve rake angles has been started with the introduction of carbide tipped tool – bcz the carbide tools are very weak in tension.

-ve rake angle is nothing but the rake angle is reducing due to this

forces ↑ Power consumption ↑ Tool life ↓

Hence maximum -ve rake angle used is only upto 10° only.

② Side rake angle (α_s)

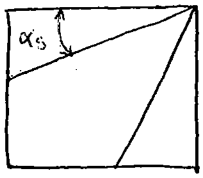
when side rake angle ↑

Strength ↓

forces ↓ slightly

Power required ↓

Tool life ↑



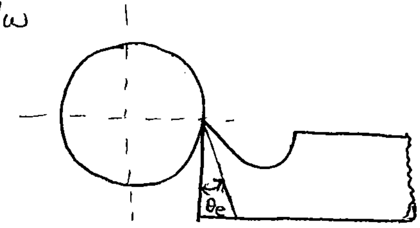
- with increase in α_s the amount of chip bending in width direction reduces

Generally it's of 5-15°.

③ Relief angle (θ_e, θ_s)

Provided mainly for avoiding the rubbing action b/w tool and workpiece

with '0' relief angle ; the tool is simply rubbing onto the workpiece without doing any machining



~~forces~~ Strength ↓

force required ↓ slightly

Power consumption ↓ slightly

Tool life ↑ slightly

Generally θ_e and θ_s = 5 to 15°

④ ~~Cutting~~ Edge angle

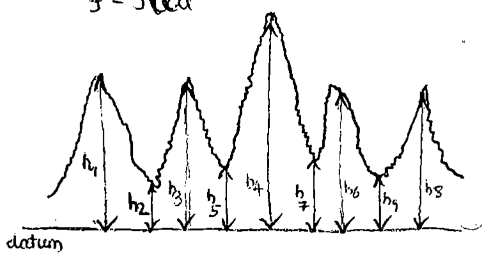
Mainly Influencing the surface finish produced in the workpiece.

surface finish is measured using R_t

R_t = max peak to valley height

$$\boxed{R_t = \frac{f}{\tan C_s + \cot C_e}}$$

f - feed



The increase in the value of R_t will indicate that the surface finish produced on the component is poor.

C_e ↑ R_t ↑ - poor surface finish

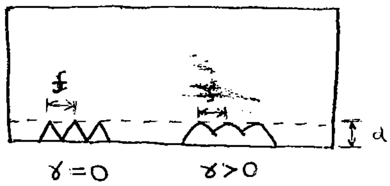
C_s ↑ R_t ↓ - Good surface finish.

C_e = 8-20°

C_s = 0-90°

⑤ Nose Radius

With increase of nose radius - the surface finish produced on the workpiece would be better.

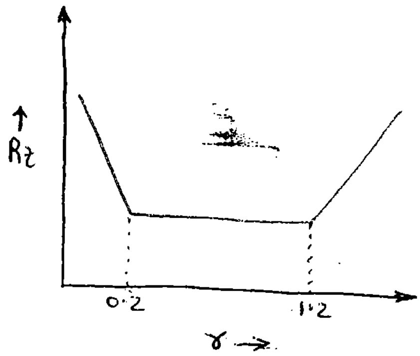


The surface finish obtained

$$\boxed{R_z = \frac{f^2}{8\gamma}}$$

f - feed mm/rev

$\gamma \uparrow$ $R_z \downarrow$ surface finish would be better.



On the otherhand on increase of nose radius the contact area b/w the tool and workpiece will increase. It increases the forces induced during machining, vibrations and chattering will take place.

This results into the poor surface finish.

The optimum nose radius which gives better surface finish is 0·2 to 1·2 mm

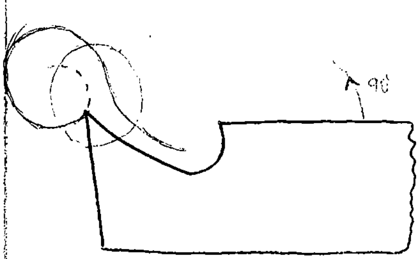
Q A tool 5-7-3-8-12-75-0·3mm ; feed = 0·1mm/rev - Surface finish ?

$$R_t = \frac{0·1}{\tan 75 + \cot 12} = 0·0118$$

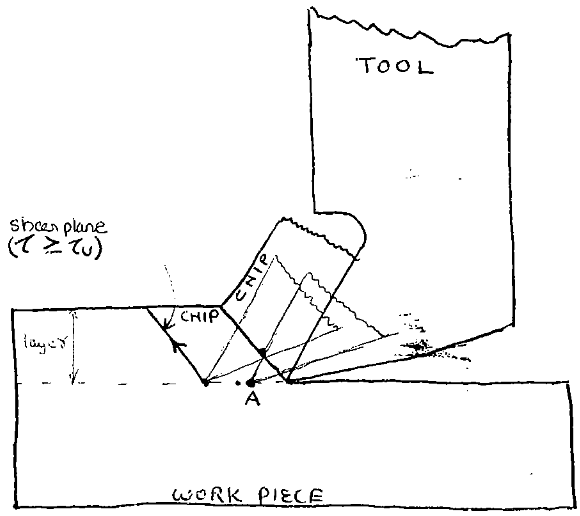
$$R_t = \frac{(0·1)^2}{8 \times 0·3} = 0·00416$$

Take the lowest (Rt) as the surface finish

Mechanism of chip formation:-



⇨



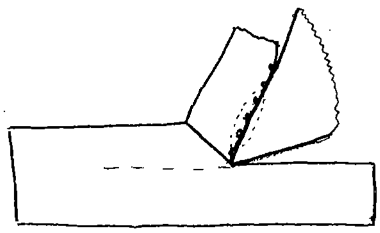
When the force is applied by using tip of the tool on to the layers of workpiece material; the material start deforming plastically and slide over the rake face of the tool producing shear stresses in the layers of work piece material. On further application of the force by using tip of the tool; the shear stress induced in the layer of work piece material are incr of work material so that the shearing or cracking ~~is~~ start taking place. at the tip of the tool and propagate towards the surface producing shear plane and chip.

From the above the mechanism by which, the chip formation taking place is shearing and tearing

During machining of soft workpieces - bcz of higher toughness, whatever the shearwave or energy wave propagating in the material is absorbed by the material and dissappearing somewhere in the middle maintaining continuity of the chip at the topside. Hence continuous chips are produced.

In case of machining of hard and brittle work pieces bcz of lower toughness; the energy wave can propagate very easily upto the surface producing discontinuous chip.

builtup edge formation



During machining - always microchips or powdered particles are produced and moving on the rake face of the tool.

when powdered particles are moving on the rake face; they may get adhered or welded on to the rake face bcz of presence of the very high temperatures at the chip tool interface.

This adhering of microchip on the rake face is called built up edge.

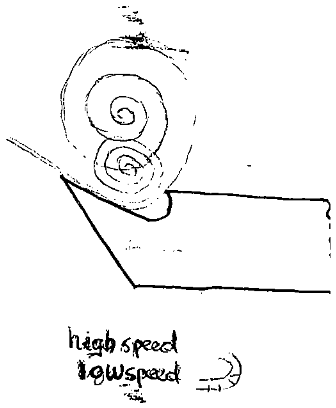
Builtup edge formation is taking place only with continuous chips bcz in case of discontinuous chips ~~or~~ as and when the chip is producing; It is immediately thrown away from the machining zone. So that microchips also will be thrown away. and No adhering will be taking place.

Due to the formation of builtup edge - the advantage is that whatever the wear has to takeplace on the rake face, only builtup-edge is wearing out. Hence toollife increases.

But with the formation of builtup edge - the surface finish of the rake face of the tool will reduces, the friction increases and forces and power consumption will increase.

Types of chips :-

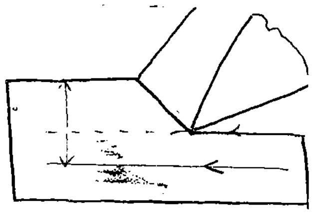
① Discontinuous chip :-



Hard and brittle w.p when worked ; irrespective of work conditions. Only discontinuous chips are formed.

If we work with soft work pieces
low speed
During machining of softwork pieces with low speed; the radius of curling of chip is low - amount of bending of the chip is high. ∴ the cracks which are already present in the chip will propagate easily and produces discontinuous chip.

small rake
With small rake angle ; the forces in machining are higher — the magnitude of energy wave is high. ∴ it can easily propagate upto the surface and produces discontinuous chips.



large uncut chip.
During machining with large uncut chip thickness ; the forces to be applied by using the tool is high and the magnitude of energy wave is high. ∴ the energy wave can easily propagate upto the surface.

* with use of cutting fluids

During machining operations bcz of high temperatures ; the chip is expanding due to thermal expansion. when the cutting fluid is supplied into the machining zone - whatever the heat generated will be carried away by the cutting fluid ; so that the temperature of the chip is reducing and it contracts. ie with in short duration the chip is expanding & then contracting. During the process of expansion & contraction any cracks which are present in the chip will propagate easily & converted into ~~a~~ discontinuous chip.

② Continuous chip without builtup edge

Only possible with soft and ductile materials.

highspeed machining.

large rake angle - forces and power consumption reduces; heat generation is reducing temperature is reducing and at low temperatures - the adhering of micro chips to will be eliminated.

Small uncut chip -

* with cutting fluids - heat carried away , so no - adhering.

③ Continuous chips with builtup edge.

Soft and ductile materials
Low speed
Small rake
Large uncut chip
without cutting fluid.

Q During face turning of ductile workpiece material with optimum cutting velocity; from surface towards the centre. The type of the chips produced is.

(A) Continuous throughout
(B) Discontinuous throughout
(C) Continuous in beginning and discontinuous at end
(D) Discontinuous in beginning and continuous at end.

$$V_c = \frac{\pi d N}{1000}$$

as d - reduces — V reduces

Thus V falls below optimum & thus forms discontinuous at end.

Ans 'C'

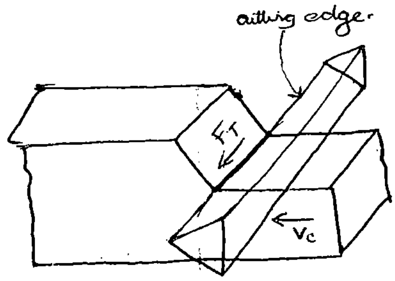
* In general it's preferable to have the discontinuous chip bcs it's very easy to dispose them.

In certain situation only continuous chips are produced, in such cases chipbreakers are used to break them to discontinuous.

Methods of machining :-

① Orthogonal machining

If the cutting edge of the tool is ⊥ to the cutting velocity vector, it's called as orthogonal machining



eg:- Jack plane operation used in carpentry.
parting off operation, sawing

② Oblique machining

If the cutting edge of the tool is not ⊥ to the cutting velocity vector;

eg:- Turning, shaping, drilling, milling.

whenever the machining is ~~k~~ taking place. Two components of force will be acting. One parallel to the cutting edge called as thrust force and other acting ⊥ to the cutting edge called as cutting force.

In orthogonal machining - only F_T and F_C are acting. So they are also known as 2-dimensional cutting.

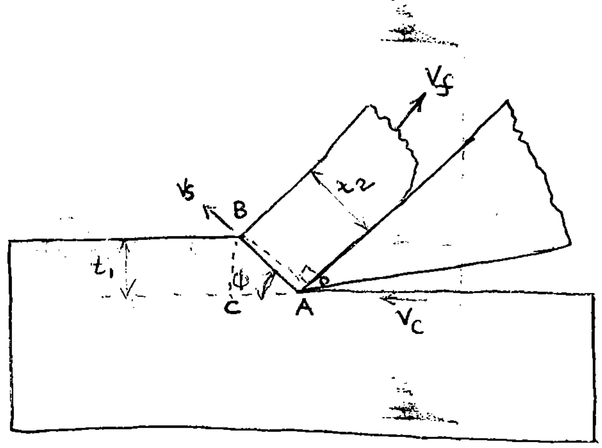
In oblique machining - F_C remains same; but F_T can be resolved to $\boxed{F_T \cos\theta = F_a}$ and $\boxed{F_T \sin\theta = F_r}$. Thus 3 components of forces are acting in machining. So it is also called as 3-Dimensional machining.

Bcz there are no direct methods available for analysis of oblique machining operation, it is always converted into orthogonal and analyse it as orthogonal.

31-8-11
2-5:30pm

ANALYSIS OF ORTHOGONAL MACHINING

Let $\alpha = \alpha_b$ (ASA)
$= \alpha$ (ORS)



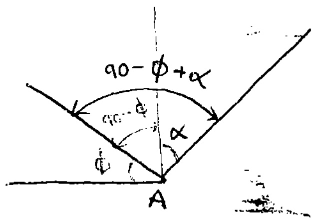
t_1 = uncut chip thickness

t_2 = Thickness of chip after machining opstn.

b_1, b_2 = width of the chip before and after machining operation respectively.

l_1, l_2 = length of the chip per revolution before and after machining operation.

ϕ = Shear angle or shear plane angle (angle made by shear plate w.r.t the cutting velocity vector)



V_c = Cutting velocity or relative velocity b/w the tool and workpiece

V_f = Chip flow velocity or velocity of the chip relative to the tooling.

V_s = Shear velocity (Velocity of chip relative to the workpiece) or shear plane velocity

assumptions taken for the analysis of orthogonal machining are

① Every material undergoing machining operation is considered as incompressible i.e the volumetric changes in the material is taken as zero. 'o

Vol of material before machining = volume of material after machining.

② Width of the chip remains constant

$b_1 = b_2 = b$

During machining operation; the force applied by using tip of the tool is acting like a compressive force along the length direction of the chip so that the volume is reducing in the length direction.
Bcz of incompressibility of the material; whatever the volume reducing the length direction has to be increased in the either thickness direction of width direction; but bcz the width of the chip is much higher than the thickness; the increase in volume takes place only in the thickness direction. Hence the width of the chip is taken as 'constant'.

$$\text{Vol. before} = \text{volume after}$$

$$t_1 b_1 L_1 = t_2 b_2 L_2$$

$$\frac{t_1}{t_2} = \frac{L_2}{L_1}$$

Also

$$t_1 b_1 V_c = t_2 b_2 V_f$$

$$\frac{t_1}{t_2} = \frac{V_f}{V_c}$$

$$\boxed{\frac{t_1}{t_2} = \frac{L_2}{L_1} = \frac{V_f}{V_c} = r}$$ chip thickness ratio.

from $\triangle ABC$;

$$\sin\phi = \frac{BC}{AB} = \frac{t_1}{AB}$$

length of shear plane $$AB = \frac{t_1}{\sin\phi} = L_s \longrightarrow (1)$$

from $\triangle ABD$;

$$\sin(90-(\phi-\alpha)) = \frac{BD}{AB} = \frac{t_2}{AB}$$

$$AB = \frac{t_2}{\cos(\phi-\alpha)} = L_s \longrightarrow (2)$$

$$(1) = (2)$$

$$\frac{t_1}{\sin\phi} = \frac{t_2}{\cos(\phi-\alpha)}$$

$$\frac{t_1}{t_2} = \frac{\sin\phi}{\cos(\phi-\alpha)} = r$$

$$\Rightarrow \quad r = \frac{\sin\phi}{\cos\phi\cos\alpha + \sin\phi\sin\alpha}$$

$\div$ numerator & denominator by $\cos\phi$

$$r = \frac{\tan\phi}{\cos\alpha + \tan\phi \sin\alpha}$$

$$r\cos\alpha + r\tan\phi \sin\alpha = \tan\phi$$

$$\tan\phi - r\tan\phi \sin\alpha = r\cos\alpha$$

<u>shear angle</u>
OR
<u>shear plane angle</u>

$$\boxed{\tan\phi = \frac{r\cos\alpha}{1 - r\sin\alpha}}$$

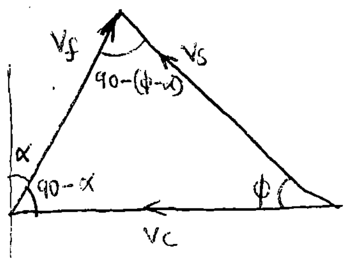
$$\text{ie } \phi = f(r, \alpha)$$

If $\rightarrow$ $r\uparrow \Rightarrow \phi\uparrow$

upto $45^\circ \rightarrow$ $\alpha\uparrow \Rightarrow \phi\uparrow$

* compared to cos, sin has greater var

$\cos 0 = 1$	$\sin 0 = 0$
$\cos 10 = 0.98$	$\sin 10 = 0.17$
$\cos 20 = 0.93$	$\sin 20 = 0.3$
$\cos 30 = 0.86$	$\sin 30 = 0.5$



Applying sin rule

$$\frac{V_c}{\sin[90-(\phi-\alpha)]} = \frac{V_f}{\sin\phi} = \frac{V_s}{\sin(90-\alpha)}$$

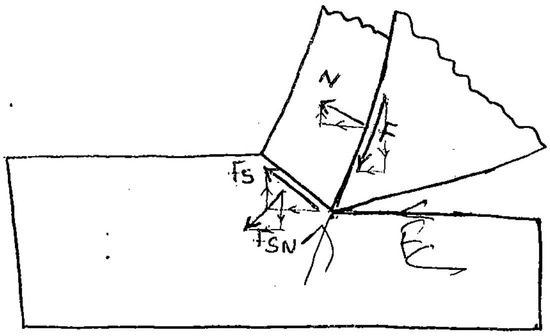
$$\frac{V_c}{\cos(\phi-\alpha)} = \frac{V_f}{\sin\phi} = \frac{V_s}{\cos\alpha}$$

better derive than mug up

also

$$\frac{V_f}{V_c} = \frac{\sin\phi}{\cos(\phi-\alpha)} = r$$

Forces



F = frictional force acting on the rake face of the tool.

N = force normal to the frictional force.

F_s = Shear force acting along the shear plane.

F_{SN} = force normal to the shear plane

These are the 4 actual forces acting during machining operation.
But these forces are not measurable.

F_H - Algebraic sum of the horizontal components of the 4 actual forces - $\boxed{F_T}$ - Thrust force

F_V - Vertical component of 4 actual forces (algebraic sum) - $\boxed{F_C}$ - Cutting force

These vertical and horizontal forces could be measured by using a dynamometer or spring balance

F_H and F_V are actually the resolved components of actual forces. They are also known as measurable forces. (F_T, F_C)

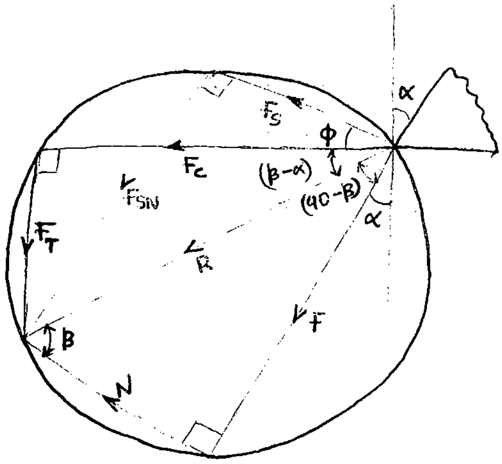
The actual forces are been used in analysis. Since these forces are not measurable. Thus we would find a relationship b/w the measurable force with actual force.
Actual forces are been obtained from the measurable force by using merchant's circle and by using the actual forces machining operations could be analysed.

Resultant force

$$R = \sqrt{F_C^2 + F_T^2}$$

This resultant force could be assumed as the diameter of the merchant cycle.

In merchant circle it is found that 3 right angled Δ's are present and all the 3 triangles are possessing common hypotenuse.
This is used as a basis for establishing the relationship between the measurable and the actual forces



In fig:-
F_T is vertical and F_C is horizon

This is bcz.

In theoretical explanation forces are refered based on the actual machining operation.

But merchant circle is been dra based on machining zone diag (which is been ~~transversed~~ by 9 in anticlockwise direction)

$$\sin\beta = \frac{F}{R}$$

$$R = \frac{F}{\sin\beta} = \frac{N}{\cos\beta} = \frac{F_C}{\cos(\beta-\alpha)} = \frac{F_T}{\sin(\beta-\alpha)} = \frac{F_S}{\cos(\phi+\beta-\alpha)} = \frac{F_{SN}}{\sin(\phi+\beta-}$$

α - came from the tool designation

ϕ - we could calculate from the eqn for shear angle.

β - ?

$$\tan(\beta-\alpha) = \frac{F_T}{F_C}$$

$$\boxed{\beta = \alpha + \tan^{-1}\left(\frac{F_T}{F_C}\right)}$$

also the coefficient of friction at chip tool interface $\boxed{\mu = \tan\beta}$

for detailed eqn for finding coefficient of friction.

$$\tan(\beta-\alpha) = \frac{F_T}{F_C}$$

$$\frac{\tan\beta - \tan\alpha}{1+\tan\beta\tan\alpha} = \frac{F_T}{F_C}$$

$$F_C\tan\beta - F_C\tan\alpha = F_T + F_T\tan\beta\tan\alpha$$

bring $\tan\beta$ to one side and $\tan\alpha$ to other side

$$F_C\tan\beta - F_T\tan\beta\tan\alpha = F_T + F_C\tan\alpha$$

$$\boxed{\tan\beta = \frac{F_T + F_C\tan\alpha}{F_C - F_T\tan\alpha} = \mu}$$

In general cases cutting force > thrust force is $F_c > F_T$

In special cases $F_T > F_c$ — Facing, grinding, broaching

$$\frac{F_T}{F_c} \approx 2.5 \quad \text{for grinding.}$$

$\beta = \alpha + \tan^{-1}\left(\frac{F_T}{F_c}\right)$ since $\frac{F_T}{F_c} > 1$ $\tan^{-1}\left(\frac{F_T}{F_c}\right) > 45^\circ$ so whatever be the 'α' value $\beta > 45^\circ$ [friction angle $\beta > 45^\circ$]

$\mu = \tan\beta$. → Thus coeff of friction μ become >1. But in general μ should be less than 1. Hence for the cases where the coefficient of friction become >1, classical friction Theorem will be used to determine μ.

According to Classical friction Theorem :-

$$\boxed{\mu = \frac{\ln\left(\frac{1}{\gamma}\right)}{\frac{\pi}{2} - \alpha}}$$

or

$$\boxed{\mu = \frac{\ln(K)}{\frac{\pi}{2} - \alpha}}$$

where $K = \frac{1}{\gamma} \Rightarrow$ coefficient of elongation

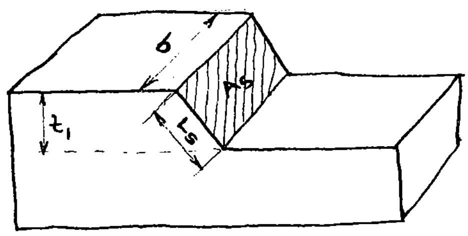
$K = \frac{1}{\gamma} = \frac{t_2}{t_1} = \frac{L_1}{L_2} = \frac{V_c}{V_f}$

α = rake angle in radians

* It's applicable only if μ is found >1 when calculated otherwise.

Shear stress induced

$$\boxed{\tau = \frac{F_s}{A_s}}$$



$$\tau = \frac{F_s}{b \times L_s}$$

$$= \frac{F_s}{b \times \frac{t_1}{\sin\phi}}$$

$$= \frac{F_s \times \sin\phi}{b \times t_1}$$

$$\boxed{\tau = \frac{F_s \sin\phi}{A_o}}$$

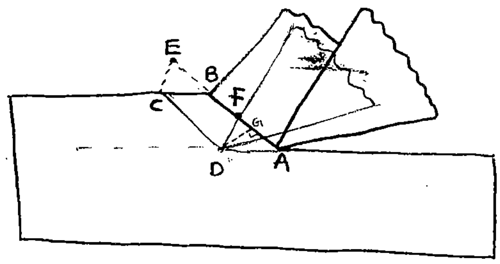
A_o – Area of uncut thickness

For possible machining operation τ must be $\geq$ ultimate shear stress of the work material.

Shear Strain

ABCD - Initial chip

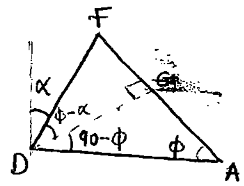
FECD - Final chip



$$\text{Shear strain} = \frac{\text{Deformation in chip at the line of fracture}}{\text{shortest distance b/w two shear planes}}$$

$$= \frac{AF}{OG}$$

$$= \frac{AG}{OG} + \frac{GF}{OG}$$



$$\boxed{SS = \cot\phi + \tan(\phi - \alpha)}$$

for a given tool; the α is fixed; ∴ the shear strain mainly depends on the shear angle ϕ

for minimum shear strain is to be induced in the chip;

$$\frac{d(ss)}{d\phi} = 0$$

$$2\phi - \alpha = 90$$

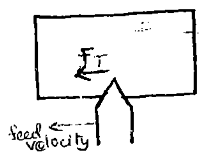
$$\boxed{\phi = \frac{90 + \alpha}{2}}$$

optimum shear angle relationship for minimum shear strain in chip.

WORK DONE OR ENERGY OR POWER REQUIRED FOR MACHINING OPERATION

$$WD = E = P = \text{Force} \times \text{Velocity} + F_T \times \text{feed velocity}$$

$$= F_c \times V_c + F_T \times \text{feed velocity}$$



$$P = F_c \times V_c$$

$$\text{Feed velocity} = f \times N$$

$$= 0.1\,\text{mm} \times 500\,\text{rpm}$$

$$= 50\,\text{mm/min}$$

$$= \frac{50 \times 10^{-3}}{60}\,\text{m/s}$$

$$= 0.000\ldots$$

In actual practice - the shear stresses induced in the machining is > the ultimate shear stresses; so that work done will be high; but if it is required to perform the machining operation; The minimum shear stresses to be induced is just equal to the ultimate shear stress. The corresponding

WD or $P = F_c \times V_c$

$$= \frac{F_s}{\cos(\phi+\beta-\alpha)} \times \cos(\beta-\alpha) \cdot V_c$$

$$\tau = \frac{F_s}{A_o} \times \sin\phi$$

$$= \frac{A_o \tau}{\sin\phi} \frac{\cos(\beta-\alpha)}{\cos(\phi+\beta-\alpha)} \cdot V_c$$

$$F_s = \frac{A_o \times \tau}{\sin\phi}$$

for minimum work done.

$$\frac{d(W.D)}{d\phi} = 0$$

$$\boxed{2\phi + \beta - \alpha = 90}$$

$$\boxed{\phi = \frac{90+\alpha-\beta}{2}}$$

optimum shear angle relation for minimum workdone in machining operation.

OR

MINIMUM ENERGY CRITERIA OF MACHINING

OR

MERCHANTS CRITERIA

To validate this equation (merchant's shear angle relation) practically, Lee & shaffer has tried to conducted experiments. But they failed to prove the merchant's shear angle relation.

They proved another optimum shear angle relation at which the minimum energy of machining will be taking place.

$$\boxed{\phi + \beta - \alpha = 45°}$$

Lee & shaffer shear angle relation

This equation is ~~der~~ obtained by experimentation.

It's not been proved theoretically.

Simultaneously stabler also conducted experiments for proving the merchants shear angle relation. But he also failed. He obtained another shear angle relation.

$$\boxed{\phi + \beta - \frac{\alpha}{2} = 45°}$$

stabler shear angle relation.

*In exam; if simply mentioned - use merchant's relation.

If mentioned use other equations. Once ~~sta~~ lee and shaffer was asked.

Machining constant or Merchant's constant (C_m)

$$\boxed{C_m = 2\phi + \beta - \alpha} = 90^\circ$$

Merchant's constant is used for indicating the amount of shear stresses induced in the material and also the efficiency of energy utilization during machining operation.

If $C_m = 2\phi + \beta - \alpha = 90^\circ$

- $\tau = \tau_u$
- work done is minimum
- $\eta_{\text{Energy Utilization}} = 100\%$

If $C_m = 2\phi + \beta - \alpha > 90^\circ$

- $\tau < \tau_u$ [Impossible case of machining operation]

If $C_m = 2\phi + \beta - \alpha < 90^\circ$

- $\tau > \tau_u$
- $\eta_{EU} < 100\%$

* For every 1° reduction in the machining constant from 90°, nearly 1% reduction in the efficiency of energy utilization $[\eta_{EU}]$ will take place

Q Thus for $C_m = 65^\circ$ $\eta = ?$

Reduction $= 90 - 65 = 25^\circ$

$\eta_{EU} = 100 - 25 = \underline{\underline{75\%}}$

Specific Cutting Energy

The amount of energy required to remove unit volume of material from the work piece.

$$\text{Sp. Cutting Energy} = \frac{\text{Work Done}}{\text{Material Removal Rate}} \quad \underline{J/m^3}$$

$$= \frac{WD}{MRR}$$

$$= \frac{F_c \times V_c}{t_1 \times b \times V_c} \qquad A_0 = t_1 \times b$$

$$\text{Sp. Cutting Energy} = \frac{F_c}{t_1 \times b} = \frac{F_c}{A_0} \quad \underline{N/mm^2} \qquad \boxed{Sp.C.E = \frac{F_c}{A_0}}$$

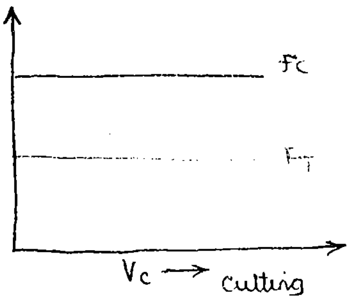
Bcz; the units of specific cutting energy can also be taken as pressure units; the specific cutting energy can also be called as as a specific cutting pressure or specific cutting force.

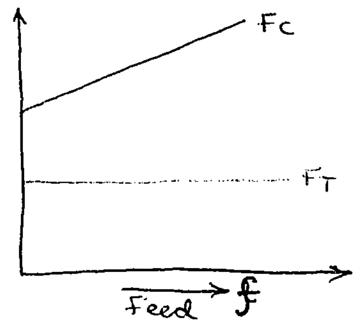
The specific cutting energy will be used for indicating the machinability of the work piece material.

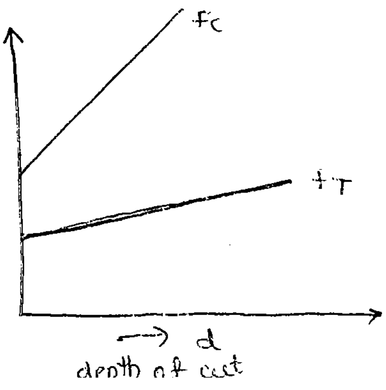
Higher the specific cutting energy for a given material indicate that lower is the machinability of work piece material and viceversa.

Factors affecting the forces in machining

① Process Parameters







Slope of Fc is more.

② Back rake angle (α_B)

For every 1° increase in the rake angle nearly 10% reduction in the F^c in machining will takeplace from the previous value.

$$\alpha b \uparrow \quad F_T, F_C \downarrow$$

③ Use of cutting fluids or coolents

Reduces forces in machining by about 25-40%

④ In case of orthogonal ~~cu~~machining

In case of orthogonal machining only 2 forces are only acting. F_C and F_T. F_C will be 33% and F_T is 66%.

Thus ratio of $F_C : F_T = 2 : 1$

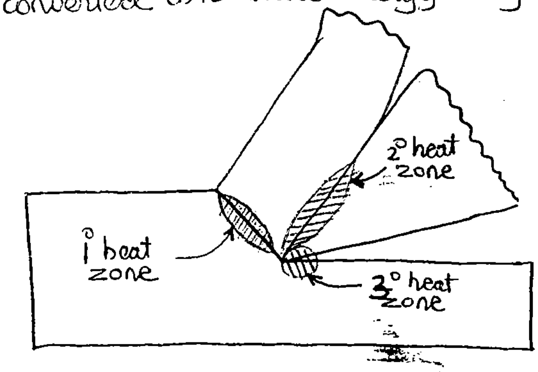
⑤ In case of oblique machining

$$\left.\begin{array}{l} F_C \rightarrow 67\% \\ F_T \rightarrow 27\% \ (F_a) \\ \quad \rightarrow 6\% \ (F_r) \end{array}\right\} \quad F_C : F_a : F_r = 11 : 4.5 : 1$$

Heat Generation in Machining

According 1st law of thermodynamics; whatever be the energy supplied to machining operation would be simply converted into heat energy only.

$$HG = W.D = F_C V_C$$



what ever the energy supplied for machining would be converted to heat energy by 3 zone wise.

① 1° heat zone

In primary heat zone; the energy is supplied for breaking the atomic bond b/w the atoms of the material; so that the atoms release equivalent amount of energy in the form of heat energy. ∴ the heat is generated in the 1° heat zone

60-65% of energy supplied is utilized in 1° zone.

The maximum amount of heat is carried away by the chip and ~~some~~ small amount of heat is carried away by the W.P.

② Secondary heat zone

Bcz of presence of friction at the chip tool interface; the energy supplied is converted into heat energy.

30-35% of energy supplied is converted to heat in this zone.

Maximum amount of heat generated in 2° zone is been carried away by the chip and a small amount carried away by the tool.

③ Tertiary heat zone

The energy supplied is converted into heat energy bcz of presence of friction at the toolwork interface.

5-10% of energy supplied is converted to heat in this zone.

Out of the heat generated in this zone; maximum is carried away by the workpiece and small amount is carried away by the tool.

By neglecting heat energy lost to the surroundings or environment by convection and radiation, whatever be the heat generated in the machining operation is simply carried away by the chip, workpiece and the tool in decreasing order.

$$H \cdot G = W \cdot D = W = \text{heat carried away by } (\underbrace{\text{chip}}_{75-80\%} + \underbrace{w \cdot p}_{15-20\%} + \underbrace{\text{Tool}}_{5-8\%})$$

Bcz the heat carried away by tool is very small and if neglected;

$$\text{Heat Generated} = \text{heat carried away by } (\text{chip} + w \cdot p)$$

Bcz the chip is carrying away the maximum amount of the heat; the rise in temperature of the chip is maximum and if this temperature is very near to the melting point temp of workpiece, the chip may get adhered back either on the workpiece or on the tool.

To avoid this 1st determine the rise in temperature of the chip. If it goes near to the M.P; adjust the process parameters such that the temperature induced during machining is well below the M.P temp of work material.

$$\text{Heat carryed by Chip} = W - \text{heat carried away by } w \cdot p$$

$$= W - aW$$

$$= W(1-a)$$

a – fraction of heat generated which is carried away by w.p (0.15 – 0.2)

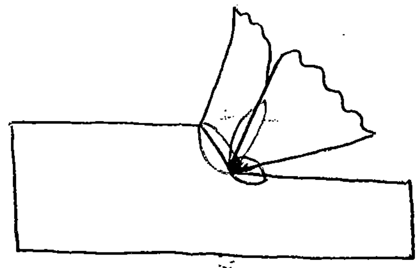
$$m C_p \Delta T = W(1-a)$$

$$\Delta T = \frac{\omega(1-a)}{m C_p} = \frac{\omega(1-a)}{Vol \times \rho \times C_p}$$

$$= \frac{f_c \times V_c (1-a)}{Vol \times \rho \times C_p} = \frac{f_c \times V_c (1-a)}{(A_0 V_c)\, \rho \times C_p}$$

$$\boxed{\Delta T = \frac{f_c (1-a)}{(t_1 \times b)\, \rho\, C_p}}$$

<u>Temp of chip</u> $\boxed{T_{chip} = \Delta T + T_r}$ T_r - room temp

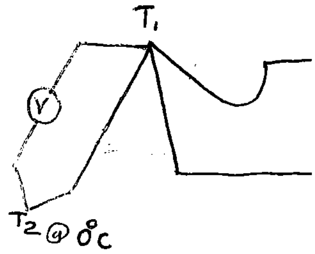


In machining operation; all the 3 heat zones ~~are~~ meets at one junction ie at the tip of the tool so that the temperature at the tip of the tool becomes very high. If this temperature goes beyond the hot hardness temp of tool material, tool lip loses its hardness considerabley and it deform plastically so that it cannot perform the machining operation satisfactorily after. To avoid this, practically measure the temp of tip of the tool; if it goes beyond the hot hardness temperature; either change the tool material or change the process parameters such that the temperature induced is < the hot hardness temp of tool material.

methods of measurement of tool tip temperature

① <u>Tool-work Thermocouple</u>

A small hole will be drilled at the tool tip such that it will not affect the strength of the tool material.



Bcz of existence of temp difference b/w the 2 junctions of thermocouple an emf will flow through the circuit due to <u>seebak effect</u>, <u>peltier effect</u> and <u>thomson effect</u>.

This emf is directly proportional to temp difference.

$$emf \propto temp\ diff$$
$$\propto (T_1 - 0)$$
$$emf \propto T_1$$

<u>Limitations</u>:-

① They are generally used for measurement of temperatures accurately upto ... beyond that the ...

* temp induced at the tip of the tool during machining of titanium alloy is about 15,000 t. 18,000°C.

② Tool work thermocouple could be used only for measurement of temperature of stationary tools. (can't be used for moving or rotating tools) (drilling bit, shaping tool etc.

② Optical Pyrometer

Non contact type of temp measurement equipment. (lim ① is overcomed)

③ Calorimetric setup

Limitation ② is overcomed.

Tool failure

whenever the tool is not performing the machining operation satisfactorily, it is assumed that the tool has been failed.

parameters indicating satisfactoriness of machining — which is to be measured online.

① Surface finish

At the beginning of machining operation the surface finish looks like a mirror. After some time of machining when the lines are observed on the machined surface — it indicates the tool failure.

② Forces in machining

During machining - the forces induced will be measured online using dynamometers.

whenever the increase in forces during machining is greater than 15% indicate that machining is not satisfactory and tool is assumed to be failed.

③ Power consumption

whenever the forces are increasing — power consumption also increases.

This is been measured by mounting the ammeter ~~at~~ the inlet of electrical motor and current drawn by the motor is monitored.

whenever the increase in current drawn by the motor is more than 15% it's assumed that the tool has been failed.

④ Colour of the chip :-

During normal machining conditions ; the colour of the chip is found to be metallic or light blue colour.

whenever the colour of the chip is changed black or burnt type of colour - it's assumed that the tool has been failed.

⑤ Machining of high carbon steel WP

During machining of high carbon work piece with ~~failured~~ tool. Bcz of higher temperature ; the carbon present on the surface of the workpiece get easily combined with the oxygen present in the atmosphere and produces carbon monoxide which is observed as a white coloured gas i.e whenever machining of high carbon ~~working~~ pieces - if ~~which~~ white coloured gases are ~~observed~~ observed - it's assumed that tool is failed.

Modes of tool failure

① Failure through plastic deformation - abnormal failure.

During machining operation ; if the temp at the tip of the tool is > the hot hardness temp of tool material, tool tip is using its ~~to~~ hardness considerably, ~~and car~~ it deforms plastically and cannot perform the machining satisfactorily called as plastic deformation failure of the tool.

This is mainly bcz of wrong selection of the tool materials or the wrong selection of the process parameters - Non repeatable failure

② Failure through mechanical breakage - abnormal failure

Initially the tool performing or machining satisfactorily ; gets its tip chipped away and cannot perform machining satisfactorily.

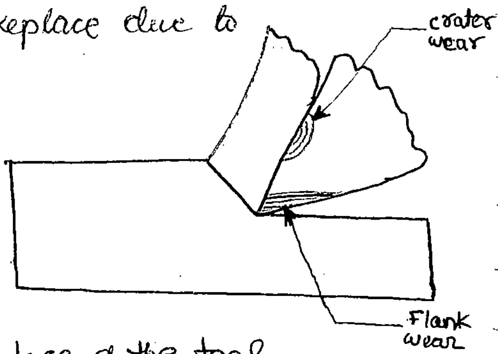
This happens due to the presence of blow holes in the workpiece or hard inclusions in the workpiece so that during machining of blowholes and hard inclusions - the forces will be increased suddenly and the tip of tool chips away.

On similar conditions of machining - the failure duration of the tool is not repeatable. ∴ it's also considered as abnormal failure and is not ~~ca~~ considered for tool life calculation.

③ Falure through Gradual wear :- - normal failure

During machining operation - the tip of tool wears out slowly so that whenever the wear on the tool becomes considerable & it cannot perform the machining satisfactorily and assumed that the tool is failed.

The gradual wear failure mainly takeplace due to 2 types of wear mechanisms.

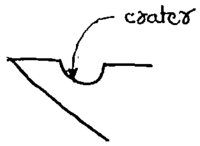


ⓐ Crater wear

ⓑ Flank wear

ⓐ Crater wear

Wear taking place on the rake face of the tool like a crater is called crater wear.



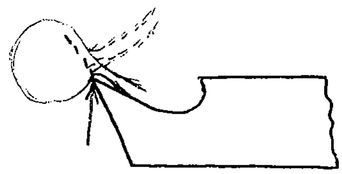
crater – shallow spherical depression on the surface

This is caused due to

- → the presence of friction in the chip tool interface
- → abbrasive action of microchips present on chip-tool interface
- → abbrassive action of fragments of builtup edge present on the chip tool interface.
- → diffusion wear – sometimes during machining bcz of atomic attraction b/w the tool and the work piece – the atoms of the tool material are diffusing from the tool and depositing over the workpiece.

  eg:- during machining of Ferrous workpieces using diamond cutting tool. Since in diamond pure carbon is present. Thus atoms of C will be attracted by iron.

Q During machining operation, the crater wear will start at some distance away from the tip of the tool. Why?



when the upward force is applied by using tip of the tool; the chip produced is lifting directly upward. But bcz of self wt of the chip; it is falling back on the rake face of the tool. In the process of lifting upward and falling back on the rake face, no contact is existing b/w the tip of the tool and chip. ∴ no friction ⇒ no abrasive action ⇒ No diffusion

when the chip is falling back on the rake face of the tool, It is trying to penetrate onto the tool at some distance away from the tip of the tool; at that point; the friction is high, Heat generation is high; temperature is high. Due to high temp – the mechanical properties of tool material at that point deteriots. which will increase the wear of the tool and produces crater.

ⓑ Flank wear

The wear takingplace on the flank face of the tool

This is caused due to :-

⑥ Shear angle

Under similar conditions of machining if the shear angle produced is ↑ machinability is ↑

⑦ Type of chip produced.

Discontinuous chip ⇒ better machinable

The above methods could only be used to compare 2 or more w.p. Thus they are only applicable if more than 1 wp is given; then only we could conduct machining on those w.ps and measure any one of those parameters and based on that; the decision of higher machinability w.p are taken.

When only one wp is given, the machinability can be determined by comparing with standard w.p and calculate the machinability index. Using this machinability index, the easiness of machining of a workpiece can be determined.

Machinability Index $\boxed{MI = \frac{V_T}{V_S}}$

V_T – cutting velocity for 60 min too, on a test w.p.

V_S – Cutting velocity for 60 min tool on a standard workpiece.

Free cutting Steel or Free Machining is used as standard wp.

Any steel (low or mild or high C) upto 0.05 % – phosphorus, upto ~~0.05~~ 0.05 % – sulphur, upto 2–4 % – lead is called FCS or FMS

Addition of lead more than 4% also increases the machinability further but it reduces the MP of steel drastically. So – only 4% is

addition of Sulphur or Phosphorus above 0.05% also increases the machinability but the increase in brittleness is very high. ∴ the material cannot be used in Engineering application.

Why free Cutting ~~Material~~ Steel as standard ?

While formulating MI; the FCS was known to have highest possible machinability.

But later on many materials was found to be having greater machinability than FCS. Hence value of MI — could be 'any value' (>or<1)

Another machinability is also been Defined – Universal Machining Index (UMI) or also called Absolute Index – bcz it even doesnot require even standard wp

$$\boxed{UMI = \frac{\cos(\beta-\alpha)}{\cos(\phi+\beta-\alpha)} = \frac{F_c}{F_s}}$$

Economics of Machining

The method of determining the optimal process parameters for a given economic criteria machining is called economics of machining.

Out of the process parameters; the cutting velocity is having the highest influence on the machining.
∴ the optimum cutting velocity is only determined.

1. Minimum Cost Criteria
2. Maximum Production Criteria
3. Maximum Profit Criteria

1. Minimum Cost Criteria :-

Total Cost

$$TC = C_r + C_{L\&S} + C_m + C_t + C_{U\&I}$$

C_r - Cost of raw material
$C_{L\&S}$ - Cost of loading and setting
C_m - cost of machining
C_t - Cost of tooling
$C_{U\&I}$ - Cost of unloading & inspection.

out of the above costs - the cost of machining and cost of tooling would be influenced by cutting velocity.

$$TC = K_1 + C_m + C_t$$

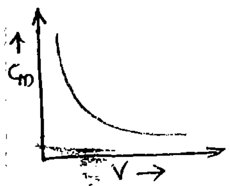
$$C_m = T_m \times L_m$$

$$T_m = \frac{L}{f \times N} \quad \text{(next chapter)}$$

$$\boxed{C_m = \frac{\pi D L \times L_m}{1000 f V}}$$

T_m - machining time for 1 component (minutes)
L_m - machining labour charges in Rs/min.

$$N = \frac{1000 V}{\pi D}$$



$$\boxed{C_m \propto \frac{1}{V}}$$

$$C_t = \frac{T_m}{T} \times C_g$$

$$= \frac{L/fN}{\left(\frac{C}{V}\right)^{1/n}} \cdot C_g \qquad VT^n = C$$

$$\boxed{C_K = \frac{\pi D L V^{\frac{1}{n}-1}}{1000 f C^{1/n}} \cdot C_g}$$

$$\boxed{C_K \propto V^{1/n - 1}}$$

T_m - machining time
T - tool life
C_g - Cost of regrinding tool 1 time (if regrindable) or cost of 1 cutting edge (if it is a throwaway type of tip of tool)

* If cost of a tool is given - one tool has 4 cutting edge (corner) so divide by 4 to get cost of 1 cutting edge

- presence of friction in the tool-work interface
- abbrasive action of microchips present at the tool, work interface
- diffusion wearing.

Tool life

Actual machining time between 2 successive regrinds of cutting tool
Generally it's expressed in minutes.

It's also defined as number of pieces produced b/w the successive regrinds of a cutting tool.
This methodology is been used in mass production.

It's also defined as the vol. of material removed b/w two successive regrinds of a cutting tool.
This methodology is used for rough machining.

Factors influencing tool life

① Properties of work material

As the hardness of work piece is increases; the forces in machine ↑, tool wear ↑, tool life ↓

With increase of ductility of workpiece material, the forces ↓ tool wear ↓, tool life ↑

② Tool Geometry

back rake angle α_b ↑ ⇒ tool life ↓. Qualitatively we could tell this but no quantitative relation.

③ Use of cutting fluid

when cutting fluids are used; forces in machining reduces by about 25-40% so that the wear of the tool is reducing and tool life increases by about 25-40%.

④ Process parameters (v, f, d) :-

Bcz the process parameters are unique and independent; The researchers try to co-relate process parameters with toollife Quantitatively.

Out of the 3 parameters 'Taylor' first assumed that the cutting velocity is the one which has the highest influence on the tool life. Hence the Taylor has invented quantitative relationship b/w the tool life and cutting velocity and named as Taylor's tool life equation.

$$\boxed{VT^n = C}$$

n - taylors exponent (depends on cutting material)
V - cutting velocity - m/min
T - tool life - (min) ...

Taylors constant - ~~C~~ cutting velocity for 1minute tool life.

n -	0.05	- 0.1	—	HCS
	0.1	- 0.2	—	HSS
	0.2	- 0.4	—	Carbide
	0.4	- 0.6	—	Ceramics
	0.7	- 0.9	—	Diamond / CBN

Later on Taylor has invented the relationship b/w the toollife and other process parameters also; called as modified Taylor's toollife eqn:

$$\boxed{V T^n f^p d^q = C}$$

f - feed in mm/rev

d - depth of cut in mm

p, q - exponents
value < 1
In general p > q

Out of the 3 process parameters; the cutting velocity have highest influence on the toollife, depth of cut is having lowest influence and feed is in between.

$$V > f > d$$

Machinability

The ease with which machining of a given work piece can be done is called machinability.

parameters determining machinability (check or measure)

① Surface finish

Under similar conditions of machining; the w.p on which better surface finish is produced is called as better machinable.

② Tool life

Under similar conditions of machining; the w.p on which higher tool life is obtained is better machinable.

③ Forces in machining

Under similar conditions of machining; the w.p on which the forces induced are lower is called better machinability w.p.

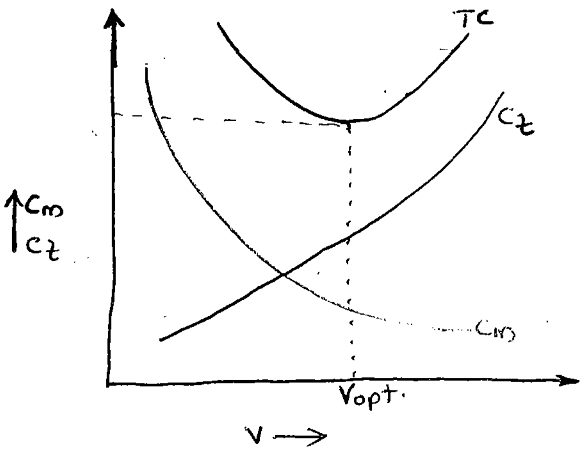
④ Specific cutting energy:-

Under similar conditions of machining; lower the specific cutting energy, higher the machinability.

⑤ Material Removal Rate

Under similar conditions, w.p on which higher MRR can be obtained is better machinable

$$TC = K_1 + \frac{\pi DL}{1000 fV} L_m + \frac{\pi DL V^{1/n - 1}}{1000 f C^{1/n}} \cdot C_g$$



for minimum TC

$$\frac{d(T.C)}{dV} = 0$$

$$V_{opt} = C\left[\frac{n}{1-n} \cdot \frac{L_m}{C_g}\right]^n$$

C – Taylors constan

n – Taylors expon

L_m – machining labou charge in Rs

V_{opt} – Optimum cut velocity.

