

(238)

-: HAND WRITTEN NOTES:-

OF

238

MECHANICAL ENGINEERING

(1)

-: SUBJECT:-

MATERIAL SCIENCE &
PRODUCTION ENGINEERING

32/4

②

WWW.GATENOTES.IN



Phase Diagram

Phase diagram is a plot on temp. Composition space showing the stability of various phases.

In other words phase diagram tells us what is the melting point of an alloy at a particular composition.

Phase: chemically same, mechanically separable, Physically distinguishable degrees of Freedom: No of independent variable to define a State.

Component (C)

Gibbs phase Rule

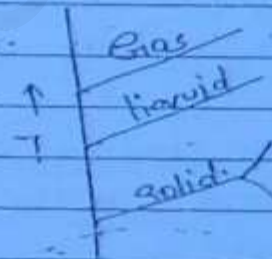
$$C + 2 = F + P$$

(3)

Phase diagram depend on No of Component:

- (1) $C=1$ (unary phase diagram)
generally plotted on T-P diagram.

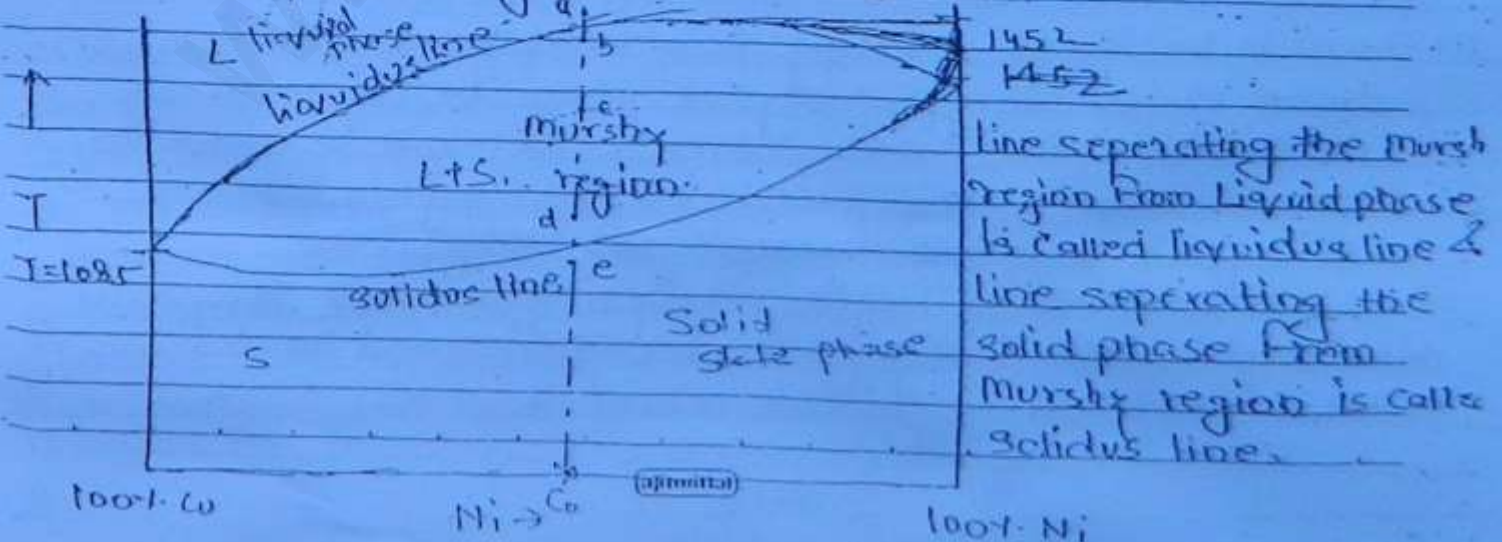
WWW.GATENOTES.IN

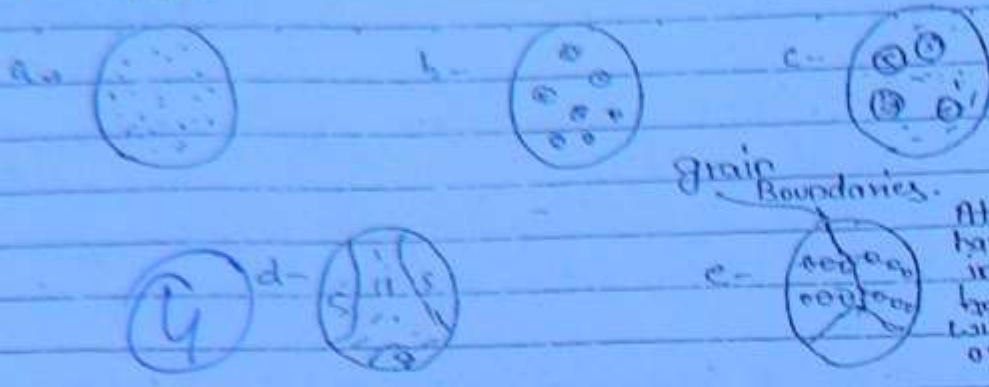


- (2) When No. of Component $C=2$
(Binary phase diagram)

It is divided into sub category:

- (A) Materials which are completely soluble into liquid as well as solid state. These phase diagram are also called isomorphous diagram. ex: Cu-Ni





Cu-Ni mixes with each other at the atomic level both in liquid as well as in solid state & produces a single phase;

has to

Hume-Rothery condition ~~should~~ be satisfied for the alloy formation. These conditions are

- (1) The atomic size difference should be less than 15-1.
- (2) Valency of both the material should be same.
- (3) Electronegativity difference should be min.

upon cooling a sample of Cu-Ni with 60% of Ni along line a to e, following transformation are observed →

At point a → entire sample will be in the liquid state. As soon as the temp. slightly decreases below the liquidus line to point b, solid will nucleate at no. of places due to mushy zone. By decreasing the temp. mass fraction of solid phase is increasing. As soon as the temp. slightly decreases below the solidus line entire sample will be converted into the solid phase. So in such alloys there is no fixed melting point and the solidification takes place over a range of temp. The regions where two solidification front meets there will be orientation mismatch called grain boundaries. At the grain boundary the grain length bond length will be higher. Larger the bond length easily it can break. So atm. oxygen attacks the grain boundaries and corrode the material.

To give the corrosion resistance to material Cr is added. It reacts with the atm. oxygen and produces Cr_2O_3 which gets accumulated over the grain boundaries protecting the atm. from further oxidation. In stainless steel there is 16% Cr and 8% Ni which is a phase stabilizer (Austenite)

For Ni

mass fraction of Solid = m_s

mass fraction of liquid = m_l

$$m_s + m_l = 1 \quad \text{--- (I)}$$

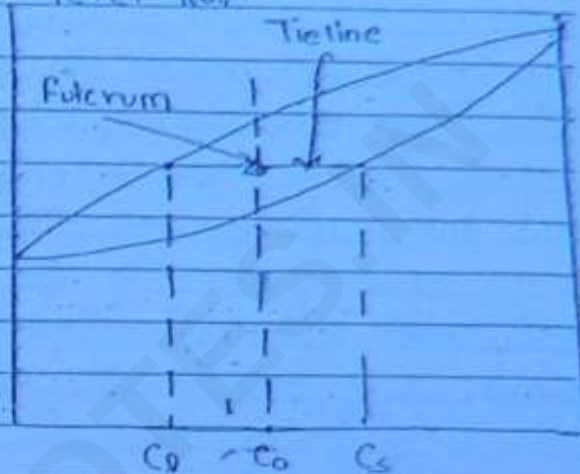
$$m_s \times C_s + m_l \times C_l = C_0 \quad \text{--- (II)}$$

on solving this

$$m_s = \frac{C_0 - C_l}{C_s - C_l} \quad \text{--- (III)}$$

$$m_l = \frac{C_s - C_0}{C_s - C_l}$$

Lever Rule



Cold working $< 0.4 T_m$ (melting point in K)
 Warm working $0.4 T_m$ to $0.6 T_m$
 Hot working $> 0.6 T_m$

when temp. decreases metal become brittle.

By drawing no. of tie lines in the mushy zone following observation can be made

1: As the temp. decreases mass fraction of solid phase also increases.