T_{opt} – Optimum tool

substituting value of V_{opt}.

optimum toollife

$$T_{opt} = \left(\frac{C}{V_{opt}}\right)^{1/n}$$

$$T_{opt} = \left[\frac{1-n}{n} \cdot \frac{C_g}{L_m}\right]$$

② Maximum Production Criteria

This refers to minimum Total time

Total Time

$$TT = T_{LBS} + T_m + T_{tc} + T_{U and I}$$

T_{tc} – tool changing tir

out of above times only machining time and tool changing time (T_{tc}) are influenced by the cutting velocity.

$$TT = K_2 + T_m + T_{Tc}$$

$$T_m = \frac{L}{F_N} = \frac{\pi DL}{1000 fV}$$

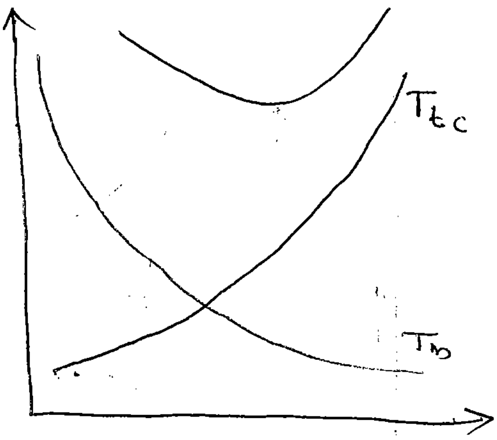
$$\boxed{T_m \propto \frac{1}{V}}$$

$$T_{tc} = \frac{T_m}{T} \times T_c$$

T_c – time needed to chang the tool onetime

$$= \frac{\pi DL V^{1/n - 1}}{1000 f C^{1/n}} \cdot T_c$$

$$T_{tc} \propto V^{\frac{1}{n}-1}$$



$$TT = K_2 + \frac{\pi DL}{1000fV} + \frac{\pi DL V^{\frac{1}{n}-1}}{1000 f\, C^{1/n}} \cdot T_c$$

For minimum total time.

$$\frac{d(T.T)}{dV} = 0$$

$$V = V_{opt} = C\left[\frac{n}{1-n} \cdot \frac{1}{T_c}\right]^n$$

$$T_{opt} = \left[\frac{1-n}{n} \cdot T_c\right]$$

(3) Maximum Profit criteria

$$\uparrow \text{Profit} = S.P - T.C \downarrow$$

Bcz the selling price is not influenced by the cutting velocity, the profit can be maximized ~~the~~ by minimising the total cost.

∴ maximum profit criteria is nothing but the minimum cost criteria,

So $$V_{opt} = C\left[\frac{n}{1-n} \cdot \frac{L_m}{C_g}\right]^n$$

$$T_{opt} = \left[\frac{1-n}{n} \cdot \frac{C_g}{L_m}\right]$$

$$(V_{opt})_{min.\ cost} = (V_{opt})_{max\ profit}$$

But if we consider the surface finish — (there is no quantitative relationship between ~~velocity~~ cutting velocity and surface finish)

when $V\uparrow \Rightarrow$ Surface finish $\uparrow \Rightarrow$ Quality$\uparrow \Rightarrow$ S.p could be increased

Thus. $$(V_{opt})_{max\ profit} \underset{(\text{slightly})}{>} (V_{opt})_{min\ cost}.$$

Thus the cutting velocities ~~for~~ would be slightly higher than ~~that~~ f for maximum profit than minimum c[illegible]

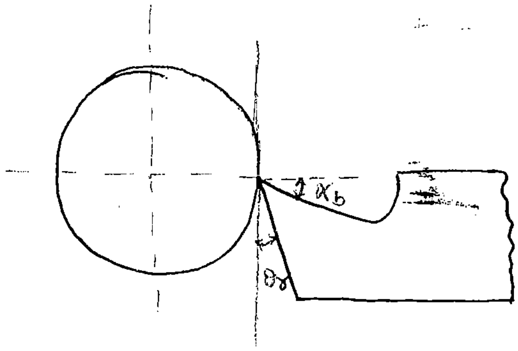
① Vopt for min cost
② Vopt for max Podcts
③ Vopt for max profit

② > ③ > ①

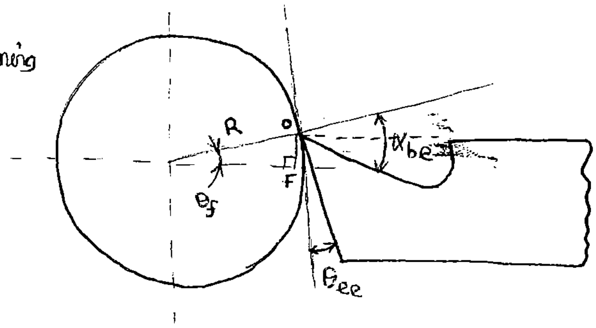
Effective Rake and Relief angle

During turning operation - it is required to set the tool such that the tip of the tool can coincide with the axis of the workpiece.

This setting of the tool will be done with reference to the deadcentre of tailstock. just by seeing through human eye.



During setting, by mistake, the tool tip may set slightly above or below the workpiece; This will affect the machining operation.



when tool is set above central line

① Effective rake angle ↑
   Forces ↓
   Power consumption ↓
   Tool life ↑

② Effective relief angle ↓
   rubbing actn b/w tool & work piece ↑

$$\sin\theta_f = \frac{OF}{R}$$

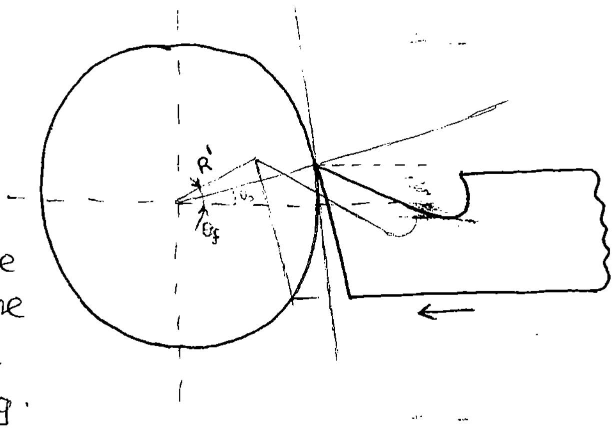
$$\theta_f = \sin^{-1}\left(\frac{OF}{R}\right)$$

$$\alpha_{be} = \alpha_b + \theta_f$$

$$\theta_{ee} = \theta_e - \theta_f$$

In case of parting off operation, if tool is set above the centre line of work piece, as the tool is proceeding towards the centre bcz of reduction in radius; even though offset remains same - the offset angle will increase↑ & effective relief angle ↓

At some point; the effective relief angle may become equal to '0'. so that the tool is simply ~~working~~ rubbing on the workpiece without doing any machining.



If R' is the radius at which $\theta_{ee} = 0$

$$\sin\theta_f = \frac{OF}{R'}$$

$$R' = \frac{OF}{\sin\theta_f} = \frac{OF}{\sin\theta_e}$$

when $\theta_{ee} = 0$ $\theta_f \to \theta_e$

eg:- $D = 50mm$, $OF = 1.5mm$, $\alpha_b = 10°$, $\theta_c = 6°$ find dia at which the tool just rubs.

$$\theta_f = \sin^{-1}\left(\frac{1.5}{25}\right)$$

$$\alpha_{bc} = 10 + \theta_f$$

$$\theta_{ee} = 6 - \theta_f$$

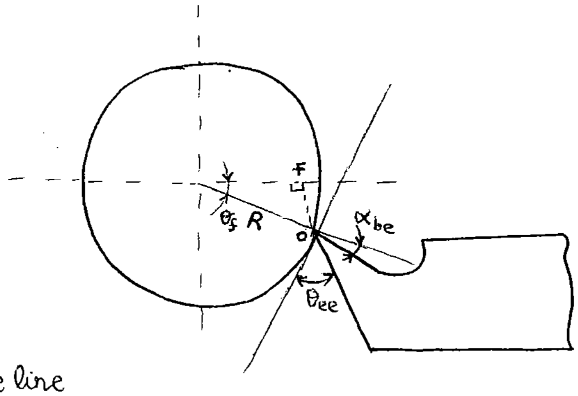
$$R' = \frac{1.5}{\sin 6°} \qquad D' = 2 \times R' = \underline{28.7mm}$$

Setting below centre line

$$\theta_f = \sin^{-1}\left(\frac{O.F}{R}\right)$$

$$\alpha_{be} = \alpha_b - \theta_f$$

$$\theta_{ee} = \theta_e + \theta_f$$



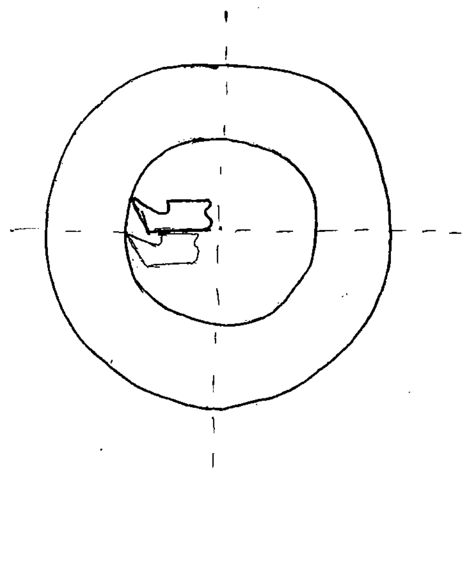
When the tool is set below centre line

① Effective rake angle will be reduced. Due to this – forces ↑, Power consumption ↑ tool wear ↑, tool life ↓
Tool become blunt very fast.

② The effective relief angle ↑
Rubbing action b/w tool and wp will be completely avoided.

Effect of setting tool above the centre line in case of Internal Turning Operation

Boring operation remains same as that of setting tool below centre line in external turning operation and vice versa.



Basic parameters required for analysing the given machining operation as Orthogona

1) α = Rake angle
2) t_1 = uncut chip
3) b = width of cut
4) F_c = cutting force
5) F_T = Thrust force

If f and d are given. assume $t_1 = f$, $b = d$

If d and w are given assume $t_1 = d$, $b = w$

If f and w are given assume $t_1 = f$, $b = w$

only 2 parameters out of 3 would be given at a time in any Question.

Oblique Machining Operation

Since there is no direct methods available for analysis of direct oblique machining, the oblique machining problem can be converted into orthogonal machining problem and analyse it as orthogonal machining problem.

When converting oblique into orthogonal; the above 5 parameters are to be determined.

1) Shaping and planing

It's a single point cutting tool oblique machining operation.

Conversion to single point cutting tool orthogonal $\Rightarrow$ $\alpha = \alpha_b$ (ASA) $= \alpha$ (ORS)

$$t_1 = f\cos\lambda = f\sin C_s$$

$$b = \frac{d}{\cos\lambda} = \frac{d}{\sin C_s}$$

F_c = largest force

F_a = next largest $= F_T\cos\lambda \Rightarrow F_T = \frac{F_a}{\cos\lambda}$

F_r = least force $= F_T\sin\lambda \Rightarrow F_T = \frac{F_r}{\sin\lambda}$

F_T is obtained by any of the above equation.

$$MRR = t_1 b V_c$$
$$= f\, d\, V_c$$

② Turning and boaring

Also single point cutting tool - oblique machining operations and is to be converted to single point cutting tool orthogonal system

$$\alpha = \alpha_b \ (ASA)$$
$$= \alpha \quad (ORS)$$

$$t_1 = f \cos C_s = f \sin \lambda$$

$$b = \frac{d}{\cos C_s} = \frac{d}{\sin \lambda}$$

F_c = largest

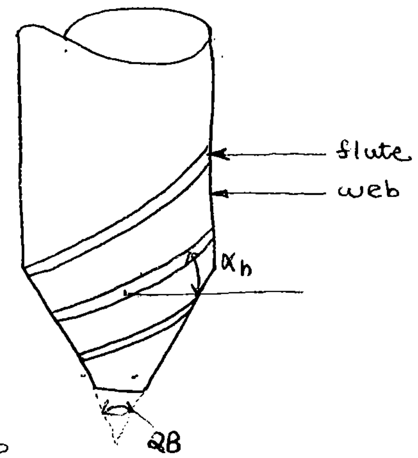
F_a = Next largest $= F_T \cos C_s \Rightarrow F_T = \frac{F_a}{\cos C_s}$

F_r = Smallest $= F_T \sin C_s \Rightarrow F_T = \frac{F_r}{\sin C_s}$

$$MRR = t_1 b V_c = f d V_c$$

③ Drilling

Multipoint cutting tool - oblique machining operation. and It is to converted into single point cutting tool - orthogonal machining operation -



The slot present in drill bit is called - flute

Always in a drill bit

$$\boxed{\text{No: of flutes} = \text{No of webs}}$$

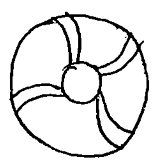
and it is equal to an even number for balancing of forces acting on the drill bit.

The angle made by flute or web with the horizontal is called helix angle (α_h)

The flutes are provided on drill bit to obtain rake angle of tool tip and facilitate disposal of chip.

$$\alpha = \alpha_h = \tan^{-1}\left(\frac{\frac{1}{2}\tan \alpha_h}{\sin B}\right)$$

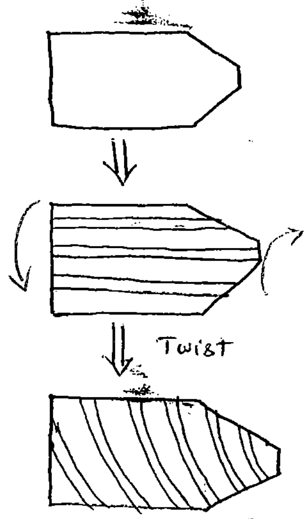
For easy On drill bit smaller helix angle will be taken at the centre for making the tool tip strong, and towards the periphery helix angle can be increased and maximum angle at periphery for easy disposal of the chip - variation of helix angle :-



This variation is done only at the central portion of the

Bcz of helix angle variation – the rake angle also varies from minimum at the centre to the maximum at the periphery.

manufacturing by twisting operation so called twist drill bit.



2β – <u>point angle</u>. It's taken as $\underline{118^\circ}$ (standard)

$2\beta > 118^\circ$ – drilling hard work piece.

when 2β is less – the conical height ↑ and there is chance of buckling failure ↑ when hard w.p is used more force is induced and again the chance increases. Thus $>118^\circ$

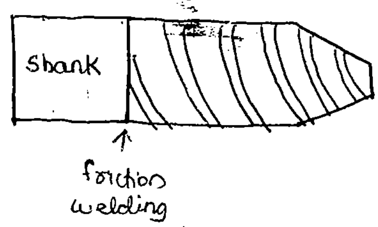
$2\beta < 118^\circ$ – soft w.p

$= 45\text{-}50^\circ$ – Very soft w.p.

During machining of very soft w.p the type of chips produced is continuous, To dispose them easily; the helix angle must be as maximum as possible. for this the conical length of drill bit must be large. So to get this smaller point angles must be used.

Anyway during machining of soft w.p – forces ↓ so chances of buckling failure is very less. So less angles could be used

* The twisted portion is join to straight or shank por by using <u>friction welding operation</u>.



$$t_1 = \frac{f}{2} \sin\beta$$

$$b = \frac{D}{2\sin\beta}$$

Total thrust force $= 5 F_T \sin\beta$

$$F_T = \frac{\text{Total thrust force}}{5 \sin\beta}$$

Torque $= 0.6\, F_c\, D$

$$F_c = \frac{\text{Torque}}{0.6 \times D}$$

$$MRR = t_1 b V_c$$

$$= \frac{f d V_c}{4}$$

Though drilling is an oblique machining operation it's not possible to measure the 3 component of forces. But the measurable quantities are; The total thrust force acting on drill bit and Torque req to rotate the drill bit.

-9-11.
-9am

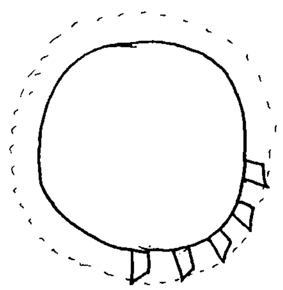
4) Milling :-

It is a multipoint cutting tool - oblique machining

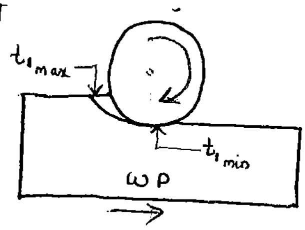
It is to be converted to single point cutting - orthogonal machining

α - rake angle.

If many number of single point cutting tools are mounted along the circumference of a circular disc, the milling cutter will be formed.



The uncut chip thickness will be varying from minimum to maximum.



$$t_{1min} = 0$$

$$t_{1max} = \frac{2 f_m}{N z}\sqrt{\frac{d}{D}}$$

$$\boxed{t_{1max} = 2 S_z \sqrt{\frac{d}{D}}}$$

d - depth of cut

f_m - table feed mm/min

$= fN = S_z zN$

f = tablefeed mm/rev

f_z = table feed mm/tooth

z = No of teeth

N = rpm

D - dia of milling cutter

b - width of cut

$$\boxed{t_1 = \frac{t_{1min} + t_{1max}}{2}}$$

b = min(width of cutter, width of w.p)

In milling 3 components of forces are measurable out of which largest force is taken as f_c, f_a the next largest and f_r the smallest

f_c - largest force

f_a - Next largest $= F_T \cos\lambda \Rightarrow F_T = \frac{f_a}{\cos\lambda}$

f_r - Smallest $= F_T \sin\lambda \Rightarrow F_T = \frac{f_r}{\sin\lambda}$

} use any one eqn and find F_T

$MRR = t_1 b f_m$ ... always use the table feed in mm/min

Dont use V_c - since one tool is performing cutting action only upto a certain angle.

Cutting Tool Material :-

Properties

1. Hardness of cutting tool material must be atleast 30-50% higher than the work piece material.

2. Hothardness temp. of tool material should be as high as possible

3. It should have higher toughness to withstand impact load.

4. Thermal conductivity should be as high as possible to distribute the heat without producing high heat concentration.

5. Coefficient of thermal expansion should be as low as possible to avoid variation of dimensions of components.

6. Coefficient of friction on the surfaces should be as low as possible

7. Easiness in fabrication and cheaper.

High Carbon Steel

Hardness = Rc 65.

Carbon content = 0.6 - 2.11

Hot hardness temp = 250°C

Manufacturing method = Forging – To obtain directional stability. Also forged tools are regrindable. So total body of the tool is made by using same material, so that whenever the tool is failing it can be resharpened by grinding.

Toughness = Very high (highest – No cutting tool material is having greater toughness than HCS)

Maximum cutting velocity, V_c = 5 m/min

Speed↑ Power↑ heat generated↑ tool life↓

Applications:-

1 Used for machining of **very soft** W.p materials like Al, Cu, Ag, brass etc

2 After HCS, many ~~tougher~~ cutting tool materials have be introduced or developed but still today HCS is been used for manufacturing of chisels b/s of high toughness.

② High speed steel or High alloy steel

Composition = 18 - 4 - 1

W/Mo Cr V → increase wear resistance & maintain sharpness.

Cr → increase the strength or resistance to deformation

W/Mo → Tungsten or Mo is added to increase the hot hardness temp of tool material.

Total alloying elements	
< 5%	low alloy steel
5 - 10%	medium alloy steel
> 10%	high alloy steel

If 18% W is used in HSS - it is called - Tungsten based HSS

If 18% Mo is used - it is called - Molebdenum based HSS.

Even Mo is cheaper than W - Tungsten based HSS is been used commonly bcz it's having high wear resistance as compared to Mo.

hot hardness temp = 600°C

Toughness < HCS

Manufacturing method = forging - So entire body of tool is made of same material in order to enable regrinding.

$V_{c_{max}}$ = 40-50 m/min nearly 10% greater than HCS ∴ name 'high speed steel' and it became popular than High allow steel.

Applications :-

1. It's a General purpos cutting tool material used for making singpoint cutting tool in - lathe, shaping multipoint cutting tools in - milling, drilling etc.

Limitation

Bcz of presence of 76% Fe in HSS. During machining of high carbon workpieces - the carbon atoms will be diffusing from the workpiece and depositing on the tool forming as a Builtup edge. Hence HSS should not be used for machining of High carbon workpieces.

3 Stellite or Non-ferrous cast Alloy

cobalt - 40-50%

chromium - 27-32%

Tungston - 15-25%

carbon - 2-4%

Manufacturing method = casting (so name cast alloy) casting components are ~~not~~ also regrindable so total body is made of same material, hot hardness temp = 800°C

All other properties remain same as the HSS

Stellite is developed as a substitute cutting tool material for machining high carbon wp in placed of HSS.

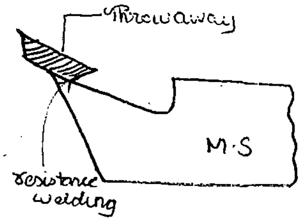
4 Carbides or Tungston Carbides or Cemented Carbide or Sintered Carbide.

W is the major constituent

Manufacturing method – powder metallurgy – So it contains very hi hardness and it's not regrindable.

Thus Throw away type of tip of tool is made.

Tip of tool and body is made of diff material.



Hot hardness temp – 1000°C

Toughness < HSS

$V_{c\ max}$ = 300 – 350 m/min

3 type of carbides are there.

P-type Carbides – used for machining of steels and ferrous materials

K-type carbides – machining of Cast Iron, non-ferrous metals, non-metal

M-type carbides – General purpose.

Also each one is sub divided into P_{10} P_{20} P_{30} P_{40} P_{50}

K_{10} K_{20} K_{30} K_{40} K_{50}

M_{10} M_{20} M_{30} M_{40} M_{50}

lower the number indicates higher the hardness and brittleness of the tool material and higher number indicates – higher ductility and toughness

lower number tools – finish machining operations

larger number tools – Rough machining operations

5 Ceramics

Major constituent is Aluminium Oxide (Al_2O_3)

Manufacturing Method – Powder metallurgy
Throw away type of tool.

Hot hardness temp – 1,200°C

V_c max – 400-500 m/min.

It gives excellent surface finish on the rake face of the tool.

Coeff of friction b/w chip tool interface – low

Toughness – Very low [highly brittle material] – It's been only used for continuous machining applications like turning, drilling etc.

6 Ceramics + Metals = Cermets

Ceramics 90% Metals 10%

Bcz Ceramic is the major constituent element; the properties of ceramics is almost same as ceramics and bcz of addition of 10% metals; the toughness of cermets is higher than ceramics. Hence ~~cerament~~ cermets can be used for intermittent machining also.

Same as ceramic
[hot hardness – 1200°C $V_{c\,max}$ = 400 – 500 m/min
Manufacture – Powder Metallurgy]

7 Diamond

major constituent is Carbon.

Manufacturing method – Powder metallurgy/Graphatization – Throw away type tip of tool

Thermal conductivity – high Coeff of thermal expansion – low

Toughness – high
Hardness – high
} * bcz of orderly arranged C atoms both are high.

hot hardness temp – 2000°C

V_c max – 1500 to 2000 m/min

Limitation

① Very costly material

② ... Machining ferrous w.p bcz of diffusion wear

8 Cubic Boron Nitride (Borozone)

major constituent is boron

manufacturing method — powder metallurgy.

Hot hardness — 2000°C

Vc max — 1500 - 2000 m/min

cost — same as diamond.

only reason:-
CBN could be used as a substitute cutting tool material for machining of ferrous w.p. in place of diamond.

9 UCON

major constituent -

Columbium - 50%
Titanium - 30%
Tungsten - 20%

UCON is rolled into sheets and cut in the form of throw away type of tip of tool using wirecut EDM.

Qualities of UCON is better than Diamond & CBN

Cost is also higher than Diamond & CBN

So its not a commercially used cutting tool material.

10 Sialon

Si + Al + O + N

Manufacturing method - powder metallurgy

Qualities and cost both are higher than UCON.

∴ Not used commercially.

* Except toughness almost all other qualities, "hardness, hot hardness, Cutting velocity, cost etc are in the increasing order from 1 to 10

Decreasing order of toughness of cutting tool materials 1-2-3-7-8-9-10-4-6-5

5 ceramic is having least toughness.
6 Cermets
4 Carbide

HSS and stellite are cheaper

1st considers - $V_{c_{max}}$ - then go for cheaper - then ferrous or nonferrous -

points to be remembered while solving metal cutting problems

1 check whether orthogonal machining operation is indicated in Qn or not.

If indicated - analyse the problem as orthogonal.

If non mentioned - check whether the problem belongs to parting off operation, broaching operation, sawing operation etc.

If so :- the problem can be analysed as orthogonal even not mentioned as orthogonal

- check whether the problm belongs to toollife problems, economics of machining problem, effective rake and relief angles problem.

If so :- Need not worry about oblique or orthogonal analyse the problem directly as orthogonal. (parameters are not used)

2 If the problm doesn't belong to the above cases - consider it as ~~as~~ oblique - convert it to orthogonal and analyse

Casting Questions

1. $A_s = A_g = 200 \qquad h = 175 \qquad V = 10^6\,mm^3$

$A_C = A_{min}$

$$P.T = \frac{Vol}{A_C \times V_{max}} = \frac{10^6}{200 \times \sqrt{2 \times 1000 \times 175}}$$

$$= \underline{\underline{2.67}}$$

2. $$P_N = \frac{501.28}{PT} = \frac{501.28}{10 \times 0.5} = 100.2$$

3. Flow rate $= A_c \times V_{max}$

$$V_{max} = \sqrt{2gh} = \frac{\text{flow rate}}{A_c}$$

$$= \frac{0.8 \times 10^{-3} \times 10^9}{400}$$

$$\left.\begin{aligned} G:R &= 1:4:4 \\ &= 1:2:2 \end{aligned}\right] \qquad h = 200 \qquad h = 250$$

4. $$\frac{\tau_{sp}}{\tau_{cube}} = \left(\frac{M_{sp}}{M_{cube}}\right)^2 = \left(\frac{(V/A_s)_{sp}}{(V/A_s)_c}\right) = \left(\frac{A_{sc}}{A_{sp}}\right)^2$$

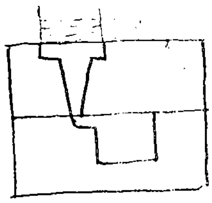
or

$$\left(\frac{\frac{D}{6}}{\frac{a}{6}}\right)^2 = \left(\frac{D}{a}\right)^2 = \left(\frac{2R}{a}\right)^2 \qquad \boxed{\frac{4}{3}\pi R^3 = a^3}$$

$$= \underline{\underline{1.54}}$$

5. Ans $\left.A\right] = 0.767$

6.



$h = 200 + 50$

$= 250$

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

$A_c = \min(A_s, A_g)$

$= A_s$

$A_g = 400\,mm^2$ — 2 part

$A_s = 1 \text{ part} = \frac{400}{2} = 200$

$$P.T = \frac{Vol}{A_c \times V_{max}} = \frac{\pi/4 \times 150^2 \times 200}{200 \times \sqrt{2gh}} = 8$$

Ans (C)

7. Ans 'C'

8. C_1 Circular disc $d = 20\,cm,\ t = 10\,cm$ | C_2 Square disc $d = 20\,cm$;

$$F.R = X = \frac{(A_s/V)_c}{(A_s/V)_r} = 1.4 \qquad X_2 = ?$$

$$Y = \frac{V_r}{V_c} = 0.8 \qquad Y_2 = ?$$

$$(A_s/V)_r = \frac{(A_s/V)_c}{1.4} =$$

Same riser in both cases $\qquad X_2 = \frac{(A_s/V)_{c_2}}{(A_s/V)_r} =$

$V_r = 0.8\,V_{c_1}$

Same ht is used in both cases $\qquad Y_2 = \frac{V_r}{V_{c_2}} = 0.$

Ans. A

9. $V_c = 15 \times 15 \times 15$

$V_r = \frac{65}{100} \times V_c =$

$V_r \geq 3\,V_{sc}$

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

Top riser

$D = 2H \qquad = 11.5 \qquad D = 11.5$

$H = \frac{D}{2} \qquad = 11.5$

Check $\quad \tau_r \geq \tau_c$

$M_r \geq M_c \qquad \frac{11.8}{6} \geq \frac{15}{6} \quad X$

$\frac{D}{6} \geq a/6$

So $\tau_r = \tau_c \qquad M_r = M_c \qquad \frac{D}{6} = \frac{a}{6}$

$D = a = \underline{\underline{15\,cm}}$

10. 6.19 mm 'B'

11. cube $= 35 \times 35 \times 35$

$$PT = 25\text{ sec} \Rightarrow \frac{Vol}{A_c \times V_{max}} = \frac{35^3}{\left(\frac{\pi}{4} d^2\right) \times V}$$

$$V = \frac{35 \times 4}{\pi d^2 \times 25} \longrightarrow (1)$$

$Re \leq 2000$

$$Re = 2000 = \frac{\rho V d}{\mu} = \frac{Vd}{\nu} \qquad (1) = (2)$$

$$V = \frac{2000\,\nu}{d} \longrightarrow (2) \qquad d = 1.21$$

Ans 'C'

12.

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

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

$75g = \frac{D}{2}(2\pi N)^2$

$N^2 D = \frac{75g \times 2}{4\pi^2} = \frac{75 \times 9810 \times 2}{4\pi^2}$

$= \underline{37273}$ (A)

13.

$D = \frac{D_0 + D_i}{2} = \frac{0.52 + 0.5}{2} = 0.51 = \underline{510\,mm}$

$N = \sqrt{\frac{37273}{D}} = \sqrt{\frac{37273}{510}} = \underline{8.5}$ (A)

14. 0.97 (A)

15. (A)

16. D

17.

18. B

19. D

20. $\left(\frac{T_c}{T_{sp}}\right) = \left(\frac{m_c}{m_{sp}}\right)^2$

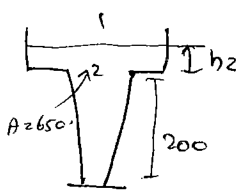
$= \left(\frac{As_{sp}}{As_c}\right)^2 = \left(\frac{4\pi r^2}{6l^2}\right)^2 \times \cancel{\left(\frac{r}{l}\right)^4}$

$= \left(\frac{4\pi}{6}\right)^2 \left(\frac{r}{l}\right)^4$

21.

$A_3 V_3 = Q$

$V_2 = \frac{Q}{A_2} = \frac{65 \times 10^5}{650}$



$V_2 = \sqrt{2gh_2}$

$h_2 = -$

$h_T = 200 + h_2 =$

$V_3 = \sqrt{2gh_T} =$

$A_3 = \frac{Q}{V_3} =$

22. net B.f $= Vg(\rho_s - \rho_l)$

$= \frac{\pi}{4} \times 120^2 \times 180 \times 10^{-9} \times 9.81 \times (11300 - 600)$

$= 193.7$

Ans 'C'

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

24. $T_c = K_1 m^2$

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

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

$= 1078$ Ans 'B'

25. $L = 13t = 13 \times 10 = 130$

Ans (B)

26. D

27. (A)

28. (A) - false

(R) - True

29. 4 cm

Ans (B)

HW

Machine Tool construction

Lathe
1. Bed — (a) functions
2. Headstock — (b) Material
3. Tail stock — (c) Mfg. method
4. Guideways — (d) Shape

casted components have higher damping qualities than components.

3-9-11
6-9am

Machining Time :-

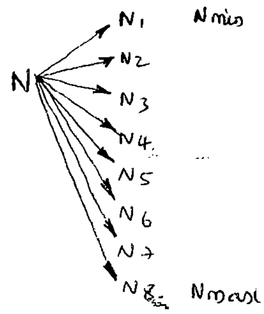
In the conventional lathe tool - The best preferable mechanical transmission syste is the belt drive bcz any sudden increase in the forces may cause ~~to sleep~~ only too sleep the belt and nothing will fail.

The number of speed steps taken can be 4-12

To design we decide

D_{min} and D_{max} - D-range

V_{min} and V_{min} - V-range



$$N_{min} = \frac{1000 V_{min}}{\pi D_{max}}$$

$$N_{max} = \frac{1000 V_{max}}{\pi D_{min}}$$

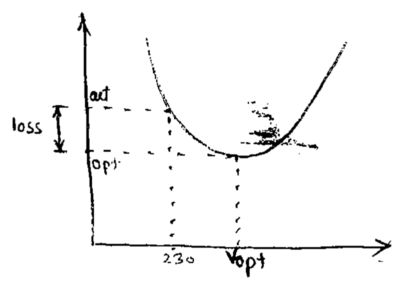
N_{min} to N_{max} = Speed range.

$$\text{speed range ratio} = \frac{V_{max} D_{max}}{V_{min} D_{min}}$$

The speeds (intermediate speeds b/w the N_{min} & N_{max}) is been selected in Geometric progression only.

The required rpm or spindlespeed maynot be available in machine tool. Thus in this case we would select the nearer spindle speed. Thus a productivity loss may occur.

This productivity loss is minimum if the spindle speeds are designed in G.P.



available spindlespeed $N = 230$ $N = 2$

optimum N required $N_{op} = 252$

in this case we select 23 0 which is nearer

Q $N_1 = N_{min} = 34$ rpm $N_6 = N_{max} = 353$ rpm Calculate the speeds.

$$a_n = a\gamma^{n-1}$$

$$353 = 34\,\gamma^{n-1}$$

$$\gamma = \sqrt[5]{\frac{N_6}{N_1}}$$

$$= \sqrt[5]{1.596}$$

$$= \underline{1.6}$$

353/74 x

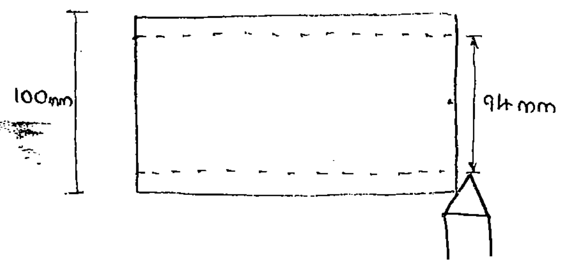
$N_1 = 34$ $N_2 = \gamma N_1$ $N_3 =$

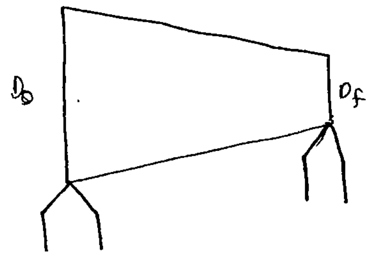
$= 54.4$

* During machining always select the maximum diameter to which the tool is exposed while machining is to ~~be~~ for the calculation of speed or rpm of the machine Tool.

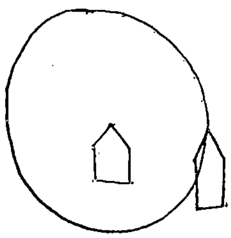
eg:-

Turning





100 mm is taken for calculation of $N = \frac{1000V}{\pi(D)}$



Feed :-

The linear distance travelled by the tool for 1 revolution of the w.p is called feed.

f = feed mm/rev

Feed velocity :-

The linear velocity at which the tool is linearly travelling along the w.p

fN = feed velocity mm/min

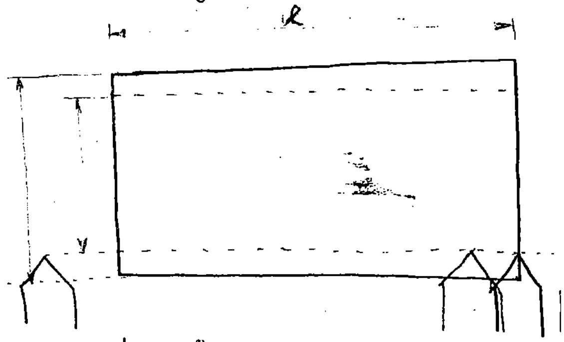
Depth of cut :-

The depth by which the tip of the tool is penetrated into the w.p.

d = depth of cut mm

1. Plane turning

The turning operation is used for reducing the dia of the w.p is called plane turning operation.



$$\text{Time per cut} = \frac{L}{\text{feed Velocity}}$$

$$T = \frac{L}{f N}$$

$$\text{No: of cuts} = \frac{D_o - D_f}{2 d_{max}}$$

$L = l + \text{approach} + \text{overrun}$ mm
(only use it if given in Qstn)

f = feed mm/rev

$N = \frac{1000 \, V_{opt}}{\pi D}$ take $D = D_o$

$$\text{Total Time} = T_1 + T_2 + T_3 + T_4 \cdots$$

$$= \frac{L}{fN_1} + \frac{L}{fN_2} + \frac{L}{fN_3} + \frac{L}{fN_4} \cdots$$

$$= L\left[\frac{1}{fN_1} + \frac{1}{fN_2} + \frac{1}{fN_3} + \cdots\right]$$

$$= \frac{L}{f}\left[\frac{1}{N_1} + \frac{1}{N_2} + \frac{1}{N_3} + \cdots\right]$$

$$= \frac{\pi L}{1000 f V}\left[D_0 + D_1 + D_2 + D_3 + \cdots\right]$$

$N_1 = \frac{1000 \, V}{\pi D_o}$

$N_2 = \frac{1000 \, V}{\pi D_1}$

$\vdots$

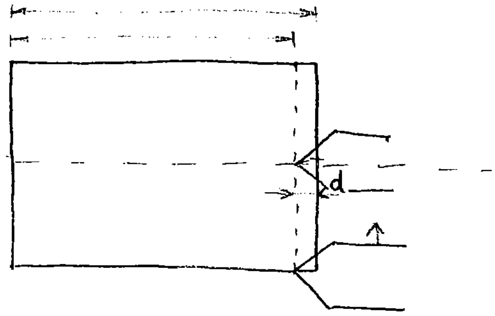
The above method of calculating the total time will be used when the no: of cuts required is ≤ 5. If the no: of cuts is more than 5 it's very difficult and time consuming. So we use the

$$\text{Total Time} = \text{No of cuts} \times T_{avg}/\text{cut}$$

$$T_{avg}/\text{cut} = \frac{L}{f N_{avg}}$$

2. Face turning

The turning operation used for reducing the length of the component is called face turning operation.



$$\text{Time/cut} = \frac{L}{fN}$$

let $l = 100mm$ $\quad l_f = 92mm$ $\quad d_{max} = 3mm$

$$\text{Number of cuts} = \frac{L - L_f}{d_{max}}$$

$$= \frac{100-92}{3} = \frac{8}{3}$$
$$= 2.6 \approx \underline{3}$$

$$\text{Total Time} = \text{Time/cut} \times \text{No: of cuts}$$

$$= \frac{L}{fN} \times \left(\frac{L_o - L_f}{d_{max}}\right)$$

$L = \frac{D_o}{2} + \text{approach} + \text{overrun}$ — Solid

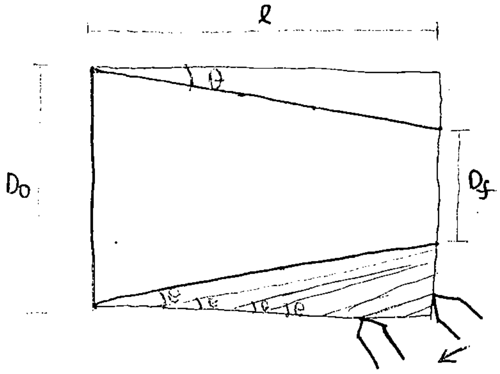
$L = \frac{D_o - D_i}{2} + ap + OR$ - hollow

f = feed mm/rev

d = depth of cut mm

$$N = \frac{1000 V}{\pi \times D_o}$$

The turning operation used for producing tapered components in a lathe machine is called taper turning



$$\text{Time per cut} = \frac{L}{fN}$$

$$\text{Total time} = T_1 + T_2 + T_3 + \cdots$$

$$= \frac{1}{fN}\left[l_1 + l_2 + l_3 + \cdots\right]$$

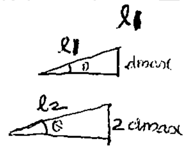
$$= d_{max}$$

$L = l_l + AP + OR$ $\qquad \theta = \tan^{-1}\left(\frac{D_o - D_f}{2l}\right)$

$l_1 = d_{max} \operatorname{cosec} \theta \Leftarrow \sin\theta = \frac{d_{max}}{l_1}$

$l_2 = 2 d_{max} \operatorname{cosec}\theta$

$l_3 = 3\, d_{max} \operatorname{cosec} \theta$

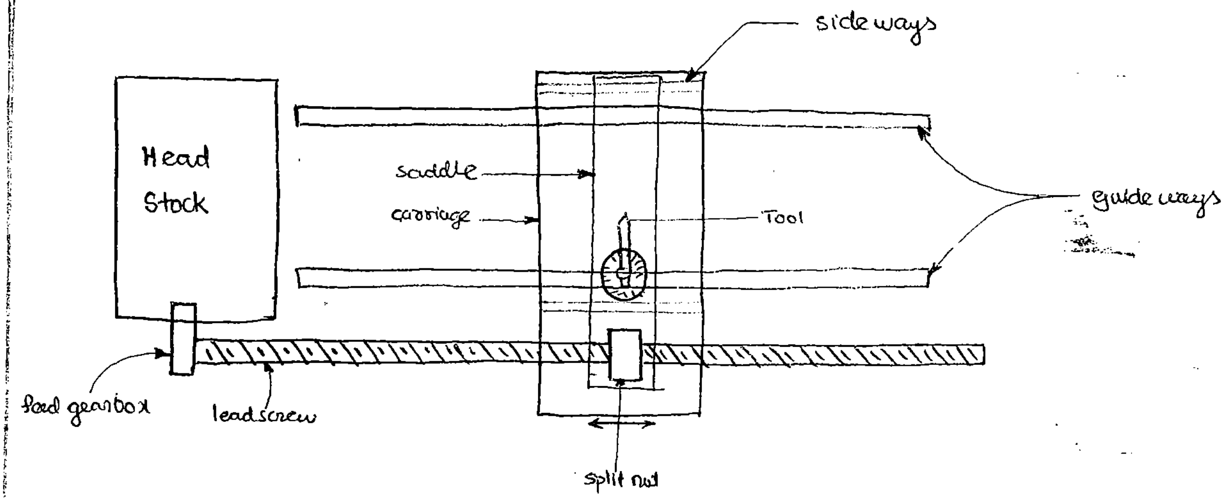


$$N = \frac{1000 V}{\pi D_o} = N_1 = N_2 = N_3$$

Methods of taper turning.

1 Compound rest method
2 Tailstock offset method
3 Taper turning attachment
4

1 Compound rest method (Compound rest swivelling method)



In case of plane turning operation; '0' of compound rest is coinciding with the fixed mark.

In case of face turning operation; '90' of compound rest is coinciding with the fixed mark.

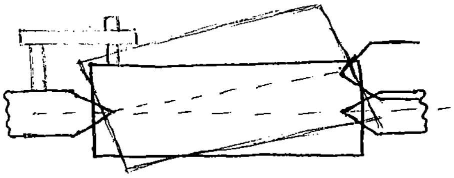
In case of taper turning operation; the compound rest is swivelled by an angle equal to taper angle of the component.

Advantages

1 Used for producing any taper angle from 0-45°
2. Used for both internal and external taper turning

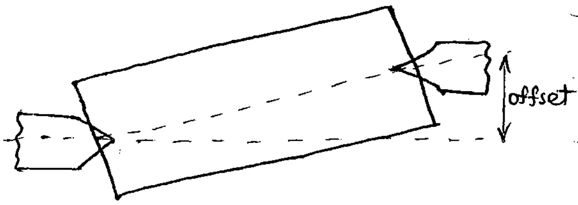
1 Accuracy of taper angle produced is only upto 0.5° only.

2. Tailstock offset method :-



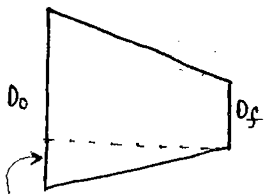
In the normal turning operations the w.p is mounted within the centres with axis of w.p coinciding with axis of machine.

with



when the w.p axis is tilted, even though the tool is moving like a plane turning operation - taper turning will takeplace on the work piece.

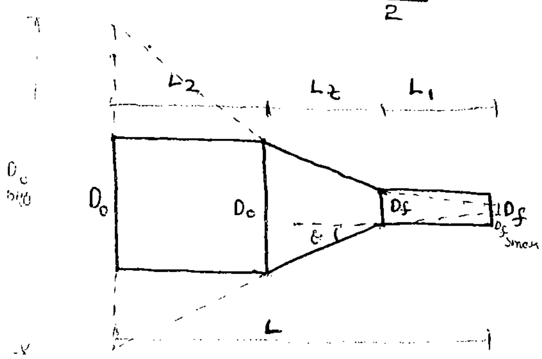
upto 0.1° accuracy tapers could be produce



used only for external taper turning operation.

Total taper = offset $= \dfrac{D_o - D_f}{2}$

The maximum offset possible on a standard lathe machine is 10mm



$$\text{Taper/mm} = \left(\frac{D_o - D_t}{2L_z}\right)$$

$$\text{offset} = \text{Total taper} = \text{taper/mm} \times L$$

$$= \left(\frac{D_o - D_z}{2L_z}\right) \times L$$

$$\theta = \tan^{-1}\left(\frac{D_o - D_f}{2L_z}\right)$$

$$\text{offset} = \text{Total taper} = L\tan\theta$$

$$\text{offset} = \frac{D_{o_{big}} - D_{f_{small}}}{2}$$

3 Taperturning attachment methodology.

In the normal turning operations; the slide ways would be kept parallel to the guide ways.

In case of taper turning attachment method; the slideways are tilted by an angle equal to taper angle of the component.

when the slideways are tilted, the saddle, compound rest, toolpost and tool will be automatically tilted and perform taper turning operation.

Advantages

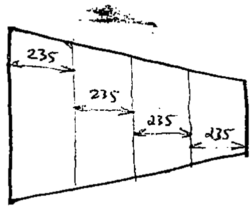
Both internal and external taperturning operation.

Accuracy of the taper angle produced is upto 0.1°

Limitations

Upto 8° taper angle or 16° included angle is only possible.

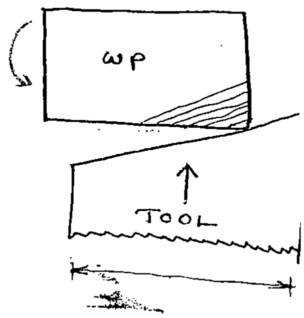
The maximum length of component which can be taper turned in one setting is 235mm only and for longer length of the components; the taper turning will be done in morethan 1 setting.



4 Form tool method :-

If the shape of the tool used remains same as the shape of the component to be produced. It is called as formed tool method of taper turning.

i for producing the tapered component - If the tapered tool is used. It's called form tool method of taperturning.



Advantages

Accuracy of the taper produced on the component depends on the accuracy of the taper present on the tool.

No setting is required and it's thus easy to do.

Limitations

Tool cost would be high since for every taper, separate tool is required

Only external taper turning could be performed

For taper turning; the width of the tool must be > length of w.p to be taper turned. But maximum width of the tool possible is 20mm. Hence maximum length of w.p which can be taper turned is 20 mm only.

A 200 mm length of the component in which the central 70 mm length of the component is to be taperturned to an included angle of 4°. Which of the following methods can be used for doing the job.

(A) Compound Rest method (B) Tailstock offset method
(C) Taper attachment method (D) Form tool method.

Ⓐ ✓ Ⓑ ✓ Ⓒ ✓ Ⓓ ✗

offset $= 200 \tan 2°$
$= 7\,mm < 10\,mm$

$> 20\,mm$

A - B - C

4 Thread Cutting Operation :-

The method of producing threads on using turning operation is known as Thread cutting operation.

$$\text{Time/cut} = \frac{L}{fN}$$

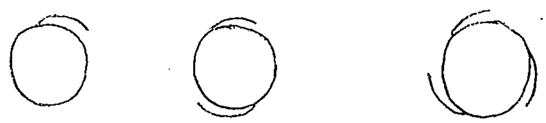
$$L = l + AP + OR$$

f = pitch of the thread - single start
= Lead of the thread - multi start

In case of plane, face and taperturning; large amount of feed will be given for rough machining and small amount of feed to finish machining. whereas in thread cutting operation, pitch is always fixed.

$$\text{Lead} = p \times \text{No of starts}$$

p - pitch.



Single start double start (2) multistart

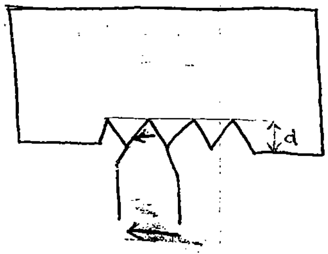
Multi start threads are used
→ To produce leak proof joint.
→ To get higher mechanical advantage $\left(MA = \frac{\text{Load}}{\text{Force}}\right)$

$$N = 5 - 10\ rpm$$

A very low rpm is set to enable easy engagement and disengagement of the

The very low RPM can be obtained by using back gear arrangement. It's also called as reverted gear train.

$$\text{Total time} = \text{Time}/_{cut} \times \text{No. of cut}$$



Though the depth of thread is less than max. depth of cut possible in a lathe machine, it is always preferable to perform the thread cutting operation in more than one cut - bcz if thread cutting is done with large depth of cut → the thrust force acting will be higher and it may weaken the threads.

$$\text{No of cuts} = \frac{25}{TPc} \text{ - external}$$

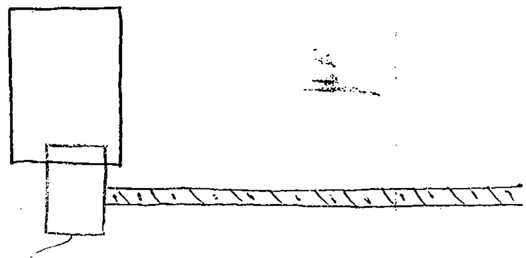
$$= \frac{30}{TPC} \text{ - internal}$$

T_{PC} - Threads per Cm

The earlier turning operations like plane, face and taper turning operations; the feed used is either manual or automatic, depending on the operator. But in case of thread cutting operation; the feed used must be only automatic feed.