2: % of Ni in the Solid phase keeps on decreasing and approaches towards the overall composition C_0

Upon slow cooling the sample, a phenomenon called diffusion will take place which homogenise the % of Ni in the solid phase. every 10°C increase in temp. diffusion gets doubled. Upon rapidly cooling the sample, since there is not sufficient time for the diffusion, Ni freezes at its location and there is concentration gradient of Ni within the grain boundary. Material on the grain boundaries will have lower % of Ni and according to phase diagram such material will have lower melting point. upon warm or

To Making a phase diagram, generally we keep pressure constant because pressure is a degree of freedom and we make it constant. So available degree of freedom will become $F^P = f - 1$.

α phase is solid solution of tin in lead and β phase is solid solution of Pb in Sn. The line on the phase diagram which separates a single phase with a mix of solid phases is called Solvus. The point at which liquid converts into 2 different solid is called eutectic point which is invariant. 3 phases are will be in equilibrium at any invariant point.

Q: Determine the mass fraction of phases present in an alloy of Sn & Pb with 35% Sn in it at a temp of 184°C .

Sol: $m_L = m_\alpha = \frac{62 - 35}{62 - 18} = 0.61$ (7)
 $m_\beta = 1 - m_\alpha = 0.39$

Q: if temp 182°C $m_\alpha = \frac{97 - 35}{97 - 18} = 0.784$
 $m_\beta = 1 - m_\alpha = 0.215$

Q: Determine the mass fraction of phases present in an alloy of Sn & Pb with 35% tin at 100°C at this temp.

Solid solubility of Tin in Pb is 10% and Pb in Tin is 2%. if the density of Pb and Tin at this temp are 8.28 g/cc and 11.56 g/cc determine the volume fraction of the phases.

Sol: $m_\alpha = \frac{98 - 35}{98 - 10} = 0.715$
 $m_\beta = 1 - m_\alpha = 0.284$

Volume Fraction

$\alpha \rightarrow 90\% \text{ Pb} + 10\% \text{ Sn}$

$\beta \rightarrow 98\% \text{ Sn} + 2\% \text{ Pb}$

$$\frac{1}{\rho_\alpha} = \frac{0.9}{8.28} + \frac{0.1}{11.56} = 8.5211$$

$$\frac{1}{\rho_\beta} = \frac{0.02}{8.28} + \frac{0.98}{11.56} = 11.469$$

$$V_v = \frac{m_v}{\rho_v} = \frac{0.715}{8.5217} = 0.0839$$

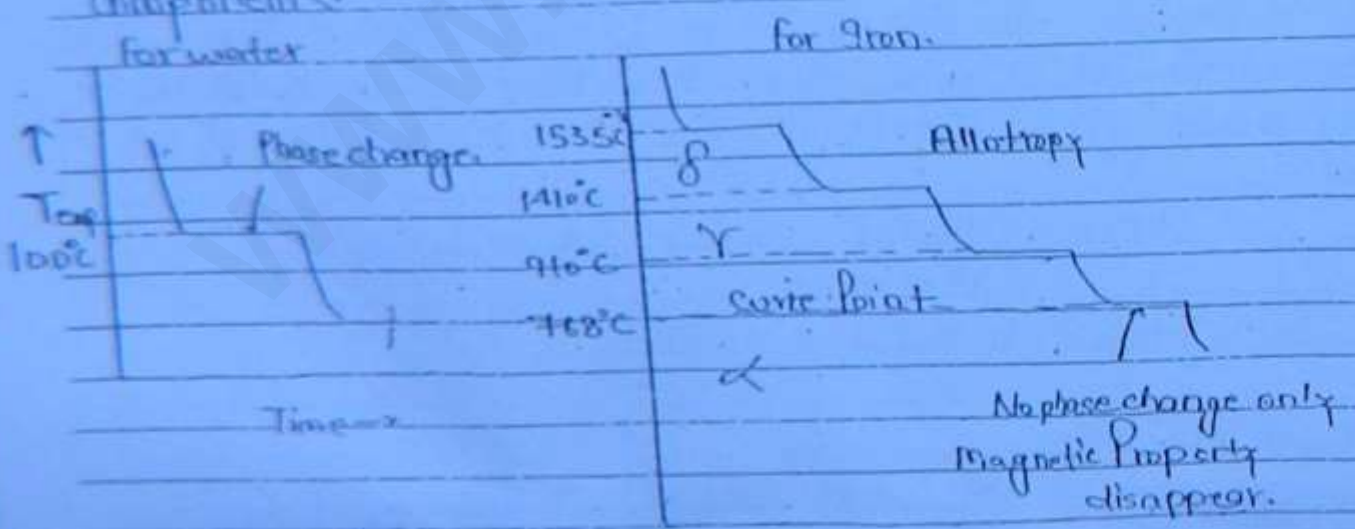
$$\frac{m_v}{\rho_v} + \frac{m_p}{\rho_p} = \frac{0.715}{8.5217} + \frac{0.284}{11.469} = 0.0839 + 0.02479 = 0.10869$$

$$V_p = 1 - V_v = 0.89131$$

For Binary Isomorphous Systems of Copper-Nickel System

In ordinate $\rightarrow$ Temperature
 Abscissa $\rightarrow$ Ni. By weight percent (Bottom)
 By atom percent (Top).

For this system, liquid solid solution consisting of both Cu and Ni atoms. At temp below about 1080/1085°C, copper and nickel are mutually soluble in each other in the solid state for all compositions. This complete solubility is explained by the fact that both Cu and Ni have the same crystal structure (FCC), Nearly identical atomic radii and electronegativities and similar valences. The copper-nickel system is termed isomorphous because of this complete liquid and solid solubility of the two components.



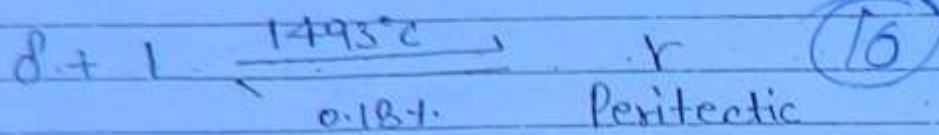
- (1) Paramagnetic
- (2) Diamagnetic
- (3) Ferromagnetic

Time $\rightarrow$

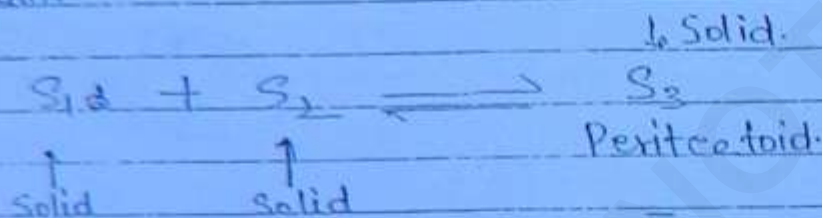
the microstructure. It is called Pearlite.

Pearlite is not a phase but it is a phase mixture of ferrite and cementite. and only Eutectoid composition can produce pearlite.

Similarly Eutectic decomposition will also come out in the form of Alternate plates of Austenite & cementite. This phase mix is called Ledeburite. Ledeburite.



Material in which there is large difference in their melting point, peritectic reaction will appear on their phase diagram.



Material with

$n - 0.3\% \text{ C}$ low C Steels.
(mild steel)

$0.3 - 0.7\% \text{ C}$ medium C Steel

> 0.7 High C Steel

Small Quantity of S will be present in iron in the form of impurity. S reacts with Fe and produces FeS.

Being a foreign material, it will be pushed towards the grain boundaries. FeS is having a very low melting point so upon warm working of material

FeS will meltout producing large no. of cracks which lead to Brittle fracture. This phenomena is

called hot shortness. To avoid it small quantity of

Mn is added in the material. Mn captures sulphur before S capture iron and MnS is having a

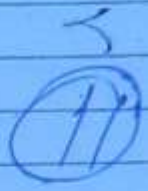
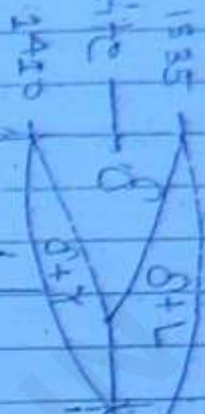
very high melting point. The shear strength of

MnS is very low and it improves the machinability of the material by decreasing the power consumption.

Date

Austenite $\rightarrow$

Ferrite $\rightarrow$



Ferrite $\rightarrow$

Solvus line

Before Hypoeutectoid

Steel

After Hypoeutectoid Steel

0.02

0.81

2.14

✓ C $\rightarrow$

4.81

6.67% Fe₃C
Cementite

Eutectoid point

$\pm 25^\circ\text{C}$

Hypoeutectic Cast Irons

Cast Irons

$\gamma + \text{Fe}_3\text{C}$

1150°C

Eutectic point

$L + \text{Fe}_3\text{C}$

$\alpha + \text{Fe}_3\text{C}$

Hypereutectic C.I.

In machining, when C is as high as 1.2%, the material becomes extremely hard and strong called Hadfield steel which is used in heavy duty application like bulldozer rolls etc. Along with other elements around 4 to 6% Mn is added in the materials of railway tracks.

During the solidification steel is having a tendency to capture O_2 from oxygen. The material is deoxidised by adding Si into it. When the deoxidisation process is complete it is called killed steel & when deoxidisation process is partial it is called semikilled steel.

Steel designation

(12)

X X (X X) gives % of C in steel
↑ ↓
major alloying element

2 X X X $\rightarrow$ Ni-steel

3 X X X $\rightarrow$ Ni-Cr

3 1 X X $\rightarrow$ Hadfield

4 X X X $\rightarrow$ Mo

5 X X X $\rightarrow$ Cr

✓ More than 6.67%

(1) Gray Cast Iron:

It is the cast iron in which C is present in the free or flake form. The major application is in making M/C beds, piston rings etc.

(2) White cast iron:

If all the C present in the C.I. appears to be in the combined form it is called white cast iron.

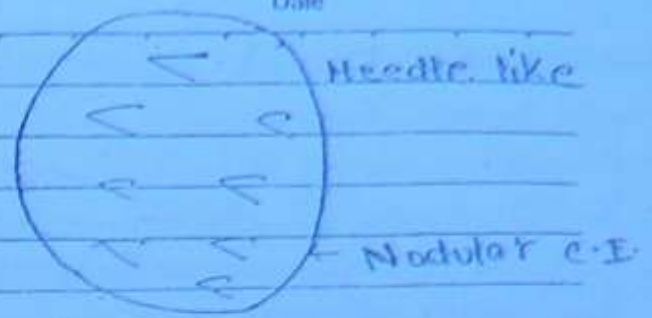
Cast iron of such composition if in white it will normally freeze at gray but forced to freeze as white by rapid cooling called chilled cast iron. Application of these cast irons is in making ductile cast iron.

Three form of C.I.

(1) Malleable C.I.

(3) Malleable C.I.

(4) Spheroidal C.I.


$$\text{Equivalent} = 1 \cdot C + \frac{1}{3} (1 \cdot Si + 1 \cdot P)$$

$$= 1 + \frac{1}{3} (1 + 1)$$

$$= 1 + \frac{2}{3}$$

$$= \frac{5}{3}$$

3.3-1. C will behave like 4.3-1. C

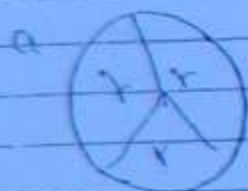
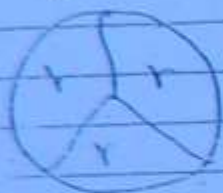
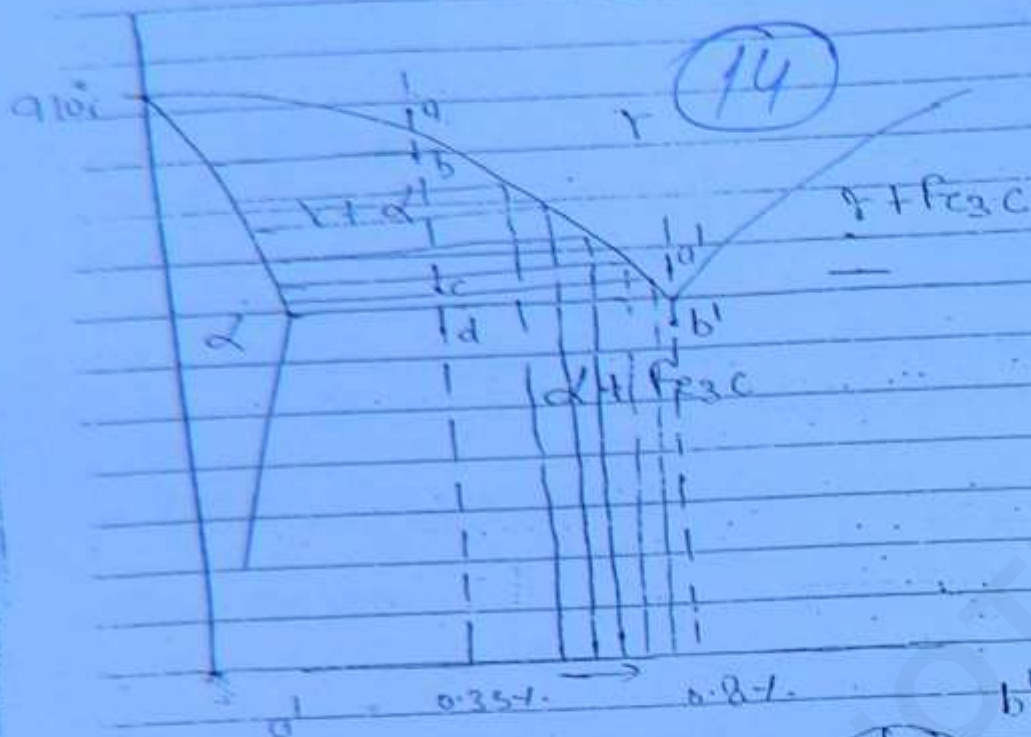
∴ Si shift the iron-C diagram towards left.

Si is a graphitizing agent and it shifts the eutectic point towards left as a result of it that graphite discharges at a much lower % of carbon. Since the graphite is having low density it comes over the surface of liquid iron in the red hot condition and sparks. This phenomenon is called Kish.

	Gray C.I.	White C.I.
C	2.5-4	1.8-3.6
Si	1-3	0.5-1.9
Mn	0.4-1	0.25-0.8
S	0.025-0.5	0.06-0.2
P	0.05-1	0.06-0.18

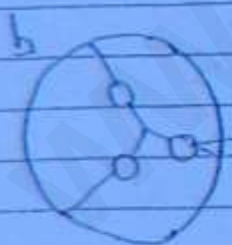
Developments of microstructures in steel

Date

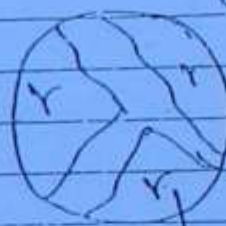


Eutectoid Ferrite

Pearlite



Proeutectoid α
(Pro-α)



Pro-α
0.8% C



Pro-α

Pearlite

Eutectoid composition only produces pearlite structure. In case of hypoeutectoid steel with 0.35% Carbon at point A shown in figure it will all be ^{the} austenite within the grain with 0.35% Carbon.

Upon decreasing the temp. slightly to point B, ferrite phase appears in the microstructure. Being the foreign material it will be accumulated at the grain boundaries.

This ferrite which appears before eutectoid temp. is called proeutectoid ferrite. Upon decreasing the temp. of sample from point B to C following transformations are observed by plotting different tie lines.

(1) Mass fraction of proeutectoid ferrite is increasing.

(2) At point C there are canals of $\text{Pro } \alpha$ at the grain boundaries.

(3) % of Carbon in Austenite within the grain is increasing and approaching towards the eutectoid composition.

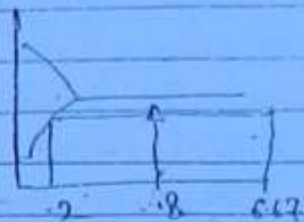
Upon decreasing the temp. slightly to point D, the austenite within grain will convert into pearlite. Ferrite present in the pearlite structure is called eutectoid ferrite and summation of eutectoid ferrite and proeutectoid ferrite is called total ferrite.

(13)

Q.1 Calculate the mass fraction of $P_{Fe\alpha}$, eutectoid α and total ferrite in a steel sample with 0.35% Carbon.
 Sol. Q.2: Calculate the mass fraction of Ferrite & Cementite in pearlite.