Automatic feed required is obtained by using leadscrew and splitnut mechani

To get the required amount of pitch or feed it is required to select the proper gears and gear train in the feed gearbox.



Feed gear box

Gears of 20-120 teeth in steps of 5 teeth and 127 teeth.
"20, 25, 30 . . . 120"
"127"

Indian standard

Gear ratio = Train value

$$= \frac{N_f}{N_d} = \frac{N_{LS}}{N_{job}}$$

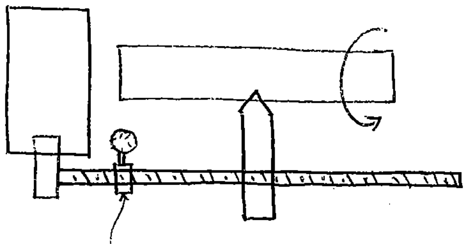
$$= \frac{T_d}{T_f} = \frac{P_{job}}{P_{LS}} = \frac{\text{lead of job thread}}{\text{lead of lead screw}}$$

127 teethed gear is used for producing English threads on a metric lathe or metric threads on English lathe.

If pitch of thread indicated in terms of inches -- called as English threads
If pitch of thread indicated in terms of mm or cm - called as Metric threads.

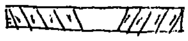
If the pitch of leadscrew threads of lathe indicated in terms of inches - English lathe
If the pitch of leadscrew threads of lathe indicated in terms of mm or Cm - Metric lathe

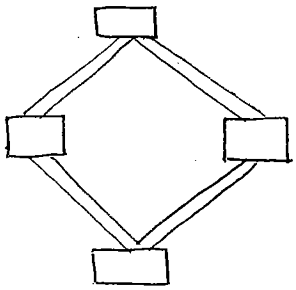
Refer the illstns on the next pages:



- All common application
  lead screw
  When bolt is kept stationary and nut is rotated if it goes inside toward right (clockwise - if it moves inside

only for limited applications
Jewellery
O_2 cylinders in gaswelding
turn buckle





It's simple mechanism used instead of screw jack. It's used for lifting cars. It's light wt than leads screw jack.

for cutting process to takeplace the w.p should always rotate in ccw when seen through tailstock side.

- for producing RH threads with the assumption of direction of rotation of job as a counter clockwise direction; the direction of movement of the tool required is right to left direction ① - for this the direction of rotation of the leadscrew required is counter clockwise direction ②.
- for producing RH threads; the direction of rotation of job and leadscrew is same ③.

To produce the same direction of rotation
- a) If the designed gear train is a simple gear train
  use 1, 3, 5 . . . . . . odd ④ number of idlers.
- b) If the designed gear train is a compound gear train
  use 0, 2, 4 . . . . . . even ⑤ numbers of idlers.

LH - exact reverse. - ①, ②, ③, ④, ⑤

Q Calculate the gear train to cut 3mm thread on an english lathe having the lathe ~~consisting~~ of constant 8, the gear propagation is 4 and the gears available 24, 28, 32 . . . . . 100 and 127.

* Lathe constant = TPI in case of english lathe
= TPC in case of metric lathe

So 8TPI

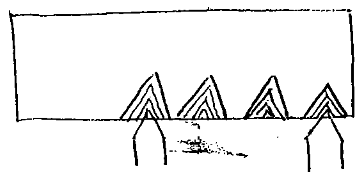
$$GR = \frac{N_f}{N_d} = \frac{3 \times \frac{127}{5}}{\frac{1}{8} \times \frac{127}{5}} = \frac{120}{127}$$

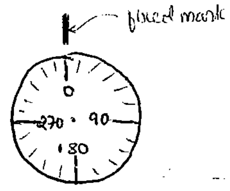
$$= \frac{40}{127} \times 3$$

$$= \frac{40}{127} \times \frac{3 \times 24}{24} = \frac{40}{127} \times \frac{72}{24}$$

During thread cutting operation - the path followed by the tool during 2nd and subsequent must remain same as that of the 1st cut itself.

To satisfy the above condition; a thread chasing dial will be used.
It's always encaged with the leadscrew and is having very low rpm.

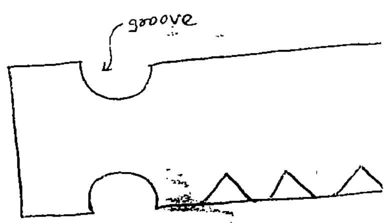




TCD

During thread cutting operation 1st bring the tool away from the workpiece; set the depth of cut for the 1st cut and encage the lever of the split nut mechanism when selected position of TCD is coinciding with fixed mark and continue the thread cutting.

At the end of the 1st cut; disencage the lever of split nut mechanism; take the tool back and bring the tool away from the w.p in front side. Again set the tool for 2nd depth of cut and encage the lever when selected position of TCD is coinciding with fixed mark.



At the end of the length of the threads to be produced, for easy disencagement of the lever, a groove has to be produced - called as **grooving or necking** or undercutting.

During thread cutting whenever the tool comes to groove zone operator will be feeding certain time for easy disencagement of the lever.

Q Calculate the suitable geartrains for cutting 10 mm ~~thick~~ pitch 3 start threads on a lathe, with a leadscrew having 6.25 mm pitch.

$$G.R = T.V = \frac{N_f}{N_d} = \frac{10 \times 3}{6.25 \times 1} = \frac{30}{6.25}$$

$$= \frac{30 \times 4}{6.25 \times 4}$$

$$= \frac{120}{25}$$

If compound Geartrain $= \frac{10 \times 4}{6.25 \times 4} \times \frac{3 \times 20}{1 \times 20} = \frac{40}{25} \times \frac{60}{20}$

For Every problem it is possible to design the compound gear train. But simple gear trains could be designed only for few cases.

Make sure that all the gears

Q Find the change wheels for cutting 1.75 mm pitch threads on a lathe of 6 TPI leadscrew.

$$G.R = TV = \frac{N_f}{N_d} = \frac{1.75\ mm}{\frac{1}{6}\ inch}$$

$$= \frac{1.75}{\frac{1}{6} \times 25.4}$$

$$= \frac{1.75}{\frac{1}{6} \times \frac{127}{5}} = \frac{1.75 \times 30}{127}$$

$$= \frac{52.5}{127}$$

$$= \frac{105}{254}$$

$$= \frac{105}{127} \times \frac{1}{2}$$

$$= \frac{105}{127} \times \frac{1 \times 20}{2 \times 20}$$

$$= \frac{105}{127} \times \frac{20}{40}$$

here simple gear trains are not obtained

here we can produce metric threads on English lathe.

Q 1. Thread cutting 2. Taperturning 3. Undercutting 4. Plainturning. write these operation in sequence.

In general Thread cutting would be the last operation and after thread cutting only champhering is allowed to do it on the component.

Ans: 4 - 2 - 3 - 1

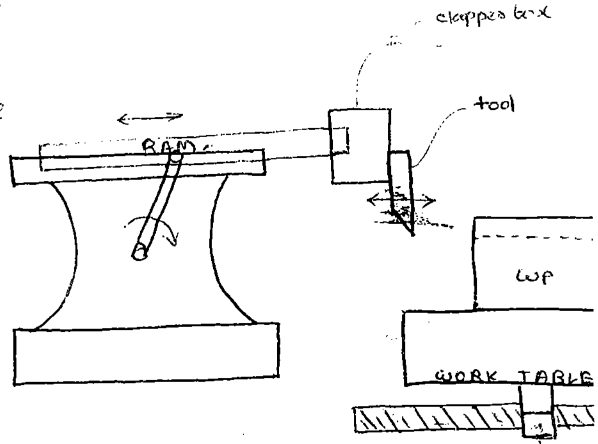
Shaping and Planing

Shaping is the operation used for removing a layer of materials from the w.p using reciprocating single point cutting tool.

1 rev of crank = 1 Forward Stroke + 1 return stroke

= 1 double stroke.

= 1 Cutting stroke + 1 ideal stroke



Shaper

During forward movement of the tool only; the tool is removing material from the work-piece ∴ called the **cutting stroke**

During return movement of the tool, it is simply moving without removing any material ∴ called as **ideal stroke**.

The tool has to travel at optimum cutting velocity during forward or cutting stroke

To minimize the production time; the tool has to travel at maximum possible velocity during returning stroke or ideal stroke.

Eventhough crank is rotating at uniform velocity, to get the variable velocity of the ram; there is a witworth Quick return mechanism is used b/w the crank and the ram.

witworth Quickreturn mechanism is one of the inverses of the simple slider crank mechanism.

Through out the movement of the Ram; at the middle of the return stroke; the highest velocity will be obtained;

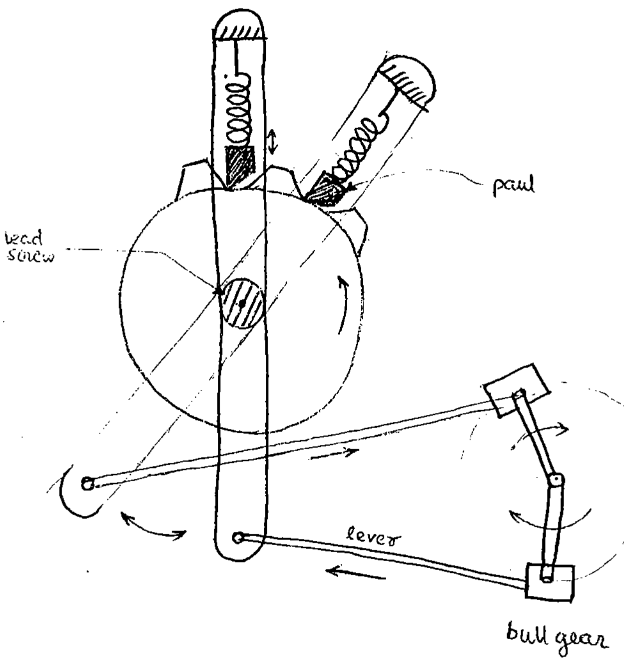
The next highest velocity is obtained at the **end of the returnstroke**

The lowest velocity is obtained at the **Beginning of the forward stroke**

During shaping operation when the tool is moving in the cutting stroke; the tool should be in position for removing the material from the w.p. At the beginning of the return stroke the tool should be lifted upwards to avoid the contact b/w the tool and the w.p and again at the beginning of the forward stroke, the tool should take the position for removing the material from the w.p. This will be done by using the clapperbox with rocker arm fitted in front of the ram.

Only automatic intermittent feed will be given bcz the machining also takeplace intermittantly. Whatever the intermittent feed required for the shaping operation is ~~obtained~~ given to the work table only. bcz the tool is always moving on a fixed guideways.

The intermittent feed required for the work table will be given only during return stroke which is ~~given~~ obtained by using Rachet and Paul mechanism.



During 1st half revolution on the crank; the lever is moving from right to left direction, the arm is rotating in the clockwise direction ~~with~~ respect to the pivot. During this time the paul is lifting upwards bcz of presence of inclination at one side of the paul without disturbing the ratchet and when even it is finding the gap b/w two teeth it is falling downwards due to springforce.

During 2nd half revolution of the crank, the lever is moving from left to right direction, the arm is rotating in counter clockwise direction.

Bcz there is no inclination present in the paul on the other side, the paul is rotating the ratchet.

When the ratchet is rotating - the leadscrew is rotating, which moves the splitnut ~~work~~ table, and workpiece linearly.

Now by matching the 1st half revolution of the crank with cutting stroke and 2nd half revolution of the crank with return stroke, the feed of the worktable can be obtained only during return stroke.

Ratchet - 20 teeth, Pitch of LS = 5mm. Paul is indexing methody by 1 teeth during every Return / double stroke. $f(mm/DS) = ?$

1 rev of ratchet

Let L = stroke length of Ram

V = optimum cutting velocity or velocity of ram during forward or cutting stroke

M = Quick return ratio (<1) $\quad M = \frac{1}{2}$ to $\frac{2}{3}$

$= \frac{\text{cutting velocity}}{\text{return stroke velocity}} = \frac{V}{V_r}$

$= \frac{\text{time taken for return stroke}}{\text{cutting stroke}} = \frac{T_r}{T_c}$

B = width of the workpiece

f = feed of the work piece or work table in mm/double stroke.

Time taken for cutting stroke $= \frac{L}{V}$ $\quad T_c = \frac{L}{V}$

Time taken for return stroke $= T_c \times M$ $\quad T_r = T_c \times M$

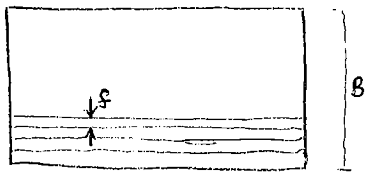
Time / DS $= T_c + T_r$

$= \frac{L}{V}(1+M)$

$\frac{1}{\text{Time/DS}} = \frac{V}{L(1+M)}$

DS/time = RPM of crank $= \frac{V}{L(1+M)}$

$$\text{Time/cut} = \text{Time/DS} \times \text{No of DS}$$



$$\text{No: of DS/cut} = \frac{B}{f}$$

$$\text{Time/cut} = \frac{B}{\cancel{N}}\ \frac{L}{V}(1+m) \times \frac{B}{f}$$

$$= \frac{B}{f} \cdot \frac{L}{V}(1+M)$$

$$= \frac{B}{f} \times \frac{1}{\text{RPM of crank}}$$

$B = 2m$, $f = 0.1\,mm$, No of D $= \frac{2000}{0.1} = 20{,}000$

$$\text{Time/cut} = \frac{20{,}000}{10} = 2000 \text{ min}$$

for Machining a large wp using shaping machine - the time taken will be very high. ~~to~~ reduce the machining time It is recomented to use more than one cutting tool simultaneously.

To use more than one cutting tool in shaping - more than one ram has to be used. It is nothing but more than one shapers are kept in parallel and it is not economical. Hence when more than one cutting tool is used in machining operation, the tools are fixed on the beam and wp is allowed to reciprocate with optimum cutting velocity in the cutting stroke and maximum velocity in the return stroke. This is called as Planing Machine

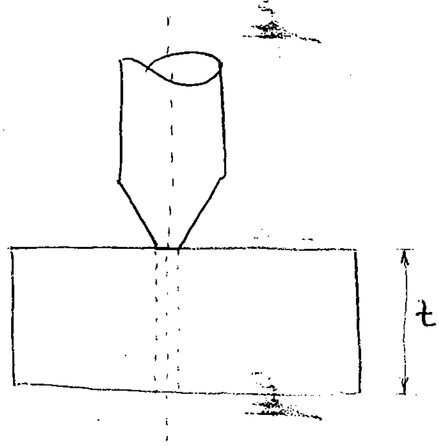
If the shaping machine is rotated by 90° so that the wp is kept vertical and the tool is reciprocating in the vertical axis called as Slotting machine.

Drilli

6/9/11
6-9

Drilling Operation

Drilling operation is used for producing holes in the w.p.

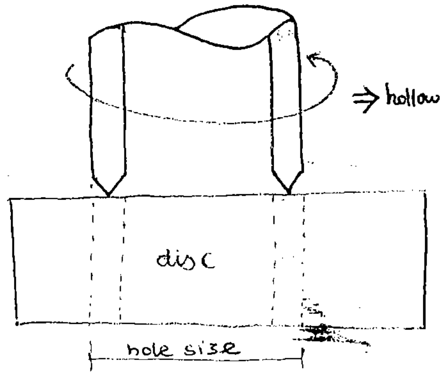


In general, it is not preferable to produce the required size of the hole by using corresponding size of the drill bit. bcz the forces acting during making the large sized holes directly are very high. These forces causes vibrations in the drill bit and results in poor positional accuracy of the hole produced.

Hence it is always reccomended to produce the smallest size of the hole first. ie the 5mm dia hole and then enlarge the hole by using different sizes of the drill bits like 8,10,12,15,20 . . . . .

Using the above method the maximum size of the tool preferable to produc is 50mm only, beyond which the time taken for producing the hole is large, hence the cost of manufacturing would be high.

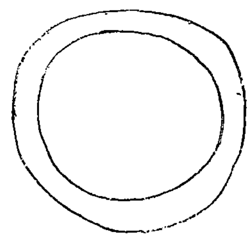
Trepanning Operation

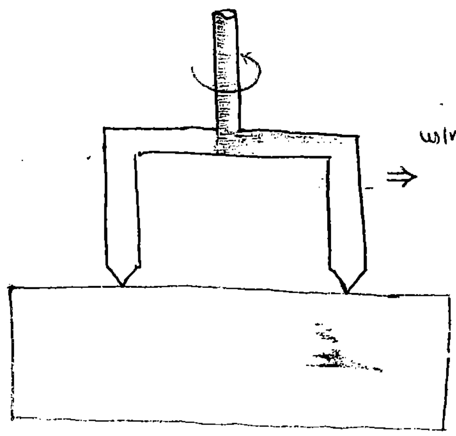


Operation of producing the large sized holes without drilling.

disadvantage

Can be used only for producing 'through holes' but not for blind holes.





Reaming operation :-

operation used for sizing and finishing of hole.

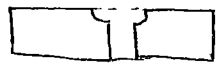
In this very small sized toothed drill bit can be used so that it removes very small quantities of materials from the w.p.

Boring Operation :-

The method of enlarging the existing hole by using internal turning operation.

Counter boring :-

The method of enlarging the end (counter) of the hole by using internal turning operation

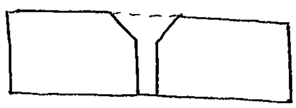


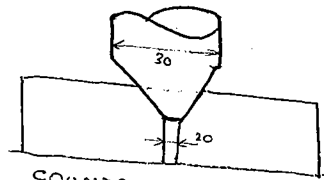
COUNTER BORING

Counter sinking :-

Making the conical enlargement at the end of the tool.

It's been done by using large sized drill bits



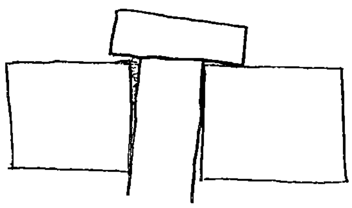


COUNTER SINKING

Spot facing :-

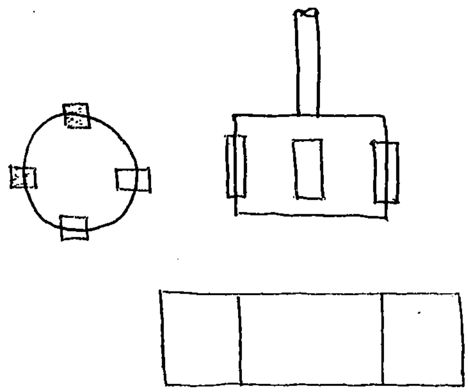
During drilling operation, some of the chips may be left over at the edge of the hole. This will make the improper seating of the bolt head or nut and causes to produce the eccentric loading on the bolt. To avoid this, the spot facing will be done to make the hole surface perfectly flat and square.

It's been done using end mill cutter with drilling machine.



Honing :-

Operation of producing excellent surface finish on holes.



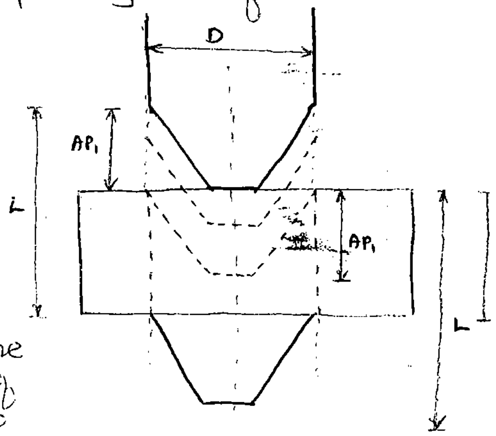
The honing tool, having abrasive coating, rotates and reciprocates inside the already existing hole.

This produces excellent surface finish.

Machining Time for drilling

$$\text{Time/hole} = \frac{L}{fN}$$

For the theoretical calculation of machining time in drilling, eventhough the hole is produced in stages; it is always assumed that the required size of the hole can be produced by using corresponding size of the drill bit directly.



$L \rightarrow$ length of tool travel

$$L = t + AP_1 + AP + OR$$

AP_1 – compulsory approach
- distance to be travelled by the tool for complete diameter of the hole has star just start to produce.
- depth of cut in drilling

0.5 D – through holes
0.3 D – blind holes

$f \Rightarrow$ feed mm/rev

$$N = \frac{1000V}{\pi D}$$

D – diameter of drill bit.

MILLING OPERATION

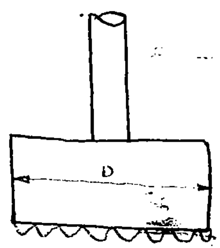
A multipoint cutting tool machining operation used for producing the slots in the component and also used for removing a layer of material from the flat surfaces.

① End mill cutter

② Perepheral milling cutter

If the cutting teeth or tips are provided at the end or face of the circular disc – it is called as end mill cutter.

The end mill cutter can be used either with vertical milling machine or drilling machine also

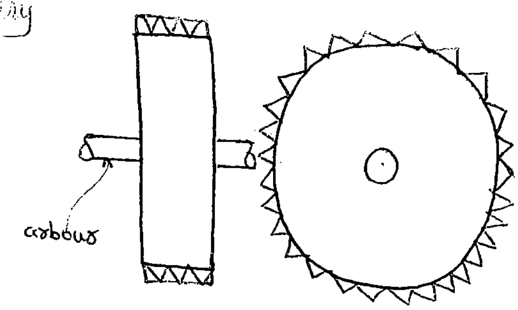


end milling cutter.

If the cutting teeths are provided at the perephery of the circular disc - it is called as peripheral milling cutter.

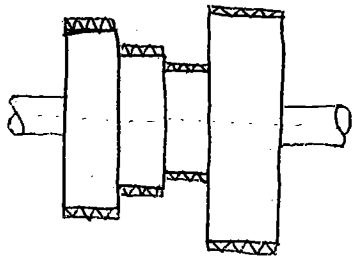
Used only with horizontal milling machine.

- Usually they are mounted on a shaft called as arbor — It is having keyways in it and it is expandable shaft.



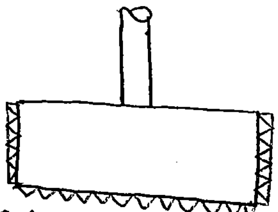
Perepheral milling cutter

If a gang of different sizes of perepheral milling cutters are kept together to remove the material simultaneously from one work piece itself - it is called as ganged milling cutter



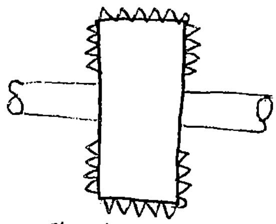
ganged milling cutter -

In addition to the face of a circular disc if the teeth are provided on the perephery also, then it's is called as side milling cutter.



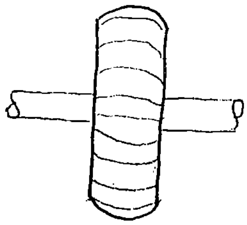
Side milling cutter

In addition to the perephery - if the teeths are also provided on the face - it is called as stradle milling cutter.



Stradle milling cutter.

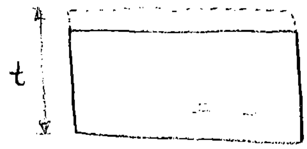
If the peripheral milling cutter is made like a gear teeth profile to be produced - called as the gear milling cutter or formed milling cutter.



Gear milling cutter

Types of milling

1 Face milling
2 slab/slot milling



If the milling operation is used for removing a layer of material from the flat surfaces of w.p. Face milling.

If the milling operation is used for producing the slots in the components – called as slab or slot milling

In general; both the types of milling cutters can be used for performing both the types of milling operations – like facemilling done by using end mill cutter or perepheral milling cutter.
But preferably the face milling operation can be done by using end mill cutter.
and slab milling operation is done by using the peripheral milling cutter.

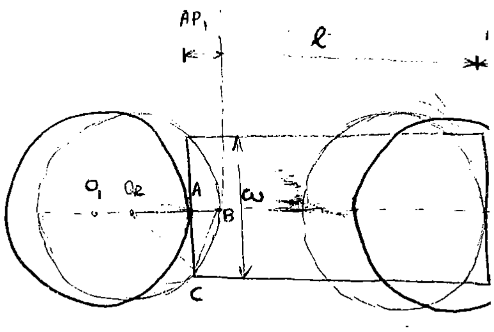
Machining time for milling

$$\text{Time/cut} = \frac{L}{f_m} = \frac{L}{fN} = \frac{L}{f}$$

f_m - Table feed in mm/min
f - Table feed in mm/rev
f_t - Table feel in mm/teeth

$$f_m = f \times N = f_t \, t \, N$$

t - No: of teeth
N - RPM of cutter



$$L = l + AP_1$$

AP_1 - compulsory approach
- distance to be travelled by the tool for complete width of the w.p is started machining

AP_1

① face milling with end mill cutter

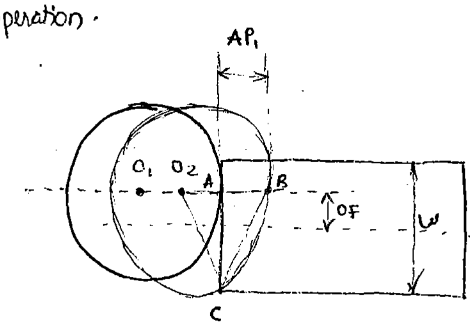
$$AP_1 = AB$$
$$= O_2B - O_2A$$
$$= \frac{D}{2} - \sqrt{O_2C^2 - AC^2}$$
$$= \frac{D}{2} - \sqrt{\left(\frac{D}{2}\right)^2 - \left(\frac{w}{2}\right)^2}$$

$$AP_1 = \frac{1}{2}\left(D - \sqrt{D^2 - w^2}\right)$$

D – diameter of milling cutter
w – width of wp.

During face milling with end milling cutter;
If the axis of the milling cutter is coinciding with the axis of the wp – symmetrical milling operation.

If the axis are not coinciding called as – asymmetrical or non-axi symmetric milling.



for asymmetrical

$$AP_1 = AB = O_2B - O_2A$$
$$= O_2B - \sqrt{O_2C^2 - AC^2}$$
$$= \frac{D}{2} - \sqrt{\left(\frac{D}{2}\right)^2 - \left(\frac{w}{2} + of\right)^2}$$
$$= \frac{1}{2}\left(D - \sqrt{D^2 - w_i^2}\right)$$

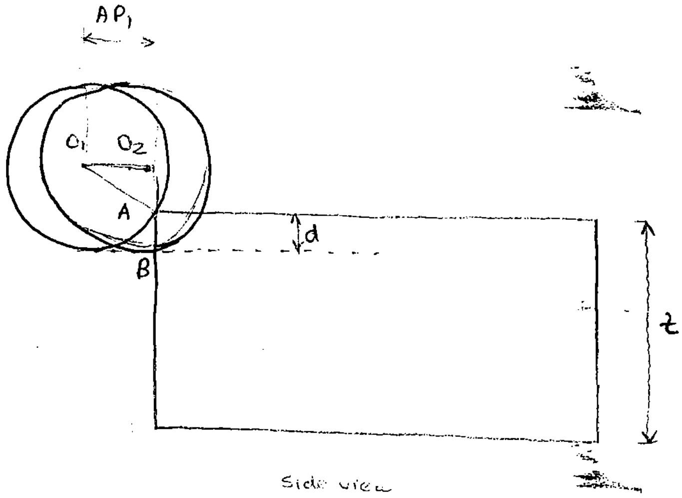
$$w_i = w + 2of$$

* Approach AP_1 would be always ~~>~~ than the is greater for the asymmetric milling than symmetric milling. and thus the time for machining would be greater for asymmetric than symmetric.

* Based on stability symmetrical milling is better than the asymmetric mill-

* ∴ most commonly used is the symmetrical milling and asymmetrical milling is used only when symmetrical milling is not possible.

2 face milling with peripheral milling cutter.



$$AP_1 = O_1O_2$$

$$= \sqrt{O_1A^2 - O_2A^2}$$

$$= \sqrt{\left(\frac{D}{2}\right)^2 - (O_2B - AB)^2}$$

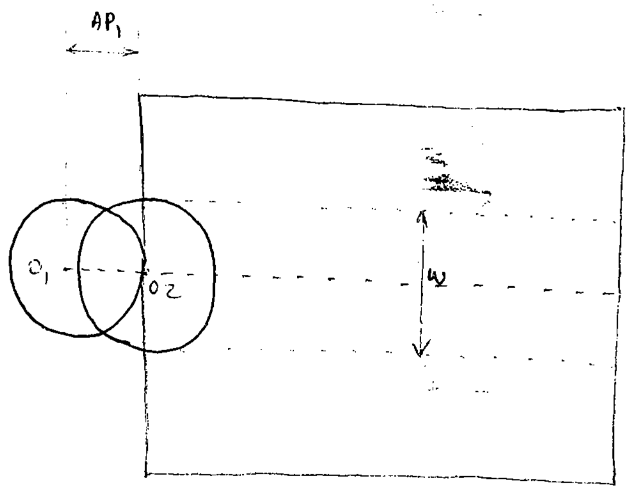
$$= \sqrt{\left(\frac{D}{2}\right)^2 - \left(\frac{D}{2} - d\right)^2}$$

$$= \sqrt{Dd - d^2}$$

$$= \sqrt{d(D-d)}$$

$$AP_1 \simeq \sqrt{Dd}$$

3. Slab milling with end milling cutter.



$AP_1 = \frac{D}{2}$ [when

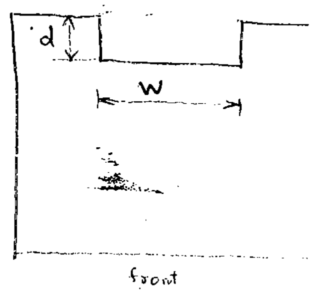
$= \frac{1}{2}\left[D - \sqrt{D^2 - w^2}\right]$

4

$$AP_1 = \sqrt{d(D-d)}$$

Same as 2

side view



End milling cutter $AP_1 = \frac{1}{2}\left[D - \sqrt{D^2 - w^2}\right]$

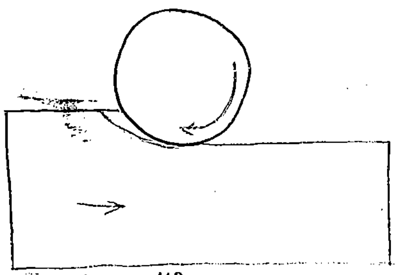
Peripheral milling cutter $AP_1 = \sqrt{d(D-d)}$

$\simeq \sqrt{Dd}$

when milling is done by using perepheral milling cutter ; the milling process can be divided into 2 methods

① Up or Conventional milling operation.

② Down or climb milling operation.



UP

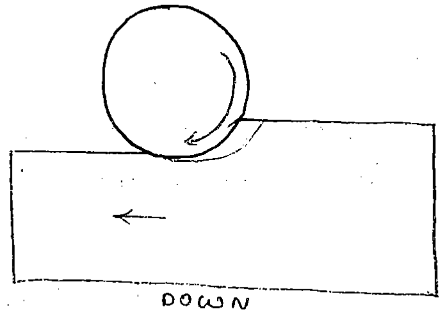
If the direction of movement of the w.p and direction of rotation of the milling cutter are opposite called as upmilling operation

Bcz of opposite direction of movement, the forces acting in milling are higher; power consumption is high and tool life is low.

The uncut chip thickness is varying from minimum to maximum to maximum

Thus the surface finish would not be so less as compared to down milling.

advantage
with up milling bcz of direction of movement are opposite, even though backlash is present in the machine gears; there is no fluctuations are produce in w.p. hence as the machine is becoming old; it is preferable to use the up milling only.



DOWN

If both are moving in the same direction ; called as down milling operation.

In case of down milling ; bcz of same direction of movement ; the forces acting are low, power consumption is low, tool wear is low and tool life is high.

The uncut chip thickness is varying from maximum to minimum and

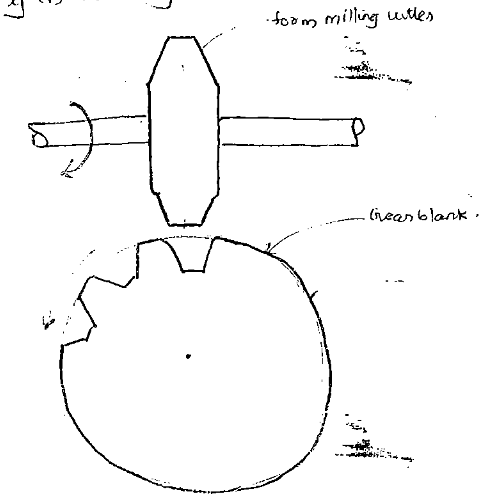
Thus the surface finish produced is better in down milling

They are commonly used due to less power consumption, less forces, more tool life and greater surface finish.

disadvantage
As the machine is become old ; the transmission part experience wear & tear and produces backlash or clearance in the machine gears. This produces fluctuations in the w.p. and causes the mechanical breakage failure of the tool tips or poor surface finish may be taking place.

Indexing of milling

The operation of rotating the job through required angle in b/w the two successive cuts of a machining is called Indexing in milling.



Depth = addendum + dedendum

= 1m + 1.25m

= 2.25m

For the indexing to be done mainly 2 devices are required

1. Device – to rotate the job to required angle – crank

2. Device – to ensure that the given rotations are correct – Indexing plate

It's a circular disc having holes at various diameters. The angle b/w each consecutive holes at any circles are same.

2 types of indexing plates are used

(a) Brown and sharp.

3 plates are used

plate 1 – 15, 16, 17, 18, 19, 20 – 6 circles

plate 2 – 21, 23, 27, 29, 31, 33 – 6 circles

plate 3 – 35, 37, 39, 41, 43, 47, 49 – 7 circles

(b) Parkinson

plate 1 – 24, 25, 28, 30, 34, 37, 39, 41, 42, 43

plate 2 – 46, 47, 49, 51, 53, 54, 57, 58, 59, 62, 66.

only Brown and sharp indexing plates are used in Indian standard

methods of indexing :-

1 Direct indexing

2 Simple indexing or plain indexing

3 Angular indexing

4 Compound indexing

5 Differential indexing.

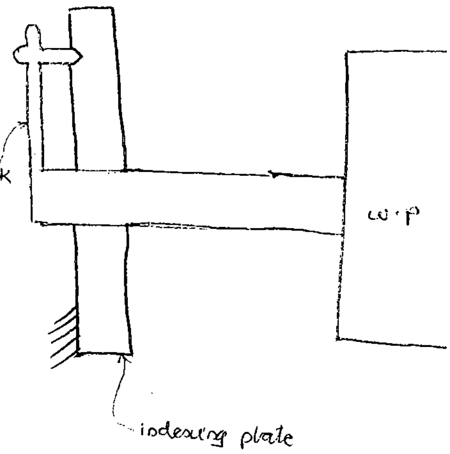
①

Work piece and crank is directly connected without any speed reduction.

It has a special indexing plate which has only one circle with 24 holes.

The special indexing plate is always fixed.

∴ One revolution of crank give one revolution of the job.



- Be what ever the number by which 24 can be divided without any residue — the corresponding no: of divisions by which the circumference of a job can be divided.

eg:- 2, 3, 4, 6, 8, 12, 24 . . .

If No of teeth req. $N = 4$

crank rotation required after every cut $= \frac{24}{4} = 6$.

we should move 6 holes after every cut.

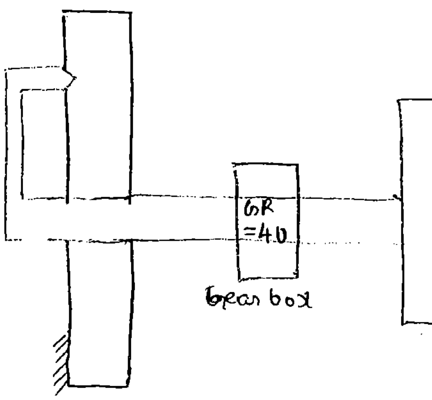
If $n = 5 \Rightarrow CR = \frac{24}{5} = 4.8$ X not possible.

2 Simple or plain indexing:-

B/w the job and crank - a Gearbox is introduced with a gear ratio of 40

both parkinson and brown and sharp is been designed with a gear ratio of 40.

If we can want to use another gear ratio we should design our own gear indexing plate (☺)



N = No: divisions by which the circumference of a job is to be divided.

$$\text{Crank rotation required} = \frac{40}{N}$$

If $N = 24$

∴ Crank rotation req. $CR = \frac{40}{24} = 1\frac{2}{3}$

$$= 1\frac{2 \times 5}{3 \times 5} \Rightarrow 1\frac{10}{15}$$

so after 1 cut then rotate by 1 revolution and 10 holes in a 15 hole circle.

If $N = 36$

$$C.R = \frac{40}{36} = 1\frac{4}{36} = 1\frac{1}{9}$$

$$= 1\frac{1\times 3}{9\times 3} \rightarrow \text{also possible}$$

$$= 1\frac{3}{27}$$ 1 rev + 3 holes in 27 ~~circle~~ hole circle

$N = 13$

$$CR = \frac{40}{13} = 3\frac{1}{13} = 3\frac{3}{39}$$ 3 rev + 3 holes in 39 hole circle.

(3)

If we give 1 rev of crank $= \frac{1}{40}$ rev of job

$$= \frac{360}{40} = 9^\circ \text{ of job.}$$

θ = angle b/w two consecutive divisions.

If $N = 24$

$$\theta = \frac{360}{24} = 15$$

$$CR = \frac{\theta}{9} = \frac{15}{9} = 1\frac{6}{9}$$

$$= 1\frac{2}{3}$$

$$= 1\frac{10}{15}$$ Same as that of simple indexing but only the method is different

Limitation of simple indexing

~~Whatever the~~ Upto 40 divisions; any no. of divisions are possible; to divide the circumference of the job. But beyond 40 only some numbers are possible and others are not possible

If $N = 46$

$$CR = \frac{40}{46} = \frac{20}{23}$$

If $N = 53$

$$CR = \frac{40}{53}$$ 53 not available in index plate
53 not divisible also

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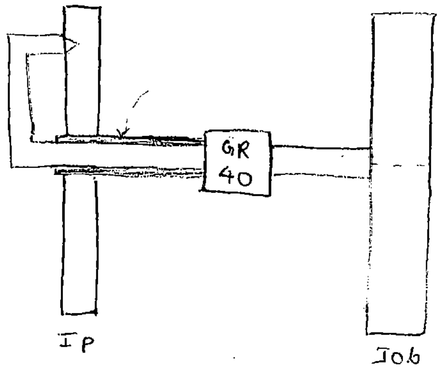
Compound Indexing :-

In simple indexing - the indexing plate is always fixed and only crank is rotated to rotate the job. But in case of compound indexing, either plate or crank can be rotated to rotate the job with a gear ratio 40 i.e only one is rotated at a time.



$$C.R = \frac{40}{N}$$

N - No of div by which the circumference is to be divided

In this method, the required crank rotation is first divided into two fractions, one fraction of rotation 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.

With this compound indexing, it is possible to divide the circumference of a job into any no: of divisions.

If $N = 27$

$$C.R = \frac{40}{27} = \frac{2}{3} + \frac{22}{27}$$

$$= \frac{2 \times 5}{3 \times 5} + \frac{22}{27}$$

$$= \frac{10}{15} + \frac{22}{27}$$

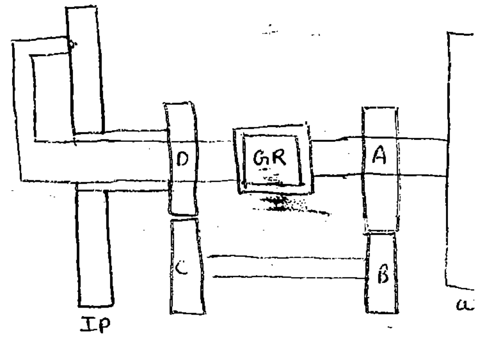
After every cut; by fixing the plate the crank can be rotated through 10 holes in a 15 holes circle. and by fixing the crank, the plate can be rotated through 22 holes in 27 holes circle

The major difficulty of compound indexing is that it is very difficult to divide the required crank rotation into two fractions and even after division also it is necessary to ensure that the hole circles required for both the fractions must be available in one plate itself.

5) Differential indexing :-

N - No of divisions

n - number slightly greater or smaller than N



$$CR = \frac{40}{n}$$

The difference from required is

$$\text{diff} = \frac{40}{N} - \frac{40}{n}$$

Bcz the n is used for calculation of crank rotation ; the difference in crank rotation can be given to the indexing plate simultaneously through externally mounted gear train to the indexing plate. So that whenever the crank is rotating , the indexing plate is also rotating simultaneously either in the same direction or in the opposite direction.

Gear ratio for the gear train is

$$G.R \text{ or } GT = (n-N)\frac{40}{n}$$ ⇒ +ve - same direction

-ve - opposite direction

direction of rotation of crank & index plate opposite

let $N = 53$

$n = 55$

$$C.R = \frac{40}{55} = \frac{8}{11} = \frac{8\times3}{11\times3} = \frac{24}{33}$$

$$GR = \frac{n-N}{1}\times\frac{40}{n} = \frac{55-53\times40}{55} = \frac{16}{11} = \frac{16\times2}{11\times2} = \frac{32}{22}$$

$$= \frac{8}{11}\times\frac{2}{1} = \left(\frac{8}{11}\times\frac{5}{5}\right)\times\left(\frac{2}{1}\times\frac{20}{20}\right) = \frac{40}{55}\times\frac{40}{20}$$

let $N = 53$

$n = 50$

$$C.R = \frac{40}{50} = \frac{4}{5}\times\frac{3}{3} = \frac{12}{15}$$

$$GT = (50-53)\frac{40}{50} = -3\times\frac{4}{5} = \frac{-12\times5}{5\times5} = \frac{-60}{25}$$

$$= \frac{-4}{5}\times\frac{5}{5}\times\frac{3\times20}{1\times20} = \frac{-20}{25}\times\frac{60}{20}$$

we could select any number as 'n' but it is would be easier to calculate if n is a multiple of 5.

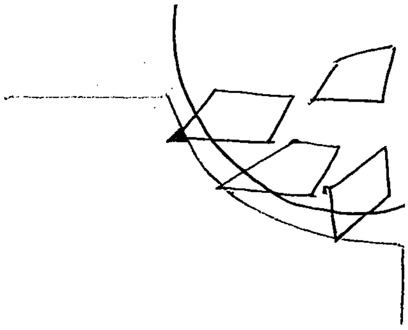
It's a slightly costly method.

GRINDING OPERATION

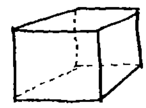
It's a conventional finish machining operation
(tool is harder than w.p)

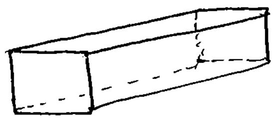
Gives better surface finish than other methods.

Many abbrasive particles are present in surf. of the grinding wheel act as a single point cutting tool for removing the material from the w.p.

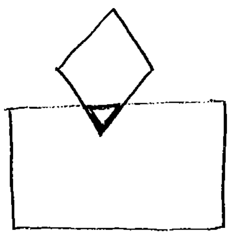


As the machining is taking place, the abbrasive particles are slowly wearing out; Once the wear becomes considerable, the abbrasive particle is start ~~wear~~ rubbing on the work piece so that the rubbing forces produced will pull out the blunt abbrasive particles, the fresh and new abbrasive particles present behind the blunt abbrasive particles are coming in contact with the w.p and start removing the material called as self sharpening of the grinding wheel.





The approximate shape of the abbrasive particles is cubical or square cross section with rectangle. Therefore the chip produced will have a triangular cross section.

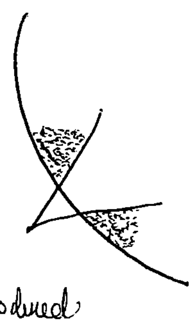


Out of all the conventional methods - Grinding is the one which requires highest specific cutting Energy b/c.

- of the random orientation of the abbrasive particles
  Due to random orientation - only about $\frac{1}{3^{rd}}$ of the abbrasive particles are acting like a single point cutting tool and remaining are simply rubbing onto the w.p without doing any machining
  ∴ the frictional energy losses are higher and specific cutting energy requirements are higher

randomly oriented b/c the grinding wheel is manufactured using powder metallurgy procedure
① powdering
② Blending
③ Compacting → Random arrange.
④ Sintering

- Even though the abbrasive particles have a capability to penetrate more into the w.p and remove large size of the chip, but the bonding material present b/w the abbrasive particles is not allowing the abbrasive particles to penetrate more to the w.p. Hence the chip size is reducing and sp cutting energy is increasing
  (... ... or (i.e. ploughing action) or Size effect of chip produced



$$\text{Machining ratio} = \frac{\text{Vol. of material Removed in w.p}}{\text{Vol. of Tool wear}}$$

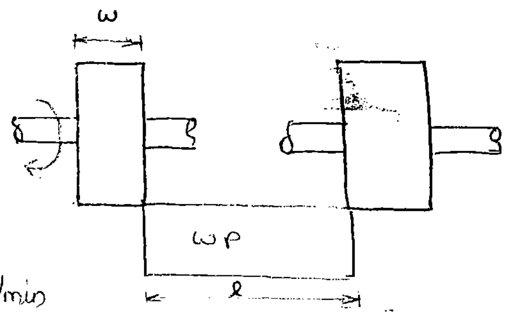
In case of turning or milling it the value of machining ratio would be very very large (if $1m^3$ removed tool wear by $1mm^3$ then $mr = 0.3\times10^{?}$). Thus it is having less significance and are not taken in those machining operation.

The machining ratio for the grinding operation is called as grinding ratio. It varies from 0.4 - 100.

$$\text{Grinding ratio} = \frac{\text{Vol of material removed in w.p}}{\text{Vol of wheel wear.}}$$

$$\text{Vol. of wheel wear} = \frac{\pi}{4}(D_i^2 - D_f^2)\times w$$

$$\text{Vol of m.r of w.p} = L\times B\times d$$



$$\text{Time / cut} = \frac{L}{fN}$$

$$V_{c_{max}} = 18{,}000 - 30{,}000\ m/min$$

(for diamond cutting tool we are using only 1500 - 2000 m/min)

$L = l + w + AP + OR$

f = feed in mm/rev

N = RPM of grinding wheel

$$= \frac{1000V}{\pi D}$$

This much velocity is required to get the metal removal.

Specification of Grinding wheel:

specified by 5 standard codes

Alphabet	Number	Alphabet	Number	Alphabet

① Types of abbrasive

A - Al_2O_3 B - B_4C C - SiC D - diamond

② Grain size

10-24 - coarse
30-60 - medium
70 - 180 - fine
220 - 600 - very fine

③ Grade of Grinding wheel

A-H - soft grade
I-P - medium grade
Q-Z - Hard grade

④ Structure

0-7 - close
8-16 - open

⑤ Bonding material

V - vitrified
B - Bakelite or
S - Silicate
E - Shellac
R - Rubber

① Type of abbrasive

Indicates the material used for manufacturing of abbrasive particles

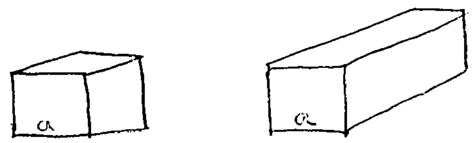
Out of the four abbrasive particles - diamond is very costly and B_4C is giving poor performance in the machining - hence Al_2O_3 and SiC are the most commonly used abbrasive particle.

Al_2O_3 is softer and tougher than SiC whereas SiC is hard and brittle than Al_2O_3

The type of abbrasive is selected based on the mechanical properties of w/p material.

Soft and ductile w/p can be machined by Al_2O_3
and hard & brittle w/p can be machined by SiC

② Grain size or Grit size



$$a = \left(\frac{1}{GSN}\right) \text{ inches}$$

reciprocal of Grain size No: indicates the size of the side of the cubical abbrasive particles in inches.

when GSN ↑ Grain size ↓

When the material Grain size ↑ the material removal rate 1st increases and then decreases.

Grain size is selected based on the surface finish requirements on the w.p.

for finish grinding operation – fine or very fine can be used.

for rough grinding operation – Coarse or medium grain size is used.

③ Grade of a Grinding wheel

The grade indicates the hardness of grinding wheel. i.e for same abbrasive particles, same size of the abbrasive particles and same bonding material; it is possible to vary the grade of a grinding wheel.

by varying the compacting pressure applied in the compacting stage of a powder metallurgical process and during manufacturing of grinding wheels.
By varying the compacting pressure actually we are varying the green compact strength or green strength of the component.

The grade of a grinding wheel is selected based on the mechanical properties of w.p material.

Hard w.p ⟶ soft Grinding wheels
soft w.p ⟶ hard Grinding wheels

If we use hard grinding wheels to grind hard w.p it results in **Glazing** of grinding wheels.

Bcz of higher hardness — the forces acting on the abbrasive particles is high, the abbrasive particle become blunt very fast, ie with in 1-2 min. This blunt abbrasive particle is start rubbing on to the w.p and produces rubbing forces. But this rubbing forces are not sufficient to pull out the blunt abbrasive particles if the grinding wheel is hard. This is called glazed grinding wheel or blunt grinding wheel. This glazed grinding wheel is simply rubbing onto the w.p without doing any machining.

To remove the glazing of grinding wheel **dressing** is to be done. Dressing is the turning operation used for removing a thin layer of material from the surface of grinding wheel with diamond [illegible] [illegible]

[illegible]

for hard w.p machining for every 1-2 minutes of grinding operation, nearly 15-20 minutes of dressing time has to be spent which is not preferable.

Hence, if soft wheels are used for grinding of hard work piece materials as and when the abrasive particle is becoming blunt; the rubbing forces produced ~~is~~ more than sufficient to pull out the blunt abrasive particles - hence self sharpening of grinding wheels will take place.

If soft wheels are ~~no~~ used for soft w.p material grinding it is not economical. i.e during machining of soft w.p forces induced are lower - hence the abrasive particles can be used for machining of longer duration. ~~But~~ if soft wheels are used as and when small ~~wear~~ amount of wear is taking place in the abrasive particle; ~~it~~ it is pulled out without effective utilization of the abrasive particle.