Sol. 2: $m_{\alpha} = \frac{6.67 - 0.8}{6.67 - 0.02} = 88.3\%$

$m_{Fe_3C} = 1 - m_{\alpha} = 11.7\%$



Sol. 1:

$m_{P_{Fe\alpha}} = \frac{0.8 - 0.35}{0.8 - 0.02} = 0.5769 \approx 57.69\%$

$m_{Total\alpha} = \frac{6.67 - 0.35}{6.67 - 0.02} = 0.9503 = 95.03\%$

$m_{eutectoid\alpha} = 0.9503 - 0.5769 = 0.3734 \approx 37.34\%$

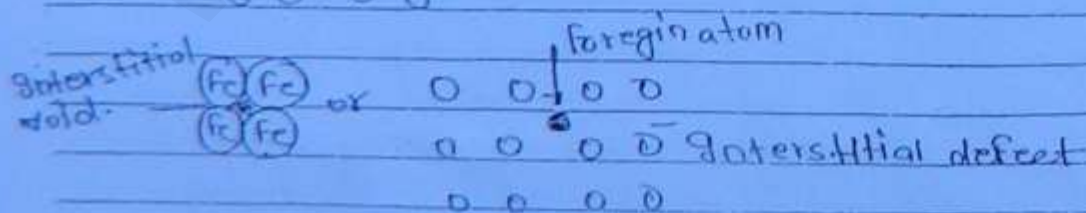
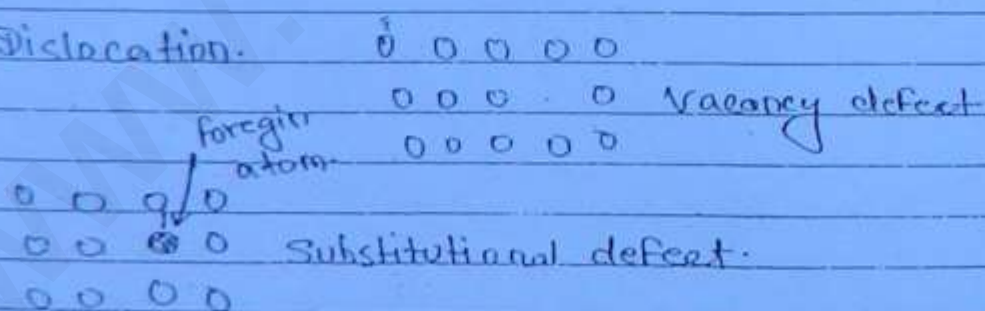
DISLOCATION.

(i) Point

(ii) Line $\left\{ \begin{array}{l} \text{edge dislocation.} \\ \text{screw dislocation.} \end{array} \right.$

(iii) Surface

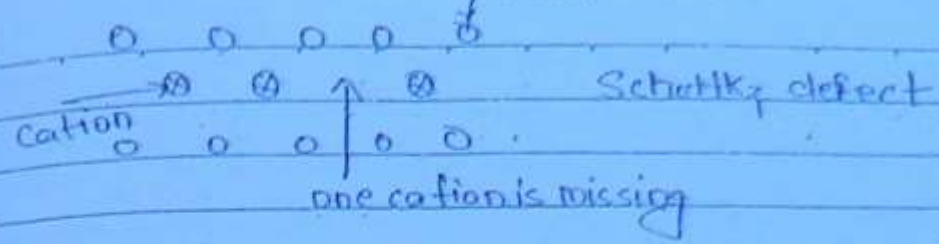
Point Dislocation.



Some atom. $\rightarrow$ Frankle defect.

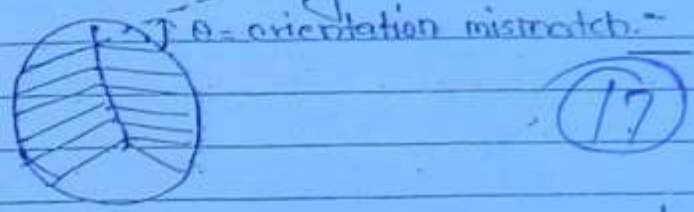
$\rightarrow$ Same atom occupies interstitial gap.

Cation
Anion



Surface defect:

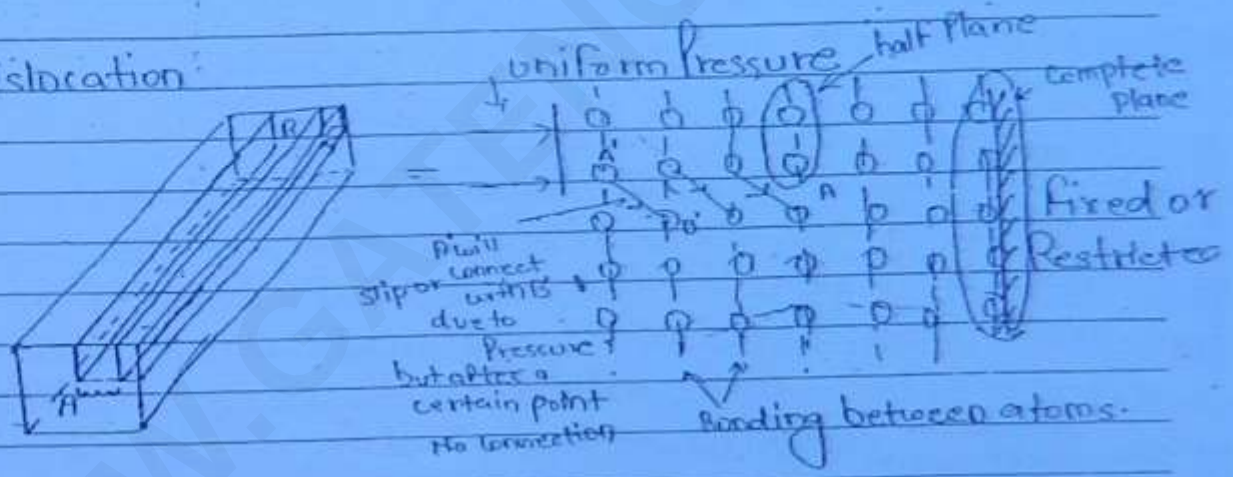
(1) Grain Boundary defect (Mismatch in orientation):



(2) When the mismatch is $\theta \sim \frac{1}{2}$ to 1° Tilt Boundary defect

(3) When the orientation of one boundary is mirror image of other orientation of another boundary it is called Twin Boundary defect.

Edge Dislocation

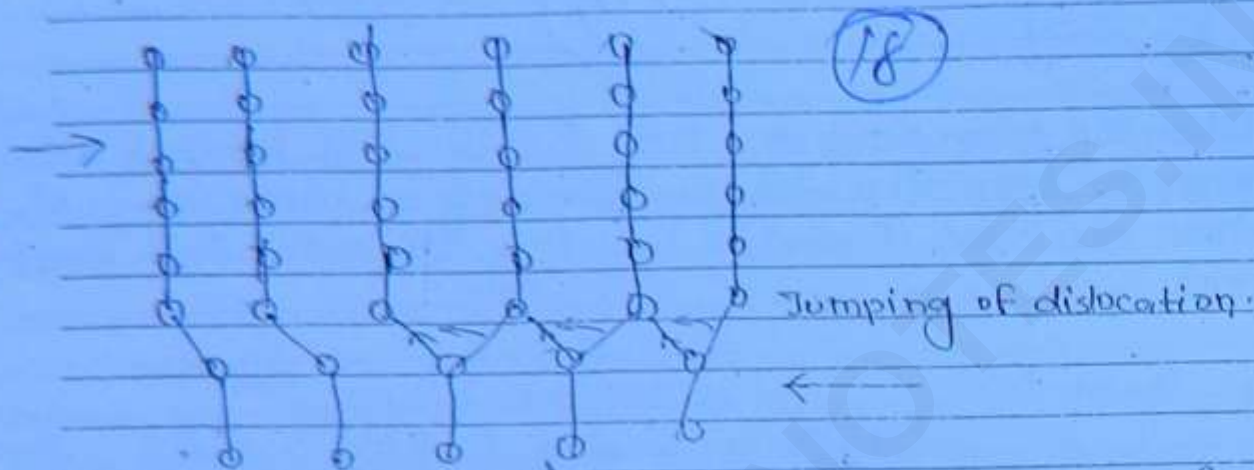


- Burger vector is Perpendicular to the edge dislocation line.
- Burger vector extra half plane is present so the interstitial gap is more.

Although millions of dislocations are already there within the material but to understand the concept let us assume that there is a perfect material without any defect. one face of the material is restricted to deform and on the opposite face pressure is applied on the 50-1 area. when the pressure exceed beyond a certain value, plastic deformation will take place in the direction of applied pressure. unit plastic deformation is called burger vector. Due to the applied pressure slipping will take place in the atom.

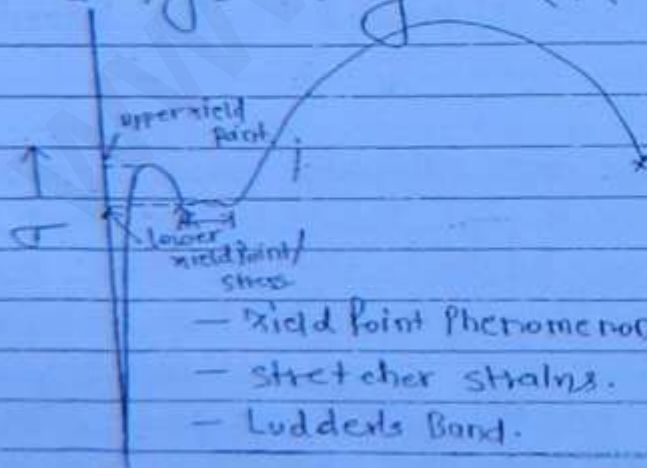
And there will be a boundary AB as shown in Figure 1.10. Slipped and unslipped region called edge dislocation. It can be seen from the diagram that at the edge dislocation site there will be an extra half plane and interstitial void will be larger.

In edge dislocation Burger vector is perpendicular to dislocation line.

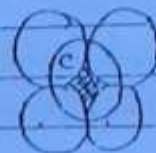
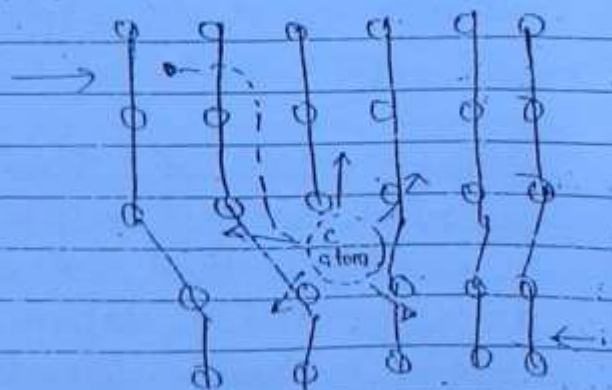


There are millions of dislocation in real material & upon applying the load dislocation in that direction starts moving within the material. When the dislocation comes out we say that plastic deformation has begun in the material. Any activity which makes the dislocation ~~more~~ difficult ~~in~~ will increase the strength. movement

Strengthening Mechanism.



- Yield Point Phenomenon.
- Strain hardening.
- Ludders Band.



Carbon is an interstitial impurity in iron. But the interstitial void is much smaller than the size of carbon atom. To decrease the strain carbon diffuses and settles down at the dislocation site. This carbon rich atmosphere at the dislocation site is called

Cottrell atmosphere. This produces strain field at the dislocation site and to jump the dislocation site it requires extra stress. That is why upper yield point appears on stress-strain diagram. At the new location since there is not Cottrell atm. C has to diffuse. Smaller stresses are required to keep the dislocation moving. That is why lower yield point phenomenon appears in the material. (19)

Yield Point phenomenon does not appear in medium and high carbon steels because carbon is not only present at the dislocation site but also on the interstitial site. So when the dislocation jumps to the new position C is ready to diffuse at the new site.

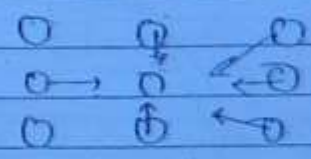
Upon unloading the sample from the region of strain hardening & reloading again yield point phenomenon does not appear. But after waiting for a brief period of time yield point phenomenon again reappears because of diffusion of C atoms at the new dislocation site. This time period after which yield point phenomenon reappears in the material is called strain aging time. Strain rolling is performed over the material to maintain the strain aging time.

STRENGTHENING MECHANISM

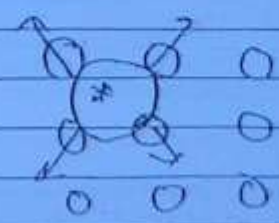
(1) Alloying:

Interstitial

Substitutional



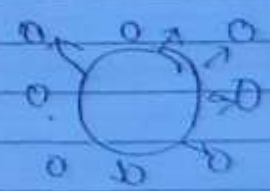
Tensile



Compressive Stress

Small

Big



Compressive

Nitride cases are harder than Carbide cases (ajmittal)

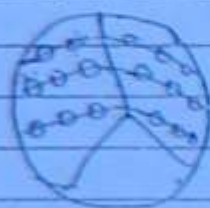
Alloying the element either produces interstitial or substitutional impurity. Interstitial void is always smaller than the impurity material. So it creates compressive strain within the material. If the atomic size of substitutional impurity is smaller, it produces tension strain field and if the size is bigger, it produces compressive strain. These strain fields create barriers in the movement of dislocation. That is why strength increases. Larger the strain field created by impurity atom, larger will be the increase in strength of the material.

(20)

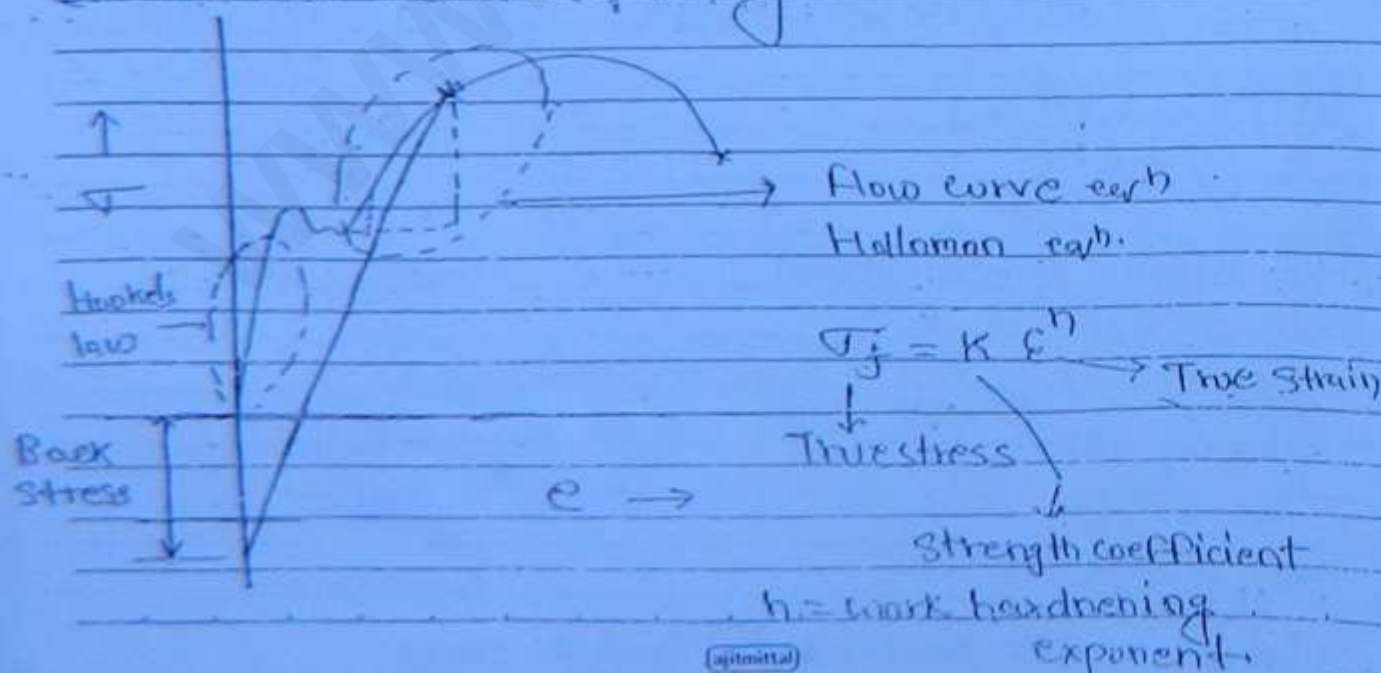
(2) Grain Refinement:

Grain Boundary: Region of orientation mismatch.