Soft wheels → Soft w.p

↳ Not economical

↳ No effective utilization of abrasive particles.

If hard wheels are used; the abrasive particles can be used effectively and at the end of effective utilization, the blunt abrasive particles can be ~~removed~~ by dressing i.e after grinding of 3-5 hours spending 15-20 minutes of dressing operation is very small & negligible.

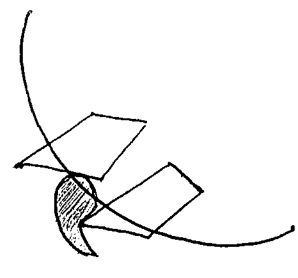
hard wheels → soft w.p

↳ effective

↳ 3-5hrs grinding could be done and only 5-20 mins dressing is req.

④ Structure of the grinding wheel.

$$\frac{SN}{1000} \text{ inch} = \text{Avg gap b/w the 2 consecutive abrasive particles}$$



The structure is selected based on the mechanical properties of work material and the surface finish requirements of the w.p

Soft w.p ⟶ open

hard w.p ⟶ closed

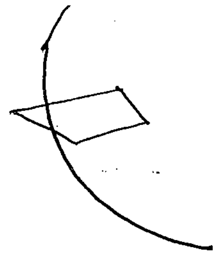
Rough grinding ⟶ open

finish grinding ⟶ closed

If dense structure is selected for grinding of soft w.p or rough grinding the loading of grinding wheel will be taking place. loading refers to the clogging of chips in b/w the two abrasive particles

During machining of soft w.p & rough grinding operation, the size of the chips produced is larger and if the gap b/w the abrasive particles is small, the chip may get clogged in b/w the two abrasive particles

If open structure is used, bcz of large gap b/w the abbrasive particle the chip falls down with out clogging



To withstand the large amount of forces acting during grinding of hard w.p ; the abbrasive particles must be very close and also for finished grinding the abrasive particles must be very close. Hence dense structure is used. [If it's not close the force would be transmitted to the binding material and they fails]

Rough grinding of soft w.p — 12 to 16
Rough grinding of hard w.p — 7, 8, 9
finish grinding of soft w.p — 6, 7, 8
finish grinding of hard w.p — 3 to 5

5 Bond

The bonding material used for producing bond b/w the abrasive particles is called bond.

The most commonly used bonding material is grinding wheels is vitrified bond. bcz it gives higher bonding strength, high temp. withstanding capability and high thermal conductivity.

Rubber or shellac can be used as a bonding material for producing flexible grinding wheels; also called as buffing wheels.

Q Select a grinding wheel for finish grinding of HSS cutting ~~tool~~.

A - 300 - K - 7 - V

A ↓ HSS not very hard

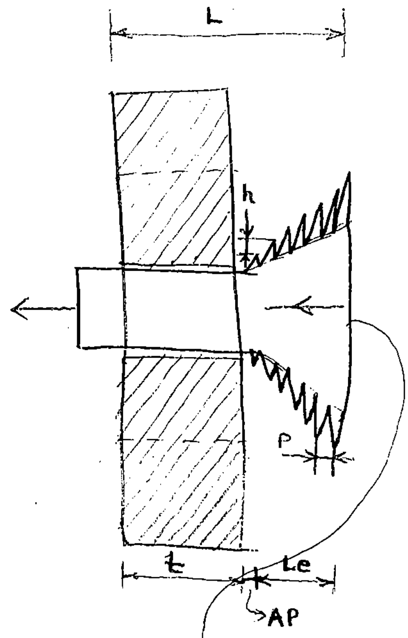
7 ↓ transition region

Q select a grinding wheel for rough grinding of brass w.p.

A - 27 - S - 12 - V

Broaching operation

It's a 2° machining operation used for enlarging the existing hole to circular or non circular hole by pulling or pushing the broaching tool through existing hole.

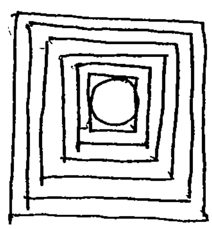


h - rise per teeth

p - pitch

$$\boxed{\text{Time for broaching} = \frac{L}{V}}$$

$$L = t + L_e + AP + OR$$



L_e – effective length of broach
– Cutting length of broach

V – 0.1 – 0.5 m/min
(very very low cutting velocity)

The cutting velocity in broaching is very low bcz when many no: of cutting teeth are in contact with the w.p, the forces acting are very high — hence if cutting velocity is also higher, the power requirement is very high.

Types of teeth :-

① Rough teeth :-

for removing the maximum amount of material from the w.p to change the shape of the component.

The number of rough tooth used is as many as required for machining (no restriction)

② Semifinished teeth :-

Removes a very small amount of material and make the size of the component as required size. The no: of semi-finished teeth is used is 4-10.

③ Finish teeth :-

Remove negligible amount of material but making the surface finish good

The number of finish teeth used is 2-6

$$L_e = l_r + l_s + l_f$$

l_r – length of broach for rough teeth

$= n_r \times p_r$ (pitch)

n_r – number of rough teeth

$= \frac{d_r}{h_r}$ – depth of material removed by rough tooth

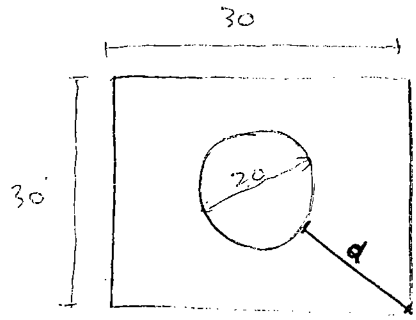
rise per tooth in rough tooth.

$$L_s = n_s \times P_s = \frac{d_s}{h_s} \times P_s$$

$$L_f = n_f \times P_f = \frac{d_f}{h_f} \times P_f$$

depth of material removed

$$d = d_r + d_s + d_f$$



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METAL FORMING PROCESS

Ref:- Metal forming by I B Prasad
Metal forming by Nag PAL

In metal forming process; 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 change the shape to required.

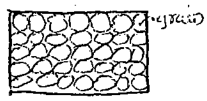
Stresses induced should be greater than yield point but less than ultimate stress.

$$\sigma_y < \sigma < \sigma_u$$

Advantages

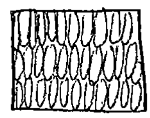
① No wastage of material
② The grain orientation is possible
③ Material would be converted from isotropic to anisotropic.
④ In certain metal forming process the strength & hardness of the material are increasing.
⑤ In some metal forming process; the surface finish produced is better and close dimensional accuracies are also possible.

casted product

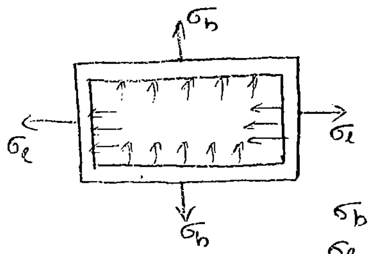


Spherical shaped grains uniformly arranged so isotropic property

forged product



elliptical grains anisotropic



IC engine cylinder

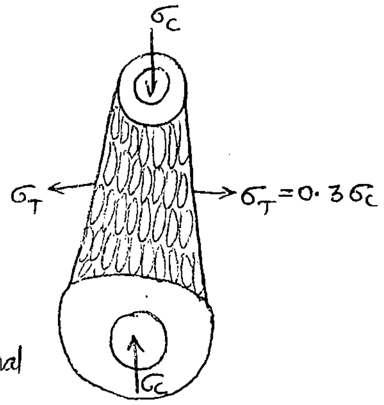
If an internal pressure is applied to a vessel. 2 stresses would be developed ← hoop stress σ_h and longitudinal stress σ_ℓ.

Though the applied internal pressure is uniform - $\sigma_h = 2\sigma_\ell$

Thus ~~the~~ if we use isotropic material for manufacture of the IC engine cylinder — then extra material is to be used to withstand σ_h. Thus anisotropic material is prefered in most of engineering application.

Disadvantages

① The force and energy required for the metal forming process is much higher than the other manufacturing process.
② Except forging operation all other metal forming process are used for producing uniform cross sectioned components only.
③ Components with cross holes cannot be metal formed.
④ In some of the metal forming process, the surface finish is poor and poor dimensional accuracies are produced



Connecting rod

~~compressive~~ stress is longitudinal direction is σ_c.

Due to poisson's ratio effect, there is a stress in the transverse direction such that

$\sigma_t = 0.3\sigma_c$
$= 30\% \text{ of } \sigma_c$

If made of anisotropic — it will be strong in long-direction & weak in transverse. ... stress is also like that it is better to use anisotropic material.

Metal forming

Cold working

$T < RCT$

Deforming the material; at a temp. less than Recrystallisation temperature is called cold working and deforming the material ~~at a temperature~~

Hot working

$T \geq RCT$

Deforming the material; at a temp greater than or equal to recrystalli- temperature is called hot working.

Recrystallisation temperature is the minimum temperature at which the formation of ~~two~~ new crystalls has been completed. Whenever the behaviour of the old crystal is completely changed to new behaviour called as new crystal formation or recrystallisation. ie changing the behaviour means the changing of physical, chemical, mechanical and thermal behaviour.

Whatever the energy required for changing the behaviour of the material is supplied by heating process. When the material is started heating; the ~~grains start~~ absorbing energy. When certain level of energy is absorbed by the grains, they start changing the behaviour called as starting point of recrystallisation. On further supplying the heat energy, at some point when the energy absorbed by the grain is crossing the threshhold level of energy, the grains completely forget their old behaviour and shows only new behaviour called as recrystallisation. On further heating the material, the energy supplied will be used for increasing the size of the grains. called as grain growth.

Generally $\boxed{RCT = \frac{1}{3} \text{ to } \frac{1}{2} \; MP}$

RCT of lead and tin are less than the room temperature.

RCT of Zn and cadmium are nearly equal to room temp.

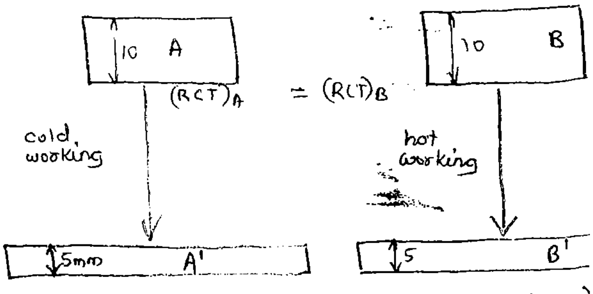
$\therefore$ deforming these four materials is done at room temp and are always considered as hotworking operation (since done at temp > RCT)

MP of tungsten is $3400^\circ C$ so its $RTC = \frac{1}{3} MP =$

$\therefore$ Deforming of tungsten at $1100^\circ C$ is still considered as cold working operation

In case of normal material and hotworked material, there is no residual stress are present in the material. $\therefore$ whatever the threshhold level of energy required for changing the behaviour of the grains is obtained only ~~the~~ through heating process.

where as in case of cold worked component the internal residual stresses are present in the material. and this also aid in the behaviour change also ... noted.



$(RCT)_{A'} < (RCT)_A$

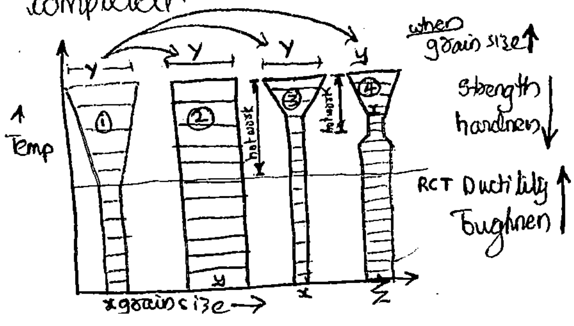
$(RCT)_{B'} \approx (RCT)_B$

$(RCT)_{A'} < (RCT)_{B'}$

when the cold worked component is heated, whatever the energy available in the energy packets in the form of residual stress is distributed to the surrounding grains. ∴ the required threshhold level of energy of grains is obtained through heating as well as distribution of energy available in the energy packets. Hence the grains are attaining required amount of ~~threshhold~~ threshhold energy at lower temp itself. So $((RCT)_{A'} < (RCT)_{B'})$.

As the amount of cold work on component ↑ RCT of the component ↓

Cold working	Hotworking
~~for~~ producing same amount of deformation in the material; the force and energy required for cold working is higher than the hot working.	for producing same amount of deformation in the material; the force and energy required for ~~total~~ hot working is less.
when the material is not heated to the higher temp; ~~every~~ [since at high temp is prone to form the oxides; by taking the oxygen from the atmosphere] Due to this no formation of oxides or scales. (a) the surface finish produced would be very ~~poor~~ excellent. (b) ~~Poor~~ close dimensional accuracies are produced. (c) Coefficient of friction produced is ~~high~~ considerably low, 0.1 - 0.2	When the material is heated to higher temp; since at high temp is prone to form the oxides; by taking the oxygen from the atmosphere. Due to formation of oxides or scales. (a) the surface finish produced would be very poor. (b) Poor dimensional accuracies are produced. (c) Coefficient of friction produced is ~~very~~ high i.e. 0.5 to 0.6
Since no heating is done - handling of workpiece is easier.	Bcz of heating of the materials handling of the components is difficult in hotworking
Always the cold worked component will have higher strength and hardness than the original material bcz fine grains are produced.	In case of hotworking of components; the mechanical properties purely depends on the temp at which the hot working has been completed.



$z > x$

(3) When ever the hotworking has been comple[ted] very near to the RCT — the grain size obtai[ned] is remains same as the original grain size and mechanical properties remains same as the original material

↑ Temp

① The body is heated upto the recrystallization temp there won't be any change in the grain size (x). After recrystallisation temp the grain size will start increasing and then reaches y.

② Annealing. The heated body is cooled slowly at room temperature we would get the material with same grain size.

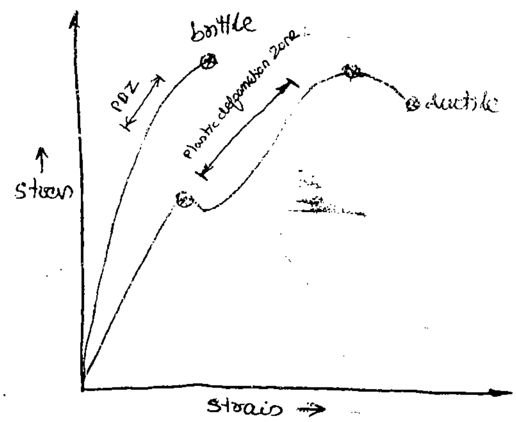
③ If ① is hot worked upto recrystallization temp. In b/w the hotworking itself the grains attain the original size x. Further no change in size occurs even when hot working is performed. After recrystallization temp. No-work is done & the slow cooling is done where size remains x itself.

④ If ① is hotworked only upto a certain higher than the recrystallization temp i.e. when the grain size just become x. Then while cooling at temp > RCT the grain size increases utilizing the extra energy available and grain size become where $z > x$.

grain size →

④ When ever the hotworking is completed well above the RCT, the grain size is increase[d]. ∴ The mechanical properties like strength and hardness are higher than the original mater[ial]. Ductility & Toughness are greater than the original material. Strength & hardness are lower than the original material.

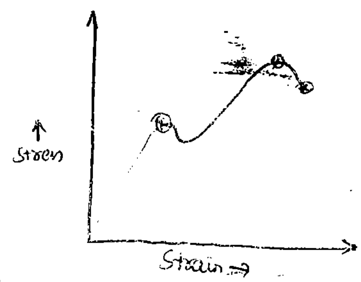
plastic deformation zone :



The zone in which material has to be in to perform metal forming process is called plastic deformation zone.

For the given materials and their stress strain diagrams, whichever the material is having widest plastic deformation zone, the corresponding material is considered as a easy in metal forming material.

For making the given material as a 'easy in metal forming process materials'; the plastic deformation zone of a given material has to be widened. This is possible by

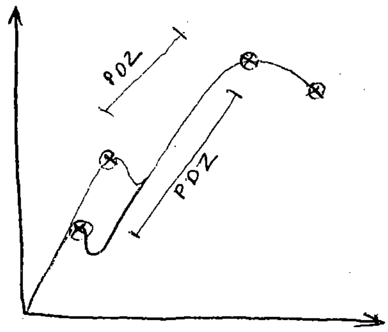


(1) Increasing the ultimate strength of the material. This can be done by cold working. But with cold working not only the ultimate strength, the yield strength

of the material also increases. ∴ the width of the plastic deformation zone almost remains constant. Hence it's not a preferable method.

(2) By reducing yield strength of the material.

The yield strength of a material can be reduced by heating the material. With heating the small amount of reduction in the ultimate strength of material also reduces but is very small & negligible. Hence the plastic deformation zone is wider. This is a possible and preferable methodology.



The yield strength of most of the materials will get reduced with increase in temp except steel:

steel

$T < 150°C$, $T\uparrow$ $\sigma_y \downarrow$

$T = 150$ to $350°C$ $T\uparrow$ $\sigma_y \uparrow$

$T = 350-750°C$ $T\uparrow$ $\sigma_y \downarrow$

$T = 750-850°C$ $T\uparrow$ $\sigma_y \uparrow$

$T > 850°C$ $T\uparrow$ $\sigma_y \downarrow$

from this data,

The steel should not be deformed in the temp ranges of 150-350°C and 750-850°C Bcz in this ranges the yield strength of the steel will be increasing with increase of temp.

1539 - solidification from
BCC

↓

1410° - δ-iron
FCC

↓

910° - α-iron [non-magnetic]
BCC

↓

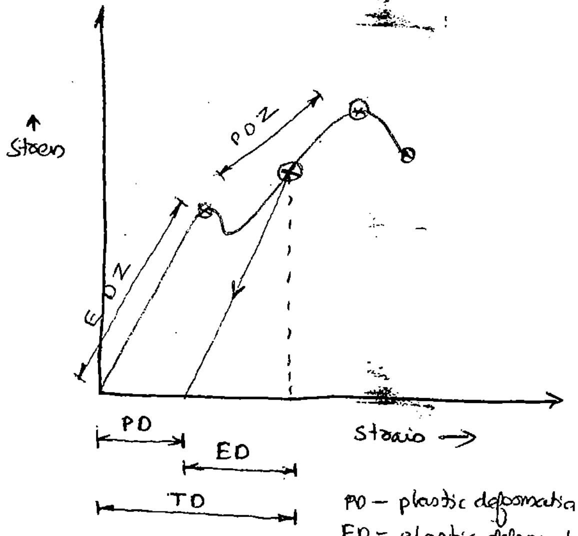
723° - α-iron (magnetic)
BCC

This is bcz of the allotropic property of iron.

allotropic property is repeatable but polymorphism is not.

TENSILE LOADING

If a total distortion is given that lie with in plastic Deformation Zone and the load is removed ; It traces a a path as shown — ie parallel to that of elastic Deformation zone. Then even as elastic defor when it was in the plastic deformation zone some reverse elastic deformation occurs and the plastic (PD) deformation obtained is less than the total deformation. [Then why ? we call it as plastic deformation zone].



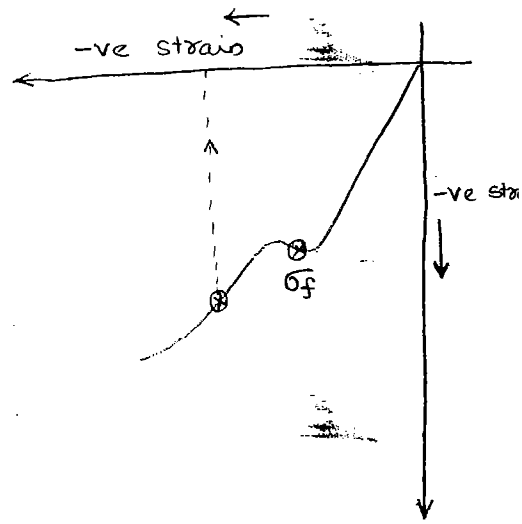
This is b/c instead of removing the load immediately ; if we ~~see~~ maintain load for some more time, this ~~plastic~~ elastic deformation (ED) could be converted to plastic defomt (PD) ie it retraces through the ⊥ direction.

ie PD = TD.

From the above – whenever the tensile loads are applied in the metal formi process, It is necessary to maintain the load applied for some more time to convert ED present in the PDZ into PD.

Compressive loading

When ever the material is experiencing the compressive stresses > flow stress, the flow behaviour of the material is like a fluid. ∴ the same called as the flow stress of the material



σ_f – flow stress of the material

$\sigma_f \approx \sigma_y$

Once we are stressing the material to a stress above σ_f ; 100% permanent deformation is obtained. [once the material is 'flown' – then permanent deformation is obtained its like the fluid behaviour of ie if we pour the liquid from a height – it won't come back with out using any external energy].

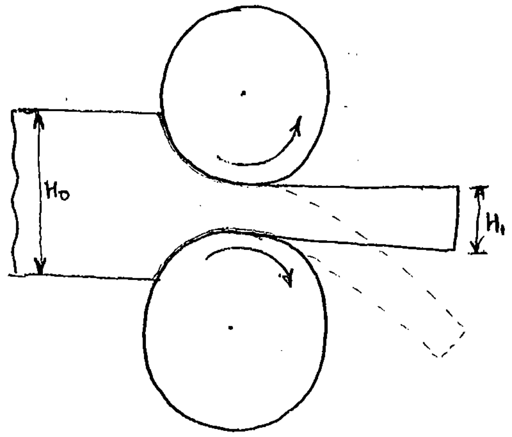
So whenever compressive loads are applied in the metal forming process, It is not necessary to maintain the load for some more time. like in the case of tensile loading condition

Metal forming Methods

① Rolling ② Drawing ③ Extrusion ④ Forging

② Drawing → wire drawing
→ Tube drawing

① Rolling



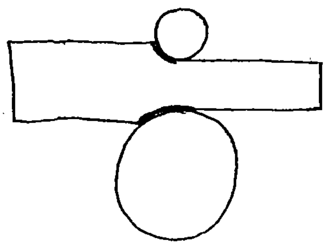
In rolling operation - the compressive forces are applied by using rotating rollers or material is compressed in b/w the two rotating rollers such that the thickness of the sheet can be reduced from H_0 to H_1.

To avoid the bending of the strip; the surface velocity of both the rollers must be same.

$$V_{top_{roller}} = V_{bottom_{roller}}$$

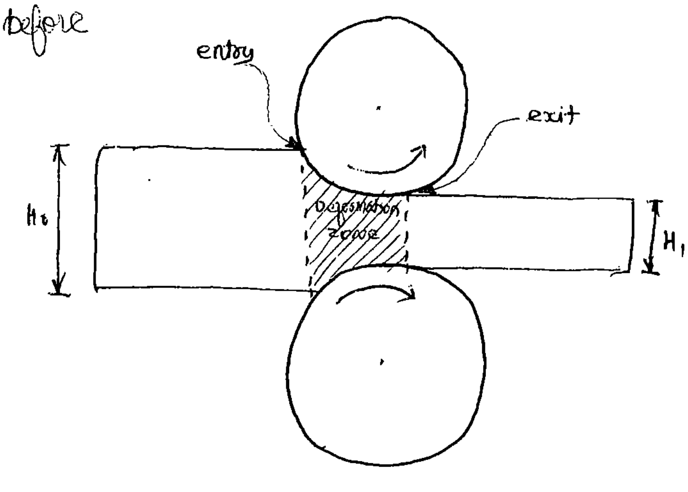
$$(\pi DN)_{top} = (\pi DN)_{bottom}$$

$$(DN)_{top} = (DN)_{bottom}$$



To maintain the same contact area b/w the rollers and the strip, same diameters of the rollers must be taken.

If diameter of rollers is same - the rpm of rollers would also be same - So same prime movers could be used for rotating both of the rollers without any gear box.



Let H_0 and H_1 be thickness of the strip before and after the rolling operation.
Then reduction in strip thickness

$$\Delta H = H_0 - H_1$$

D - diameter of rollers

$R = \frac{D}{2}$ - radius of rollers

V = surface velocity of rollers

V_0, V_1 = Velocity of strip before and after rolling operation

b_0, b_1 = width of the strip before & after rolling where ever the strip starts contacting the roller is called <u>entry point</u>.

where ever the strip starts separating from the roller - <u>exit point</u>

Zone present b/w entry and exit point is called - <u>Deformation zone</u>

<u>Assumption in Rolling</u>

① Every material which is undergoing the metal forming process is considered as incompressible. ⇒ i.e the volumetric changes of the material is taken as '0'.

② The width of the strip during rolling operation remains same.

③ when the thickness of strip is reduced; the volume of the strip is reducing in the thickness direction. whatever the reduction of volume in the thickness direction has to be increased either in the width direction or in the length direction. But bcz the rollars are rotating; the increase in volume is taking place only in the length direction so that the width of the strip remains constant.

Volume before = volume after

$$H_0 \times b_0 \times V_0 = H_1 \times b_1 \times V_1$$

$$b_0 = b_1 = b$$

Thus

$$H_0 V_0 = H_1 V_1$$

$$\boxed{\frac{H_0}{H_1} = \frac{V_1}{V_0}}$$

$$\boxed{V_1 > V_0}$$

At the entry the rollers are pulling the strip ∴ velocity of the rollers must be greater th the velocity of the strip.

∴ at entry $\boxed{V_0 < V_1}$

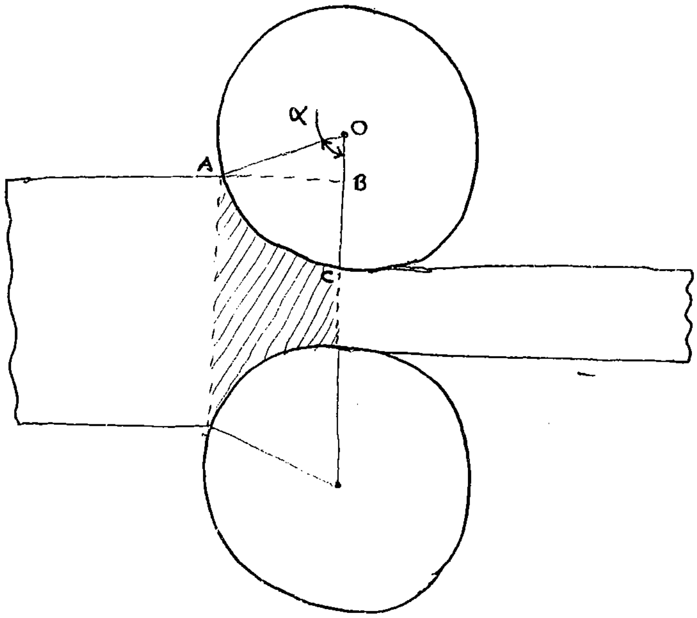
Along the deformation zone - the surface velocity of roller re const. But velocity of strip is increasing ∴ at some point the velocity of the strip will become equal to surface velocity of the roll the corresponding point is <u>neutral poi</u>

<u>Neutral point</u>

At this point; the stresses induced in the material is just equal to the flow stress of the material. Beyond which the velocity of the strip is further increasing - ∴ at exit strip velocity is greater than the surface velocity of the roller. $V_0 < V < V_1$

In rolling operation; strips will be pulled to the rollar bcz of presence of friction on the interface of the rollars and the strips.

deformation angle - is the angle made by the deformation zone w.r.t the centre of the roller. It's also called as angle of bite or bite angle (α)



α - bite angle

$$\cos\alpha = \frac{OB}{OA} = \frac{OC - BC}{OA}$$

$$\cos\alpha = \frac{R - \frac{\Delta H}{2}}{R}$$

$$R\cos\alpha = R - \frac{\Delta H}{2}$$

$$\frac{\Delta H}{2} = R - R\cos\alpha$$

$$\boxed{\Delta H = D(1-\cos\alpha)}$$

AC = Arc length of Deformation Zone (DZ)
$= R\alpha$

$$AB = \text{length of DZ} = L$$
$$= \sqrt{OA^2 - OB^2}$$
$$= \sqrt{R^2 - \left(R - \frac{\Delta H}{2}\right)^2}$$
$$= \sqrt{R\Delta H - \frac{\Delta H^2}{4}}$$

$$R\Delta H \ggg \frac{\Delta H^2}{4}$$

$$\boxed{AB = L = \sqrt{R\Delta H}}$$

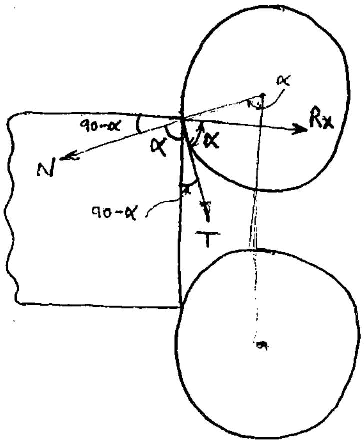
ΔOAB

$$\tan\alpha = \frac{AB}{OB} = \sqrt{\frac{R\Delta H}{R - \frac{\Delta H}{2}}}$$

$$R \ggg \frac{\Delta H}{2}$$

$$\tan\alpha = \frac{\sqrt{R\Delta H}}{R}$$

$$\boxed{\tan\alpha = \sqrt{\frac{\Delta H}{R}}}$$



R_x - Resultant resolved horizontal component of frictional force

$$R_x = T\cos\alpha - N\cos(90-\alpha)$$
$$= T\cos\alpha - N\sin\alpha$$

$$T = \mu N$$

(Tangential force component T is the frictional force)

$$R_x = \mu N(\cos\alpha) - N\sin\alpha$$

$$\boxed{R_x = N(\mu\cos\alpha - \sin\alpha)}$$

$$R_x \geqslant 0$$

$$N(\mu\cos\alpha - \sin\alpha) \geq 0$$

$$\mu\cos\alpha \geq \sin\alpha$$

$\mu \geq \tan\alpha$ If β is the frictional angle

$\tan\beta \geq \tan\alpha$

$$\boxed{\beta \geq \alpha}$$

In a given rolling operation, max. angle of ~~the~~ bite must be less than or equal to the friction angle.

If $\alpha = \beta$, [coulomb friction condition]

↳ Reduction occuring is maximum reduction,

$\Delta H = \Delta H_{max}$

$\tan\alpha = \sqrt{\frac{\Delta H}{R}} = \mu = (\tan\beta)$

$$\boxed{\Delta H = \Delta H_{max} = \mu^2 R}$$

Q $H_0 = 180\,mm$ $H_f = 95\,mm$, $D = 650\,mm$, $\mu = 0.21$ Number of passes = ?

$$\text{No: of passes} = \frac{\Delta H_{total}}{\Delta H_{max}/pass}$$

$$= \frac{180-95}{\mu^2 R}$$

$$= \frac{85}{0.2 \times 325}$$

$$= 6.7 \approx \underline{\underline{7}}$$

At the entry the relative velocity b/w the rollers and strips are maximum, as we are moving along the deformation zone, the surface velocity of the rolers remains constant and velocity of the strip will be increasing. ∴ the relative velocity is reducing.

At the neutral point the velocity is equal. ∴ the relative velocity is zero.

Beyond the neutral point, the relative velocity is again increasing and becomes maximum at the exit

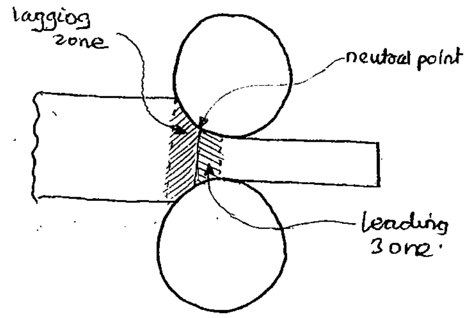
The neutral point divides the deformation zone into two zones ie lo lagging zone and leading zone.

lagging zone ↓ Strip lagged behind the roller

The relative velocity is 1st reducing and then Increasing in deformation zone.

where as

The relative velocity is only decreasing in lagging zone and only increasing in leading zone.



$$\boxed{\text{Slip} \propto \text{Relative velocity}}$$

∴ Slippage b/w rollers and strip is decreasing 1st and then increasing along the DZ

In lagging zone the slippage is gradually reducing. ∴ max % slip taking place in lagging zone is called backward slip.

$$\boxed{\text{Backward slip} = \frac{V - V_0}{V} = 1 - \frac{V_0}{V}}$$

In leading zone the slippage is increasing continuously. ∴ max % slip taking place in leading zone is called forward slip.

$$\boxed{\text{forward slip} = \frac{V_1 - V}{V} = \frac{V_1}{V} - 1}$$

$$\boxed{\text{Pressure at interface} \propto \frac{1}{\text{Slip}}}$$

At the entry pressure is minimum. Then start increasing and becomes maximum at neutral point and starts reducing and becomes minimum at the exit.

~~Along~~ the deformation zone - the pressure is increasing 1st and then reducing whereas in lagging zone, the pressure is only increasing and in leading zone the pressure is only reducing.

let $n = \frac{2\mu L}{\Delta H}$

<u>pressure at any point along the lagging zone</u>

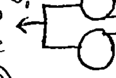
$$(P_x)_{lagging} = \left(\frac{\sigma_y}{n}\right)\left[(n-1)\left(\frac{H_x}{H_0}\right)^n + 1\right] - \left(\frac{H_x}{H_0}\right)^n \sigma_1$$

σ_y – Yield stress or hoopes stress

H_x – thickness of the chip at any point along the lagging zone where the pressure is to be determined

σ_1 – back tension.

(not compulsory – it's an accessory to improve the efficiency of rolling operation)

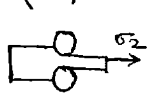


<u>pressure at any point along the leading zone</u>

$$(P_x)_{leading} = \left(\frac{\sigma_y}{n}\right)\left[(n+1)\left(\frac{H_1}{H_x}\right)^n - 1\right] - \left(\frac{H_1}{H_x}\right)^n \sigma_2$$

σ_2 – front tension

(also an accessory)



at neutral point

$$(P_n)_{lagging} = (P_n)_{leading}$$

(dont consider the accessory)

$$\cancel{\left(\frac{\sigma_y}{n}\right)}\left[(n-1)\left(\frac{H_n}{H_0}\right)^n + 1\right] = \cancel{\left(\frac{\sigma_y}{n}\right)}\left[(n+1)\left(\frac{H_1}{H_n}\right)^n - 1\right] \Rightarrow H_n = ?$$

from diagram → Neutral point is near to H_1 but not by a large margin ie (not that much near)

$$H_n = H_1 + 20\text{-}30\%\,\Delta H$$

without workingout ; just by seeing the options - we could answer.

Q $H_0 = 20$ $\mu = -$ $H_n = ?$
$H_1 = 14$ $R = -$

(A) 18·5 (B) 17 (C) 15·4 (D) 14·2

$$H_n = 14 + (0.2 - 0.3) \times 6$$
$$= 14 + (1.2 \text{ to } 1.8)$$
$$= 15.2 \text{ to } 15.8$$

Power required for rotating the roller

$$P_{total} = 2 \times P_{/roller}$$
$$= 2 \times T\omega$$
$$\boxed{P_{total} = 2 \times \frac{2\pi N T}{60}}$$

T - torque required to rotate the roller

ω - angular velocity of the roller

$\omega = \frac{2\pi N}{60}$ N - rpm.

$$\boxed{T = F_{avg} \times a}$$
$$= (P_{avg} \times \underset{(AB)}{\text{Projected area}})\, a$$
$$= \frac{2}{\sqrt{3}}\sigma_y\left(1 + \frac{\mu L}{4H}\right) \times (b \times L) \times a$$
$$\boxed{T = \left[\frac{2}{\sqrt{3}}\sigma_y (bL)\left(1 + \frac{\mu L}{4H}\right)\right] \times a}$$

Favg

$\boxed{H = \frac{H_0 + H_1}{2}}$ Avg thickness of strip.

T = Force × Radius

force is not uniform. so we should take Favg.

So we can't take R but we take

= Favg × a

a – moment arm

$a = \lambda L$

λ = arm factor
= 0·3 to 0·4

L = length of deformation zone

During rolling operation equal & opposite reaction force produced by the strip is acting on the rollers for separating the rollers. ∴ Favg is also called as roll separating force

Favg = Pavg × Projected area (AB)

↳ force acting by rollers on strip for rolling the strip for reducing the power required for rotating the rollers, mainly the Favg or roll separating force has to be reducing

<u>methods for reducing Favg</u>

① $\sigma_y \downarrow$

Bcz the power required can be ~~hea~~ reduced by heating the material in generall the rolling will be considered as a hotworking operation only

② $\mu \downarrow$

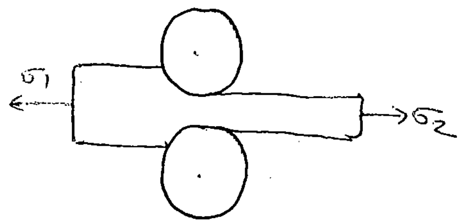
μ could be reduced untill α becomes equal to β

③ $R \downarrow$

As the roller radius is reducing $L\downarrow$ and $F_{avg}\downarrow$
but the load bearing capacity of the roller $\downarrow$ and
chances of failure of the roller $\uparrow$
To avoid this backup or <u>supporting rollers</u> should be used

④ Using σ_1 and σ_2.

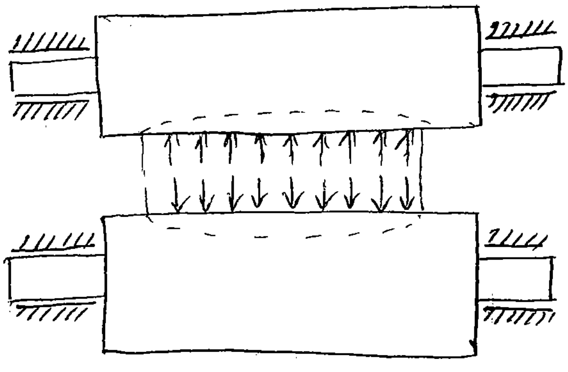
When back and front tensions are applied, it acts like a tensile loads along the length direction of the slip, which induces the compressive stresses in the thickness direction due to poisons ratio effect.



when compressive stresses are induced in thickness direction, the force to be applied by using the rollers for rolling operation to take place is reduced.

preference 1 - 3 - 4 - 2

when roll separating force is acting of the rollers; each and every roller can be considered as a simply Supported beam with UDL.
$\therefore$ the roller will be getting deflecting and the gap b/w the rollers is filled by using the material.
$\therefore$ ~~the~~ thickness of the strip in the width direction will become non uniform



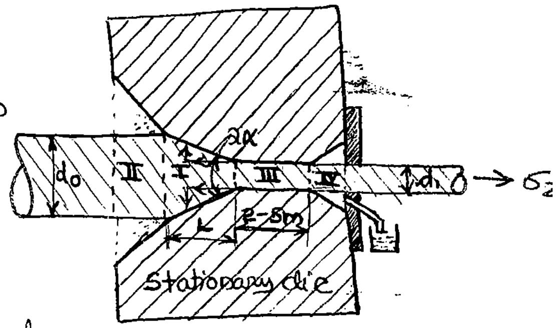
To get the uniform thickness of chip in the width direction; the rollers can be made like a convex roller or cambering of rollers.

2) Drawing

2/10/11
Sunday

Wire drawing:

The method of producing wires from the solid rods by pulling through a stationary die is called as a wire drawing operation.



Stationary dies are been used.

The wire would be divided to 4 zones

Zone 1 - deformation zone

Whatever the deformation required for converting the rod into the wire is obtained in this zone. Therefore the name gives as deformation zone.

The angle made by the deformation zone (2α) is called ~~die~~ angle or deformation angle. Usually it varies from 12 - 48°.
12° is for wire drawing of hard materials and 48° is used for wiredrawing of very soft materials.

L = length of deformation zone or ~~diezone~~ die land.

During wire drawing operation - due to the presence of friction at the interface; a backward frictional force will be acting. which is ~~resolved~~ into two components of forces.

(1) Horizontal component of frictional force

It increases the drawing force to be applied on the front side of the drawing process

(2) Vertical component of frictional force.

It tries to break or fail the die.

To minimize the above effect, the friction at the interface has to be minimised

This is done by using lubricants in the wire drawing operation.

Zone 2 - lubricating or entry zone

whatever the lubricants required for wire drawing operation is supplied from zone 2 only and ∴ called lubricating zone.

Different types of lubricant conditions

① No lubrication condition :-

If no-lubricant is used in the wire drawing operation, the frictional forces at the interface is high, heat generation is high and hence the surface of the wire can be observed as black or burned colour.

② Liquid lubricant :-

If liquid lubricants are used ; the friction is reducing & heat generation is reducing ∴ wire surface can be observed as metallic or dull surface.

eg:- Liquid lubricants used are mineral oils, vegetable oils, SAE oils, ~~salts~~ soap solution, kerosene etc.

Kerosene is used for white drawing of highly reactive metals (Al, Mg etc)

③ Solid powdery lubricants :-

When solid powdery lubricants are used ; it is reducing the friction and heat generation and also produces microscopic scratches on the wire surface which makes the surface of the wire appearing to be bright shining or silvery surface.

eg:- Carbon powder, graphite powder, glass powder etc are for
[Non ferrous materials] [Non ferrous materials]

Zone 3 - Sizing zone

This zone is used for converting the elastic deformation present in the PDZ into plastic deformation.

The length of the sizing zone is normally about 2-5 m.

Zone 4 - Exit or safety zone :-

When the lubricants are used in the wire drawing operation; it passes through the interface of the die & wire and experience higher pressure and temperature. When this high pressure and temperature comes out from zone 3; it may get fall to the front side bodies and damage them. To avoid this, a divergent zone called as exit zone is provided which is closed by using a cover; so that when the high pressure lubricants comes into the exit zone, its pressure is reducing and it can be drained out afterwards.

If lubricants are not used in the wire drawing operation No exit zone is required.

$A_0 = \frac{\pi}{4} d_0^2$ - cross sectional area of rod

$A_1 = \frac{\pi}{4} d_1^2$ - cross sectional area of wire

$\frac{A_0}{A_1} = K$ - Draft - drawing ratio

$\frac{A_0 - A_1}{A_0} = J$ - % reduction in area

μ - coeff of friction at interface

Let $\boxed{B = \mu \cot \alpha}$

$$\boxed{\sigma_2 = \text{Drawing stress} = \sigma_y \left(\frac{1+B}{B}\right)\left[1 - \left(\frac{A_1}{A_0}\right)^B\right]}$$

σ_y - yield stress of material

Drawing load or drawing force $= \sigma_2 \times A_1$

* $\boxed{\sigma_2 < \sigma_y}$

bcz we are calculating the stress σ_2 at the exit. if we calculate the stress in the deformation zone definitely $\sigma > \sigma_y$.

During calculation of the σ_2, the horizontal component of frictional force acting in the backward direction is not considered. By considering this horizontal component of frictional force; the total stress to be applied at the front side for drawing operation is called as total drawing stress (σ_t)

$$\boxed{\sigma_t = \sigma_y + (\sigma_2 - \sigma_y)\, e^{\frac{-2\mu L}{R_1}}}$$

Total drawing load

$$\boxed{T{\cdot}DL = \sigma_t \times A_1}$$

In wire drawing operation; if the drawing stress applied at the front side is equal to the yield stress of the material, the corresponding reduction in the wire drawing operation is considered as maximum possible reduction.

i.e. $\sigma_2 = \sigma_y$

$$\frac{\sigma_2}{\sigma_y} = 1 = \left(\frac{1+B}{B}\right)\left[1 - \left(\frac{A_1}{A_0}\right)^B\right]$$

$$\frac{A_1}{A_0} =$$

$$K = \frac{A_0}{A_1}$$

$$J = \frac{A_0 - A_1}{A_0} = 1 - \frac{A_1}{A_0} =$$

$K_{max} = 2$ to 6.

ε = True strain $= \ln(1+e)$ e – engineering strain

$= \ln\left(\frac{A_0}{A_1}\right)$

$\varepsilon \times \sigma_y$ = Ideal stress req. in wire drawing operation.

$\varepsilon \times \sigma_y \times A_1$ = Ideal drawing load

Q If $\begin{bmatrix} \alpha = 6^\circ \\ \mu = 0.1 \end{bmatrix}$ what is the maximum draft = ?

$$1 = \frac{(1+B)}{B}\left[1 - \left(\frac{A_1}{A_0}\right)^B\right]$$

$B = \mu \cot\alpha$

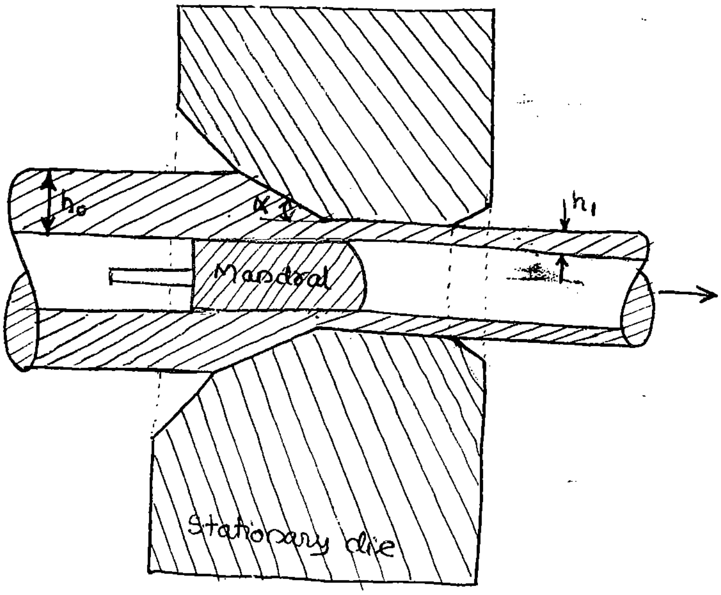
Tube drawing Operation :-

The method of reducing wall thickness of already existing tubes by pulling through a stationary dies with mandril is called as a tube drawing operation.

In the tube drawing operation, the internal dia of the tube may be maintained as constant as earlier or it may be changed.

here also stationary die is used.

Based on the shape of the mandril used - it is divided into 2 types



(1) <u>Cylindrical mandril</u>

Used for maintaining the internal dia of the tube constant.

(2) <u>Conical mandril</u>

for changing the internal dia of the tube

γ - half of cone angle of mandril.

cone angle $= \underline{2\gamma}$ - cone angle.

μ_1 - coeff of friction b/w the outersurface of the tube & die

μ_2 - coeff of friction b/w the inside surface of the tube and mandril.

$$\boxed{B = \frac{\mu_1 \pm \mu_2}{\tan\alpha - \tan\gamma}}$$

$+ \Rightarrow$ stationary mandle

$- \Rightarrow$ movable mandrle (take direction of friction on on the tube surface & not on mandrle or die surface)

Based on the usage of the mandril - mandril can be divided into 2 types

(1) Stationary mandle

(2) movable or floating mandrle.

mandle reciprocates inside.

If mandrel moves backward — direction of frictional force in tube ~~surfa~~ is in forward direct.

If mandrel moves forward — then it depends on the relative velocity of the mandrel & tube

The out surface is backward & the inside surface is forward. Hence the -ve sign can be taken with movable mandrel

$$\boxed{\sigma_2 = \sigma_y\left(\frac{1+B}{B}\right)\left(1-\left(\frac{b_1}{b_0}\right)^{B}\right)}$$

$\sigma_2 \times A_1$ = Drawing load.

If we assume $\mu_1 = \mu_2$ and we take floating mandrel.

Then $B = 0$

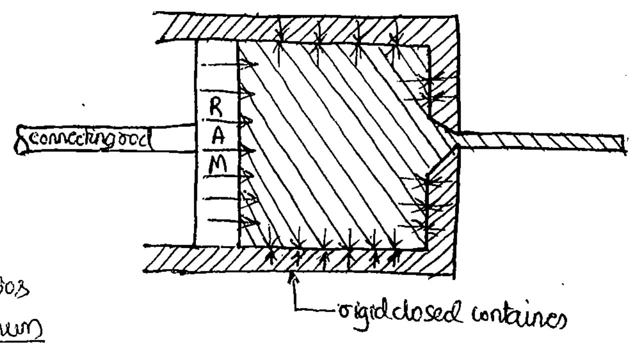
$$\sigma_2 = \infty \frac{0}{0}$$

applying L-hospitals rule; and simplify - we get

$$\boxed{\sigma_2 = \sigma_y \log_{10}\left(\frac{1}{\left(\frac{b_0}{b_1}\right)-1}\right)}$$

Extrusion Process

Process in which the raw material is compressed in a rigid closed container such that the compressive stresses induced in the material is greater than the flow stress of the material; hence the material is flowing through a small opening available in the container, taking the shape and the size as the remains same as the die opening available in the container.



forward extrusion

Advantages

when compared to drawing

(1) The lengthy sizing zone is completely absent in the extrusion process.

(2) Larger amount of extrusion ratios are possible. but the maximum reduction possible in extrusion is 8

(3) During wire drawing operation; if the drawing stress applied is greater than the yield stress of the material; the cracking tendency of the wire is very high but in case of extrusion process; there is no cracking tendency

Types of extrusion

1. Forward or direct extrusion
2. Backward or indirect extrusion
3. Hydrostatic extrusion
4. Impact extrusion

1. Forward or direct extrusion

The direction of movement of the ram and direction of movement of extruded component are same.

As the ram is moving; every point on the raw material have to travel against the container wall friction $\therefore$ force required for forward extrusion is higher

volume Before = volume after

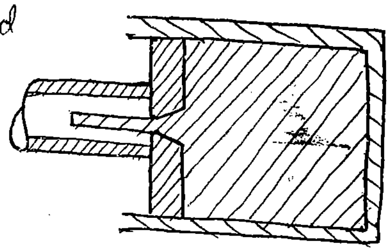
$$A_0V_0 = A_1V_1$$

$$V_1 = \frac{A_0}{A_1} \times V_0$$

$$V_1 = (40 \sim 50 \text{ times})\, V_1$$

2. Backward or indirect extrusion.

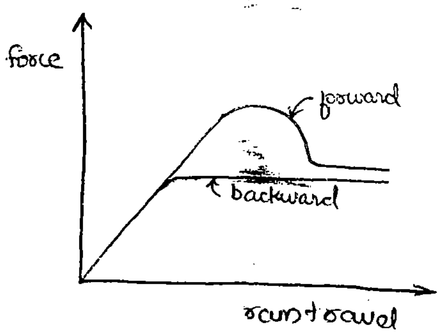
The direction of movement of ram and extruded product are in opposite direction.