Grain boundaries are the barriers in the movement of dislocation because it has to change its direction after reaching the grain boundary. So finer is the grain size, more obstacles will appear in the movement of dislocation, hence better will be the strength, but lower will be the corrosion & creep resistance.



(3) Strain or Work Hardening:



Blue Brittle phenomenon: If Cr is present as an impurity, at elevated temp Cr moves faster than the dislocation, strike the dislocation.

Dislocation density = No. of dislocation / length. (2)

Once the stress crosses the yield strength dislocation density increases. These dislocations pile up at the grain boundary & it creates a dislocation forest. Dislocation-Dislocation interactions are repulsive in nature so the dislocation forest creates back stress which increases the strength of material. How much dislocation multiplication takes place is the property of material. Upon unloading the specimen from the work hardening region and reloading in opposite direction, back stress is now to support the movement of dislocation as a result of that yield point appears prematurely this phenomenon is called Bauschinger effect.

If there is impurity of V or Cr, at elevated temperature of Cr becomes more than the dislocation. So the atom breaks the dislocation into many parts this increases the density of dislocation & hence ↑ the strength this phenomenon is called Blue Brittle phenomenon.

Flow curve equation:

$$\sigma_f = K \epsilon^n$$

$$\sigma_0 = \frac{P}{A_0}$$

A_0 = original Area.

$$\epsilon = \frac{dl}{l_0 + \text{original length}} = \frac{l - l_0}{l_0} = \frac{l}{l_0} - 1$$

$$\Rightarrow \frac{l}{l_0} = \epsilon + 1$$

(True stress)

$$\sigma_f = \frac{P}{A}$$

Instantaneous



$$P d\epsilon = \frac{dl}{l \text{ instantaneous}}$$

$$\int_0^\epsilon d\epsilon = \int_{l_0}^l \frac{dl}{l}$$

$$\epsilon = \left[\ln l \right]_{l_0}^l$$

$$\epsilon = \left[\ln \frac{l}{l_0} \right]$$

$$\Rightarrow \boxed{\epsilon = \ln(\epsilon + 1)}$$

$$\sigma_j = \frac{P}{A_0} \times \frac{A_0}{A}$$

$$\sigma_j = \sigma_0 \times \frac{A_0}{A}$$

$$A_0 l_0 = A l$$

$$\frac{A_0}{A} = \frac{l}{l_0}$$

(22)

$$\boxed{\sigma_j = \sigma_0 (e + 1)}$$

$$\sigma_j = \frac{P}{A}$$

$$P = A \times \sigma_j$$

$$\frac{dP}{d\varepsilon} = \sigma_j \frac{dA}{d\varepsilon} + A \frac{d\sigma_j}{d\varepsilon} \quad \text{--- (I)}$$

$$= \quad V = A l = \text{constant (Assumption)}$$

$$\frac{dV}{d\varepsilon} = \frac{d}{d\varepsilon} (A l)$$

$$0 = \frac{dA}{d\varepsilon} \cdot l + A \cdot \frac{dl}{d\varepsilon} \quad \text{--- (II)}$$

divide (II) By l

$$0 = \frac{dA}{d\varepsilon} + \frac{A}{l} \frac{dl}{d\varepsilon} \quad (\because d\varepsilon = \frac{dl}{l})$$

$$\frac{dA}{d\varepsilon} = -A \quad \text{--- (III)}$$

put (III) in (I)

$$\frac{dP}{d\varepsilon} = -A \sigma_j + A \frac{d\sigma_j}{d\varepsilon} \quad \text{--- (4)}$$

at ultimate tensile stress point

$$\frac{dP}{d\varepsilon} = 0 \quad \text{[Condition]}$$

(optimal)

$$0 = -\cancel{A} \sigma_f + \cancel{A} \frac{d\sigma_f}{d\varepsilon}$$

$$\frac{d\sigma_f}{d\varepsilon} = \sigma_f \quad \text{--- (5)}$$

Flow curve eqⁿ.

$$\sigma_f = K \varepsilon^n$$

$$\frac{d}{d\varepsilon} [\sigma_f = K \varepsilon^n]$$

$$\frac{d\sigma_f}{d\varepsilon} = n K \varepsilon^{n-1} = n K \varepsilon^{n-1} \times \frac{\varepsilon}{\varepsilon} = \frac{n K \varepsilon^n}{\varepsilon}$$

$$\frac{d\sigma_f}{d\varepsilon} = \frac{n \sigma_f}{\varepsilon} \quad \text{--- (6)}$$

Compare (5) & (6)

at UTS

$$n = \varepsilon$$

Ex. 2006.

at UTS = 400 MPa.

-/- elongation = 35% = 0.35

$$\sigma_f = K \varepsilon^n$$

400

$$\frac{l_f - l_i}{l_i} = 0.35$$

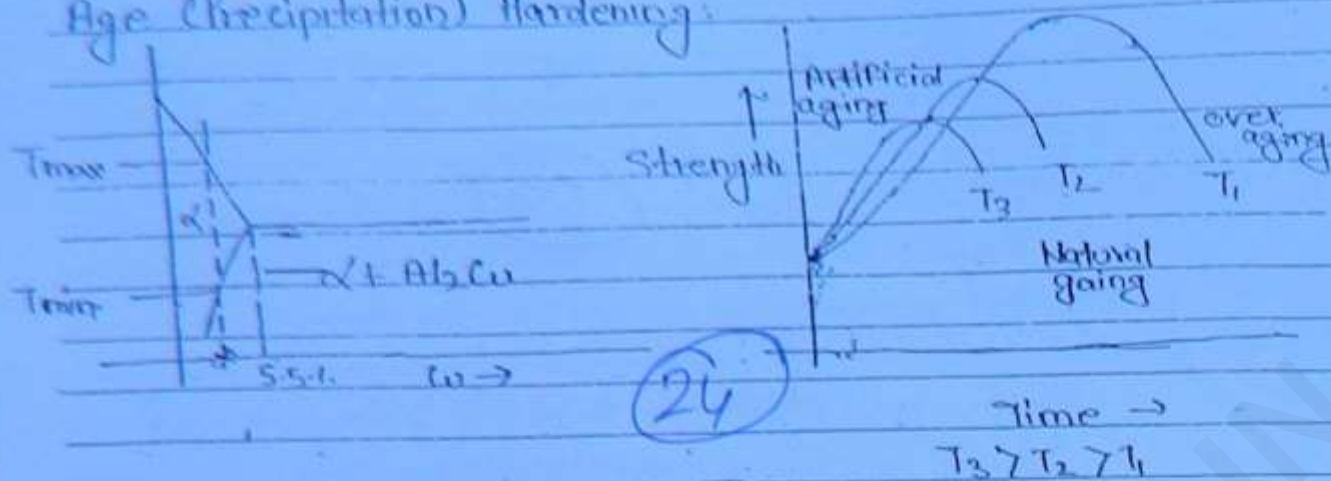
$$\varepsilon = \ln(e+1) = \ln(1.35) = n = 0.3$$

$$400 \times 400 = K (0.3)^3$$

$$540 = K (0.3)^3$$

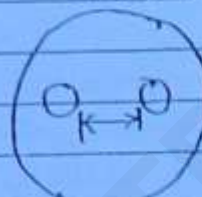
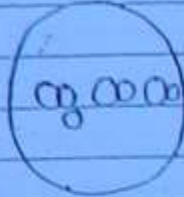
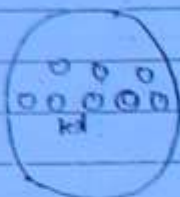
$$K = 774.92 \approx 775$$

Age (Precipitation) Hardening:



24

Time $\rightarrow$
 $T_3 > T_2 > T_1$



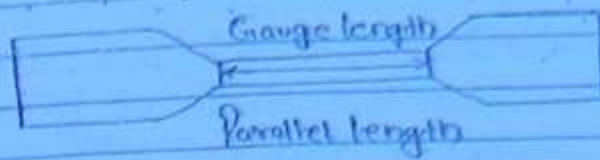
overaging.