Backward extrusion

The raw material can directly deform and flow into the die $\therefore$ No movement of the raw material is required. Hence the force required for the extrusion process is less.

From the force V/s ram travel diag →
only at initial process of forward extrusion; the force required is higher. But afterwards the force required for forward extrusion is marginally higher than the backward extrusion. Hence it is not a disadvantage of forward extrusion.



In forward extrusion bcz the extruded component is coming out into the open environment, the handling of the extruded component would be easier; but in case of backward extrusion; the extruded component is going into the connecting rod $\therefore$ the handling is difficult.

The manufacturing of both ram and die are easier in case of forward extrusion, bcz they are separate whereas [illegible]

Thus forward extrusion is better than the backward extrusion; though the force req is a bit high.

During extrusion of semibrittle and brittle materials using forward extrusion; bcz of the presence of container wall friction; the cracking tendency of the extruded component is very high. But with backward extrusion; bcz of complete absence of container wall friction; the cracking tendency of extruded component during extrusion of semi brittle and brittle materials will not exist: Hence the backward extrusion is preferable to use for extruding semibrittle and brittle materials.

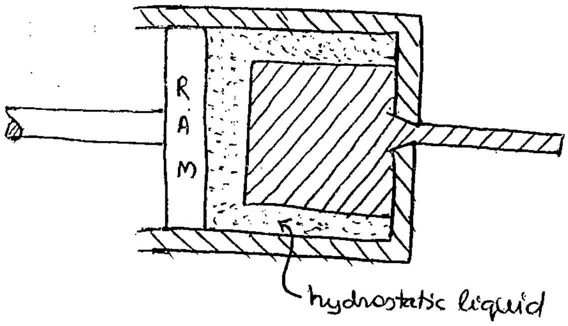
(3) Hydrostatic extrusion :-

- To extrude the semibrittle and brittle materials without container wall friction and with the advantages of forward extrusion — a new methodology called hydrostatic extrusion is developed.

It's similar to the forward extrusion.

Here the full volume of cylinder is not occupied by the raw materials.

i.e the size of the raw materials is less that the size of the container and the gap is filled by using hydrostatic liquid.



hydrostatic extrusion.

The force applied by using ram will be transfered to the raw materials through the hydrostatic liquid and bcz of presence of the hydrostatic liquid, the container wall friction is completely absent

∴ the cracking tendency can be eliminated thus extrusion of semibrittle, brittle & high strength super alloys.

Since arresting the leakages during the process of extrusion is very difficult; hence it is limited for only semibrittle, brittle and high strength super alloys only.

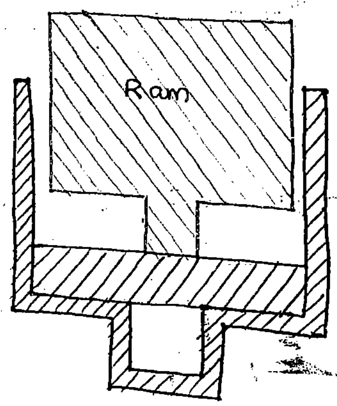
The hydrostatic liquids used in the case of hydrostatic extrusion are

(1) At room temp of extrusion → vegetable oils, glycerine, SAE oils, caster oil, isopentane etc. will be used

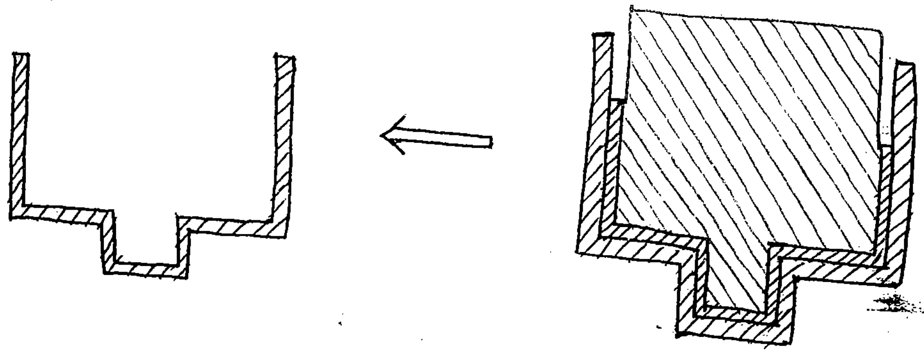
(2) At elevated temp of extrusion → wax, polymers, glass (e), et can be used

4) Impact extrusion :-

The method of producing very thin wall tubes from the solid rods mad by very soft material with the application of impact loads is called a impact extrusion.



These are been mainly used for making collapsible tubes.



Extrusion force required

① σ_0 = extrusion stress applied by using Ram

$$\sigma_0 = \sigma_y\left(\frac{1+B}{B}\right)\left(1-\left(\frac{A_1}{A_0}\right)^B\right)$$

$$B = \mu \cot\alpha$$

, α - half the die angle
μ - coeff. of friction

forward extrusion

$$(EF)_{forward} = (\sigma_0 + P_f)A_0$$

P_f = pressure required to overcome the container wall ford

backward extrusion

$$(EF)_{backward} = \sigma_0 \times P_0$$

② minimum extrusion force required.

$$(EF)_{min} = \sigma_y \times A_0$$

Actual extrusion force

$$(E \cdot F)_{actual} = \frac{(E \cdot F)_{min}}{\eta_{ext}}$$

η_{ext} – efficiency of extrusion process.

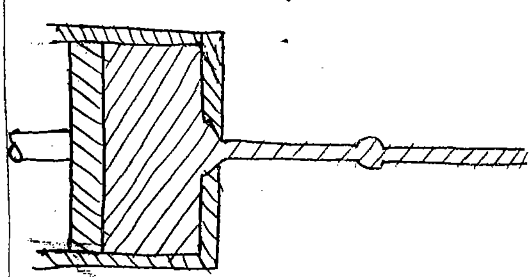
$\eta_{ext} = 0.4 - 0.5$ – forward
$= 0.5 - 0.6$ – backward

(3) $EF = K A_0 \ln\left(\frac{A_0}{A_1}\right)$

K – extrusion constant
It depends on the type of extrusion, & material to be extruded.

Defects in extrusion :- [These are special defect for extrusion apart from normal defect]

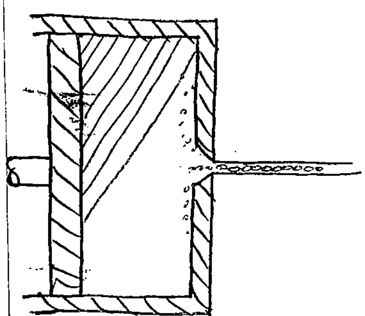
(1) Bamboo defect :-



The outer cross section of the extruded component is similar to that of the bamboo stick called as a bamboo defect.

This is bcz of non uniform velocity of the ram during extrusion.

(2) Pipe defect or centre burst



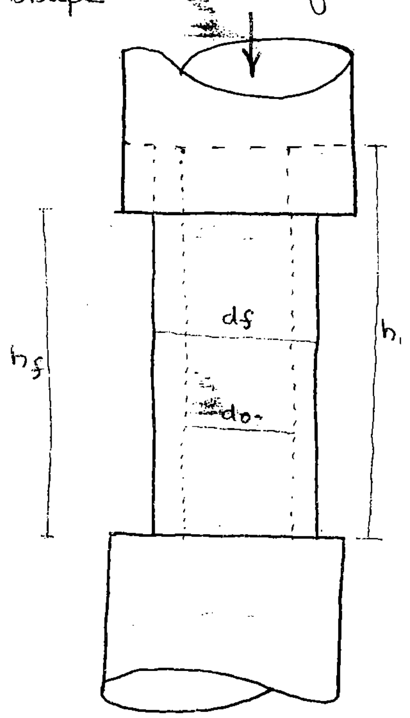
When the heated raw materials are placed inside the containers without proper cleaning, (contain scales); during extrusion; the scales present on the surface of the raw materials may be forming as a central part of extruded component and produces pinholes at the centre of the extruded component which makes the extruded component like a centre burst or high pipe shape.

∴ the same called as pipe defect of centre burst.

This can be eliminated by proper cleaning of the raw materials for the scales before placing into the container.

Forging :-

Forging is a process in which the material is compressed b/w the two dies either with the application of continuous load (press forging) or by using intermittent impact load (drop) untill the required shape and size of the component is obtained.



A top movable die and bottom stationary die.

force applied by top die and the material is compressed.

bcz of incompressible material

$$\text{Vol before} = \text{Vol after}$$

$$\frac{\pi}{4} d_o^2 h_o = \frac{\pi}{4} d_f^2 h_f$$

$$d_f = d_o \sqrt{\frac{h_o}{h_f}}$$

$$h_f = h_o \left(\frac{d_o}{d_f}\right)^2$$

Classifications

(1) based on method of force application

(a) Hand forging operation

only drop hammer type of forging could be applied.

$$P \cdot E = W \times h$$

Impact energy

$$I \cdot E = 2 \times P \cdot E$$

whatever the force applied by human hand is not sufficient to prod the deformation if continuous load application is done.

(b) Machine forging :

The force required for forging is obtained from machines like mechanical press or hydraulic press, It is possible to use either drop hammer type of forging operation or press forging opera

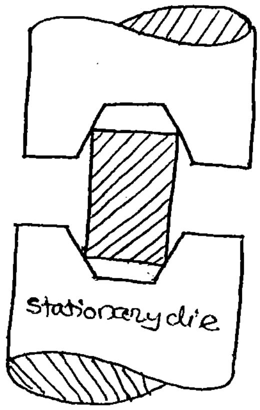
(2) based on the method of shape obtained

(a) Open die forging :-

Required shape and size of the component can be obtained by changing the position of the component in b/w the blows.

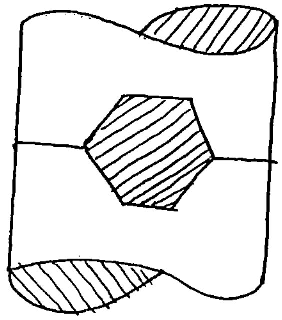
Only drop hammer type of force application could be used.

(b) Closed die forging :-



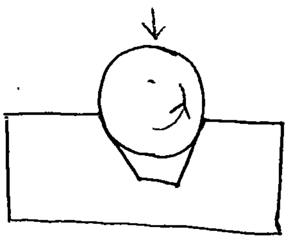
Also called as impression die forging.

If the req: shape and size of the component to be obtained is same as that of the 2 halves of the dies used in the forging operation; called as closed die or impression die forging.



Either continuous or impact type of loads could be used (drop or press forging could be applied)

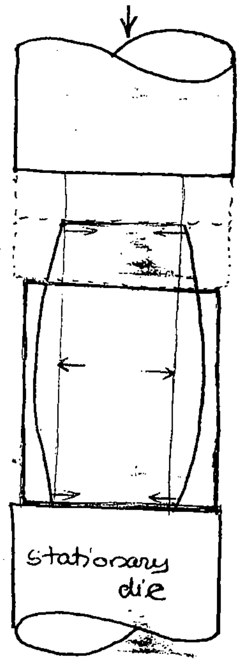
(c) Semiclosed type forging :-



In this the shape and size of the component obtained remains same as the half die used in the forging operation; but the required final size of the component can be obtained by changing the position of the component in b/w the blows.

only drop hammer type of force application could be used.

As the force is applied by using the top die and moving the top die, the outward expansion forces are acting throughout the length of the component. But b'cz of the presence of the friction at the ends; there is an inward frictional force acting.



At the initial stages of forging operation; at the ends; the inward frictional forces are higher than the outward expansion forces.
∴ the material is almost sticking to the surface of the dies. when we are moving towards the center height of the component; the effect of friction is reducing.
∴ the material starts expanding and produce barrel shape of the component. Hence the initial part of forging operation is also some times called as <u>baralling operation</u>.

During the initial stages of forging b'cz the material is sticking to the surfa of die; the initial part of forging could be analysed by using **sticking friction model**.

On further application of the force by using top die; the outward expansion forces are continuously increasing; but the inward frictional forces are almost constant. ∴ at some point the outward expansion forces becomes greater than the inward frictional forces. ∴
hence the material starts sliding and the dies produce nearly cylindrical shape of the component. This part of forging operation can be analysed by using **sliding friction model**.

By observing the   is along the length of the component; but it is transmitted to the component and acting ~~is~~ along

∴ it is similar to that of the thin cylinder experiencing the internal pressure. Hence the stresses and strains induced in the forged component similar to that of the thin cylinder experiencing ~~in~~ the internal pressure.

$$\sigma_h = 2\sigma_l$$

$$\varepsilon_h = 2\varepsilon_l$$

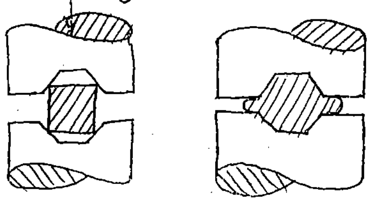
$$e_h = 2e_l$$

~~let~~ V - volume of the final finished component in forging operation.

In openType and semi closed type forging — ~~valum~~ we need the same V volume of raw materials.

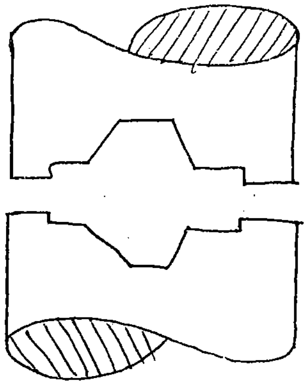
i.e the same volume of final finished component is taken as raw materials

In case of closed type forging - 10-20% higher volume ~~of~~ than the final finished volume V required is to be taken.

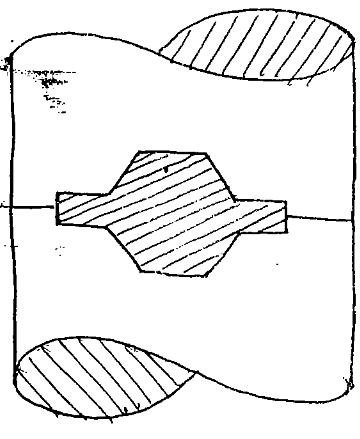


To ensure that dies can be filled completely - eventhough some material is flowing outward, the excess value of raw material has to be taken.

if >20% is used - It results in jamming of dies.



To accomodate the excess volume of material, some amount of open space must be provided in the dies, called as <u>Gutter</u>.



Bcz of provision of Gutter in the dies; the excess volume of material is filled in the gutter and produce projection in the forged component called as <u>flash</u>.

This flash is a unwanted material and it has to be removed by trimming operation

flash is only produced in closed die forging.

<u>force required in forging operation:</u>

Minimum initial force req for forging

$$F_{min} = \sigma_y \times A_0$$

Minimum final force

$$F_{f_{min}} = \sigma_y \times A_f$$

minimum force

$$F_{min} = \frac{F_{i\,min} + F_{f\,min}}{2}$$

Actual force

$$F_{act} = \frac{F_{min}}{\eta_{forg}}$$

work done

$$WD = F_{act} \times (h_0 - h_f)$$

$$= 2 \times W \times H$$

W -
H -

$$H = \frac{F_{act} \times (h_0 - h_f)}{2W}$$

Also Actual force is given by

$$F_{act} = \sigma_y A_f \left[1 + \frac{2\mu r_f}{3 h_f}\right]$$

$A_f - \frac{\pi}{4} d_f^2$

r_f - final radius

h_f - final height

μ - coefficient of friction

work done

$$WD = F_{act} \times (h_0 - h_f)$$

$$= 2 \times WH$$

height of drop of hammer.

$$H = \frac{F_{act} \times (h_0 - h_f)}{2W}$$

Types of forging or pre forming operation.

① Fullering:-

It is a method of distributing of the material from center to the outwards non uniformly.

i.e in fullering operation - the length of the component is increasing and the cross section is reducing non uniformly.

② Drawing operation:-

It's an operation of distributing the material from centre to outward uniformly.

∴ in this also length is increasing and diameter (cross section) reducing uniformly.

③ Upsetting:-

It's a forging method; to increase the CSA and reducing the length of the component.

④ Edging or Edgering:-

Forging method used for collecting the material locally.

⑤ Flattening:-

Forging method used for producing flat surfaces.

⑥ Chamfering:-

Forging method used for converting sharp edged corners into rounded corners.

⑦ Bending:-

Bending the component in the required angle.

⑧ Blocking or swaging:-

Forging method used for producing approximate shape of the components.

⑨ Finishing:-

Forging method used for producing exact shape of the [illegible] the components.

⑩ Trimming :

It's actually a cutting operation used for removing the flash present in the forged operation.

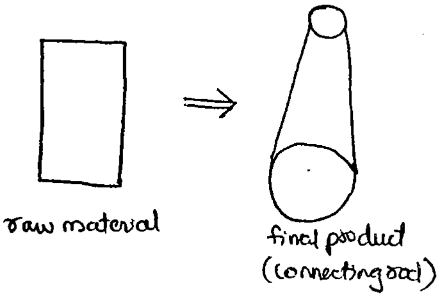
1-6] - open die forging operation

7-8] - Semi closed

9] - closed

10] - cutting

Q



write the freeforming operations in the sequence.

since non-uniform cross section and an increase in length — fullering. ①

since large qnty of materials are required at big end side — edging. ②

— blocking. ③

— ~~finishing~~. ④

— trimming ⑤

since closed die $\underset{\text{a trimm}}{\text{operation is}}$ been used so

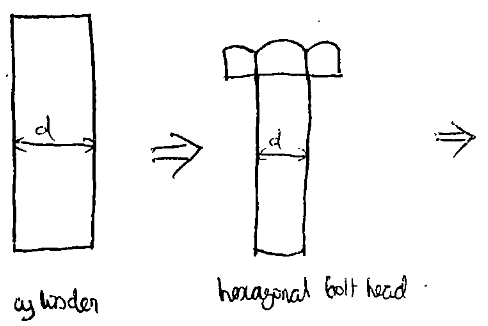
Not much sharp edges are there — so No chamfering

⊛ Except the chamfering operation — all the open die forging will be done first ; then prefer semi closed type forging operation and then if required ; go for closed die forging operation.

If the closed die forging is done — use the trimming operation to remove the flash.

After completing the process - if any sharp edges are present in the component perform the chamfering operation.

Q



⇒

① upsetting

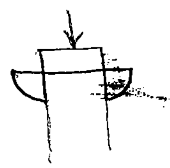
② flattening

③ Swaging

(No finishing operation is req)

④ chamfering

No trimming is required.



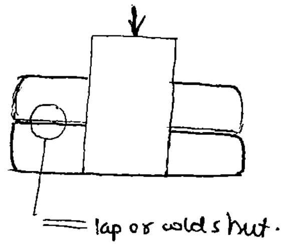
Special defect in forging

Lapping :-

Lap or cold shut :-

Discontinuity produced in a forged component due to bending of the material.

This is mainly produced in case of closed die forging operation.



p.29

Q.1

$$\text{Reduction} = \frac{d_0 - d_1}{d_0}$$

$$d_1 = d_0(1 - \text{reduction})$$

$d_0 = 15\,mm \qquad d_1 = 0.1\,mm$

(A) $d_1 = d_0(1-0.8) = 15 \times 0.2 = 3\,mm$

$d_2 = d_1(1-0.8) = 3 \times 0.2 = 0.6$

$d_3 = d_2(1-0.8) = 0.6 \times 0.2 = 0.12$

error = 0.02

(B) $d_1 = d_0(1-0.8) = 3$

$d_2 = d_1(1-0.8) = 0.6$

$d_3 = d_1(1-0.8) = 0.12$

$d_4 = d_3(1-0.2) = 0.12 \times 0.8$
$= 0.096$

0.004

(C) $d_1 = d_0(1-0.8) = 3$

$d_2 = d_1(1-0.8) = 0.6$

$d_3 = d_2(1-0.4) = 0.6 \times 0.6 = 0.36$

$d_4 = d_3(1-0.4) = 0.216$

$d_5 = d_4(1-0.2) = 0.173$

0.073

Q2.

$d_0 = 6$

$d_1 = 5.2$

$2\alpha = 18$

$L = 4$

$\mu = 0.15$

$\sigma_y = 260$

$B = \mu \cot\alpha = 0.15 \cot 9^\circ =$

$$\sigma_z = \sigma_y\left(\frac{1+B}{B}\right)\left[1 - \left(\frac{A_1}{A_0}\right)^B\right]$$

$$= \sigma_y\left(\frac{1+B}{B}\right)\left[1 - \left(\frac{d_1}{d_0}\right)^{2B}\right]$$

$$= 260\Bigg(\qquad \left[1 - \left(\frac{5.2}{6}\right)\right]$$

$=$

$$\sigma_t = \sigma_y + (\sigma_z - \sigma_y)\, e^{\frac{-2\mu L}{R_1}}$$

$TDL = \sigma_t \times A_1$

$= \sigma_t \times \frac{\pi}{4} d_1^2$

$=$

Q.3

$$\left.\begin{aligned} H_0 &= 20 \\ H_1 &= 14 \end{aligned}\right\} \Delta H = 20-14 = 6$$

$$R = \frac{480}{2} = 240$$

$$\alpha = \tan^{-1}\sqrt{\frac{\Delta H}{R}}$$

$$= \tan^{-1}\sqrt{\frac{6}{240}} =$$

at max red

$$\alpha = \beta$$

$$\mu = \tan\beta = \tan\alpha = 0.158$$

$$H_m = H_1 + (0.2 \text{ to } 0.3)\Delta H$$

$$= 14 + (0.2 - 0.3)\times 6$$

$$= 15.2 \text{ to } 15.8 = \underline{\underline{15.3}}$$

forward slip $= \frac{V_1 - V}{V}$

$$= \frac{V_1}{V} - 1 = \frac{H_0}{H_1} - 1$$

$$= 9\%$$

Backward slip $= \frac{V - V_0}{V}$

$$= 1 - \frac{V_0}{V} = 1 - \frac{H_0}{H_0}$$

$$= 23\%$$

maximum pressure $= 16.5$

Q.8

$H_0 = 3.5$ $\mu = 0.08$

$H_1 = 2.5$ $\sigma_y = 140$

$R = 125,$

$b = 450$

roll separate force

$$R.S.F = \frac{2}{\sqrt{3}}\sigma_y(bL)\left(1 + \frac{\mu L}{4H}\right)$$

$$L = \sqrt{R\Delta H} = \sqrt{125\times1}$$

$$H = \frac{3.5 + 2.5}{2} = \underline{3.0}$$

R.S.F = 2?

Q.9

$h_0 = 2.6$

$h_1 = 1.8$

$2\alpha = 18$

$\mu = 0.12$

→ both μ_1 and $\mu_2 = 0.12$ can be taken

it's supposed to take cone mandrel but for that die land is req – but not given
so impossible to calculate γ (cone angle)

So Hypothetically and $\gamma = 0$.

$$B = \frac{\mu_1 \pm \mu_2}{\tan\alpha}$$

Stationary mandrel

$$B = \frac{\mu_1 + \mu_2}{\tan\alpha}$$

$$\frac{\sigma_z}{\sigma_y} = \left(\frac{1+B}{B}\right)\left(1 - \left(\frac{h_1}{h_0}\right)^B\right) = 0.664$$

movable mandrel

$\mu_1 = \mu_2$ $B = 0$

$$\frac{\sigma_z}{\sigma_y} = \log_{10}\left(\frac{1}{\frac{h_0}{h_1}}\right) \quad 0.356$$

Q.11

$A_0 = 25\times5 = 125$ $= \frac{A_0 - A_1}{A_0} = 0.4$

$\Downarrow$

$\mu = 0.1$ (conical)

$A_1 = A_0(1-0.4)$

$\sigma_y = 300$

$= 125\times0.6$

die angle $= 26.5$

$\alpha = 13.25$

$B = \mu \cot\alpha$

$$\sigma_z = \sigma_y\left(\frac{1+B}{B}\right)\left(1 - \left(\frac{A_1}{A_0}\right)^B\right)$$

$$DL = \sigma_z \times A_1$$

Q.12

$\mu = 0.2$

$\alpha = 6^\circ$

$B = \mu \cot \alpha$

$$\frac{\sigma_2}{\sigma_y} = 1 = \left(\frac{1+B}{B}\right)\left[1 - \left(\frac{A_1}{A_0}\right)^B\right]$$

$$\frac{A_1}{A_0} = \left(\frac{d_1}{d_0}\right)^2 = (\quad)$$

$$d = d_0\sqrt{(\quad)}$$

$d_0 = 6mm \qquad d_f = 1.34$

if $d_1 \le 1.34 \quad n = 1$

$d_2 \le 1.34 \quad n = 2$

$d_1 = d_0\sqrt{\quad} \qquad \le 1.34 \qquad n = 1$

$d_2 = d_1\sqrt{\quad} \qquad \le 1.34 \qquad n = 2$

$d_3 = d_2\sqrt{\quad} \qquad \le 1.34 \qquad n = 3$

- - - - - - -

Ans $\quad n = 6$

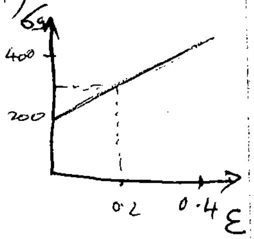
Q 14.

$$\frac{\pi}{4} d_0^2 L_0 = \frac{\pi}{4} d_f^2 L_f$$

$$L_f = L_0\left(\frac{d_0}{d_f}\right)^2$$

$$\varepsilon = \ln\left(\frac{A_0}{A_1}\right) = 2\ln\left(\frac{d_0}{d_1}\right)$$

$$= \underline{\underline{0.4}}$$



$0.2 \Rightarrow 300(\sigma_y)$.

Q.16

$$\sigma = 315\ \varepsilon^{0.54} =$$

$$\varepsilon = 2\ln\left(\frac{d_0}{d_1}\right) = 2\ln\left(\frac{d5}{5}\right) =$$

Q.17

$d_0 = 100 \qquad b_f = 40$

$h_0 = 50$

$$d_f = d_0\sqrt{\frac{h_0}{h_f}} =$$

$f_{min} = \sigma_y \times A_0$

$f_{f\,min} = \sigma_y \times A_f$

$$f_{min} = \frac{f_{i\,min} + f_{f\,min}}{2} =$$

$= f_{act}.$

$W.D = f_{act} \times (h_0 - h_f)$

Q.18

$$H = \frac{f_{act}(h_0 - h_f)}{2 \times 10 \times 10^3}$$

Q.19

$$EF_{min} = \sigma_y \times A_0$$

$$= 10 \times \frac{\pi}{4} \times 100^2$$

$$EF_{act} = \frac{E \cdot f_{min}}{0.4}$$

$= 196$ ton

Capacity $= 200$ tons.

Q.20

At max load

true strain $= \varepsilon = \frac{1}{3}$

True stress $= 1400\ \varepsilon^{0.33}$

$$= 1400\left(\frac{1}{3}\right)^{0.33}$$

$\underline{\underline{= 971}}$

7/10/11

9 - 1 pm.

SHEET METAL OPERATIONS

ref: Workshop Technology by Pollack

The operations performed on the sheets to get the required shape is called sheet metal operations.

cutting operation:
1. Punching or Piercing operation
2. Blanking

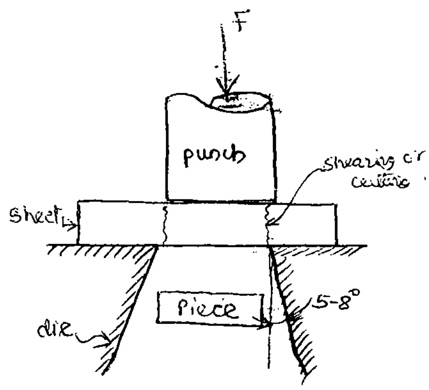
forming operations:
3. Deep drawing
4. Bending

Major operations [most commonly used] (Syllabus)

5. Perforating
6. Notching
7. Lancing
8. Slitting
9. Nibbling
10. Trimming.

minor operation. (for match the following)

Cutting operations



Punch and die operation is done.
A small 5-8° inclination is provided in the die for easy removal.
shearing occurs and a piece is been removed.

Punch size < Die size.

The shape of punch and die is same as the part to be produced.

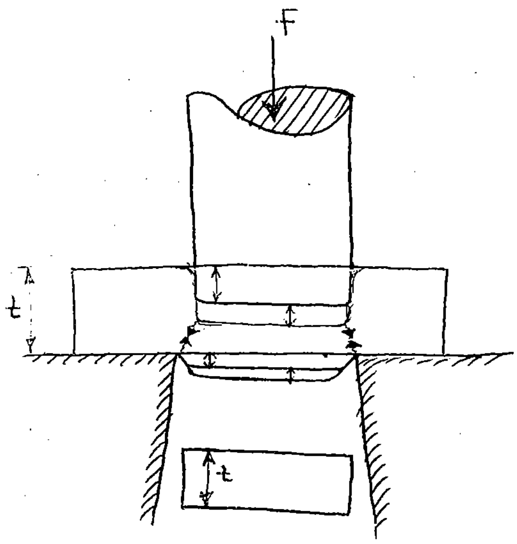
In punch and die working operation - if the hole produced in the sheet useful. Then it is called as punching or piercing operation.

In punching operation, the punch size is made equal to the hole size and the clearance is provided only on the die.
also in punching the shear is provided only on the punch.

In punch and die working operation; if the piece or blank produced is useful one; called as <u>blanking operation</u>.

In blanking the die size is made equal to blank size and clearance is provided only on the punch.

Also in blanking the shear is provided only on the die.



<u>Mechanism</u>

When the force is applied by using the punch on to the sheet, the top surface of the sheet is experiencing elastic compressive deformation and bottom surface of the sheet is experiencing elastic elongation.

But the amount of compression on the top is greater than the amount of elongation at the bottom.

Due to this difference in compression and elongation; the sheet metal present b/w punch and die is experiencing shear stresses.

On further application of force by using the punch; the difference b/w the compression and elongation increases continuously.
∴ the shear stresses is also increasing.

∴ at some point the shear stresses induced in the sheet will become greater than ~~the~~ or equal to the ultimate shear stresses of the sheet metal. Hence the shearing or cracking start take place at the ~~eg~~ edges of punch and die [only at edges ~~sn~~ due to stress concentration]

and propagating in their respective directions, meeting somewhere in the mid cross section so that the piece get [some thickness] separated from the sheet producing a hole in the sheet.

Thus the mechanism by which the cutting of the sheet ~~taking~~ place is <u>shearing and tearing</u>.

During punching and blanking operation, the optimum clearance b/w punch and die must be selected such that the crack propagations produced from the edges of punch and die is meeting somewhere in the mid crossection.

Let

c = optimum clearance [radial]

$= 0.0032\, t\sqrt{\tau_u}$

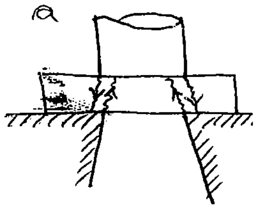
t – thickness of sheet in <u>mm</u>

τ_u – ultimate shear stress in <u>MPa</u>

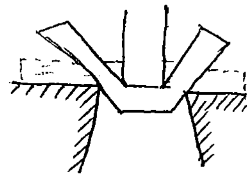
$= 5\% \, t \quad \text{if } t \leq 2\,mm$

$= 10\% \, t \quad \text{if } t > 2\,mm$

If the clearance provided is less than the optimum clearance, the crack propagations willnot meet and they produce a 3piece configuration.



If the clearance provided is ~~less~~ greater than the optimum clearance ; then no cutting takesplace and the sheet would be draged into the hole.



Punching

Punch size = Hole size

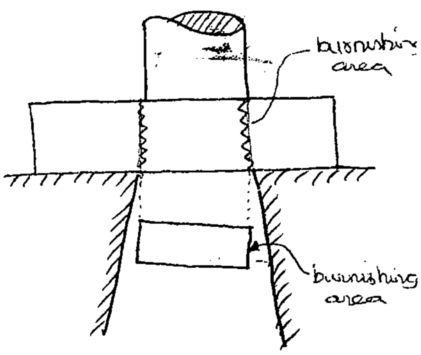
Die size = Punch size + clearance

Blanking

Die size = Blank size

Punch size = Die size − clearance

The selection of punch and die sizes in punching and Blanking operations is mainly based on the burnishing area produced on the respective useful components.



After the cutting and shearing action has been completed ; the edges of the holes and blank produced are like a zigzag edges ; hence the components cannot be used directly.

In punch and die working when the force is applied by using punch; after the cutting action ; the ~~3~~ zig zag edges present on the components will get converted to straight and smooth edges by plastic deformation as the principal

The area of the component on which the zigzag edges has get converted into straight and smooth edges is called burnishing area.

The burnishing area on the hole is produced by of the punch ... the will be taken equal to hole size in punching.

On the blank, the burnishing area is produced bcz of the die ∴ the blank size is exactly equal to the die size and hence the die size is taken as blank size in blanking.

Q If hole of dia 30mm with a sheet of a thickness 2mm and clearance of 5% t. Determine the punch and die size.

operation required is punching

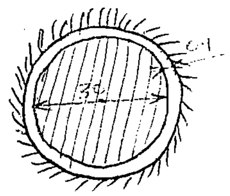
punch size = hole size

$= 30\,mm\ \phi$

die size = punch size + clearance

Since size is given a diametrical we should do in same form.

$= 30\,mm + \underbrace{2\,'c'}_{\text{radial clr}}$



$= 30 + 2 \times \frac{5}{100} \times 2$

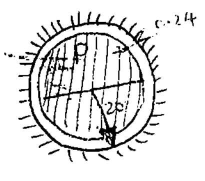
$= 30.2\,mm$

Q Produce a blank of radius 20mm on a sheet of 3mm thickness. clearance to be taken is 8% t. Determine ~~and~~ punch & die size.

blanking operation

die size = blank size

$= \underline{20\,mm}$



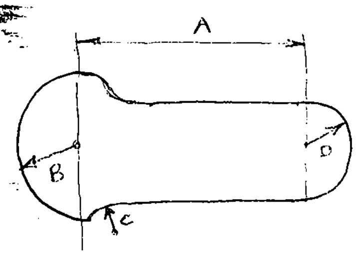
clearance $= \frac{8}{100} \times 3 = 0.24$

punch size $=$ ~~blank~~ die size − clearance

$= 20 - 0.24$

$= \underline{18.76\,mm}$

*Q



	A	B	C	D
hole	30	20	10	15

$t = 1\,mm$

$c = 5\%\,t$

$= 0.05\,mm$

Part	A	B	C	D
hole	30	20	10	15
P.S	30	20	10	15
D.S	30	20.05	9.95	15.05

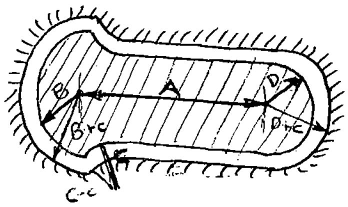
clearance

$C = 5\% t$

$= 0.05\,mm$

dimension A – Not experiencing any cutting action

so – No change – No clearance req.



Load estimation in punching and blanking operation

$$\boxed{\text{force} = F_{max} = A_s \tau_u}$$

τ_u – Ultimate shear stress

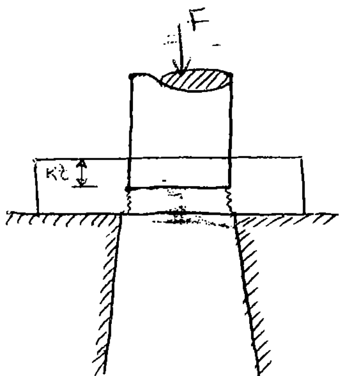
A_s – sheared area

$= (\text{perimeter}) \times t$

$= (\pi d)\, t$ – circular

$= 4a\, t$ – square

$= 2(a+b)\, t$ – rectangular.



Work Done $= E = \text{Force} \times \text{dist}$

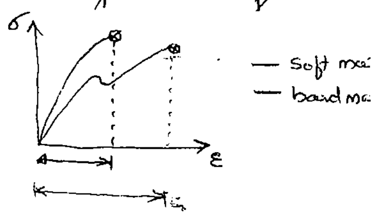
$$\boxed{E = F_{max} \times kt}$$

K – % penetration req. for complete shearing action

→ 20 – 60%

Soft materials – 60%

hard materials – 20%



Now to reduce the work done – we should reduce the force.

$\downarrow F_{max} = A_s \downarrow \tau_u \downarrow$

τ_u can't be reduced so the punching and blanking is always done at

The $A_s \downarrow \Rightarrow A_s = \underbrace{P_{\downarrow}}_{\underbrace{\pi d \downarrow}_{\text{can't do}}} \times \underbrace{t \downarrow}_{\text{can't do}}$

So we would try to reduce As in stage wise.
Like in case of apple [apple size > mouth size but we cut into pieces & eat] :)

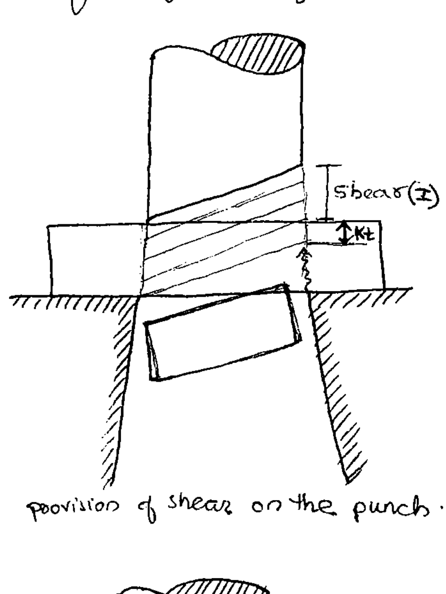
In cutting and blanking operation, when the operation is perfomed in the normal methodology, the total sheared area will be cut at a time; hence the force required will become higher. To reduce this force required, the total sheared area will be divided into number of pieces and each area will be cut slowly and progressively; At any one point of time; the sheared area under cutting action is less than the total sheared area; but by the end of the process, the total sheared area will be cut.

Methods of reducing punch force.

① By providing shear:-

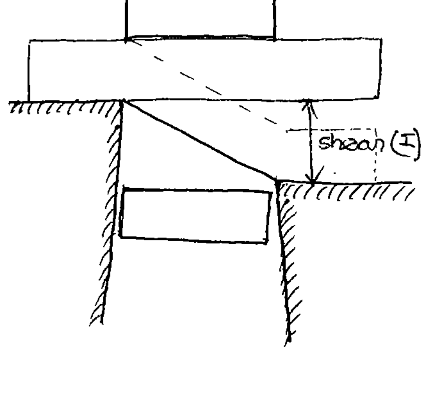
Provision of the shear is nothing but making the face of punch or die inclined.

From the figure it is clear that the sheared area under the cutting action is less than the total shear area at any one point of time during the cutting action.
Hence the force required is reduced



Provision of shear on the punch.

If shear is provided on both the elements punch & die - both the components ie hole produced in the sheet and the blank will become unuseful ∴ it is always required to provide the shear on only one element.



If punch is provided with shear - the blank will be deformed (subjected to bending)

If die is provided with shear - the sheet or hole would be deformed.

and to make it possible; the shear must be provided only on the punch. where as in case of blanking; to make the blank useful the shear must be provided only on the die.

*The workdone or energy required for performing the given operation remains constant irrespective of the method of provision of shear.

ie the workdone with shear = workdone without shear.

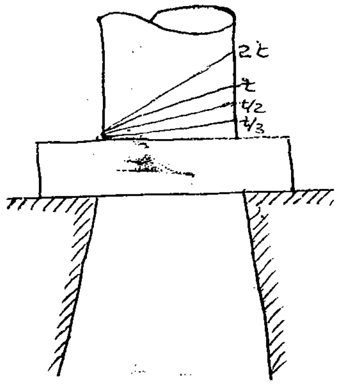
$$\boxed{F\,(Kt + I) = f_{max}\, Kt}$$

$$F = \frac{f_{max} \times Kt}{(Kt + I)}$$

$$I = \frac{f_{max}\, Kt}{F} - Kt$$

As the shear provided increases — the punch would become weaker and chance of failure increases. So there is a maximum value of shear that could be provided

Maximum value of shear that could be provided



$K = 50\%$, $I = t/3$: $F = \dfrac{f_{max} \times 0.5t}{0.5t + \frac{t}{3}} = 0.6\, f_{max}$

↓ 40% is reduced by mere $\frac{t}{3}$

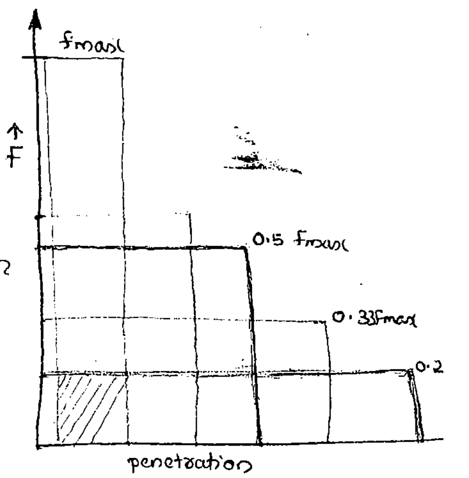
$K = 50\%$, $I = t/2$: $F = \dfrac{f_{max}}{2} = 0.5\, f_{max}$

50% reduction

$K = 50\%$, $I = t$: $F = \dfrac{f_{max}}{3} = 0.33\, f_{max}$

67% reduction

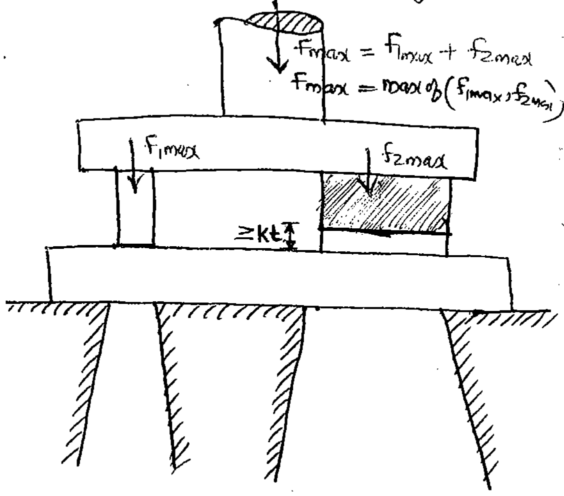
$K = 50\%$, $I = 2t$: $F = \dfrac{f_{max}}{5} = 0.2\, f_{max}$



* Area under the curves remain same

with $I = 2t$, the additional force reduction when compared to $I = t$ is only about 13%. But for the corresponding I; the life of the tool is reduced by ~~50%~~ nearly 40 – 50%. Hence it is not preferable. Hence Maximum amount of shear one can provide on the punch or die is ≤ sheet thickness

② by staggering of punches
This method is applicable only when more than one operation is performed in one stroke.



In this method the length of the successive punches has been reduced by an amount greater than or equal to the kt ($\geq kt$) so that only one punch is in contact with the sheet at any given point of time.

If both the lengths were same then the sum of the two force required should be provided initially.

but if only one comes in contact at a time then only the maximum cutting force among the punching operation is only required.

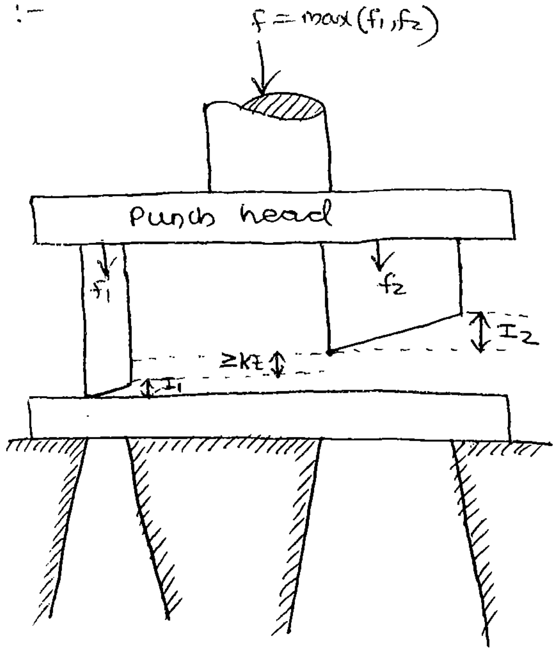
If there are n number of operations simultaneous occur then

$$F_{max} = \text{maximum of } [f_{1max}, \dots f_{n max}]$$

Limitation :-

Balancing of forces in the punchhead is very difficult.

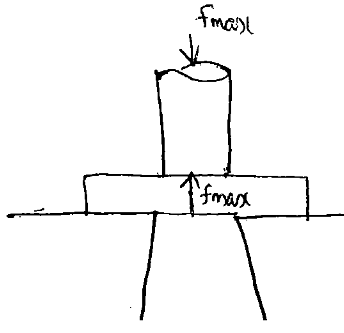
③ Combination of shear and staggering :-



Even though the combination method is reducing the force requirement to a smaller value;

the balancing of the forces on the punch head is almost impossible ∴ it cannot be used in practical applications

Compressive stresses induced in punch material



when F_{max} is the force applied by using punch onto the sheet; an equal and opposite reaction force produced by the ~~punch~~ sheet is acting on to the punch. ∴

The punch is experiencing compressive or crushing stresses.

compressive stress induced in punch material
$$\sigma_{cp} = \frac{F_{max}}{A_{cp}}$$

$$= \frac{F_{max}}{\frac{\pi}{4}d^2}$$

$$= \frac{\pi d t \tau_u}{\frac{\pi}{4}d^2}$$

$$\boxed{\sigma_{cp} = \frac{4 t \tau_u}{d}}$$

As the hole size to be produced is increasing the compressive stress induced in the punch is reducing ; hence the punch is safe. But if the dia of the hole to be produced is reducing ; the compressive stresses induced in the punch increases;
At some point the compressive stresses induced in the punch may become greater than the allowable compressive stresses in the punch material. ∴ the punch may fail at any time.
To avoid this it is required to restrict the minimum size of the hole produced.

$$d_{min} = \frac{4 t \tau_u}{\sigma_{cp\,allowable}}$$

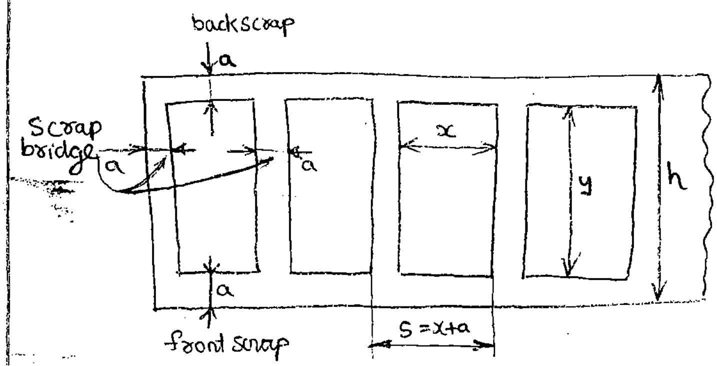
if $\tau_u = \sigma_{cp\ allowable}$ then $d_{min} = 4t$ | and if $\sigma_{cp} = 4\tau_u$ then $d_{min} = t$

This case is only taken in case of punching (only there we require the small holes - small blanks are never produced)

Strap strip layout in blanking

It is considered only in blanking operation and not in punching operation.

The layout by which the blanks are produced from the sheet such that the % utilization of the sheet is maximum



margin is always provided to remove the unevenness present on the edges of the sheet and also to remove the edge damages; taken place during the transportation of the sheet from one place to another place.

$$a = \text{margin}$$
$$= 0.8\,mm \quad , \text{if } t \le 0.8\,mm$$
$$= t \quad , \text{if } t = 0.8 \text{ to } 3.2$$
$$= 3.2\,mm \quad , \text{if } t \ge 3.2\,mm$$

$h = y + a + a = y + 2a$

S - feed of sheet $= (x+a)$

L - total length of sheet available

n - No of blanks produced

$$n = \frac{L-a}{S} \approx \frac{L}{S} \qquad \Rightarrow L = nS$$

$$\% \text{ utilization} = \frac{\text{area utilized}}{\text{Total area of sheet}}$$

$$= \frac{n \times (x \times y)}{L \times h}$$

$$= \frac{n\,(xy)}{(nS)\,h}$$

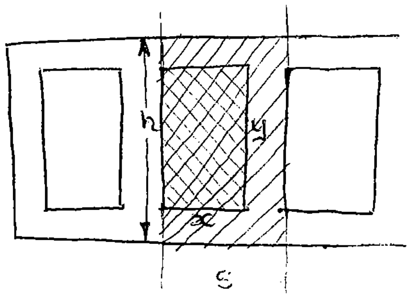
$$= \frac{xy}{S \times h}$$

control area

To determine the % utilized we does not require the length of the sheet

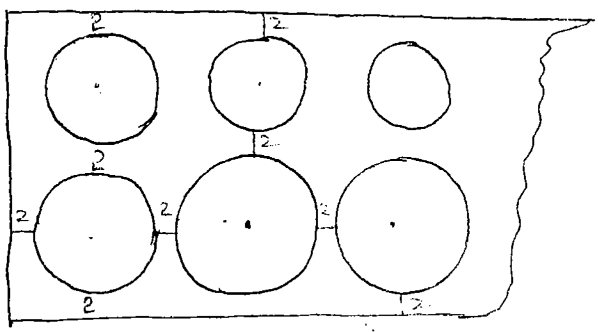
The repeatable area that can be considered is blanking operation is called as control area. [S×h]

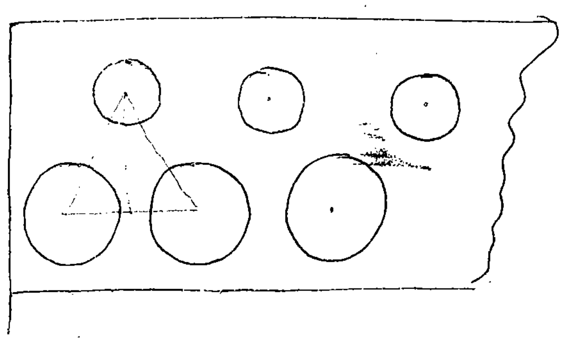
To identify the control area draw a line at ~~one~~ any point and then draw other line corresponding to the ~~same~~ ~~point~~ similar point. Then the area in b/w is called controll area.