A Sample of Aluminium with less than 5.5% Cu is taken and heated to a temp. at which a uniform phase α appears. This sample is thus quenched in water and as a result of that Cu gets trapped within water Al structure. Since it is an unstable phase copper start coming out of the structure and produces precipitates of Al_2Cu . This precipitate creates an obstacle in the movement of dislocation this increases the strength of materials.

As the time passes more and more precipitate nucleate and average distance between precipitates decreases which increases the strength further. Due to limited amount of Cu, precipitation will stop at a particular point and smaller precipitates ^{are} combined together to form a bigger precipitate. This increases the distance between two precipitates and hence there will be decrease in strength. This stage of material is called over aging.

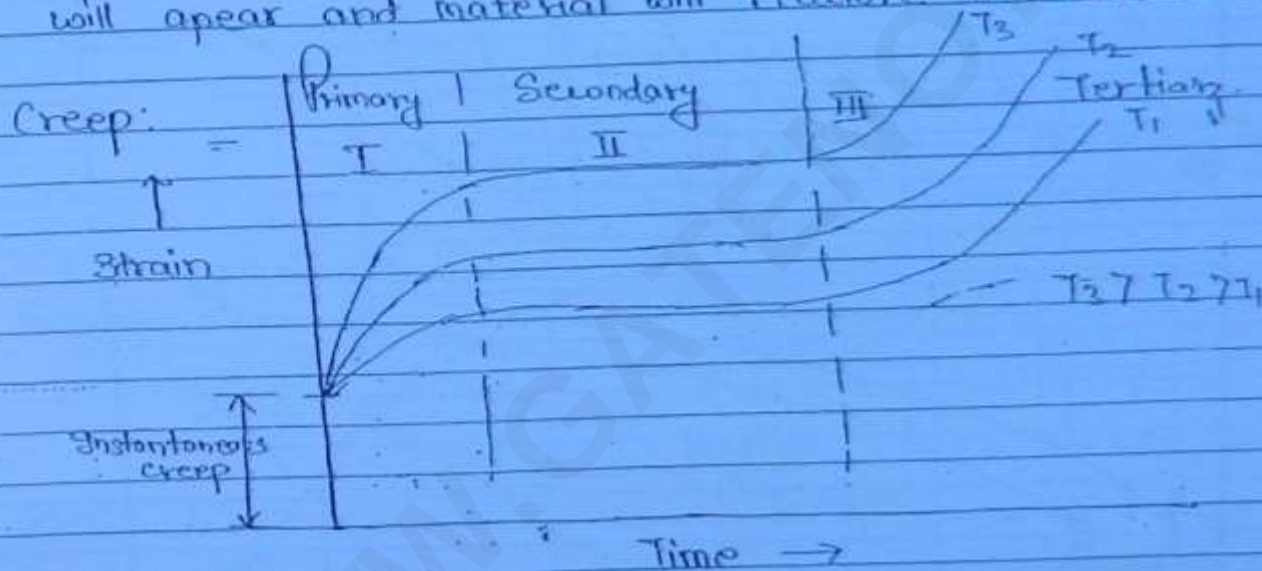
Aging observe at elevated temp. is called artificial aging and both nucleation and combination of precipitate will accelerate. So at a temp. increases mat. will become stronger in smaller time but the peak strength will decrease.

Tensile test



(25)

Gage length is marked over the parallel length for observation. Upon loading the UTM specimen the parallel length keeps on increasing, cross section keeps on decreasing. The increase in stress in $\parallel$ length are compensated by work hardening but there will be a point of weakness within the material at which sufficient dislocation multiplication has not been taken place at this point a unique neck will appear and material will fracture like that of cup and cone.



(i) Work hardening.

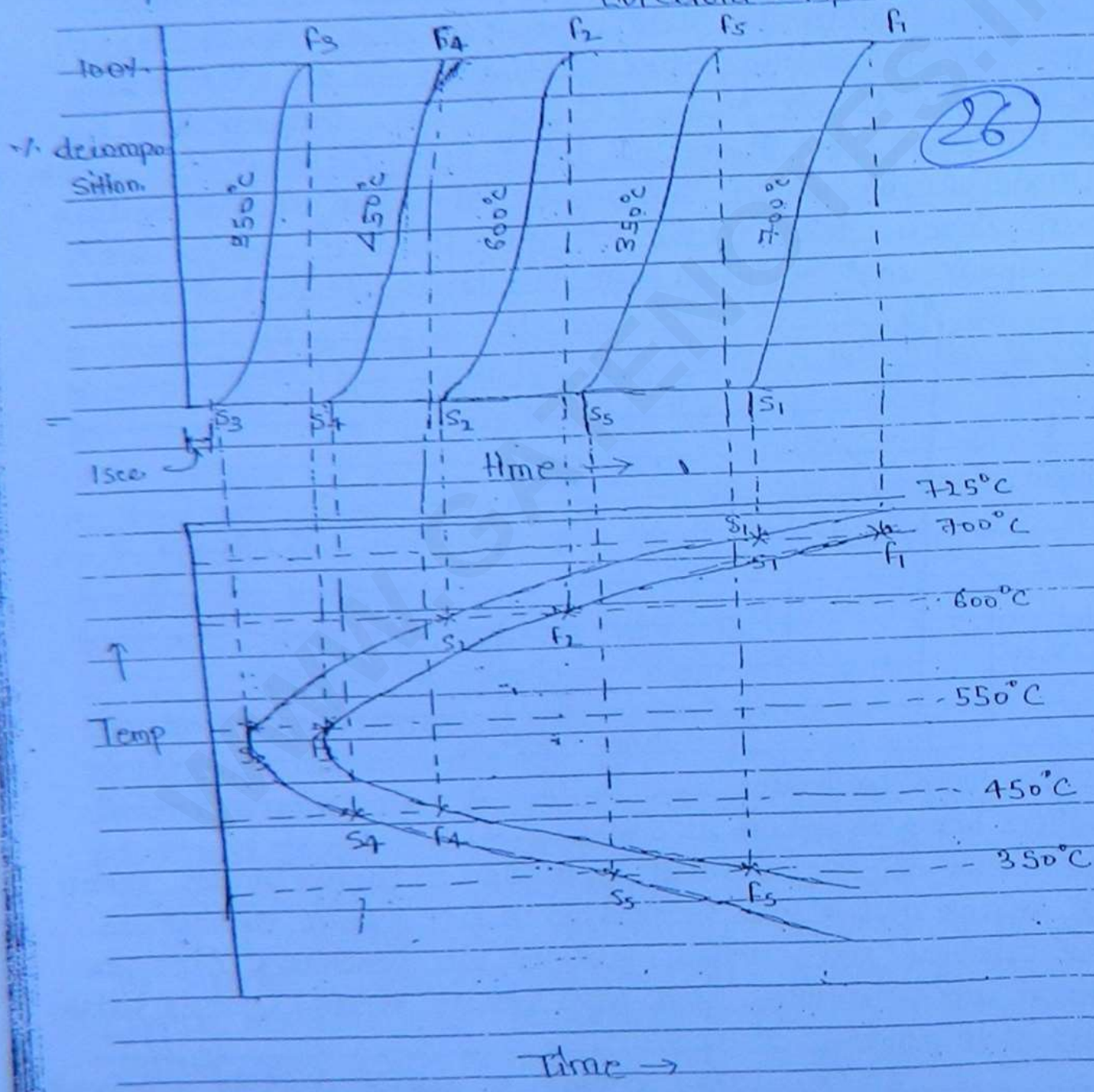
(ii) Recrystallization.

As soon as the material is loaded instantaneous creep will appear and it will be similar to the elastic strains. In the primary creep region material is becoming stronger due to work hardening and as a result of that strain rates are going down.

In secondary region a balance will be achieved between work hardening and recrystallization so that strain rates will be almost constant but there will be a limit upto which work hardening can take place and slowly

recrystallization phenomenon takes over and strain rate suddenly increases and the material breaks.
Grain boundary material is having a tendency to flow at elevated temp. So finer the grain structure, lower will be creep resistance.

Temp-Time Transformation Diagram (T-T-T diagram) Austenoid Composition.