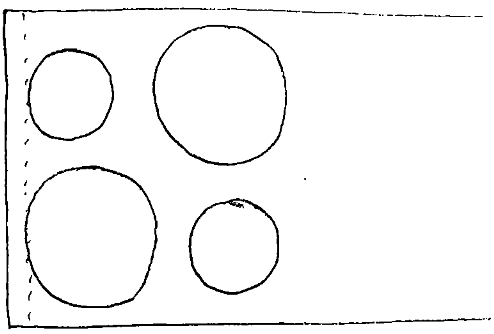


% utilization = $\frac{\text{////}}{\text{///}}$

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 strap strip layout which is giving maximum % utilization of the sheet.

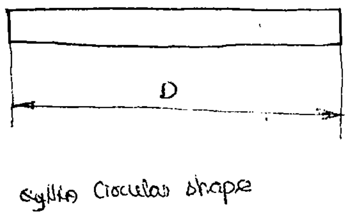


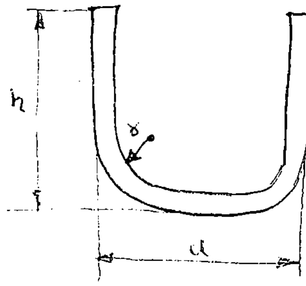




3 Deep drawing

It's a forming operation in which the forces are applied on the material such that the stresses induced is greater than the yield strength and less than the ultimate so that the material deforms plastically to change the shape of the component.





mainly it is used for producing cup shaped components.

If $\frac{h}{d} < 0.5 \Rightarrow$ shallow drawing

$\frac{h}{d} \geq 0.5 \Rightarrow$ deep

If $\frac{d}{r} \geq 20 \Rightarrow$ corner radius is negligible

By neglecting the corner radius, one side surface area of the blank is equal the one side surface area of the component.

By using this principle we could find the size of the blank required if we know the dimensions of cup to be produced.

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

$$D^2 = d^2 + 4dh$$

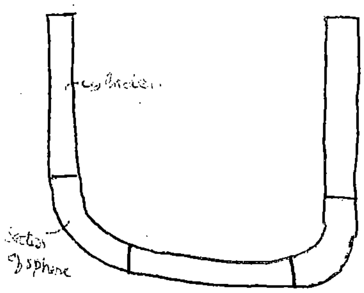
$$\boxed{D = \sqrt{d^2 + 4dh}} \qquad \frac{d}{r} \geq 20 \text{ corner radius neglect}$$

$$D = \sqrt{d^2 + 4dh} - \frac{r}{2} \qquad \frac{d}{r} = 15 - 20$$

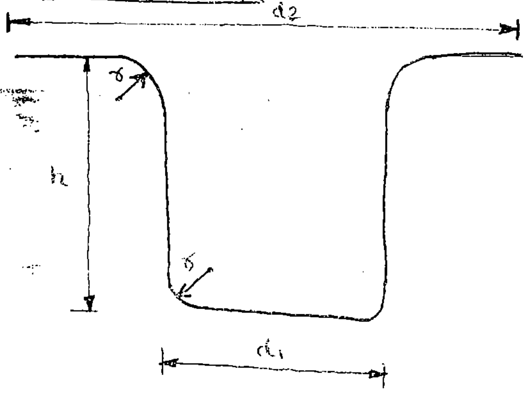
$$D = \sqrt{d^2 + 4dh} - r \qquad \frac{d}{r} = 10 - 15$$

If $\frac{d}{r} < 10$ – Total surface are of the blank must be made equal to total surface area of the component.

But findis total surface area is bit complicated, so not req. exam point of view.



* Q Design the blank



Ans:-

$$\frac{\pi}{4} D^2 = \frac{\pi}{4} d_1^2 + \pi d_1 h + \frac{\pi}{4}(d_2^2 - d_1^2)$$

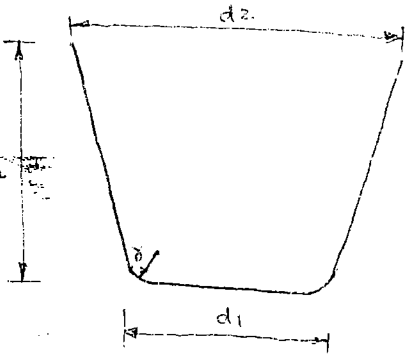
$$D^2 = d_2^2 + 4 d_1 h$$

$$D = \sqrt{d_2^2 + 4 d_1 h} \qquad \frac{d_1}{r} \geq 20$$

$$D = \sqrt{d_2^2 + 4 d_1 h} - \frac{r}{2} \qquad \frac{d_1}{r} = 15$$

$$D = \sqrt{d_2^2 + 4 d_1 h} - r \qquad \frac{d_1}{r} =$$

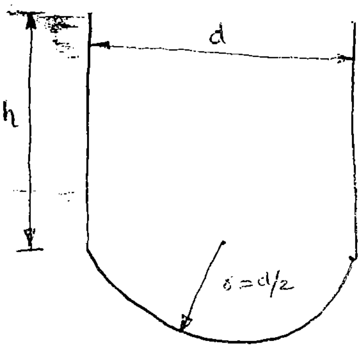
* Determine the blank dia



$$\frac{\pi}{4} D^2 = \frac{\pi}{4} d_1^2 + \pi d_{av} h$$

$$D^2 = d_1^2 + 4 d_{avg}$$

$$D = \sqrt{d_1^2 + 2(d_1 + d_2) h}$$



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

Sphere
$4\pi r^2$
πd^2

$$D^2 = 4 d h + 2 d^2$$

$$D = \sqrt{4 d h + 2 d^2}$$

In all the above cases; it is assumed that the thickness of the component and thickness of blank are same.

Q Determine the radius of the blank required; to produce a hemispherical cup of radius 200mm.

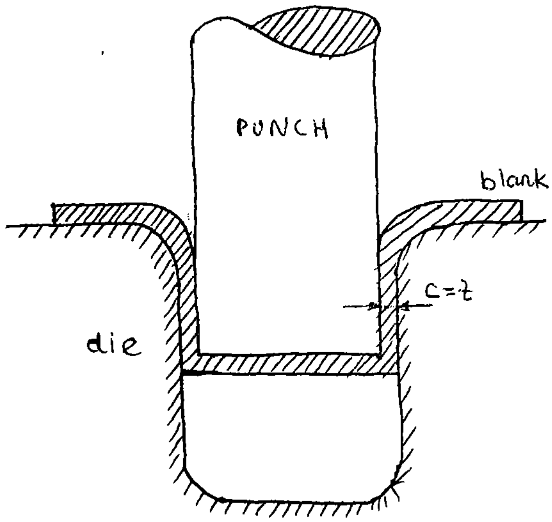
$$\frac{\pi D^2}{4} = \frac{\pi d^2}{2}$$

$D = \sqrt{2}\, d$ $\quad\quad$ $R = \sqrt{2}\, r$

$= \sqrt{2} \times 200$

$= \underline{\underline{282 mm}}$

III^{ly} to punching and drawing operation; deep drawing is also having a punch and die combination.



here the clearance varies.

$\boxed{\text{Clearance} = \text{Sheet thickness}}$

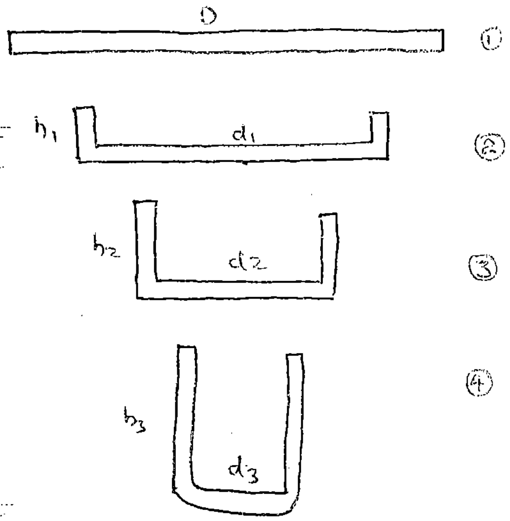
$C = t$

So In case of the punching the optimum clearance is 5 to 10% of t.

When the force is applied by using the punch; the sheet will be simply pulled into the die by shearing action. In corners the stress would become greater than yield but less than ultimate

If the deep drawing operation is performed at one stage itself; the forces to be applied on the sheet is very high. ∴ eventhough the average stresses induced in the sheet is less than the ultimate stress but some local areas of the sheet may experience stresses greater than the ultimate. Hence the localised cracking may takeplace, which leads to leakages taking place during usage of the component.

To overcome this problem; it is always reccomented to perform the deep drawing operation in more than one stage or more than one draw.



Though we are doing the drawing in stages; the eqn

$$D = \sqrt{d^2 + 4dh}$$

d, h is the final shape required for the (dimen) and D is the blank dia req.

But this eqn is also applicable for intermediate stages too (for calcu $h_1, h_2, h_3 \cdots$)

In deep drawing operation for each and every stage; a separate punch and die combination will be used.

Load required in Deep drawing

P = load required in deep drawing

$$\boxed{P = \pi d t \sigma_y \left(\frac{D}{d} - C\right)}$$

σ_y - Yield stress
D - blank dia
t - thickness of sheet
C - a constant to cover friction, bending, corner radius etc

$C = 0.6 - 0.7$

if we neglect friction, bending & corner rad $C = 0$.

Also for different stages

$$P_1 = \pi d_1 t \sigma_y \left(\frac{D}{d_1} - C\right)$$

$$P_2 = \pi d_2 t \sigma_y \left(\frac{d_1}{d_2} - C\right)$$

$$P_3 = \pi d_3 t \sigma_y \left(\frac{d_2}{d_3} - C\right)$$

d_1, d_2, d_3 - are the diameters of the component after the 1st 2nd and 3rd stages of drawing respectively

If $C = 0$

$$P_1 = \pi D t \sigma_y$$

$$P_2 = \pi d_1 t \sigma_y$$

$$P_3 = \pi d_2 t \sigma_y$$

Work done

$$W \cdot D = \text{force} \times \text{distance}$$

$$WD = P \times h$$

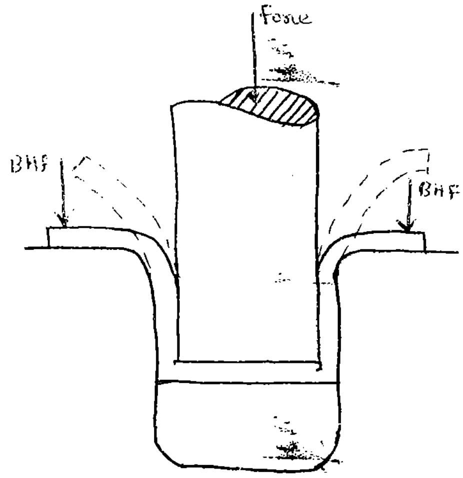
$$WD_1 = P_1 \times h_1$$

$$WD_2 = P_2 \times (h_2 - h_1)$$

distance moved by the punch.

$$WD_3 = P_3 \times (h_3 - h_2)$$

Blank Holder force



During deep drawing operation; when the force is applied by using the punch on to the blank; the edges of the blank are lifting upwards which produces wrinkles on the deep drawing component.

This wrinkles are making the appearance of the component very bad.

∴ it is required to eliminate the formation of the wrinkles.

For this the lifting of the edges has to be avoided. This is possible by applying force onto the blank called as blank holder force (B.H.F)

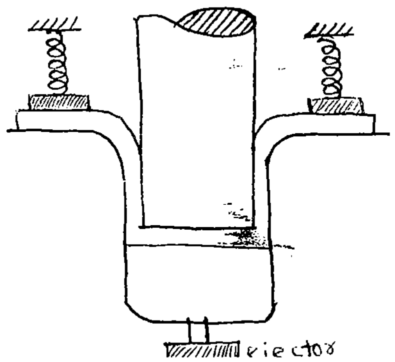
If BHF is > drawing force then tearing of sheet occurs.

so BHF should be less than drawing force. $BHF = \frac{1}{3} P$

The optimum blank holder force applied is $\frac{1}{3^{rd}}$ of the drawing force so that the lifting of the edges of the blank will be eliminated and the drawing process will also be easier.

$$BHF_1 = \frac{P_1}{3} \qquad BHF_2 = \frac{P_2}{3} \qquad BHF_3 = \frac{P_3}{3}$$

The blank holder force required in case of deep drawing operation can be obtained by using **spring loaded stripper plate**.



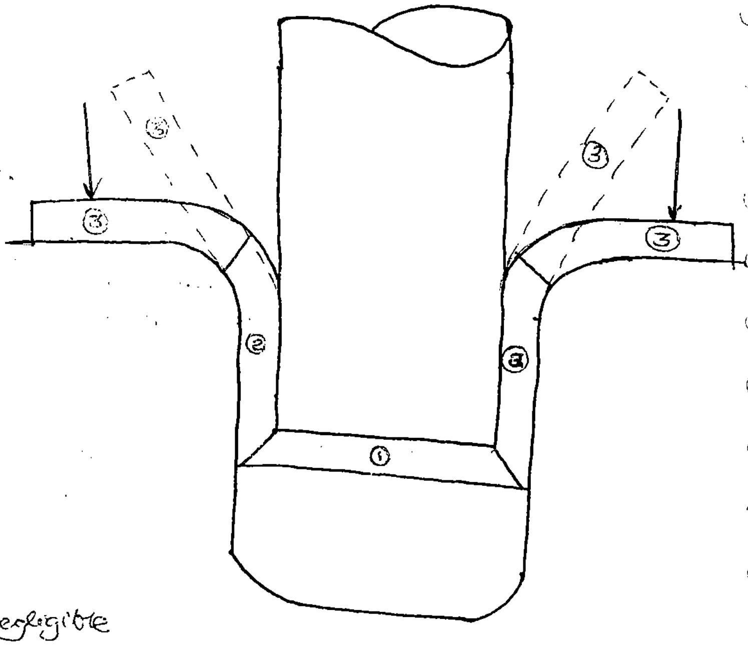
by controlling the compression of spring we could control the force. ~~requ~~

BHF is maintained till the punch is been completely removed after the ~~p~~ deep drawing operation so that componet is always retained inside the die

bcz - while deep drawing there is chance of sheet sticking to the punch. Then it would be difficult to remove.

But if in the die it could be easily removed by provide an ejector - ejector can't be used in punch as it is longer and also hole cannot (longer ejector is needed) ~~be~~ digged in punch due to stress concentration.

Stresses induced in deep drawing



Zone 1 - Bottom of punch zone

without BHF - No stresses

with BHF - Tensile stress induced.

Zone 2 - Deformation zone

Deformation req. for converting blank to component is obtained here.

without BHF - Tensile stress

with BHF - Tensile stress

Compressive stresses in the corner are negligible

Zone 3 - flange portion

without BHF - Tensile in 2-direction and compressive in 3rd direction

with BHF - Tensile (No compressive force by BHF as the component is moving; so No reaction is offered back to compress)

The stresses in the zone 2 alone is responsible for the deformation. So it is req. only to calculate the stresses induced init.

During deep drawing operation; the tensile stresses induced in the deformation zone are only responsible for changing the shape of the component. is required to calculate the magnitude of the stresses induced in the zone.

σ_{21} - Stresses induced in zone 2 of stag 1

$$\sigma_{21} = \frac{\text{load}}{\text{Area}}$$

$$= \frac{P_1}{\frac{\pi}{4}\left(d_1^2 - (d_1 - 2t)^2\right)}$$

Stress induced in zone 2 in stage 2

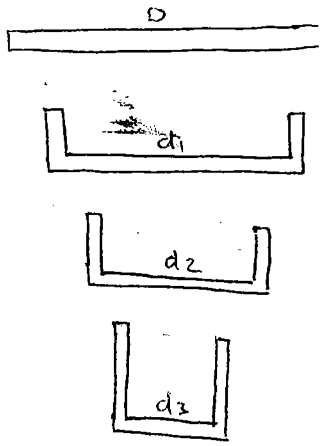
$$\sigma_{22} = \frac{P_2}{\frac{\pi}{4}\left(d_2^2 - (d_2 - 2t)^2\right)}$$

$$\sigma_{23} = \frac{P_3}{\frac{\pi}{4}\left(d_3^2 - (d_3 - 2t)^2\right)}$$

every where n zones $\Rightarrow \sigma_y < \sigma_{2n} < \sigma_U$

Number of stages required

(1) Draw ratio method :-



Draw ratio

$$DR = \frac{\text{Dia before}}{\text{Dia After}}$$

$$DR_1 = \frac{D}{d_1}$$

$$DR_2 = \frac{d_1}{d_2}$$

$$dR_3 = \frac{d_2}{d_3}$$

Limiting draw ratio,

$$LDR = DR_1 = DR_2 = DR_3 = \cdots$$

$= 1.6 - 2.3$

$= 1.6 - 2$ – hard materials

$= 2 - 2.3$ – Soft materials

$DR_1 = \frac{D}{d_1} \Rightarrow d_1 = \frac{D}{DR_1} = \_\_\_ \leq d$, $n = 1$ d – dia to be prod

if not

$DR_1 = \frac{D}{d_2} \Rightarrow d_2 = \frac{d_1}{DR_2} = \_\_\_ \leq d$, $n = 2$

if not

$DR_3 = \frac{D}{d_3} \Rightarrow d_3 = \frac{d_2}{DR_3} = \_\_\_ \leq d$, $n = 3$

if not

Q $d = 30mm$, $h = 150mm$ } number of draws req $n = ?$

$DR_1 = 1.6$

DR_2 and above $= 1.8$

blank dia $D = \sqrt{d^2 + 4dh}$

$= \sqrt{30^2 + 4 \times 30 \times 150}$

$= 137$

$DR_1 = \frac{D}{d_1}$ $\qquad d_1 = \frac{D}{DR_1} = \frac{137}{1.6} = 85 \quad > 30$

$d_2 = \frac{85}{1.8} = 47 > 30$

$d_3 = \frac{47}{1.8} = 26 < 30 \qquad \underline{\underline{n = 3}}$

3 draws are required or drawing can be done in 3 stages.

2. Draw reduction ratio

$$DRR = \frac{\text{dia reduced}}{\text{dia before}}$$

$$DRR_1 = \frac{D - d_1}{D}$$

$$DRR_2 = \frac{d_1 - d_2}{d_1}$$

$$DRR_3 = \frac{d_2 - d_3}{d_2}$$

General values of DRR

$DRR_1 = 45 - 50\%$

$DRR_2 = 30 - 35\%$ $\qquad$ No need to remember will be given in Qstn.

$DRR_3 = 20 - 25\%$

DRR_4 & above $= 16\%$

$$DRR_1 = \frac{D - d_1}{D}$$

$$d_1 = D(1 - DRR_1)$$

$d_1 = D(1-DRR_1) \le d$, $n=1$

if not $d_2 = d_1(1-DRR2) \le d$, $n=2$

if not $d_3 = d_2(1-DRR3) \le d$, $n=3$

. . . .

. . . .

Q $\left.\begin{array}{l} d = 30\ mm \\ h = 150\ mm \end{array}\right\}$ $n = ?$

$DRR_1 = 40\%$

$DRR2$ & above $= 25\%$

$D = \sqrt{d^2 + 4dh} = 137$

$d_1 = 137(1-0.4) = 82 > 30$

$d_2 = 82(1-0.25) = 62 > 30$

$d_3 = 62(1-0.25) = 46 > 30$

$d_4 = 46(1-0.25) = 34 > 30$

$d_5 = 34(1-0.25) = 26 < 30$, $n=5$

If nothing is mentioned about the values of draw ratio or draw reduction ratio It is always assumed that the draw ratio method will $DR = 2$.

Q If $d = 12mm$ & $h = 30mm$. Calculate $n = ?$

$D = \sqrt{12^2 + 4 \times 12 \times 30} = 40mm$

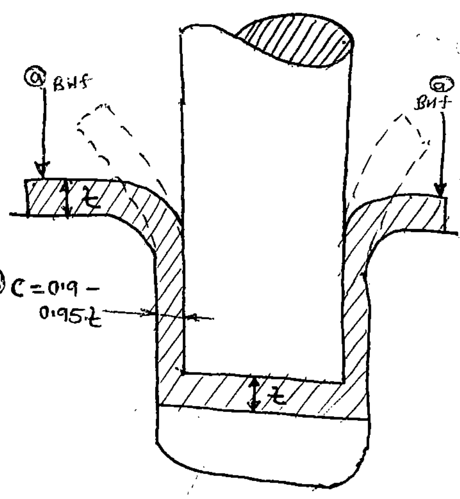
$d_1 = \frac{D}{2} = \frac{40}{2} = 20 > 12$

$d_2 = \frac{d_1}{2} = \frac{20}{2} = 10 < 12$, $n = 2$

Defects in deep drawing

1. Wrinkling :-

The formation of wrinkles or foldings on the deep drawing component is called wrinkling. wrinkling can be eliminated by



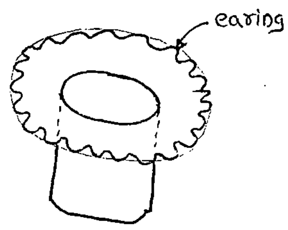
(a) blank holder force (BHF)

(b) By ironing -

normally in the deep drawing operation; the clearance b/w the punch & die = sheet thickness, but for removing the wrinkles present in the deep drawing component the clearance present b/w the punch and die is made slightly less than the sheet thickness so that the squeezing of the material is taking place which removes the wrinkles present in the deep drawing component.

(c) By using draw bead

2. Earing :-



The presence of edge wrinkles or waviness present on the flanges of a deep drawn component is called as earing defect.

This is produced mainly b'cz of anisotropic properties of a sheet metal

During deep drawing, when a wrinkle is forming on the component, at the inside surface of a wrinkle, compressive; outer surface of a wrinkle - tensile stresses are induced. but the magnitude of compressive and tensile stresses are different.

$$\boxed{\text{Number of ears or waves} = 2^n}$$

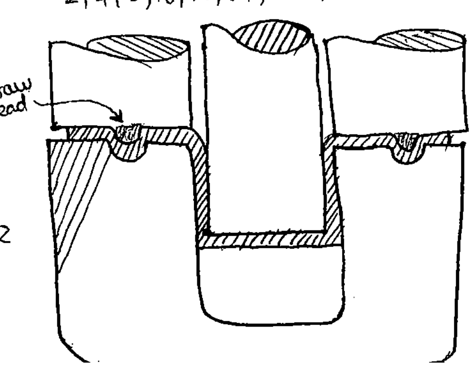
where n = an integer 1, 2, 3, 4 .....

the amount of work hardening taking place in the sheet metal is different in different directions

Due to this, the material has got converted from the isotropic to the anisotropic.

in multiple choice choice would be given in such a way that only powers of 2 will be given 2, 4, 8, 16, 32, 64, 128, 256 . . .

elemination :-



Complete elimination of earing defect is not possible. but it can be minimised by using the draw bead.

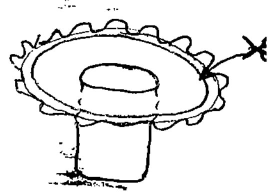
Semicircular strip provided around the circumference of a blank holder is called draw bead. It has a dia of 13 - 20 mm.

by using draw bead ; the sheet metal is experiencing diff. types of stresses at diff. locations [compressive & tensile] ∴ the amount of workhardening in the sheet is nearly uniform.

∴ the properties of the sheet metal becomes nearly uniform which minimizes the formation of earings.

effect of draw bead

(1) wrinkling is eliminated
(2) Earing is minimised
(3) BHF is reduced
(4) Drawing load is increased



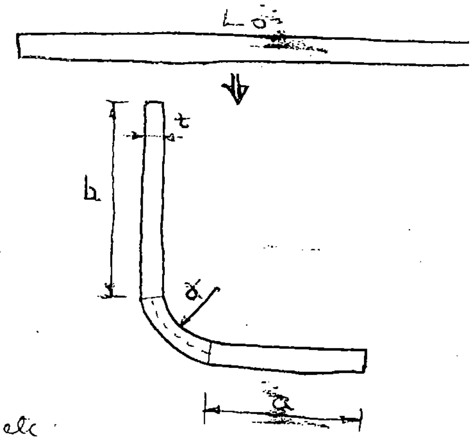
Bcs the earing defect can't be completely eliminated it can be removed by trimming or edge trimming operation.

due to edge trimming operation - the dimensions of a deep drawing operations will be reduced, to maintain required dimensions of a component; the original blank size has to be increased

$$\boxed{D_{total} = D + 2 \times T.A}$$

T.A - trimming allowance

4 Bending



Bending is also the forming operation & forces induced in the sheets will produce the stresses greater than yield & less than the ultimate $(\sigma_y < \sigma < \sigma_u)$.

eg:- drawing board
window frames, tubelight frame, fan leaf etc.

L_0 - developed length of sheet or original length of the flat starting strip.

$$\boxed{L_0 = a + b + B}$$

from the simple bending theory

$$\frac{M}{I} = \frac{\sigma}{y} = \frac{E}{R} \rightarrow r_n$$

but we are not going that way.

Simply

$$r_n = r + Kt$$

K - bend factor = stretch factor

$= \frac{1}{3}$ if $r < 2t$

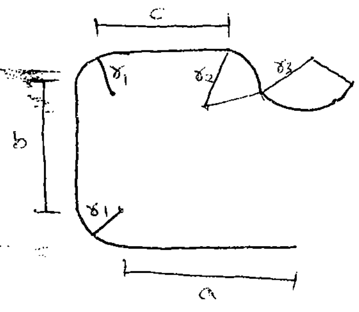
$= \frac{1}{2}$ if $r \geq 2t$

θ = bend angle in radians

B - bend allowance
[original flat strip required for producing the bent portion of the component]

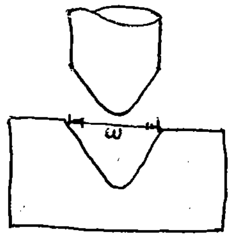
= arc length of neutral plane

$$B = r_n \times \theta$$



$$L_0 = a+b+c+2B_1+B_2+B_3$$

Force required



$$F = \frac{C L_0 \sigma_y t^2}{w} \quad \text{Newton}$$

w - width of die opening $= 8t$ or $16t$

σ_y - Yield stress of material

t - thickness of strip

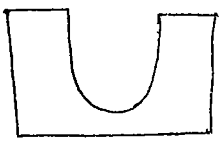
C - die opening factor

$= 1.2$ if $w = 16t$

$= 1.33$ if $w = 8t$

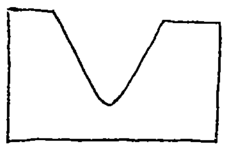
Types of bending

1. U. bending



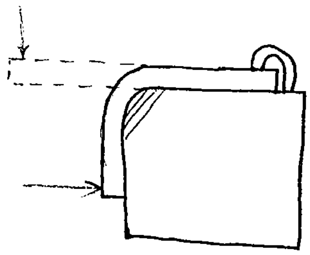
Shape of die is U shaped

2. V bending



Shape of die is V shaped

3. Edge bending



If edge of die is been used for bending

If a given component is possible to produce by using all the 3 methods of bending, the force required for U bending is largest and edge bending is smallest and V-bending is in b/w.

force req :- U : V : Edge = 2 : 1 : 0.5

Let r_{min} is the minimum radius to which the sheets can be bent ; without producing the cracks on the outer surface of a bent portion.

$$r_{min} = t\left[\frac{50}{a} - 1\right]$$

a - % reduction in area at the time of fracture during tensile testing.

50% is the maximum % of reduction obtained E any material , (al, cu, mild steel) etc (very soft materials) are gives 50%. No material will have ~~more~~ less than 50% reduction ~~in~~ area.

$$\text{so } r_{min} = t\left[\frac{50}{50} - 1\right]$$

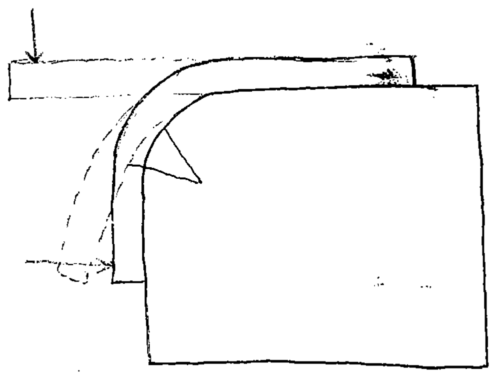
$$r_{min} = 0$$

but for most of other metals a = 14.5% - titanium

$$r_{min} = t\left[\frac{50}{14.5} - 1\right] = 2.5t$$

Spring back :-

Bcz of presence of elastic deformation in the material, after withdrawing the load from the component, some amount of be regaining of original shape will be taking place. This is called as spring back in bending.



This is indicated by using the ratio

$$\frac{R_f}{R_i}$$

If $\frac{R_f}{R_i} = 1 \Rightarrow$ Spring back $= 0$

As the $\frac{R_f}{R_i}$ is increasing the spring back in bending is increased.

$$\frac{R_f}{R_i} = 4\left(\frac{R_i \sigma_y}{E \cdot t}\right) - 3\left(\frac{R_i}{EK}\right) + 1$$

S.B depends on

R_i/t - Geometrical factor

σ_y

E - Young modulus

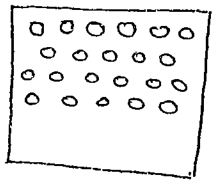
To minimize S.B $R_i/t \downarrow$ $\sigma_y \downarrow$ $E \uparrow$

Minor operations

(1) Perforating

The operation of producing many number of smaller size of the holes in the sheet is called perforating.

Mainly used for manufacture of sheaves.

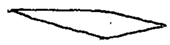


(2) Notching

The method of removing a piece of material from the edge of the sheet is called as Notching

(3) Lancing :-

The method of producing an incomplete hole or blank at the centre of the sheet

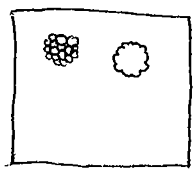


(4) Slitting :-

Method of producing an incomplete hole or blank at the edge of the sheet is called slitting

(5) Nibbling :-

Method of producing a large size hole by using small size punch in many No: of repetetive strokes



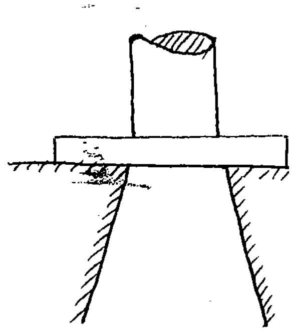
(6) Trimming :-

Method of removing small amount of material from complete circumference of a component is called trimming operation.

Types of dies in sheet metal operation

1. Simple die :-

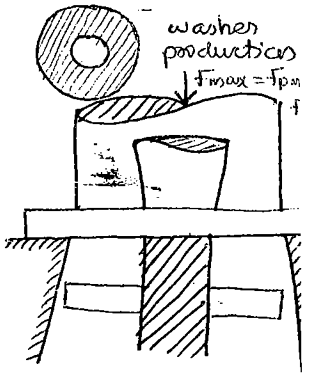
If only one operation is performed in one stroke at one stage is called as simple die



2. Compound die :-

If more than one cutting operation is performed at one stroke at one stage is called compound die

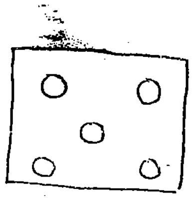
eg :-



Advantage of compound die is that one component could be produced per stroke ∴ the production rate is high.

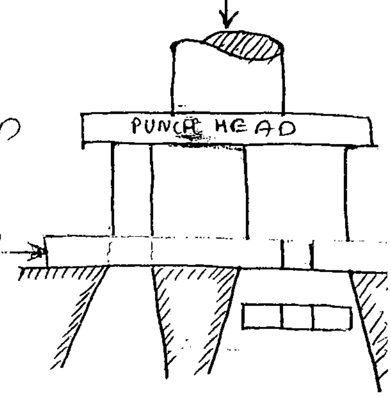
The force required is very high and both the methods of reducing the force required cannot be used for reducing the force req in punching or blanking.

If the number of operations to be performed is greater than 3, the design and manufacturing of punch and die combination for compound die is very difficult.



3. Progressive die :-

In this die also more than one cutting operation is performed in one stroke, but at different stages so that the punched out sheet is progressing from one stage to another stage for completing the punching operations and blanking will be the last operation.



with progressive die

(1) one component will be produced per stroke ∴ the production rate is same as that of the compound die

(2) Bcs; the operations are performed at different stages; it is possible to stagger the punches or provide the shear on the punch or die. hence the force required for punching or blanking operation; can be reduced

(3) Bcs of more that one stage; the design and manufacturing of punch & die combination is easier.

Limitation of the progressive die is that the balancing of forces on the punch head is difficult.

4) Transverse die

In transfer die, more than one cutting operation is performed in one stroke at different stages but the blanking will be the 1st operation so that the blank produced in the 1st stage is travelling from one to the another stage for completing remaining punching operation.

Among the transverse and progressive die

5) Combination die :-

If more than one cutting and forming operations ~~are~~ performed in one stroke at one stage, is called as combination die.

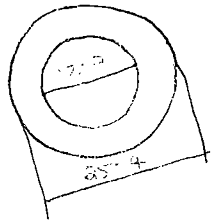
In combination die, the blanking and deepdrawing or blanking & bending or punching and deepdrawing etc can be combined together.

6) Multiple die :-

In all the above dies only one component will be produced ~~th~~ per stroke. But to produce more than one component per stroke more than one of the above dies will be kept in parallel; called as multiple dies. ie for producing 10 washers per stroke 10 compound dies ~~a~~ or 10 progressive dies ~~in~~ will be kept in parallel.

~~Q.35~~

Q.1



Punching

$HS = 12.7$

$PS = HS = 12.7$

$DS = PS + 2C$

$= 12.7 + 2 \times 0.04$

$=$

Blanking

$B.S = 25.4$

$DS = BS = 25.4$

$PS = DS - 2C = 25.4 - 200 \times 0.4$

$=$

$F_{max} = F_{p\,max} + F_{b\,max}$

$= \pi d_p + \tau_c + \pi d_b + \tau_c$

$= (\pi \times 12.7 \times 1.25 \times 800) + (\pi \times 25.4 \times 1.25 \times 800)$

$= 40 + 80 = \underline{120\ kN}$

with progressive dies

$F_{max} = \max(F_{p\,max}, F_{b\,max})$

$= \max(40, 80)$

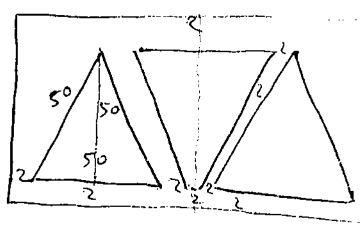
$= \underline{80\ kN}$

$F(Kt + I) = F_{max}\, K\, t$

$F = \dfrac{120 \times 0.6 \times 1.25}{0.6 \times 1.25 + 1}$

$= \underline{51.5\ kN}$

Q.2



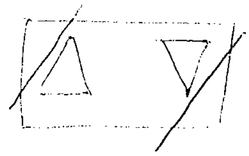
X

$\frac{\sqrt{3}}{4} \times 50^2 + \frac{1}{2}\frac{\sqrt{3}}{4} \times 50^2 = \frac{3}{2}\frac{\sqrt{3}}{4} 50^2$

$54 \times \sqrt{50^2 - 25^2} = 2338.268$

$n = \frac{L}{S} = \frac{220}{54} \times 2 = 8 - 1$

2 half of ban ... there ... cu ... te ... to scrap



Q.8

$F_{b\,max} = P t \tau_c$

$= 317.5 \times 1 \times 420$

$= 133.3\ kN$

$F_{p\,max} = \pi d t \tau_c \times 2$

$= \pi \times 12.5 \times 1 \times 420 \times 2$

$= 32.9\ kN$

Q.9

$L_0 = 98 + 184 + 92 + B_1 + 2B_2$

$B_1 = (15 + \frac{1}{2} \times 2)\, 180 \times \frac{\pi}{180} = 16\pi$

$B_2 = (6 + \frac{1}{2} \times 2)\, 90 \times \frac{\pi}{180} = 7 \times \frac{\pi}{2}$

Q.10

$D = \sqrt{d^2 + 4dh}$

$= \sqrt{5^2 + 4 \times 50 \times 75}$

$=$

$DR_1 = 1.8 = \frac{D}{d_1} = d_1 = \frac{13.2}{1.8} = 7.3$

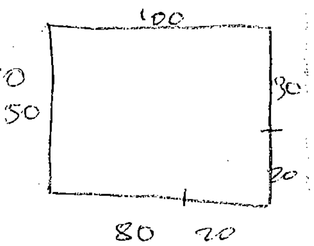
$DR_2 = 1.8 = \frac{d_1}{d_2} = \frac{7.3}{1.8} = 4.07 < 5$

$P_1 = \pi d_1 t \sigma_y\, C \frac{D}{d_1}$

$= \pi D t \sigma_y =$

$W.D = P_1 \times h_1 =$

Q11



$P = 50 + 100 + 30 + 452 + 80$

$F_{max} = P t \tau_u$

$= P \times 2 \times 145$

$= 83.5 \text{ kN}$

$W.D = f_{max} \times Kt$

$= 83.6 \times 10^3 \times 0.4 \times 2 \times 10^{-3}$

$= 66.\ J$

$F(Kt + I) = f_{max} \times Kt$

$I = \dfrac{f_{max}\, Kt}{f} - Kt$

$= \dfrac{83.6 \times 0.4 \times 2}{24} - 0.4 \times 2$

$=$

Q19

$d = 30$

$h = 150$

$D = \sqrt{d^2 + 4dh} = 137.$

$DR = \dfrac{\text{dia after}}{\text{dia before}}$

$DR_1 = \dfrac{d_1}{D} = d_1 = 0.6 \times D = 82 > 30$

$d_2 = 0.8\, d_1 = 65 > 30$

$d_3 = 0.8 \times d_2 = 54 > 30$

$d_4 = 0.8\, d_3 = 42 > 30$

$d_5 = 0.8 \times d_4 = 33 > 30$

$d_6 = 0.8 \times d_5 = 27 < 30$

$n = 6$

Q21

$\dfrac{d}{r} = \dfrac{100}{6} = 16.. = 15 - 20.$

$D = \sqrt{d^2 + 4dh} - \dfrac{r}{2}$

$D_{total} = D + 2 \times T.A$

Q.18

$0.4 = \dfrac{D - d_1}{D} \Rightarrow d_1 = D(1 - 0.4) = 30 \times 0.6$

$= 18 > 12$

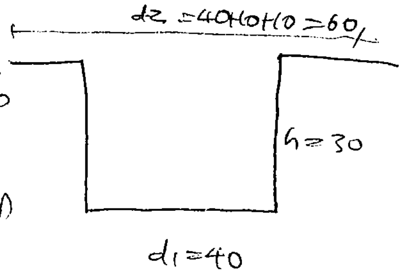
$0.25 = \dfrac{d_1 - d_2}{d_1} \Rightarrow d_2 = d_1(1 - 0.25) = 18 \times 0.75$

$= 13.5 > 12$

$d_3 = d_2(1 - 0.25) = 13 \times 0.75$

$= 10 < 12$

$n = 3$



$D = \sqrt{d_2^2 + 4 d_1 h}$

$D_{total} = D + 2 \times TA$

$=$

Q.17

$D_1 = \pi D t \sigma_y = \pi \times 30 \times 2 \times 2 \times 35$

$=$

$\sigma_{2t} = \dfrac{P_1}{\pi/4\left(d_1^2 - (d_1 - 2t)^2\right)}$

66

65

$=$

Q.23

$F(kt + I) = f_{max}\, kt$

$F = \dfrac{f_{max}\, kt}{(kt + I)}$

$= \dfrac{f_{max}}{3}$

$D = \sqrt{D^2 + 4dh}$

$= \sqrt{5^2 + 4 \times h \times 0} - 15$

$LDR = 2$

$$d_1 = \frac{D}{LDR} = \frac{15}{2} = 7.5 > 5$$

$$d_2 = \frac{d_1}{LDR_2} = \frac{7.5}{2} = 3.7 < 5,$$

$n = 2$

Q.26 'B' Q & R.

Q.27 'B'

Q 28

$$T = \pi d t \tau_u$$

$$= \pi \times 1.5 d \times 0.4 t \tau_u$$

$$= \pi d t \tau_u (1.5 \times 0.4)$$

$$= 5 \times (0.6) = 3 \text{ kN}$$

Q29

$BS = 35$

$DS = BS = 35$

$PS = DS - 2C$

$= 35 - 2 \times 0.04$

$= 34.92$

Q30

$$f_{max} = p \times t \times \tau_u$$

$$= 200 \times 5 \times 100$$

$$= 10 \text{ kN}$$

400

20

$$W.D = f_{max} \, k \, t$$

$$= 100 \times 10^3 \times 0.2 \times 5 \times 10^{-3}$$

$$= 100 \text{ J}$$

Q.31

$400 - 200$

$$200 - \frac{20}{400} \times 200 = 10 = 2$$

$$F = \frac{f_{max}\, kt}{kt + I} = \frac{100 \times 0.2 \times 5}{0.2 \times 5 + 1.0}$$

Q.33

30°)

Q.35 'A'.

Q.36

Am 'B'

CI = 8 - 20° after TDC

5 - 15° after TDC

Q.37 'D'.

$BS = 30$

$DS = 30$

$PS = 30 - 2 \times C$

$= 30 - 2 \times 0.6$

$= 28.8$

Q.38 14.88 A

its not a punching operation to prod by blanks, so.

$PS = 20 - 2 \times 0.06$

$= 19.88$

Q.39

$$TA = \frac{3}{25} \times 48.5 =$$

$$\frac{48.5}{1.5} = 32 > 20$$

$$D = \sqrt{d^2 + 4dh}$$

$D_{total} = D + 2 \times T \cdot A$

$= 126.5$

Q 40 50%

Q 41

τ_u – shear stress

Q 42

$F_{max} = 37.7\ kN$

$x = 2$

$F = 14.3\ kN$

Q43

$\beta = \gamma_n \theta$

$= (\gamma + k\bar{z})\theta$

$= (100 + 0.5 \times 2)1$

$= \underline{\underline{101}}$

4. MACHINING

Q.1

$$\text{Time/hole} = \frac{L}{f_N} = \frac{l + AP_1}{f_N}$$

$$= \frac{l + 0.5}{f_N}$$

$$= \frac{25}{0.25 \times 300} = \frac{1}{3} = 20\,\text{sec}$$

Q.2

$$\text{Time/cut} = \frac{B}{f} \cdot \underbrace{\frac{L}{V}(1+\mu)}_{\text{time per double stroke}}$$

$$= \frac{300}{0.3} \times \frac{\cancel{L}}{\cancel{V}} \frac{1}{10} = 100\,\text{min}$$

Q.3

$$\text{speed range ratio} = \frac{N_{max}}{N_{min}} = \frac{V_{max} D_{max}}{V_{min} D_{min}} = \frac{120 \times 25}{40 \times 5}$$

$$= 15$$

Q.4

$$\text{high spots/rev} = \frac{360}{30} = 12$$

$$\text{high spots/sec} = \text{high spot/rev} \times \text{RPS}$$

$$= 12 \times \frac{500}{60} = 100\ \text{high sp/sec}$$

Q.5

$$GR = \frac{\text{metal removed on wp}}{\text{Grinding wear}} = \frac{200 \times 2.5 \times 5}{\frac{\pi}{4}(D_i^2 - D_f^2)\,20}$$

$D_i = 300$

$D_f = 300 - 2 \times 0.02$

$= 299.96$

$$= \frac{200 \times 2.5 \times 5}{\pi/4\,(300^2 - (299.98)^2) \times 25}$$

Q.6

$T = 1000$ sec

$V_c = 0.5$ m/sec

$$\text{Time/piece} = \frac{L}{f_n}$$

$$= \frac{80}{0.1 \times 1000 \times 0.5} =$$

$$\text{No of pieces} = \frac{1000}{\text{time/piece}} = 4$$

Q.7

radial depth = acceleration + deceleration

$= 1m + \cancel{\ldots}$

$= 2.25m$

$= 2.25 \times 3 = 6.75\,\text{mm}$

Q.8

$d = AP_1 = 0.5D$

$= 0.5 \times 20 = 10\,\text{mm}$

Q.9

$$\text{tapering/mm} = \frac{10 - 7.5}{2 \times 80} = \frac{x}{80}$$

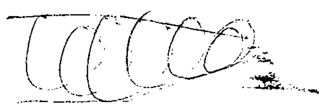
Q.10

offset = Total tapering

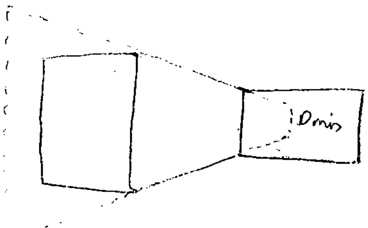
= Taper/mm × Total length

$$= \left(\frac{10 - 7.5}{2 \times 80}\right) \times 180 =$$

Q.11



D bar



Q.11
~~Q.12~~

$P = 1.5$ KW

$\phi 20 = \phi 26$ mm

$h = 0.0075$

$\rho = 10$

$V_c = 0.5$ m/min

depth of metal remove

$d = \frac{26-20}{2} = 3mm$

$n = \frac{d}{h} = \frac{3}{0.0075} =$

$Le = n \times p$

$L = Le + t = Le + 25$

$time = \frac{L}{V} = \frac{L}{500} =$

Q.12

$RPM\ crank = No:\ of\ DS/min$

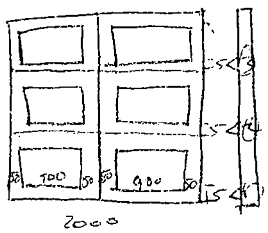
$= \frac{v}{L(1+m)}$

$= \frac{18000}{200(1+2/3)}$

Q.13

$m = 1/2$

$L = 2m$



$B = 300 + 5 + 5$

$= 310$

$Time/cut = \frac{B}{f} \frac{L}{V}(1+M)$

$= \frac{310}{1} \times \frac{2000}{1000}\left(1+\frac{1}{2}\right)$

$= 930\ sec$

$Time/pie = \frac{930}{2} = 465\ sec$

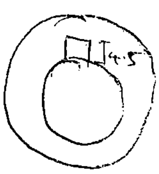
Q.14

$Le = Ln \times Ls + Lf$

$Ls = 8 \times 20 = 160$

$Lf = 4 \times 20 = 80$

$d = d\delta + ds + df = 4.5$



$d\delta = d - (ds + df)$

$ns = \frac{ds}{hs}$, $ds = ns \times hs$

$= 4.5 - (8 \times 0.0125 + 4 \times 0)$

$= 4.4$

$n\delta = \frac{d\delta}{h\delta} = \frac{4.4}{0.1} = 44$

$L\delta = n\delta \times P\delta$

$= 44 \times 22$

$= 1208$

Q

$AP_1 = \frac{1}{2}\left(D - \sqrt{D^2 - w^2}\right)$

$= \frac{1}{2}\left(100 - \sqrt{100^2 - 80^2}\right)$

$Time/cut = \frac{1}{fN} = \frac{l + AP_1 \times AP \times OR}{f_z \times z \times N}$

$= \frac{200 + AP_1 + 5 + 5}{0.1 \times 12 \times \frac{1000 \times 50}{\pi \times 100}}$

$=$

Q

Assymetrical

$w' = w + 2 \times 0f$

$= 80 + 2 \times 5 = 90$

$AP_1 = \frac{1}{2}\left(100 - \sqrt{100^2 - 90^2}\right)$

$Time/cut = \frac{l + AP_1 + AP + OR}{f_z \times z \times N}$

Q.16

R.H → Direction of rotation of job & L.S is same

Compound GT, $\frac{a}{b} = \frac{c}{d}$ → Same direction - No idler or even idler

LH → opp dir - Compound GT ⇒ Same

use 1, 3, 5 - odd No of idler - (A)

Q.17 gear size not correct.

2

ADVANCED MACHINING METHODS

Limitation of Normal machining methods :-

In the normal machining method, the accuracy of components produced depend on the efficiency of operator

Consistency in manufacturing is not possible

Manufacturing of complex shapes of the components is not possible.

Bcz of lot of man power is involved, the labour law problem will be present

Frequent design changes of the component can't be incorporated in the existing manufacturing system.

Bcz of Inconsistency in manufacturing, 100% inspection of the component is required. Therefore cost of inspection is increasing

NC machine [Numerically controll]

If each and every axis is controlled by using numbers or numerals; called as numerically controlled m/c tool

Basic Parts :-

1. MCU (m/c control unit) or CPU (central processing unit)
2. Drive unit (DU) (O/P)
3. Feed back device (FBD) (I/P)
4. Tape Reader system (TRS) (I/P)
5. Manual Controls (MC) (I/P)

1. MCU

MCU is working like a brain of the human being. It is taking the input information from the input devices available in the NC machine like tape reader & system (+ rs), feed back device (FBD) etc; analysing the data and taking the decisions. The decisions taken by the MCU will be implemented by using the output devices available in the NC machine.

The machine can only understand the low level language; ie the binary system. But when human being is given the input information in the form of decimel, to convert the decimal to the binary and vice versa, a unit is required in the MCU called as arithmetic logic unit which is a part of the MCU.

2. Drive unit (O/P)

Drive unit is an energy conversion device; This is taking the input information from the MCU in the form of electrical energy or electrical signals and converting into the mechanical energy required for travelling the axis to the destination.

The drive unit used in NC machine is the electrical motor. The major type of motors ~~used~~ are:-

(1) Induction motor X

(2) Stepper motor

(3) Servo motor

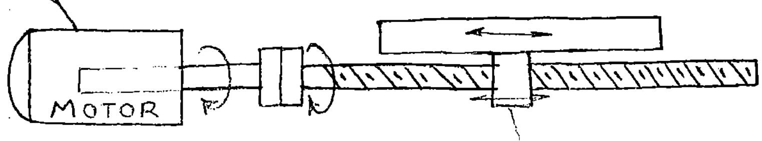
Bcz the induction motor is rotating at only one particular rpm, ie the designed rpm, it is not possible to use as a drive unit in the NC machine

Stepper motor is taking the input as pulsed electrical energy and produce mechanical energy in the form of rotations. Either by changing the no. of pulses of electrical energy input or by changing the rate of pulses of electrical energy input, it is possible to vary the rpm of the motor. This is used as a drive unit in the NC machine.

Servomotor is also working like a stepper motor ie; it ~~is~~ taking the pulsed electrical energy as input and produce variable speed of a motor. In addition; the servo motor also consists of quick action breaking system, so that whenever the power supply is stopped to the motor; the breaking system will be activated immediately and stop the motor and axis immediately without any over travelling ∴ high positional accuracies are possible.

By the time, the NC machines were developed; the servomotors were not developed. ∴ Only stepper motors are used as a ~~drive~~ unit in the NC machine.

MCU pulsed electrical energy



eg:-

200 pulses → 1 rev of motor
→ 1 rev of lead screw
→ 1 pitch or 1 lead
→ 5mm

200 pulse → 5 mm

1 pulse → $\frac{5}{200} = \frac{1}{40} = 0.025$ mm = 1 BLU = Positional accuracy

↑ basic Length Unit

200 pulse → 5 mm

1mm → $\frac{200}{5}$ = 40 pulse

50mm → 40x50 = 2000 pulse

3. Feed back device :-

It is a displacement measuring equipment mounted on the axis of a machine so that it measures the actual distance travelled by the axis and sending it as a feed back to the MCU. The MCU will calculate the difference in the distance ie it compares the actual distance travelled by the axis with distance to be travelled by the axis. Corresponding to this difference in the distance, the MCU will generate the electrical energy pulses and send it to the drive unit. The drive unit will again generate the mechanical energy required for travelling the remaining distance. Again FBD measures the actual distance and send them to MCU. This process continue until the difference in the distance become ≤ 1 BLU.

The displacement measuring equipments which are giving the displacement o/p in the form of electrical energy can be used as feed back device.

50mm → MCU $\xrightarrow{\text{2000 Pulse}}$ Drive Unit   Mechanical Energy   axis moves   Feed Back Device

DU   4×40=160   diff = 50-46 = 4   MCU   46mm

ME   axis moves   FBD   49.5   MCU   diff = 50-49.5 = 0.5

diff ≤ 0.025mm ← - - - - - - - - - - axis moves   ME   DU   0.5×40

The different feed back devices used in the NC machine in the increasing order of the accuracy.

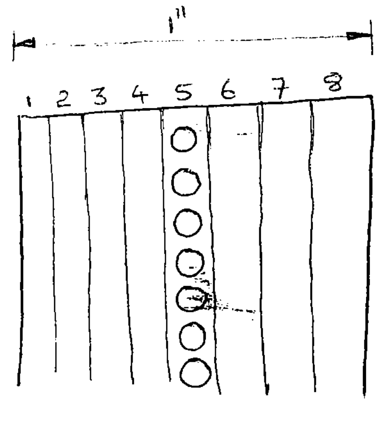
order of mm ↑
Potentiometer, LVDT, capacitance transducer, Inductance transducer, Resolver, Synchros, Inductosyn, Tachogenerator, Tachometer, Encoder.
↳ order of nanometer.

Tape reader System

It's a device used for transfering of the ideas available in the human brain into the machine tool.

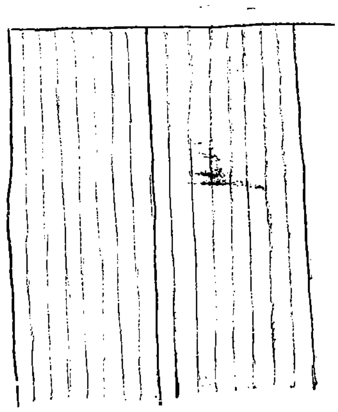
punched taper tape.

1" punch paper tape



Track 1 to 4 – Alphabets
5 – parity check
6 and 7 – Numbers
8 – EOB

Track 1 – N (block NO)
2 – X-axis
3 – Y-axis
4 – Z-axis



one block of information in NC program indicates that one complete instruction will be given to the machine for travelling the axis from present position to the next

N15 X50 Y30 L.f

↓ ↓

↳ line feed or EOB or ;

2|15 → 2|7-1 → 2|3-1 → 1-1

2|50 → 2|25-0 → 2|12-1 → 2|6-0 → 2|3-0 → 1-1

1 1 1 1

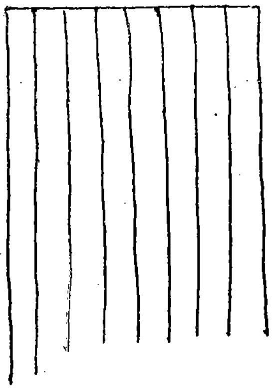
$2^3\ 2^2\ 2^1\ 2^0$

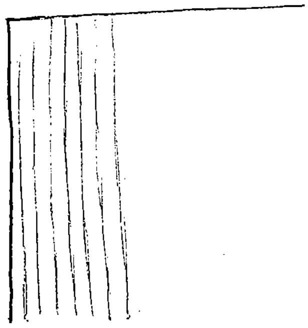
1 1 0 0 1 0

$2^5\ 2^4\ 2^3\ 2^2\ 2^1\ 2^0$

drill hole

o o o o   oo   o





Tape reading

Total 21 readable tracks are there. Corresponding to this 21 track we provide light receiving sensors.

The punched tape is loaded on to the tape reader system. In tape reader system; one side of the tape, the light source is present and other side of the tape, the 21 numbers of light receiving sensors are provided corresponding to the 21 readable tracks on the tape. Whenever the tape is moving and stopping at some location, wherever the holes are there, through the holes, the light is passing and incident on the light receiving sensors. whenever the sensor is receiving the light; it is generating the electrical energy and sending it to the MCU; The corresponding positions will be assumed as 'one' as the 1 by the MCU. and the other positions will be taken as '0'.

Manual Control

Even though the above parts are present to the NC machine, still manual intervention is required for switching ON and OFF the machines, loading and unloading of the work piece, loading and unloading of the tape, winding and unwinding of the tape etc.

Classification of NC machine

based on the contool system used

(a) PTP contool System.
(b) Straight line Contool System
(c) Contour Contool System

based on the feed back device used

(a) Open loop system
(b) closed loop system

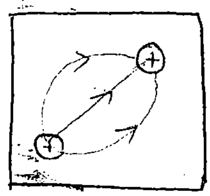
based on the number of simultaneous axis used

(a) 2-D, $2\frac{1}{2}$D, 3D, 4D 11D

Point to Point Contool System :-

In the movement of tool ; if only the end points are only important but the path followed by the tool is b/w the end points is not important called as point to point contool system.

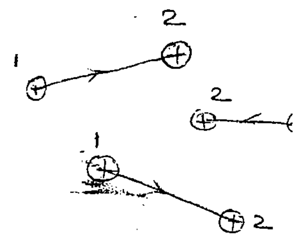
It is used in the case of drilling, reaming, tapping etc.



Straight line contool system

In addition to the end points of the movement of the tools ; if the path followed by the tool in b/w the end points is a straight line path ; called as straight line contool system

It is used in case of turning, milling, shaping, grinding etc.

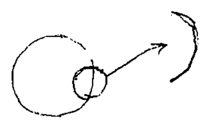


Contour Contool System

In addition to the endpoints of movement of the tool ; if the path followed by the tool in b/w the end points is a contour path called as contour contool system

It is used in case of turning, milling, grinding etc

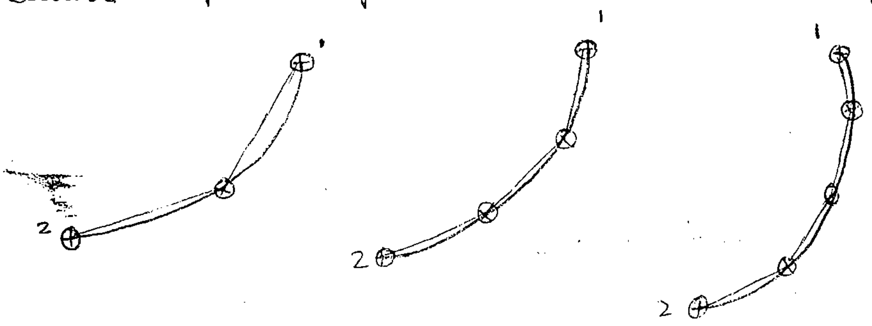
No advanced system will give the perfect contour but the smoothness of the contour depends on the interpolation parameters used in writing of the program



I - x
J - y
K - z

} interpolation parameters

The maximum distance b/w two concecutive points on a contour is called interpolation parameter. This value varies from 0.001 to 999.999 mm



As the interpolation parameter is reducing; the time taken for manufacturing of a component is increasing. Hence the cost of manufacturing increases.

~~NC~~

Open loop system:-

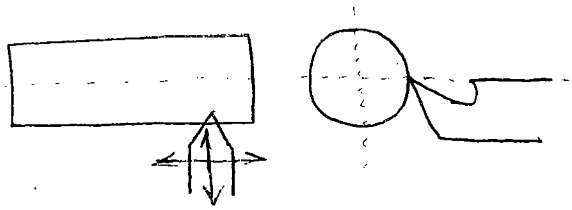
NC machine without the use of feed back device is called open loop system.

Open loop system is a unstable system and the accuracy of the components produced is very poor.

The NC machine with the use of feed back device is called closed loop system.

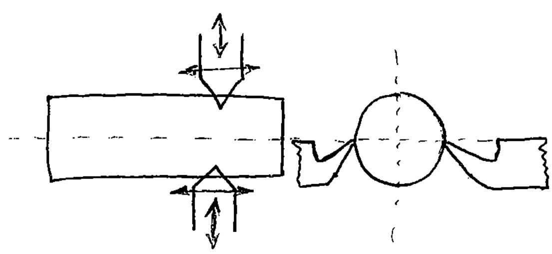
It is a stable system and produces accurate components.

based on the No: of simultaneous axis used.



If two axis of one tool can travel simultaneously; for removing material from the work piece, by taking the rotation of the job as a spindle. called as 2D machining. The spindle is nothing but the rotation of the job is constant in a given cut. But from one cut to another cut; the rotation can be varied.

- In addition to the two axis of one tool; if the rotation of job also can be varied in a given cut, called as 3D machining.



If 2 axis each of the two tools can be varied simultaneously by taking the rotation of the job as a spindle, called as 4D machine tool.

If 5 tools are removing the material simultaneously from one work piece by considering the rotation of job as a axis called as 11D machine tool.

latest NC - 840D - They have a capability to control 64 axis independently but it can only control 11D simultaneously. [CNC Systems is only developed only by FANUC and SIEMENS]

64 D refers that 32 tools are there · 16 on one side and 16 ~~on~~ other.

64 independent D means if X_{30} Y_{50} we provide then it is difficult impon to refer which tool to be moved; if 30 is provided. So we duplicate the axis i.e. instead of X, Y, Z, we provide $X_1 Y_1 Z_1$, $X_2 Y_2 Z_2$ ... ect corresponds each tool. Thus for 32 tool – 64 axis · Independently we could move 64 axis but simultaneous only 11 is possible.

every axis movement is controlled by using a vector. If we want to use 5 axis simultaneously refers that 5 vectors would be added, substracted, multiplied. But only 11 vector operation simultaneously could be solved in maths. Thus only 11 D machines are provided.

9-D m/c – only one available in India · [BHEL Hyderabad] imported before 1988 1989 – Agni-tested · Sangsungs on position - Not

6-D – 8 machines available in India – 1998 1999 – Pokran test · again 3-D imposition

$2\frac{1}{2}$ D means that programmable movement is possible along 3 axis · But simultaneous movement is possible along two axis only.

To produce cyllendrical cams – we use this.

During manufacturing of the cyllindrical cams; the variable rotation of the job is possible upto a maximum of 180°· in one setting.

∴ the name is given as a $\frac{1}{2}$ D axis.

Limitations of NC machines

(1) Preparation of punched ~~paper~~ tape is very difficult and time consuming.

(2) The punched paper tape can be used for producing a few No: of components only.

(3) The design modifications of a components cannot be incorporated in ~~the~~ existing tape

(4) Unless one component is manufactured physically, it is not possible to known wether the program written is correct or not, tape preparation is correct or not etc.

(5) Bcz of use of positional stepper motors; high positional accuracies ~~cannot be~~ is not possible.

(6) Bcz of many of the manual controls are present, complete automation or mechanization is not possible.

To overcome these limitations of NC machine, the next development is CNC

CNC machine tool - Computer Numerical Control machine tool

Components

MCU

DU [servo motor]

FBD

~~TRS~~ completely removed
MINI COMPUTER

MC - Very few.

when compared to the NC machine is CNC machine ; the complete TRS and many of the manual controls are replaced by using mini computer and very few manual controls are present. In place of stepper motor as a drive unit, the servo motor is used as a drive unit

· Advantages

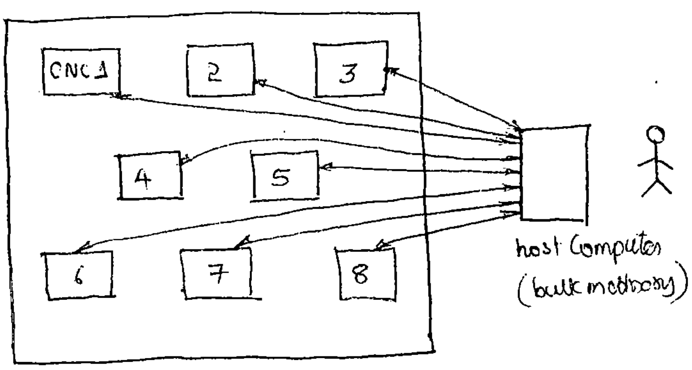
1. Bcz of usage of the servo motors higher positional accuracies are possible.

2. Due to the usage of mini computer ; the program can be fed onto the computer through keyboard and memmorise in the form of a software program . . . feeding of the program is easier , life of the software program is infinite, design modifications can be incorporated easily in the existing programs. and by using graphic stimulation software, cutter path can be generated and corrections of the program can be checked without physical manufacturing of the components

3. Bcz of very few manual controls, the CNC machine can be completely automated of mechanised so that the less man less manufacturing can be done.

DNC [Direct Numerical Control System]

DNC is the system consisting of more than one CNC machine connected to the host computer through telecommunication lines or also called LAN.



186 - 1st generation computer
286 -
386 -
486 -
pentium - only in 1995

What ever the programs required for manufacturing of different varieties of components in the industry ~~and~~ can be kept in the memory of host computer. The programs required for manufacturing a given component on the machine can be downloaded from the host computer to the machines and give a command asking to execute the downloaded program at required no: of times to produce the components. Now all the machines are started working and producing the components. After some time one of the machine in the system will complete its job and comes to rest. Now this machine will send the information to the host computer asking what to do next. The person sitting in front of the host computer has been already decided; what is the next component to be done. ∴ he deletes the existing program first on the machine, down load the next program and gives a command asking to execute the down loaded program at the required no: of times. This will take atleast 40 - 45 minutes because of the very low speed of the computer. During this time if one or more of the other machines also completes the job, they also will try to interact with host computer; but the host computer is busy with the 1st machine. Like this, when more than one machine is trying to interact with the host computer, the host computer is going into the hanging mode. This is called as traffic jam in DNC. To avoid this only a few number(s) of machines are connected to the host computer.

B'z the programs required for manufacturing of different components are to be downloaded directly from the host computer every time; it is called direct numerical control system.

As the technology is growing; the cost of manufacturing of memory capacity of minicomputer has been reduced. ∴ the memory capacity of mini computer has been increased from 5 MB to 100 MB. Now whatever programs required for manufacturing of different varieties of components can be downloaded and kept in the mini computer and so on. Whenever the machines comes to the rest and sending the message to the host computer, the person sitting in front of the host computer simply gives a command asking to execute so and so numbered program at so much no: of time. This will take less than a minute. ∴ the traffic jam is completely eliminated and many of the machines can be connected to the host computer. B'z the program has been distributed to the mini computer of the machines itself; the name given for this system is Distributed Numerical Control System [DNC]

Direct Numerical Control System become obsolete today and thus DNC refers to Distributed Numerical Control System.

ANC - Adaptive Numerical Control System

During writing of a program to the component, the programmer will calculate the optimum process parameters required for manufacturing of the given component ~~and~~ indicated in the program. Instead of the programmer is indicating the input parameters like properties of work material, tool material, tool geometry etc and output requirements like criteria of machining, surface finish requirements accuracy of the dimensions to be produced etc. so that the machine itself is automatically adapting the optimum process parameters required for machining called as adaptive numerical control system.

Implementation of ANC is very simple; Just by writing the search program. But for searching this input conditions and output requirements; it needs a database ~~which~~ is to be generated through experimentation.

Machining center:-

It is one of the advanced manufacturing method. If a machine is capable of performing all varieties of operations like turning, milling, drilling, shaping etc is called the general purpose machine tool. If the CNC is implemented to the general purpose machine tool is called as machining centre.

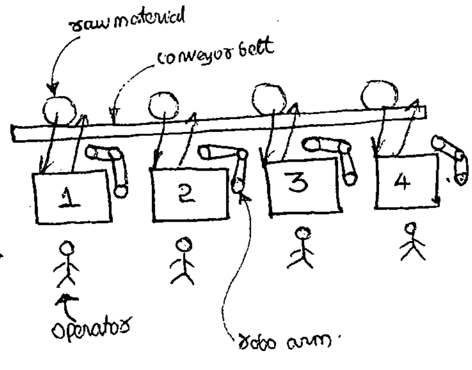
For performing different varieties of operations, the tools required must be kept in the tool storage unit called as tool magazine. Tool magazine has a capacity to store upto a maximum of 32 varieties of tool. whenever the tool is required to be changed, for automatic changing of the tool; an automatic tool changing unit (ATC) will be used in the machining centre.

Bcz of different varieties of operations performed on the machining centre, to hold the workpiece for performing different varieties of operations, the elaborative fixtures ~~are~~ required.

Transfer machines and Transfer lines :-

Normally, a device used for removing the material or processing of the material is called as machine or machine tool. In addition to the processing of material, if the machine is also capable of handling of the material called as transfer machine.

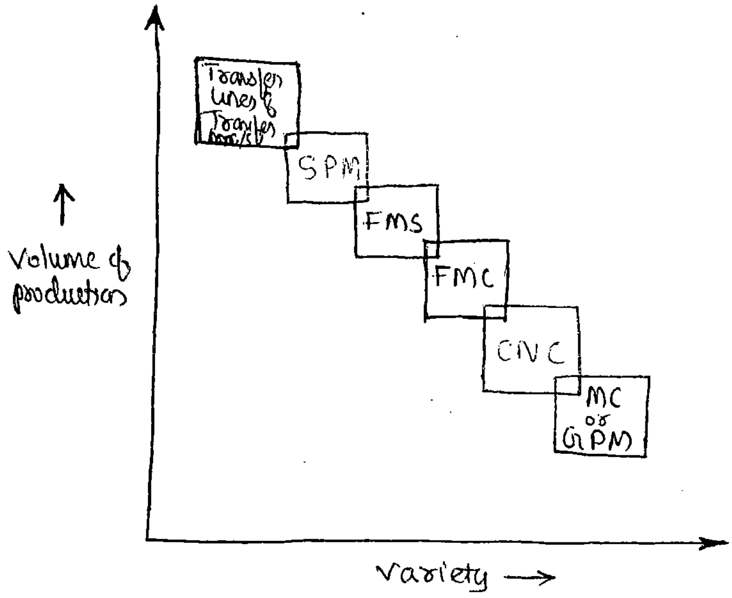
If a robo arm is attached to the CNC machine for loading and unloading of the components is called as transfer machine.



If machines are arranged in the sequential order of operation to be ~~produce~~ performed, it is called product layout or line layout.

Complete automation of product or line layout by using the transfer machines such that the manless manufacturing can be done. is called as a transfer line.

The machine used in the transfer lines are called as ~~transfer~~ transfer machines



SPM - Special purpose machine
FMS - flexible manufacturing sys
FMC - flexible manufacturing ce
CNC -
MC - machine centers
GPM - General Purpose mach.

From the above,

The FMS and FMC's are used for producing medium varieties of components with medium volume of production. ie it is used for batch production applications.

FMS

Manufacturing system with flexible and random movement of the material among the different machines is called as flexible manufacturing system.

For obtaining the flexible movement of the materials among the different machines, the automated guided vehicle (AGV) is required.

$$\therefore \quad DNC + AGV = FMS$$

FMC

Also called as cellular manufacturing.

Grouping different parts manufactured in the industry into a few number of group called as part families based on certain similarity is called as Group technology. The similarity used may be the manufacturing similarity, design similarity, shape similarity, size similarity, cost similarity and so on.

Whatever the machines required for manufacture of are kept in shop floor A. machines required for manufacture of B is kept in shop floor B and so on is ~~fitted~~ called as GT layout.

100 parts
- Gp1 - m/cs - SFA
- Gp2 - m/cs - SFB
- Gp3 - m/cs - SFC
- Gp4 - m/cs - SFD
- .. - m/cs - SFE
- ...

In GT layout once the raw materials enter into one shop floor, it always comes out as finished good. ∴ no transportation of material is required from one shop floor to another shop floor ...

If FMS is implemented in each and every shop floor independently is called as flexible manufacturing cell or cellular manufacturing.

COMPUTER AIDED DESIGN [CAD]

The basic difference b/w the conventional design and computer aided design is in the case of conventional design the total body can be used as a single element in the analysis whereas in the computer aided design, the body can be divided into many No: of finite elements and the analysis will be continued on the elements. Bcz of the elemental analysis will be done on the cad, the analysis and design will be easier and more accurate. Bcz of elemental analysis; most of the uncertainities present during the usage of the component will be considered during the design itself. ∴ maximum factor of safety used in the CAD is 1.25. But in the conventional design the minimum factor of safety is 2. Also bcz of elemental analysis at the change in cross section as small size element as possible will be taken. ∴ No need to take the stress concentration factor for accounting to the change in cross section. whereas in conventional design; the stress concentration factor should be considered to account for the change in cross section.

Inputs required in CAD

1. Approximate shape
2. loading condition
3. Material properties and allowable deflections

Process steps in CAD

1. Generation of 2-D drawings.
2. Import into the analysis package.
3. Convert into solid model.
4. Divide into many number of finite elements.
5. Apply the boundary conditions or loading conditions
6. Maximum stresses and strains can be obtained.
7. Compare maximum stresses and strains with allowable stresses and strains.
8. Change the dimensions of the components, repeat the procedure until maximum stresses induced in component is less than and nearly equal to allowable stresses. If satisfied, the dimensions of the component can be considered as the final design.

Output of CAD

1. 2-D Production drawing
2. Bill of Materials (BOM)
3. Stresses and strains induced.

COMPUTER AIDED MANUFACTURING [CAM]

Manufacturing with the uses of computer is called as computer aided manufacturing.

$$DNC + AGV = FMS$$

$$FMS + ASRS + CMM = CAM$$

ASRS stands for Automated storage and retrieval system.
It is an automation method used in the stores for retrieving the raw materials required for manufacturing and storing the finished goods.

CMM refers to Co-ordinate Measuring Machine. It is a measuring instrument (automated), used for measuring more than one dimension simultaneously.

Inputs

1. 2-D product drawing
2. BOM
3. Raw materials

Process steps

1. Generate CNC part program
2. Retrieving raw materials
3. Manufacturing of the components
4. Inspection by CMM

Output

1. Acceptable parts

CAD - CAM

It is an integral approach used for design and manufacturing of the components together without the use of manual intervention.

Inputs

Inputs of CAD

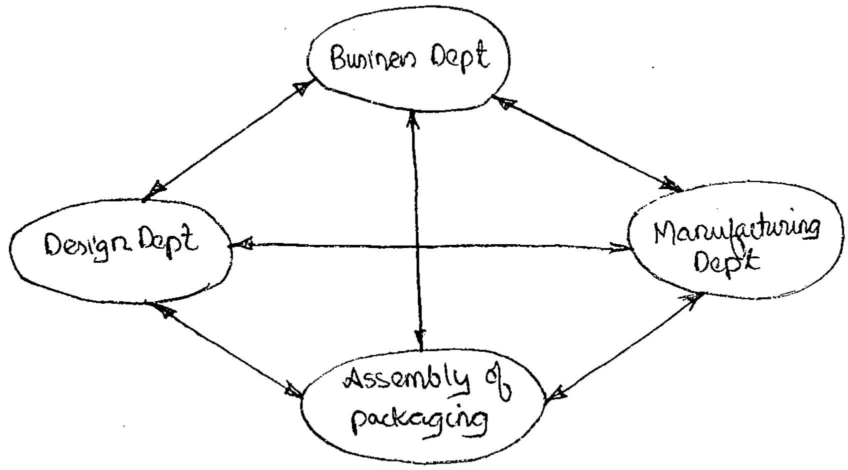
Process steps

Process step of CAD + CAM

Output

Output of CAM

Computer Integrated Manufacturing [CIM]



only firms which have implemented the complet CIM is **DEL**

If the different departments present in the manufacturing industry is integrated by using a computer such that marless manufacturing can be done, called as computer integrated manufacturing.

Part Programming of CNC machines

Part programming is a coded programming methodology used in the CNC machine

A code used in the CNC programming indicates the name of the program given for specific movement of the tool.

G-Codes

General Purpose Codes

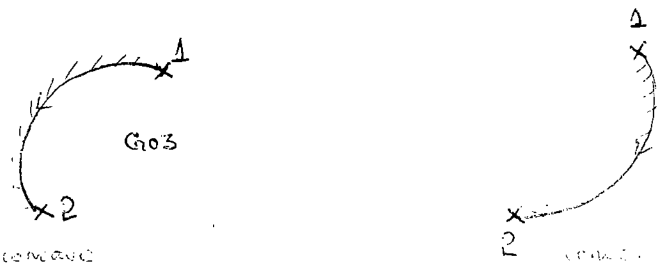
G00 to G999

G00 – Rapid traverse – whenever the tool is moving ideally ; it is required to travel at maximum possible velocity. for this when the programmer indicates G00 in the program the machine will automatically adopts the maximum possible velocity to travel the axis. So that the time taken will be minimum and axis drives are safe.

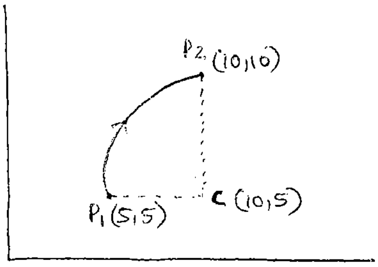
G01 – Linear Interpolation – whenever the tool is required to travel linear for producing straight line shapes of the component the G01 code will be used

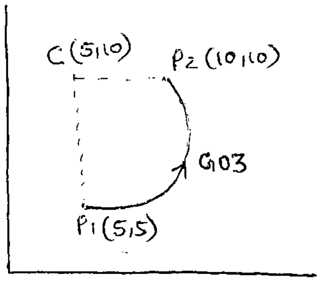
* G02 – Circular Interpolation [C.W] – whenever the tool is required to travel in a contour path ; the G02 or G03 code will be used. If tool is required to travel in the clockwise direction G02 code is used and for counter clockwise direction G03 code will be used.

* G03 – Circular Interpolation [CCW]



tool moves from point $P_1(5,5)$ to point $P_2(10,10)$ with G02 code. What is the co-ordinate of the centre of arc.





G04 – Dwell – Temporary stoppage of the tool for specified duration. F followed by number indicates the temporary stoppage duration in seconds.

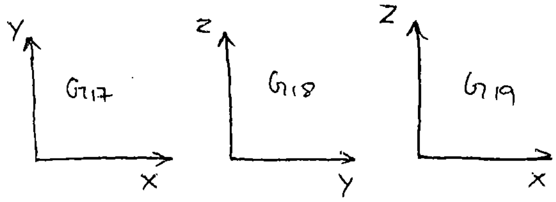
G04 F7 – temp stoppage for 70 seconds.

G05 – Hold – Temporary stoppage of the machine for unlimited duration.

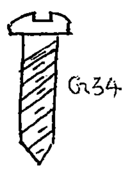
G08 – Acceleration – When G08 code is given; Even though the speed has been indicated at high velocity, the machine always start with low velocity first and then reaches to the required velocity.

G09 – Retardation – When the tool is moving at very high velocity; it is difficult to stop the tool exactly. ∴ if G09 code is given, whenever the tool is nearing to the destination; the speed of the tool is automatically reduced so that it is possible to stop the tool wherever it is required.

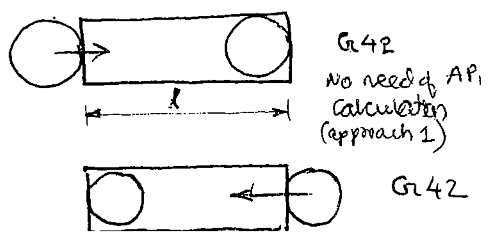
G17 – XY plane
G18 – YZ plane
G19 – XZ plane
} – plane selection



G33 – Thread cutting with constant pitch
G34 – Increasing
G35 – decreasing



G41 – Tool radius compensation left
G42 – right



G70 – English programming – programming in terms of inches

G71 – Metric programming – mm programming

In latest system G71 is a default programming. (No need to specify code). If we want to do in inches then use code G70.

G90 – Absolute programming.

G91 – Incremental programming.

If movement of the tool in the progr is always indicated w.reference to o one reference point called as absolute programming

If the present position of the tool takes as a reference point for programming of the next position of the tool is called as incremental progra

In general incremental mode of program is easy to write and easy to modify. But as per the Indian conditions; we prefer to use the absolute mode of programming.

During running of the program and producing the component, if power failure occurs, it is very difficult to identify, where the program has got stopped; if the program is ~~written~~ in the incremental mode. If the program is written in the absolute mode it is easy to identify where the location where the program has got stopped. ∴ after restoring the power, it is possible to continue the program ~~the~~ from where it has got stopped

M-Codes [M00 – M99]

M00 – Program stop ≈ G05

M01 – Planned stop ≈ G04

M02 – End of main program without usage of sub program.

M17 – End of Sub program

M30 – End of main program written with use of sub program.

During manufacturing process there is a repeatable movement is required, for this a program will be written called as sub progr. This will be called in the main program whenever the repeatable movement of the tool is required.

Subprogram

L100.SPF

SPF – Sub program function [it specify the file loc

L100 – name of sub program.

Always alphabet(L) is to ~~be~~ placed.

Maximum length of subprogram name is 64 c with only numbers only alphabets or

Name of subprogram must always start with 'L'

Subprogram.

L100. SPF

N01 . . . . Lf

N05 . . . . Lf

N10 . . . . Lf

⋮

N_{110} M17 Lf

N indicates the block Number.

In general the block numbers are taken as incremental No's only but not continuous No's bcz any modification in the design of component can be incorporated in the existing program. without changing the next block No's of the program.

Main program

200. MPF

N01 . . . . Lf

N05 . . . . Lf

N10 . . . . Lf

⋮

N16 M02 Lf.

Here also maximum 64 characters can be used for the name.

(either number, character or combination of both)

But donot start with 'L'.

.MPF and .SPF is actually not given but automatically generated by the machine.

eg:- 200.MPF, 2AB10.MPF, ABZOBC.MPF

100. MPF

N01 . . . . Lf

N05 . . . Lf

N10 L100 P5 Lf

N15 . . . . . Lf

N20 . . Lf

N_{120} M30 Lf

P followed the number indicates the number of times the subprogram is to be executed at this location.

~~MD~~ N10 L100 LF = N10 L100 P1 LF

M03 - Spindle start in CW

M04 - spindle start in CCW

M05 - Spindle stop.

M03 S500 Lf

M04 S800 Lf

S followed by number indicates the spindle speed in rpm.

M06 - Tool change

M06 T_{10} Lf

M07 - Coolant pump No 1 ON

M08 - No: 2 ON

M09 - Coolant pump OFF

T followed by number indicates the tool number. It indicates that the present tool is to be changed with Tool No 10 by the ATC (automatic tool changing device

M10 - Clamping

M11 - Declamp

G code and M codes are the major codes used. Other codes used are

Other than M01 and G04; where ever F followed by number indicates; the feed of the tool in mm/minute.

M01 F70 }
G04 F60 }

In all other case it represents

N15 X60 Y90 F5000 Lf

GVGR

JIGS & Fixtures

Ref:- edward Hackmas

Jig is a device used for holding and positioning of the work piece, locating and guiding of the tool. Generally Jig is light in construction and used in drilling, reaming tapping etc.

Fixture is a device used for holding and positioning of the w.p, locating and positioning of the tool but doesnot guide the tool. Generally fixture is heavy in construction and used in turning, milling, shaping, grinding etc.

In general the jigs and fixtures are considered as accessories in the manufacturing industry. The advantages of using jigs and fixtures in the manufacturing industry are

1. The time taken for loading and setting of w.p is minimum.
2. Even unskilled person also can be able to load and set the wp in m/c.
3. Bcz of use of jigs and fixtures, consistancy in manufacture is very high.
4. Accuracy of the component produced would also be very high.
5. Production rate will increase.
6. Due to consistancy in manufacturing, 100% inspection is not required. ∴ cost of inspection is reduced.
7. Reduction in lead time of manufacturing.
8. Safety in manufacturing is also very high.

The use of jigs and fixtures is economically justifiable only when sufficient quantity of components are manufactured.

Basic Parts

1 Body

It should be rigid enough to withstand the self weight of the wp and the forces acting during machining. It also can able to absorb the vibrations generated during machining.

Body can be made by using grey cast iron with casting as a manufacturing method.

2. Locating elements

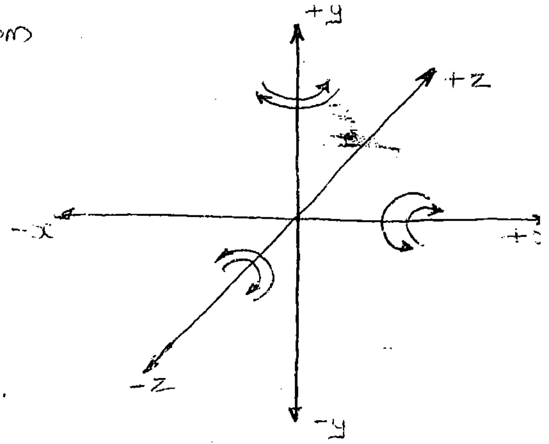
3. Clamping elements

4. Tool guiding elements in ~~space~~ jigs. — Bushes

5. Tool setting elements in fixture — Reference point marked ~~on~~ fixture

2. Locating elements :-

A body in space has 12 degree of freedom



+x, -x - 2
+y, -y - 2
+z, -z - 2
Cw, Ccw, along x - 2
- 2
- 2

6 linear and 6 angular degrees of freedom.

12 degrees of freedom.

In general by using locating elements, it is always allowed to arrest maximum of 9 degrees of freedom only. so that the 3 degrees of freedom will be left over. Out of the 3 DOF, 2 DOF will be used for loading and unloading of the component, 1 DOF will be used for movement of the tool.

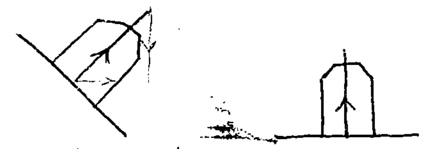
During actual machining operation, the 2 DOF used for loading and unloading will be arrested by using clamping elements and 12th DOF is arrested by using cutting forces acting by the tool.

principles used in location

During designing of locating elements there are 3 priciples which needs to be satisfied by the locating elements.

1. Principle of perpendicular planes :-

whatever the locating elements used for locating the w.p, must be provided only in the perpendicular planes.



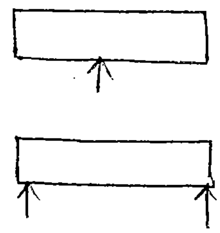
resolved components remains unbalanced So extra clamp is to be provided.

2. Principle of minimum location

whatever the locating elements used for locating the w.p in the given plane must be as minimum as possible to arrest maximum number of degrees of freedom.

3 Principle of extreme position

If only one pin is used for locating, in a given plane — provide in the centre. But when more than one pin is provided. It is always recomended to provide at the extreme position only.

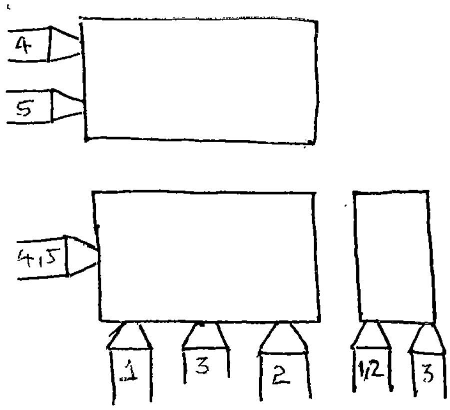


methods of location :-

1. 3-2-1 method of location

This method is used for locating cartesian coordinate system of a component.

3,2,1 represents the no: of pins used in the ~~two~~ 3 mutually ⊥ planes for arresting required No: of degree of freedom.



3 pins - 5 DOF [1L + 4R] is arrested

(max. No of DOF arrested in a single plane is 5. whatever the No of pins we use we could only arrest 5DOF ; so we use 3)

2 pins - 3 DOF [1L + 2R] is arrested

(if we arrest 5DOF here total (4+4) = 8R but only 6R ie we arrest 2 R which is already arrested. To avoid this redundancy we only arrest 3)

1 pin - 1 DOF

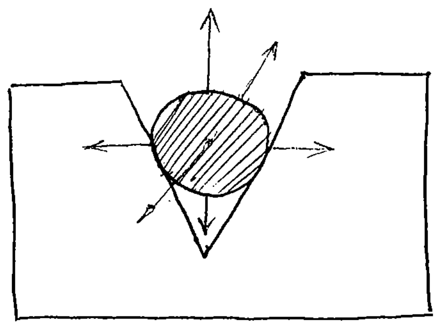
9 DOF Total is arrested

2. V-location

This method is used for locating cylindrical co-ordinate system of a component.

V-block is used.

V-block - 7 DOF [3L, 4R] is arrested

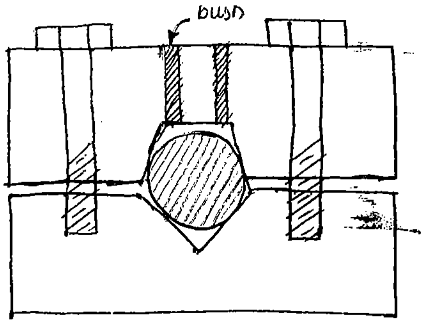


3. Bush location cum clamping

This method is used for locating spherical co-ordinate system of a component

All 12 DOF is arrested

so that whenever the component is to be unloaded or new component is to be loaded, the bush clamp can be removed

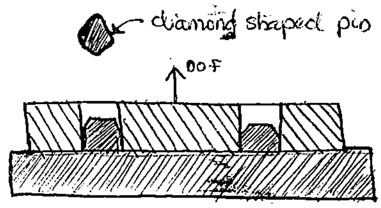


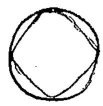
4. Pin/Radial/Diamond location

This method of location is used for locating a plate like component with very small thickness and having atleast 2 holes.

In total 11 DOF is arrested

Only 1 DOF is available for the movement of tool aswell as loading and unloading of the w.p



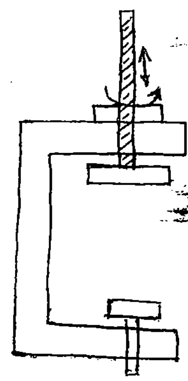


only 4 points contact will be there so easy to remove and also it won't allow the lateral movement. the hole size is larger in case of circular pin.

3 Clamping elements

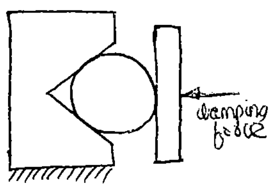
a C-clamp

used for clamping cartesian co-ordinate since the body looks like C - it is called as C-clamp

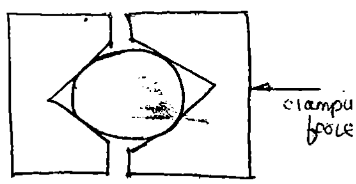


b. Rectangular clamp or V clamp

for clamping cylindrical coordinate system of a component



Rectangular clamp



V-clamp

c. Bush location cum clamping

Common principles used in design of Jigs and fixtures.

1. The design of jig or fixture must be such that the time taken for loading and unloading must be as minimum as possible.

2. The design of jig or fixture must be such that the loading and unloading of the component must be as easy as possible and even unskilled persons should be able to load and set the component.

3. The design of jig or fixture must be such that ~~the~~ it should be as open as possible for easy removal of the chips

4. The design should be such that the variation in dimension of the component can be accomodated easily.

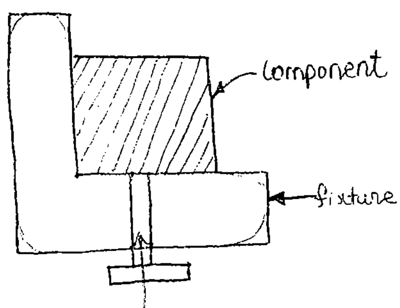
5. It should be rigid enough to withstand the forces and weight of the w/p.

6. The design should be fool proof. The design is such that during loading of the component, the jig or a fixture should allow the component only if it is loaded in the specified direction.

7. For easy handling of the fixtures, it is required to provide the eye bolts, trunions etc on the C.G location.

8. Soft inserts must be available for locating delicate components without damaging

9. Ejectors must be available for easy unloading of the component from the ~~of~~ jig or a fixture.



Here surface contact is there. During machining coolant is supplied and it may get adhered and stick both the component and fixture. Thus it would be difficult to remove. Thus Ejectors should be provided

10. Safety in the working conditions. No sharp edges and projections of bolt heads, nuts etc should be allowed.

11. The machine operator should be able to see the machining zone; just by standing away from the jig or fixture without bending his body or head.

12. Design must be simple and cheaper.

P.59 !

chapter 13

Production / CNC machines / CNC classroom Obj

Q.1

1 rev of L.S → 5 mm

1 mm → $\frac{1}{5}$ rev

200 mm → $\frac{1}{5} \times 200 = 40'$

$= 40 \times 360°$

$= 14400$

(a)

Q.2

BLU = dist travelled per pulse

No of pulse $= \frac{9}{BLU} = \frac{9}{0.005} = 1800/-$

(b)

Q.3

1° per pulse

1 rev → 360°

→ 360 pulses/rev

360 pulse → 1 rev of motor

= 1 rev of L.S

= 3.6 mm

1 pulse $= \frac{3.6}{360} = 0.01$ mm

= 10 micron

(b)

Q.4 (C)

Q.5 (d)

Q.6 10 V → 100 rpm

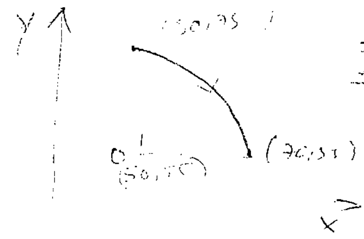
→ 100 × 5 = 500 mm/min

3000 mm/min → $\frac{10}{500} \times 3000 = 60$ Volt

Q.7 (b)

Q.8 (c)

Q.9



(C)

Q.10 (B)

Q.11 (A)

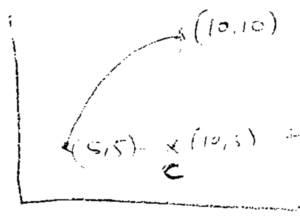
Q.12 (B)

Q.13 (B)

Q.14 A

Q.15 (15,15) C

Q.16



C

In the block of info more than 1 coordinate should not be more than option in C option

N05 X5 Y5

N10 G02 X10 Y10

Q.17

1 pulse → 1.8°

$\frac{360}{1.8} = 200$ pulse

200 pulse = 1 rev

= 2 mm

1 pulse $= \frac{2}{200} = 0.01$

10 micron

Q.18 ~~200 pulse → 1 rev/4~~

→ 4/4

gear ratio 1 (4)

200 pulse → 1 rev of motor

→ 1/4 rev of LS

→ 4/4 mm

1 Pulse → 1/200 m = 5 micro

Q.19 (C)

Q.20 $\frac{4}{150} \times 200 \times 60 =$

~~Q.21~~

Q.22 batch production, large

Q.23 (d)

Q.24 (a)

Q.25 C

Q.26 (d)

~~Q.27~~

Q.28 (A)

Q.29 (A)

Q.30 (B)

~~Q.31~~

~~Q.32~~

Q.33 A

Q.34 C

Q.35 C

Q.36 C

Q.55 – (D)

Q.56 – C

Q.57 – A

Q.58 – D

Q.37

A ✓

R ✓ (A)

Q.38

A ✓

R ✓ (A)

Q.39 A X – closed load

R – ✓ –

am false reason true

Q.40

B

Q.41

A – 4

B – 5

C – 1

D – 3

4, 5, 1, 3

Q.42 batch production

Q.43 false.

Q.44 FAPT – is a progr lan

part prog lang no langs.

Q.45

(A)

Q.46 DNC

Q.47 (B) – servo motor sh be use but

Stepper is also point to point

Q.48

(A) consistence (B) hazard.

↳ spray pnt.

Q.49 (A)

Q.50 (A)

Q.51 (C)

~~Q.52~~ Q.53 – (A) Q.54 C

29/11/11

NON TRADITIONAL MACHINING

non conventional machining

Limitations of the traditional machining method

The tool must be atleast 30-50% harder than the wp material but sometime wp itself will be very hard and there will be no-tool available which is harder than the work piece.

Some materials will have very poor machinability. Such materials cannot be machined with conventional methods.

Small size non-circular holes cannot be produced by using conventional methods. but large size non-circular holes can be produced by broaching process.

Making small size circular hole is also not possible.

Making holes in the higly brittle materials is not possible.

Machining of very soft materials like rubber is not possible.

Manufacturing of complex concave curvature is not possible

Non-Traditional Machining

1 USM

2 EDM

3 ECM

4 WJM

5 AWJM

6 EBM

7 LBM

For all the above methods ; we deals with

(a) mechanism of chip formation

(b) tool material

(c) medium

(d) wear ratio/machining ratio

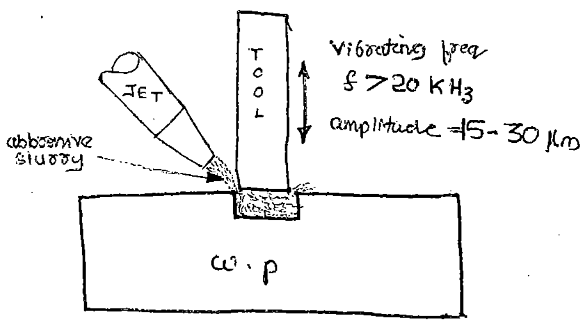
$$WR = \frac{\text{volume of Material Removal on w.p}}{\text{volume of tool wear}}$$

(e) advantages

(f) disadvantages

(g) applications

(i) Ultrasonic Machining Methods



when the tool is vibrating at high frequency, the impact load produced by the tool will be acting on to the abbrasive particle, which inturn produces the impact loads onto the work piece. when the impact loads are acting on the work piece; if the w.p material is a highly brittle material, bcz of lower toughness the w.p is getting fractured due to brittle fracture. The chips produced due to this will be moving along with the abbrasive slurry. from the above; the mechanism by which the chip formation takes place is brittle fracturing.

when the impact load is acting on to the abbrasive particle, the equal and opposite reaction force produced by the abbrasives will be acting on to the tool. ∴ if the tool is made by using hard material, the brittle fracturing will takeplace on the tool also. Hence wear of the tool will be higher. To minimize the wear of the tool, the tool must be made by using very soft or very soft materials. The most commonly used tool material is Cu, brass, mild steel etc.

The medium used is abrasive slurry. ie abbrasive + slurry. The most commonly used abrasive particle is Al_2O_3, Silicon Carbide, Boron Carbide, diamond etc. As the size of abbrasive particle is increasing, the material removal rate, increases first and then reduces. The most commonly used size of the abbrasive particle is 200-600 μm. Boron Carbide abbrasive will be used with water as a slurry and other abbrasives will be used with paraffin as a slurry. The composition of abbrasive-slurry is 50-60% by volume is abbrasive.

wear ratio varies from 1.5 to 100. The wear ratio mainly depends on the brittleness of the work piece material. ie higher the brittleness higher will be the wear ratio.

Tool	WP	WR
Cu	Glass	100
Cu	Ceramic	75
Cu	Tungston	15
Cu	Quartz	50
Cu	H.C steel	1.1

advantages

Highly brittle materials can be machined very easily.
smaller size non-circular holes can be produced.
electrical conductivity of w.p is not required.
It's not a hazardous process

disadvantages

$\frac{L}{D}$ ratio upto 3 only will be possible [deeper holes cannot be produced]

Bcz of brittle fracturing mechanism — poor surface finish — poor dimensional accuracy

Specific cutting energy requirements are higher.

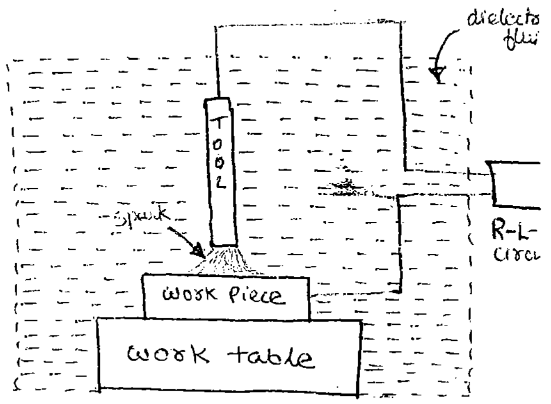
Applications

Used for producing, circular and non-circular holes in highly brittle materials like glass, ceramic, tungsten carbide etc.

The dentist uses USM for producing holes in the human teeth; since it a painless drilling method.

Holes of size upto 0.1mm can be produced by using ~~E~~ USM.

2 Electric Discharge Machining Operation



When the power supply is given to the RLC circuit, nearly 75-80% of cycle time duration, the energy supplied by the powersupply unit will be stored in the RLC circuit bcz the RLC circuit in electric technology is working like a flywheel in mechanical system. During remaining 20-25% of cycle time duration, the energy stored in the RLC circuit and energy supplied by the power supply unit will be released spontaneously so that where ever gaps are provided in the circuit, such place spark are produced. (ie b/w the tip of tool and w.p). Bcz of sparking; the heat is generated at ~~tool~~ the interface of tool and wp. By using this heat the w.p material is melting and evaporating. To increase the evaporation efficiency of the metals; the sparking zone will be immerse in a dielectric fluid. Bcz the evaporation is ~~taking~~ taking place inside the liquid and vapours are continuously coming out, at the sparking zone, the pressure falls to below the partial pressure of water vapour in the atmosphere. Hence ~~cavitation~~ cavitation is occuring. This cavitation promotes the material removal. Thus the mechanism of chip formation is melting and evaporation associated with cavitation or spark erosion and cavitation.

To avoid the heat generation with in the tool; the tool material must be made by using high electrical conductivity material and to minimize the melting of tool; the high MP material is to be used. The most commonly used tool materials are Cu, W or copper tungsten alloy, graphite

The medium used is dielectric fluid. The most commonly used is

[illegible]

WR = 0·1 to 10. The wear ratio is mainly depends on the difference b/w MP of the tool and w.p material.

If MP of tool ≫ than MP of w.p – W.R ↑

eg:- During machining of Al using tungston Carbide as tool WR = 10.

During machining of Steel w.p using Cu (less MP) as a tool WR = 0·1

Advantages

$\frac{L}{D}$ ratios as high as 20 is possible

There is no physical contact b/w the tool and w.p — No forces are acting in machining. Hence no residual stresses are developed in the w.p.

Out of all the unconventional machining methods EDM is the one which gives the highes MRR and EBM will give the lowest MRR (material Removal Rate)

Bcz melting and evaporation is the mechanism of chip formation, the mechanical properties of w.p materials will not affect the material removal rate.

Surface finish produced will be better.

Disadvantages

Work piece material must be electrically conductive.

Perfect square corner holes cannot be produced.

Hardening of the work piece will take place i.e near to the hole hardness of w.p will be high.

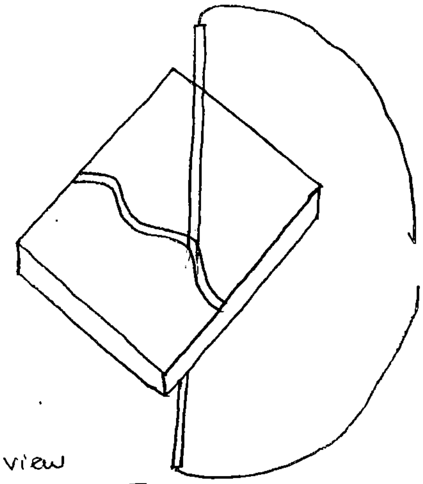
Applications

It's used for producing very small sized holes like holes in the diesel injection nozzle.

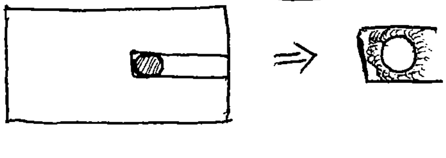
Used for producing holes in the air brakes.

Used for die sinking.

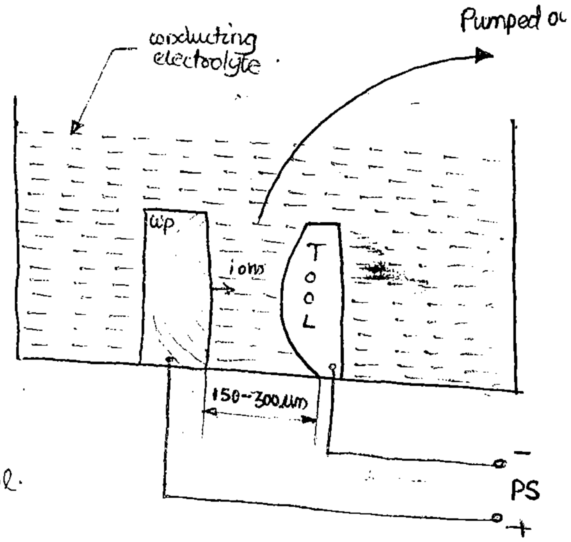
Wire cut EDM – is similar to EDM but used for cutting sheets into complex shapes. In this process a continuously moving wire will be used as a tool so that the sparks are produced b/w circumference of the wire and w/p. As the machining is progressing, in case of EDM length of the tool will be reducing. But in case of wire cut EDM; dia of the wire is reducing.



top view



3. Electro chemical Machining



When the power supply is given to the w.p and the tool, bcz of faraday's laws of electricity; the ions are displacing from the workpiece and trying to deposit over the tool. Before they are depositing, when the electrolyte present b/w the tool and w/p will be pumped out continuously so that the ~~ions~~ ions displaced from the wp are also moving along with the electrolyte. Hence there is no disturbance taking place to the tool. The same tool can be used for producing infinite number of components. from this the mechanism by which the chip formation taking place is due to ion displacement. The no: of ions displaced or MRR in ECM

(a) directly proportional to the gram atomic wt of the w.p material.

(b) directly proportional to the current density of the ECM process.

(c) Inversely proportional to the distance b/w the tool and w.p.

(d) Directly proportional to the electrical conductivity of the electrolyte ie

For rough machining of operation – high electrical conducting electrolyte is used also called as passivating electrolyte.

For finish machining operation – low electrical conductivity electrolyte is us[ed] also called as nonpassivating electrolyte.

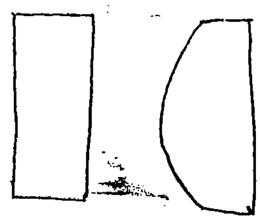
(e) In addition to the above, the electrolyte must be chemically stable, low visc[osity] and having high specific heat.

If the tool and w.p are made by using same material and wp is connected to +ve terminal of the power supply, more no: of ions are displacing from the w.p. ∴ the tool must be made by using ~~same~~ same material as that of the w.p.

The medium used is conducting electrolyte; preferebly salt solution.

Bcz the tool wear $= 0$ - $WR = \infty$

Advantages



Complex concave curvatured components can be easily produced by using complex convex curvatured tool. (which can be produced by normal or CNC machining)

Since tool wear $= 0$. same tool can be used for producing infinite No: of components

Bcz there is no direct contact b/w tool and wp, No forces and no residual stresses.

Bcz of ion displacement mechanism; the surface finish produced is excellent

Disadvantage

Out of all the unconventional machining method, ECM require highest specific cutting energy.

w.p must be electrically conductive

Generally preferable for producing contours only.

Sharp corners is not possible to produce.

Applications

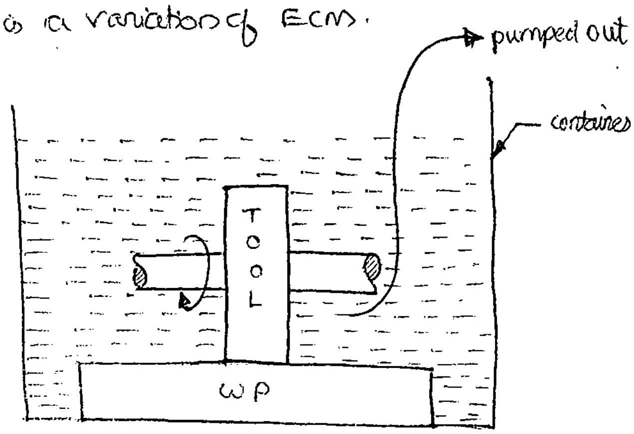
Used for producing complex shape of components like turbine blades.

for ECM

$$MRR = \frac{AI}{ZF}$$

A – Atomic wt. of w.p
I – Current passing thru the circuit
Z – Valency of the w.P material.
F – faradays constant
= 96500

Electro chemical Grinding (ECG) is a variation of ECM.



In ECG, the rotating grinding ~~wheel~~ will be used as a tool; material So that the material removal is taking place due to electrochemical process and mechanical process as 90 : 10 %.

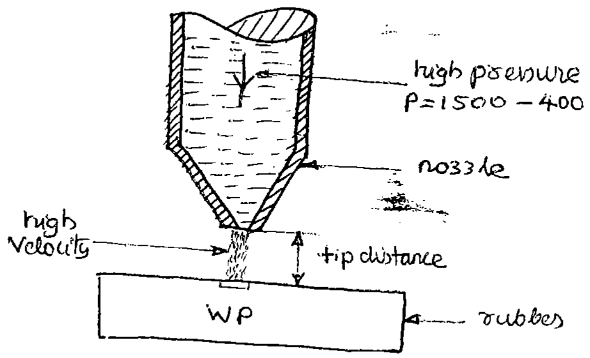
The gap b/w the tool and wp is mainly controlled by using the size of the abbrasive particle present in the grinding wheel.

It's developed for grinding of very hard work pieces like grinding of carbide cutting tools.

Eventhough carbide cutting tools are regrindable by using ECG, but is not preferable bcz; the cost of ECG is much higher than the new cutting tool itself.

4 Water Jet Machining

When the very high pressure water is passing through the convergent nozzle, the pressure energy is converted into velocity energy. ∴ the water is coming out from the nozzle at very high velocity. When this high velocity water jet is impinging on to the w.p, the continuous impact load will be produced on the w.p so that the workpiece material is plastically deforming and fracturing will be taking place. i.e the mechanism by which material removal is taking place by plastic deformation and fracturing or called as etching process.



The nozzle would be considered as the tool.

To withstand the high pressure of water; the nozzle or tool is made by using WC.

Medium is water.

$WR = \infty$

Advantages

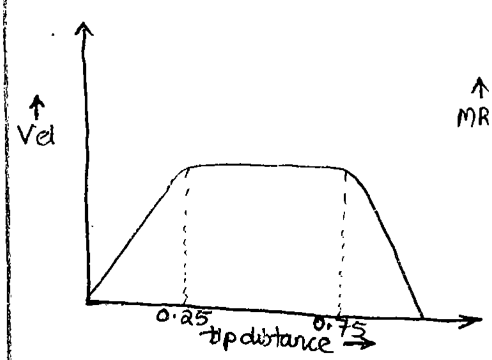
Used for machining of very soft materials like rubber.

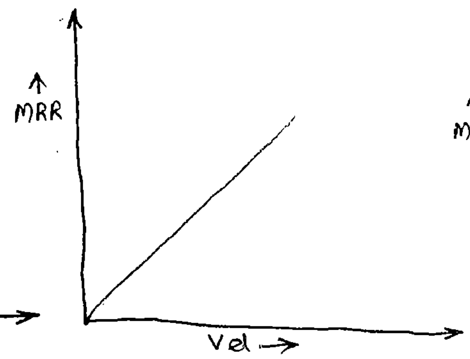
Limitations

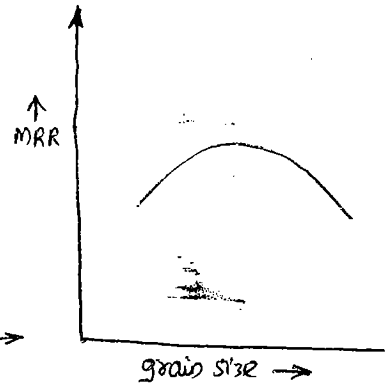
Pressurising the water to very high pressure is difficult.

It can't be used for machining of hard w.p.

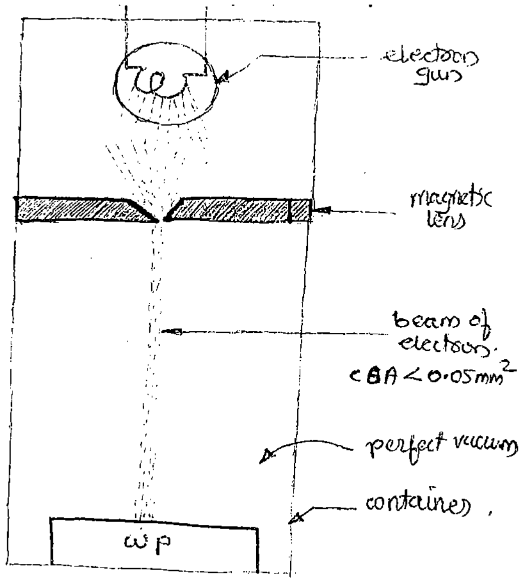
- To overcome this disadvantage – abbrasives are added to water so that the abbrasive particle also will be coming out from the nozzle tip at very high velocity and when this high velocity abbrasive are impinging on to the hard w.p; it is possible to produce the hard plastic deformation in the hard w.p also. Hence the fracturing and chip formation is taking place. This is called abbrasive water Jet Machining.







(6) 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 form like a beam of electrons which is having the cross sectional area less than 0.05 mm².

when this high velocity electron beam is impinging onto the w p, the KE of electrones is converted into heat energy. ∴ The heat is getting generated at the w.p. This heat will be used for melting and vapourisation of the w.p material. from the above the mechanism of material removal is by melting and vapourisation.

After the magnetic deflector; b/c of presence of air resistance; the electrones may get dispersed again. To avoid this the total setup will be kept in the container and perfect vaccum is maintained inside the container. B/c of the perfect vaccum, highly reactive metals can be machined very easily without any oxidation.

Electron gun is used as tool

medium is perfect vaccum

TWR = ∞

Advantages

Very very small size holes and narrow slots can be produced very easily.

Highly reactive metals like Al and Mg can be machined easily.

Dis advantages

maintaining perfect vaccum is difficult.

Lowest MRR

B/c the total equipment is kept inside the container, the machining process cannot be seen by the operator.

Applications

Used for producing very small sized holes and narrow cavities in electrically conducting material.

If voltage of power supply to the electron gun is reduced to about 70-80,000 V the velocity of electrons is reducing, the heat generated at wp is reducing. ∴ the wp is only melting, but no-evaporation takes place. This melting of the wp can be used for joining purpose. It is called as electron beam welding.

7 Laser Beam Mathining

When the power supply is given to the laser gun, it produces high intensity electro magnetic waves having the wavelength 0·1 to 70 µm;

Laser beam has a crossectional area of $< 0{\cdot}05\ mm^2$.

When this laser beam is impinging on to the w.p, the electromagnetic wave energy is converted into heat energy at the surface of the w.p. ∴ the surface layer of the wp is melting and evaporating. But for further layers, the heat is transfering by conduction process. When the 1st layer is evaporating, the second layer of material is exposing for electromagnetic waves. This also get melted and evaporated. Like this; the layer by layer of WP material is getting exposing for electromagnetic waves, melting and evaporating. Hence this process is looking like a ladded called as cladding process. From the above the mechanism of material removal is by melting and vapourisation.

Tool material is Ruby rod.

Medium is air

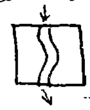
$W \cdot R = \infty$

Advantages :-

No vaccum is required; hence the process will be easier.

The size of holes / Dos slots produced is same as EBM.

Bcz ruby rode is flexible - to some extend zig zag holes can be produced by using LBM.



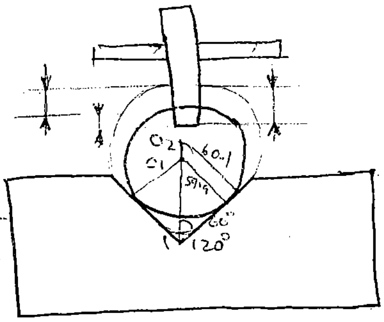
Disadvantage.

Major dis advantage of LBM is that huge amount of power is required (5000 to 6000 MW) ∴ Every country would be having only 1 such machine. (India not having). That too operated once is a blue moon.

Jigs and fixtures

Q.1 (A)

Q.2



$$O_1A = \frac{59.9/2}{\sin 60}$$

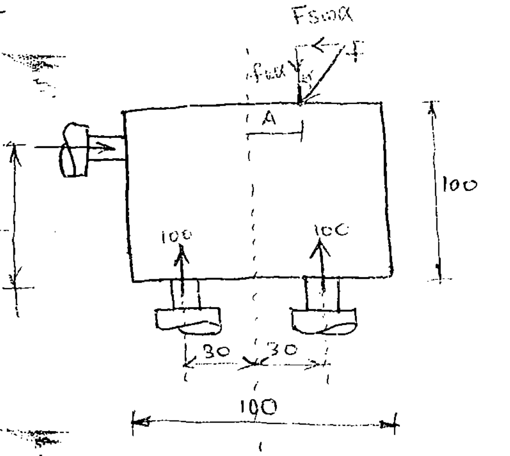
$$O_2A = \frac{\frac{60.1}{2}}{\sin 60}$$

$$O_1O_2 = O_2A - O_1A$$
$$=$$

error in depth $= 2 \times O_1O_2$
$= \underline{0.22m}$ (C)

Q.3 C

Q.4



(a) $\frac{F\sin\alpha}{F\cos\alpha} = \frac{100}{100+100} = \frac{100}{200}$

$$\tan\alpha = \frac{100}{200}$$

$$\alpha = \tan^{-1} 1/2$$

$$f = \frac{100}{\sin\alpha} =$$

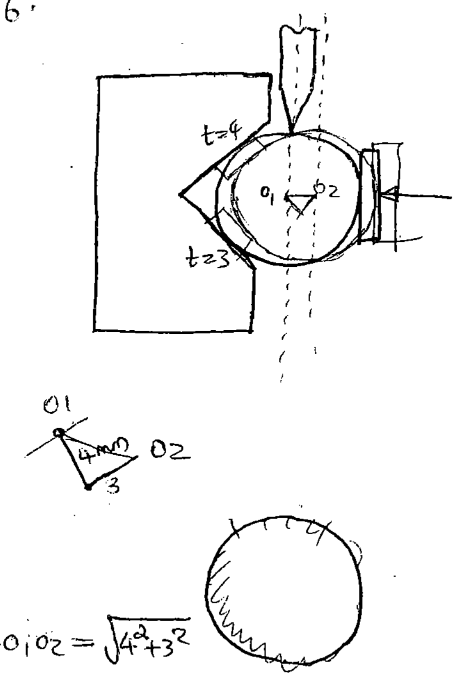
(b)
$(F\cos\alpha \cdot A) + (100\times 30) = 100\times 30 + (100\times 20)$

$$A = \frac{100\times 20}{F\cos\alpha} = \frac{100\times 20}{200}$$

$$A = 10\ mm$$

~~Q.5~~

Q.6.



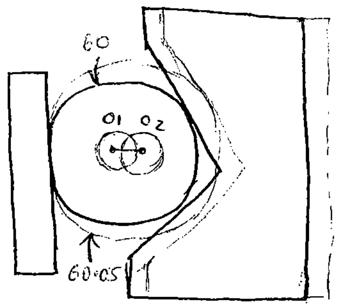
$$O_1O_2 = \sqrt{4^2+3^2}$$

$$= O_1O_2 = \underline{\underline{\sqrt{5}}}$$

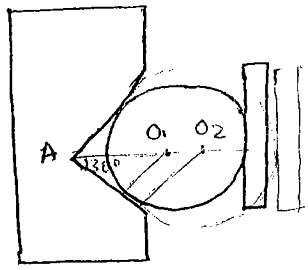
$$\sqrt{x^2+x^2} = 5$$
$$2x^2 = 5^2$$
$$x = \sqrt{\frac{5^2}{2}}$$

(2) is preferable ⇒ stable method

Q.7



error in position of hole
$= O_1O_2 = 30.025 - 30.00$
$= \underline{\underline{0.025}}$



$AO_1 = \frac{30}{\sin 60}$

$AO_2 = \frac{30.025}{\sin 60}$

$O_1O_2 = AO_2 - AO_1 = 0.029$

Positional error is depends on the fixed element alone.

(c) same as ~~two~~ (2)

position error $= 0.029$.

best one is 1^{st} case

p.76

Q.8 (A) 3 component to be is fixed part

Q.9 (D)

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NTM - chapter 14

Q.1 A-5, B-3, C-2, D-4

Q.2 (B)

Q.3 (C) diamond is the abrasive particle

Q.4 A-3 B-4 C-5 D-2

Q.5 A-4 B-1 C-3 D-2

Q.6 rigid

Q.7 (C)

Q.8 (a), (d)

Q.9 A- electrochemical
B- mechanical.

Q.10 USM- Orlan is machined only with USM.

Q.11 (b)

Q.12 (b) 2-1-4-3

Q.13 (d) 2-3-1

Q.14 (d) 3-4-2-1

Q.15 A-5 B-2 C-6 D-1

Q.16
A ✓
B X - It's easy to process but it is environmentally non-bio degradable.

Q.17 A-4 B-3 C-1 D-2

Q.18 A-1 B-2 C-3 D-4

Q.19 A-1 B-2 C-4 D-3

Q.20 (d)

Q.21 (c)

Q.22 A-2 B-4 C-1 D-3 (c)

Q.23 5-1-4-2 (a)

Q.24 (C) erosion & cavit

Q.25 2-3-5-6 (d)

Q.26 (c)

Q.27

Q.28 (a)

Q.29
A ✓
R ✓ (b)
but reason is not correct.

Q.30 (B) ~~highest~~ lowest for EBM
~~lowest~~ highest for EDM

Q.31 (C)

Q.32 (a) ?

Q.33 (C)

Q.34 (a)

Q.35 4-2-1-3 (c)

Q.36 (d)

Q.37 (d)

Q.38 (d)

Q.39 (a) 4-3-1-2

Q.40 $MRR = \frac{AI}{Z}$ (a)

Q.41 (d)

Q.42 $\frac{AI}{ZF} = \frac{63 \times 1500}{1 \times 96500} = 3.26$
(B) 3.

Q.43

$MRR = \frac{AI}{2f}$

$A = 35.85$

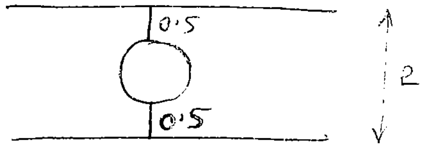
$I = \frac{V}{R}$

$f = 96540$

$z = 2$

$R = \frac{\delta l}{A} = \frac{2mm \times 0.02cm}{\frac{2 \times 10 \times 0.2}{20 \times 20}} = 0.3471$ (a)

Q.44



$MR = 2 \times 5 \times 20$
$= 200\ mm^3/m$ (b)

Q.45 (d)

Q.46 (a) as $\phi \uparrow$ incre $\alpha \uparrow \uparrow$

Q.47 (d)

Q.48 (d)

 Metal cutting :-

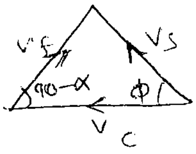
Q.1

$V_c = 30$
$V = 15$
$\alpha = 10$

$r = \frac{V_f}{V_c} = 0.5$

(a) $\phi = \tan^{-1}\left(\frac{r \cos\alpha}{1 + r\sin\alpha}\right)$

Q.2



$\frac{V_s}{\cos\alpha} = \frac{V_f}{\sin\phi}$

$V_s = \frac{V_f \times \cos\alpha}{\sin\phi}$

$=$ (d)

Q3

$t_1 = 2$
$b = 15$
$V_c = 0.5$
$\alpha = 0$
$F_c = 900$
$F_r = 600$
$\phi = 30$

$\tan(\beta - \alpha) = \frac{F_T}{F_C}$

$\beta = \alpha + \tan^{-1}\left(\frac{F_T}{F_C}\right)$

$\mu = \tan\beta$

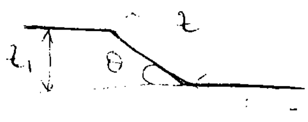
Ans (C) 2/3

Q.4

$P = F_c \times V_c$
$= 900 \times 0.5 = 450\ \underline{W}$ (b)

Q.5

$L_s = \frac{t_1}{\sin\phi} = \frac{2}{\sin 30} = 4\ mm$ (d)



Q.6

$2\phi - \alpha = 90$
$\phi = \frac{90 + \alpha}{2}$
$= \frac{90 + 12}{2} = \underline{51}$

Q.7

$f_2 = \frac{f_1}{2}$

$d_2 = 2d_1$

$a = 0.3$

$b = 0.3$

$c = 0.15$

$V_1 \cancel{T_1^a} f_1^b d_1^c = V_2 \cancel{T_2^a} f_2^b d_2^c$

$v_2 = V_1 \left(\frac{f_1}{f_2}\right)^b \left(\frac{d_1}{d_2}\right)^c$

$= V_1(2)^{0.2} (1/2)^{0.5}$

$= 1.11 V_1$

% change $= \frac{V_2 - V_1}{V_1} = 11\%$ (b)

Q.8

productivity $\propto$ MRR

% change in productivity $= \frac{MRR_2 - MRR_1}{MRR_1}$

$= \frac{V_2 f_2 d_2 - V_1 f_1 d_1}{V_1 f_1 d_1}$

$= 110\%$

(b)

Q.9

$\alpha = 6°$

$V = 0.5$

$b = 3$

$t_1 = 1$, $t_2 = 1.5$ } $r = \frac{t_1}{t_2} = \frac{1}{1.5} =$

$2\phi + \beta - \alpha = 90°$

$\phi = \tan^{-1}\left(\frac{r\cos\alpha}{1 - r\sin\alpha}\right)$

$2\phi + \beta - \alpha = 90$

$\beta = 90 + \alpha - 2\phi$

$\mu = \tan\beta$

0.467 (c)

Q.10

$r = \frac{V_f}{V_c} \Rightarrow V_f = r V_c$

$= \frac{1}{1.5} \times 0.5 \times 60$

$= 20$ mm/min

(b)

Q.11

Area of shearplane

$A_s = L_s \times b$

$= \frac{L_1}{\sin\phi} \times b = \frac{1}{\sin\phi} \times 3$

$= 5.2\ mm^2$ (c)

Q.12

$V_0, T_0 \rightarrow$ original value

$V_1 = 1.2 V_0$

$T_1 = 0.5 T_0$

$V_0 T_0^n = V_1 T_1^n$

$\left(\frac{T_0}{T_1}\right)^n = \left(\frac{V_1}{V_0}\right)$

$n \ln\left(\frac{T_0}{T_1}\right) = \ln\left(\frac{V_1}{V_0}\right)$

$n = \frac{\ln\left(\frac{V_1}{V_0}\right)}{\ln\left(\frac{T_0}{T_1}\right)}$

$V_2 = 0.8 V_0$, $T = ?$

$V_0 T_0^n = V_2 T_2^n$

$T_2 = 2.33 T_0$

$\frac{T_2 - T_0}{T_0} = 133\%$

$=$

Q.13

$\alpha = 35$
$V = 10$
$D_0 = 32$
$d = 0.125$
$L_2 = 60$
$F_T = 200$
$F_c = 80$
$\mu = ?$

$L_1 = \pi D_0$
$= \pi \times 32$

Q14 $\gamma = \frac{L_2}{L_1} = \frac{60}{\pi \times 32} = 0.59$

$f_t >$

classical friction theorem

Q(13) $\mu = \frac{\ln(1/\gamma)}{\pi/2 \cdot \gamma} = 1.52$

Q(14) $\phi = \tan^{-1}\left(\frac{\gamma \cos\alpha}{1 - \gamma \sin\alpha}\right)$

$= 36.4$

(9) (9)

$D' = 28.7$ (5)

Q.18

oblique machining

$t_1 = f \cos C_s = f \sin \lambda$
$= 0.15 \times \sin 75°$
$=$

$t_2 = 0.36$
$= \frac{d}{\sin \lambda}$

$K = \frac{t_2}{t_1} = \frac{0.36}{t_1} =$

$\gamma = \frac{1}{K} =$

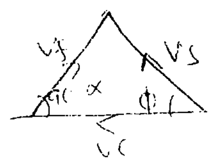
$\theta = \tan^{-1}\left(\frac{\gamma \cos\alpha}{1 - \gamma \sin\alpha}\right)$

$\alpha = 10°$

Q.15

$V_f = \gamma V_c$

$V_s = \frac{V_f \cos\alpha}{\sin\phi}$



Q19

$\alpha = 10°$
$t_1 = 0.125$
$f_c = 517$
$f_T = 217$
$t_2 = 0.43$
$\boxed{C_m} = 2\phi + \beta - \alpha$

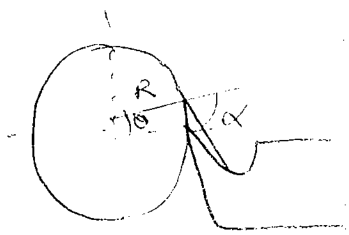
$\gamma = \frac{t_1}{t_2} =$

$\phi = \tan^{-1}\left(\frac{\gamma \cos\alpha}{1 - \gamma \sin\alpha}\right)$

$\beta = \alpha + \tan^{-1}\left(\frac{f_T}{f_c}\right)$

Q.16

$O_f = 1.5$
$O_\gamma = 6°$
$\alpha_b = 10°$
$D = 50$



$\sin \theta_f = \frac{O_f}{R}$

$\theta_f = \sin^{-1}\left(\frac{1.5}{25}\right)$

$=$

$= \alpha_b + \theta_f$

Q 17

$\theta_{ve} = \theta_e - \theta_f$

at rubb $\theta_f = \theta_e \Rightarrow \theta_{ve} = 0$

$\sin\theta = \frac{O_f}{R'} \Rightarrow R' = \frac{1.5}{\sin 6°} = 14.36$

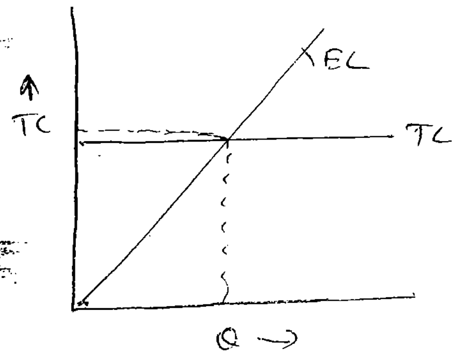
Q.20

let Q = No: of parts produced

$(TC)_{E.L} = \frac{30}{60} \times Q \times 80 = 40Q$

$(TC)_{TL} = 500 + \frac{6}{60} \times Q \times 160$

$= 500 + 16Q$



At BEQ,

$(TC)_{EL} = (TC)_{TL}$

$40Q = 500 + 16Q$

$24Q = 500$

$Q = \frac{500}{24} = 21.$

$n > 21$ – turret is economical

$n < 21$ – engine lathe is eco

Q.21

$n = 0.12$, $C = 130$

$c' = 1.1 \times 130 = 143$

$VT^n = c'$

$T = \left(\frac{c'}{v}\right)^{1/n}$

$= \left(\frac{143}{90}\right)^{1/0.12} = 47.4\,m$

(a)

Q.22

$\cancel{T^{0.2} = \frac{9.8\, D^{0.4}}{V_S}}$

(i) $VT^{0.2} = \frac{9.8\; D^{0.4}}{v_s^{0.5}}$

$= \frac{98 \cdot 30^{0.4}}{0.4^{0.5}}$

$= 60.4$

$VT^{0.2} = 60.40$

$n = 0.2$

$C = 60.40.$

$V_{opt} = C\left[\frac{n}{1-n} \cdot \frac{Ln}{Cg}\right]^n$

$= 60.4\left[\frac{0.2}{1-0.2} \times \frac{\left(\frac{60}{40}\right)}{400}\right]^{0.2}$

$= 13.81$

Q.23

$P_z = S_o\, t\, \tau_s\left(\zeta \sec\gamma - \tan\gamma + 1\right)$

$S_o = 0.12$

$t = 2.0$

$\tau_s = 400$

$\zeta = \frac{t_2}{t_1} = \frac{0.2}{S_o} = \frac{0.2}{0.12} =$

$\gamma = 0$

$P_z =$

Power $= P = F_c \times V_c$ $\qquad \frac{V_f}{V_c} = r$

$= P_z \times \frac{V_f}{r}$

$= P_z \times \zeta\, V_f$

$=$

Q.24 $V_1 = 50$

$T_1 = 45$

$V_2 = 10$

$T_c = 2$

$V_{olt} = ?$

$$V_1 T_1^n = T_2 T_2^n$$

$$\left(\frac{T_1}{T_2}\right)^n = \left(\frac{V_2}{V_1}\right)$$

$$n = \frac{\ln\left(\frac{V_2}{V_1}\right)}{\ln\left(\frac{T_1}{T_2}\right)}$$

$$= \frac{\ln\left(\frac{100}{50}\right)}{\ln\left(\frac{45}{10}\right)}$$

$n =$

$C = V_1 T_0^n =$

$$V_{opt} = C\left[\frac{n}{1-n} \cdot \frac{1}{T_c}\right]^n$$

$$V_1 T_1^n = V_2 T_2^n$$

$$\left(\frac{T_1}{T_2}\right)^n = \left(\frac{V_2}{V_1}\right)$$

$$n = \frac{\ln\left(\frac{80}{50}\right)}{\ln\left(\frac{50}{12.5}\right)} =$$

$$V_1 T_1^n = V_3 T_3^n$$

$V_3 = 60$

$T_3 = ?$ 2.9 (a)

Q.25 Tool life $\propto \frac{1}{\text{flank wear}}$

$$T \propto \frac{1}{\cot\alpha}$$

$$T \propto \tan\alpha$$

$$\frac{T_2}{T_1} = \frac{\tan\alpha_2}{\tan\alpha_1} = \frac{\tan 7}{\tan 10}$$

$= 0.7\ T_1$

Q.26

$$R_z = \frac{f^2}{f_r}$$

$$f^2 = R_z \times f_r$$

$$f = \sqrt{\cancel{R_z}\ 0.005 \times 8 \times 0\ 1.8}$$

$=$

Q.27 (a)

Q.28 $V_1 = 50$, $T_1 = \frac{500}{10} = 50$, $f = 0.25$, $d = 1$

$V_2 = 80$, $T_2 = \frac{122}{10} = 12.2$, $f = 0.25$, $d = 1$

Q.29

$$F_s = \frac{F_c}{\cos(\beta - \alpha)} \cos(\phi + \beta - \alpha)$$

$F_c =$

F_T

$\phi = 30$

$$\tan(\beta - \alpha) = \frac{F_T}{F_c}$$

$$(\beta - \alpha) = \tan^{-1}\left(\frac{F_T}{F_c}\right)$$

(c) 474.4 N

Q.30 $\frac{1}{f_n}$

Q.31

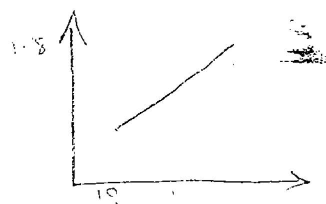
calculate slope $= \frac{60 - 10}{2 - 0.8}$ $\frac{60 \quad 10}{2 - 0.8}$

$= \frac{2 - 0.8}{60 - 10}$

at $h = 1.8$

$= 1.08$

$T = 10 + \text{slope} \times (1.8 - 0.8)$



Q.32

$z_1 = 0.24$ $\quad r = \frac{z_1}{z_2}$

$z_2 = 0.48$

$\alpha = 0$

$\phi = \tan^{-1}\left(\frac{r\cos\alpha}{1 - r\sin\alpha}\right)$

$= 26.56$ (b)

Q.33

$\frac{\text{work done}}{MRR}$

W.D = Sp cutting energy × MRR

$f_c \times V_c = 2 \times 10^3 \times V f d$

$f_c = 2 \times 10^3 \times f \times d$

$=$

Q.34

indirectly asked to calculate μ.

$\tan(\beta - \alpha) = \frac{f_T}{f_c} = \frac{800}{1000}$

$\tan\beta = 0.8 = \mu$

Q.35

$D = 147$

$L = 630$

$V_1 = 90$

$V_2 = 120$

$T_1 = 24$

$T_2 = 12$

$f = 0.2$

$d = 2$

$V_1 T_1^n = V_2 T_2^n$

$\left(\frac{T_1}{T_2}\right)^n = \frac{V_2}{V_1}$

$n = \frac{\ln\left(\frac{V_2}{V_1}\right)}{\ln\left(\frac{T_1}{T_2}\right)}$

$V_3 T_3^n = V_1 T_1^n$ $\quad V_3 = ?$ (b)

$= 97$

Q.36

$V_3 = 97 = \frac{\pi D N}{1000}$

$N = \frac{1000 \times V_3}{\pi \times D}$

Time / cut $= \frac{L}{fN}$

$= \frac{630}{0.2 \times N}$

$= 60$ (c)

Q.37

$r = \frac{0.8}{1.5}$

$V_f = V_c \cdot r$

$= \frac{0.8}{1.5} \times 1$

$=$

Q.38

Q.39 (a)

Q.40, 41

40. (a)

41. (d)

Q.42

$\beta = \tan^{-1}\mu$

$=$

$\alpha = \alpha = 18$

$2\phi + \beta - \alpha = 90$

$\phi =$

Q.43

$\tau = \tau_u = \frac{f_s}{A_0} \times \sin\phi$

$$f_s = \frac{460 \times 36 \times 0.25}{\sin\phi}$$

$$=$$

$$f_c = \frac{f_s}{\cos(\phi + (\beta - \alpha))} \cos(\beta - \alpha)$$

$$=$$

$$P = f_c \times V_c$$

Q.44

$C = 100$

$n = 0.1$

$L_m = \frac{75}{60}$

$C_q = 5$

$$T_{opt} = \left[\frac{1-n}{n} \cdot \frac{C_g}{L_m}\right]$$

$=$

Q.45

$T = 180$

$$V_a = \frac{100}{180^{0.2}} = 35$$

$$V_b = \frac{120}{180^{0.2}} = 32$$

$V_a > V_b$

tool A for h. cu spe (a)

Q.46

~~Q.46~~

$$V_{opt} = C\left(\frac{n}{1-n} \times \frac{1}{T_c}\right)^{n}$$

$$= 100\left(\frac{0.2}{1-0.2} \times \frac{1}{15}\right)^{0.2}$$

$$=$$

Q47

$$t_{1max} = \frac{2 f_n}{N t}\sqrt{\frac{d}{D}}$$

$$= \frac{2 \times 100}{500 \times 8}\sqrt{\frac{5}{100}}$$

$$= 0.011$$ (d)

Q.48

Q.49

$b = 2$

$t_1 = 0.2$

$V_c = 60$

$\frac{f_c}{A_o} = 800$

$f_c = 800 \times A_o$

$= 800 \times t_1 \times b$

$= 320$

Q.50

$$P = f_c \times V_c = 320 \times \frac{60}{60} = 320$$

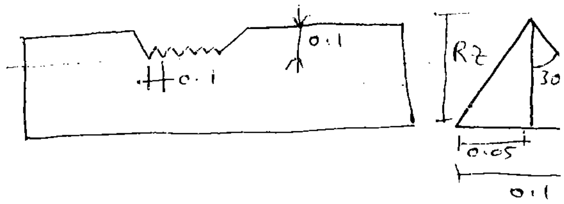
Q.51

~~Se t00~~ $R_{z1} = \frac{f}{\cancel{\tan 25} + \cot 5} = 0.00$

$$R_{z2} = \frac{f}{\tan 30 + \cot 2} = 0.11$$

(a)

Q.52



$$\tan 30 = \frac{0.05}{R_z}$$

$$R_z = \frac{0.05}{\tan 30} = 0.036$$

(c)

Q.53 (a)

Softness ↑
ductile ↑
hardness ↓
tough ↑
force ↓

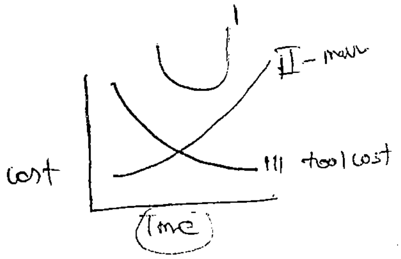
Q.54 (a)

Q.55 0.625 (b)

Q.56 (a)

Q.57 (b)

Q.58 (d)



Q.59

$V = \frac{\pi D N}{1000}$

$= \frac{\pi \times 100 \times 1000}{1000} = 314$ m/min

HSS cannot be used
diamond costly

(a).

Q.60

$\frac{f^2}{8r}$

2 ⟹ 4 times

(b)

Q.61

uncut depth

$r = \frac{t_1}{t_2} = \frac{0.1}{0.6}$

$\frac{1}{0.6}$ 1.66

(d)

Q.62 (b)

Q.63 $T_m = \frac{L}{fN} = \frac{100}{0.04 \times \left(\frac{1000 \times 22}{\pi \times 25}\right)}$

=

$T = \left(\frac{25}{22}\right)^{\frac{1}{0.25}} =$

for 425 cylinders

$\frac{T_m \times 425}{T} = 85$

(d)

Q.64

(d) — 225

Q.65

1/3 (c)

$V_1 T_1^n = V_2 T_2^n$

Q.66

Cubic boron nitride at cost

(a)

Q.67

(c) 674

Q.68

(b) 270

Q.69 27.5 (c)

Q.70 350 (d)

Q.71

$\phi = \tan^{-1}\left(\frac{r\cos\alpha}{1 - r\sin\alpha}\right)$

$SS = \cot\phi + \tan(\phi - \alpha)$

$= 3.34$

(d)

Q.72

(α – not required)

$$\beta-\alpha = \tan^{-1}\left(\frac{F_T}{F_C}\right)$$

$$2\phi + \beta - \alpha = 90$$

$$\phi = \frac{90 - (\beta-\alpha)}{2}$$

$$\phi = 40.27$$

shear strain

$$\gamma = \cot\phi + \tan(\phi-\alpha)$$

$$\alpha = ?$$

$$r = \frac{t_1}{t_2} = \frac{\sin\phi}{\cos(\phi-\alpha)}$$

$$\cos(\phi-\alpha) = \frac{\sin\phi}{r}$$

$$\phi-\alpha =$$

$$SS = \cot\phi + \tan(\phi-\alpha)$$

Q.73

$$\beta-\alpha = \tan^{-1}\left(\frac{F_T}{F_C}\right) \Rightarrow \beta =$$

$$\mu = \tan\beta =$$

Q.74 Energy lost in friction $= F \times V_f$

$=$

Q.75

$$V_1T_1^n = V_2T_2^n$$

$$n = 0.5$$

$$K = 540 \quad (a)$$

Q.76 200%

Q.77 At BEP $\Rightarrow$ $V_a = V_b = V$

$$T_a = T_b = T$$

$$T_a = \left(\frac{90}{V}\right)^{1/0.45} = \left(\frac{60}{V}\right)^{1/0.5}$$

$$V = 26.7$$

Q.78 (a)

Q.79 (a)

Q.80 (d)

Q.81

A true

R - false (c)

Q.82

A ✓

R ✗ (c)

Q.83

(a) A ✓ R ✓ ✓

Q.84

(d)

Q.85

(B)

Q.86

(A) (A) 1,2,3,4 — 1,2,4,3 also

Q.87

(d) 3&4

Q.88

(B)

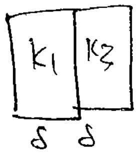
p.77 Conduction

Q.1 B

Q.2 B

Q.3

Q.4



$R_{eq} = R_1 + R_2$

$$\frac{2\delta}{KA} = \frac{\delta}{K_1A} + \frac{\delta}{K_2A}$$

$$\frac{K_2}{2} = \frac{K_1K_2}{K_1+K_2}$$

$$K_2 = 2\,\frac{K_1K_2}{K_1+K_2}$$

(d)

Q.5 B

Q.6 B and D

Q.7 C

Q.8 C

Q.9 B

Q.10 C

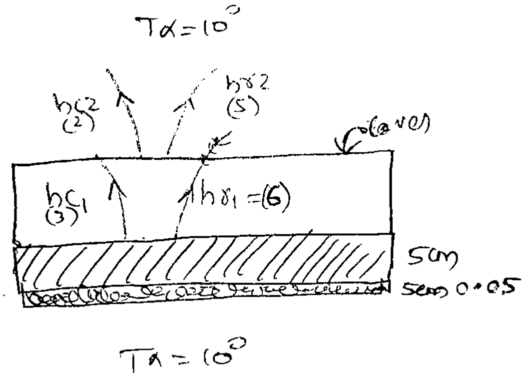
Q.11 A

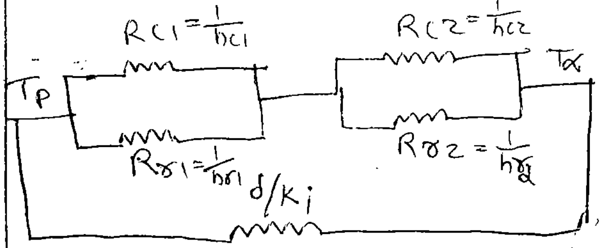
Q.12 A

Q.13 B

Q.14 B

Q.15





$$Q = \frac{70-10}{R_{eq}}$$

$=$

52.5 (a) (A)

Ans
Q.14

$Q =$ H.T from bare pipe

$= hA\Delta T$

$= h \times \pi \times d_2 \times L \times \Delta T$ $\qquad d_2 = 2.5$

$=$

$Q' =$ H.T with insulation

$= 0.207 \times Q$

$$= \frac{\Delta T}{\frac{\ln\left(\frac{r_o}{r_2}\right)}{2\pi K_i L} + \frac{1}{h_o 2\pi r_o L}}$$

$0.207 =$

$$0.207 \times h_o \pi d_2 \times L \times \Delta T = \frac{\Delta T}{\frac{\ln\left(\frac{r_o}{r_2}\right)}{2\pi K_i L} + \frac{1}{h_o 2\pi r_o L}}$$

$$\left.\begin{array}{l} h_o = 10 \\ d_2 = 25 \\ r_2 = 12.5 \end{array}\right\} r_o = \_\_\_\_\_\_$$

$r_o = r_2 + \delta$

Q.16 (C) 1680

Q.17 (a) (d) (C)

(b) (d)

Q.18 C

Q.19 B

Q.20 C

Q.21 A

Q.22 A

Q.23 A

Q.24 B

Q.25

$$Q = \frac{6\times 10^3}{10\times 60}$$

$$A = A_c = 10\,cm^2 = 10\times 10^{-4}\,m^2$$

$$l = \delta = 1m$$

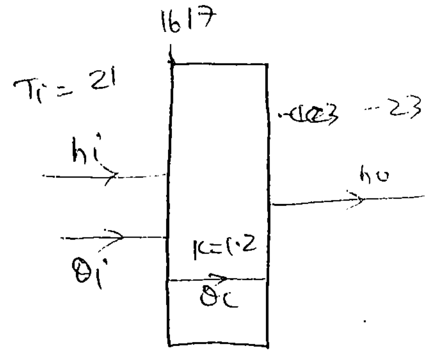
$$Q = \frac{\Delta T}{\left(\frac{d}{KA}\right)}$$

$$\Delta T = Q \times \frac{d}{KA}$$

Q.25 (d) 2.5

Q.26 0.407

inside wall temp ≥ dew point temp.



$$Q_i = Q_c$$

$$\frac{(21 - 10.17)}{\frac{1}{h_i \times A}} = \frac{\Delta T}{\left(\frac{d}{KA}\right)}$$

~~d = ?~~

$$h_i(21 - 10.17) = (10.17) - (-23)\frac{k}{d}$$

$d =$

Q.27 A

Q.28 C

29 C

30 B

31 C

32 A

33 C

34 D

35 D

36 D

37 B

38 A

39 D

40 D

Page 90 FINS

Q.1 C

Q.2 D

Q.3 B

Q.4 D

Q.5 D

Q.6 B

Q.7 A

Q.8 C

Q.9 C

Q.10 A

Q.11 B

Q.12 A

Q.13 B

97 Heat Exchangers

Q.11 B

Q.12 B 8%

Q.13 C

Q.14 C 1.22

Q.15 D

Q.16 A

Q.17 B

Q.18 B

Q.19 A

Q.20 C

Q.21 C

Q.22 D

Q.23 C AV RX

Q 24 Condensers

Q 25. A

Machining ~~Machin~~

Page 21

Q.19 – Q.25

Q.20

Q.21 –
(I)
(II)

(B)

Q.22 (B)

23 (B)

24 B

25 A

26 B

27 C

28

29 D

30 D

31 C

32 B

33 D

34 D

35 D

36 A

37 C

38 D

39 – B

40 – C

41 – B

42 – D

43 – A

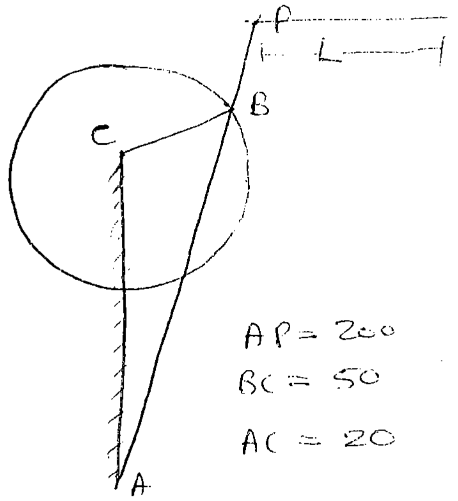
44 – A

45 – C

~~46~~

~~47~~ –

machinis
Q46



AP = 200
BC = 50
AC = 20

$L = 2\,AP\left(\frac{BC}{AC}\right)$

An 1m/min

Q(47) D

48 (a) ~~A~~ ~~B~~ (C) A✓ B✗

(49) A✗ B✗

(50) (C) A✓ B✗

(51) Arithmetic progren

(52)

(53) B

(54)

7 – 1pm – IM OR

2 – 4pm – DF

4:30 – 6 Num note

6 – 8 – Calculu

anreddy567@yahoo.co.in

175/–