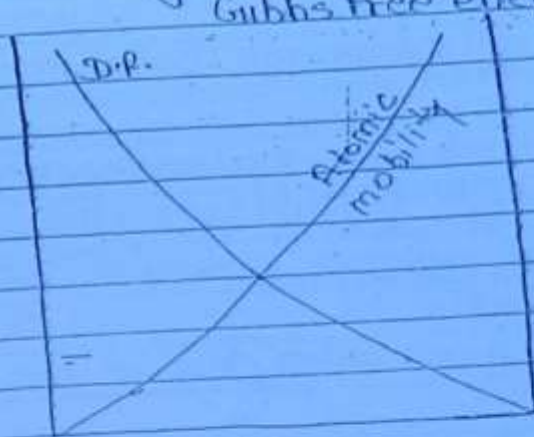


Sample of eutectoid composition are taken to a temp at which austenite is stable. Three samples are quenched to different temp. and transformation of austenite was observed. It was found that when quenching temp is very close to 725°C for a considerable period of time it was austenite phase only. This period is called incubation period. By decreasing the quenching temp. incubation period decreases and when quenching temp. goes below 550°C incubation period started increasing again. This results to formation of C curve.

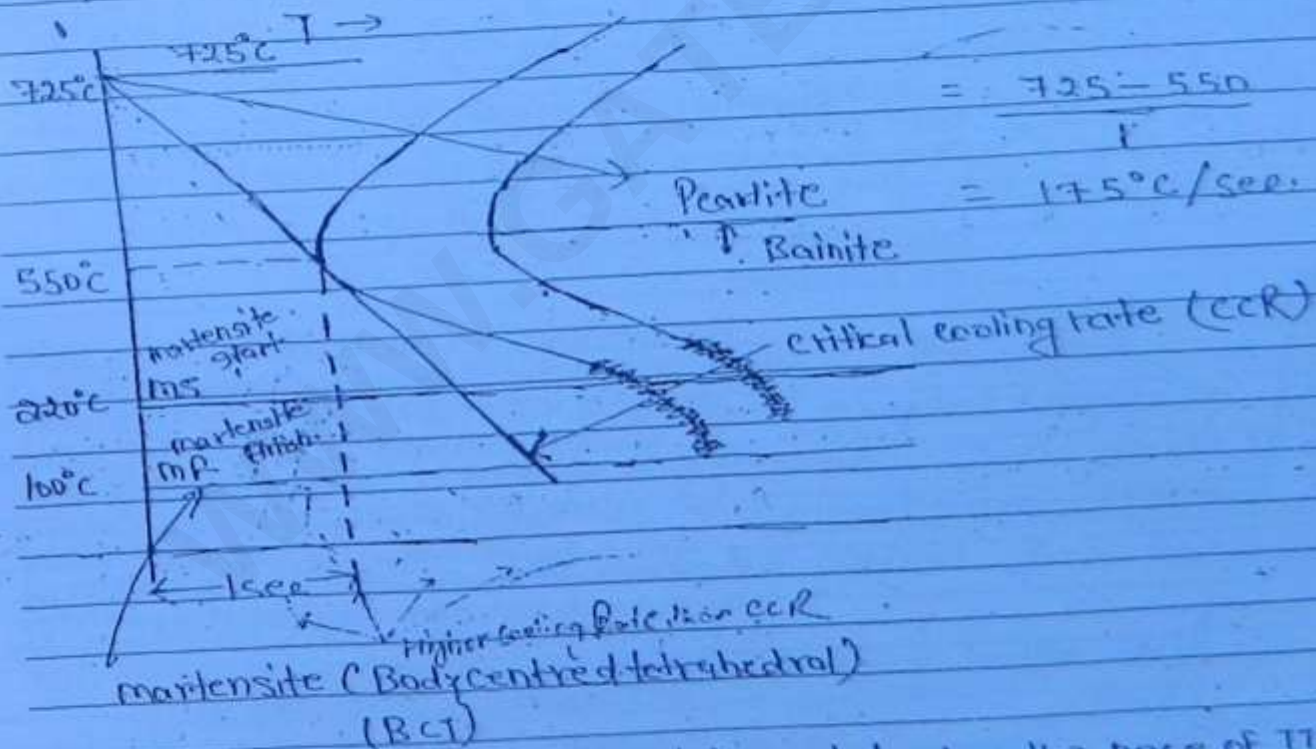
(1) Driving force

(2) Diffusion or Atomic mobility.

Gibbs free energy $\Delta G = G_{\text{final}} - G_{\text{initial}}$ (27)



when the quenching temp is close to 725°C driving force value is very low which increases the incubation period at a temp. below 550°C although the driving force value is very high but atomic mobility is very low due to lower temp.



If the cooling rate is such that it just touches the nose of TTT diag. it is called critical cooling rate. Any cooling rate equal to or higher than critical cooling rate will produce ^{optimal} martensite and it is like pulverised cementite and carbon in ferrite structure.

(γ)

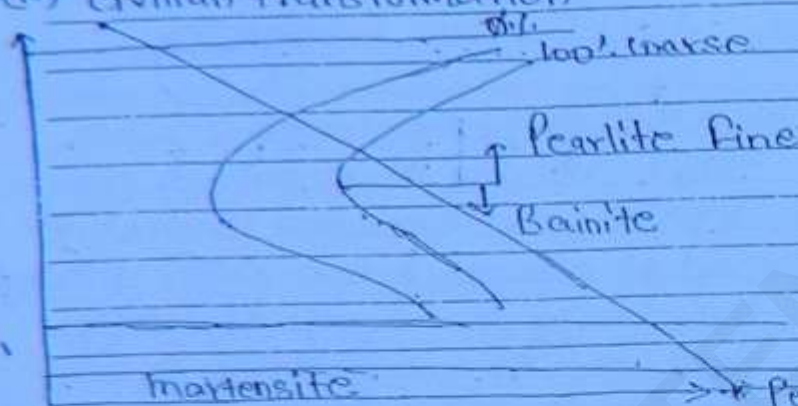
When a sphere of austenite steel heat treated is quenched it breaks because density difference.

upon quenching a specimen since surface comes in contact with medium so immediately it convert into martensite. But the core is still austenite. After some time when core converts into martensite its volume will expand because γ is having higher density compared to martensite. This produces a crack over the surface. (Austenite) $\rightarrow$ (Martensite) density

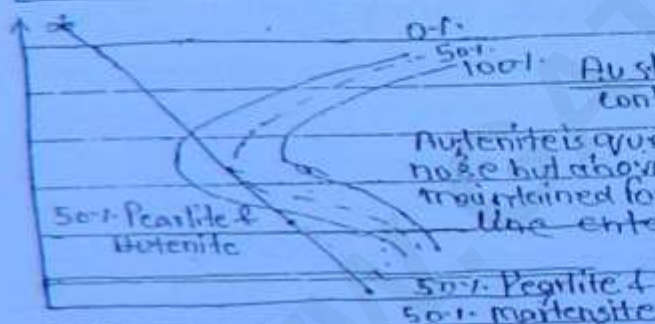
Crack cracks in quenching are due to density difference and not due to thermal stresses.

Pearlite
 1) Diffusional Process
 1) long range movement
 1) civilian transformation

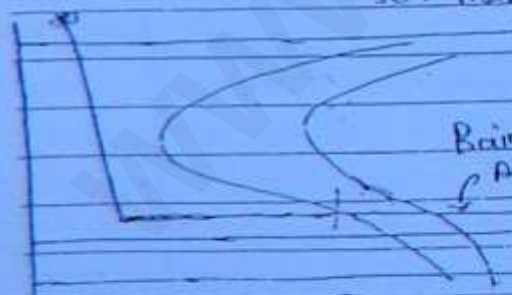
Martensite
 Non diffusional process
 Short distance
 military transformation.



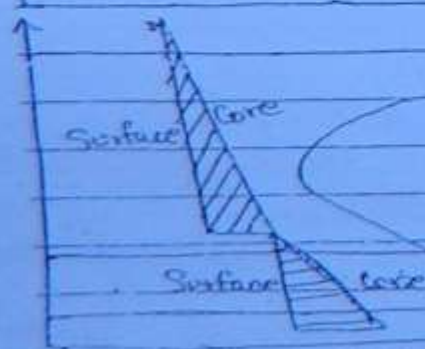
All the lines on TTT diagrams are that of transformation of austenite into some other microstructure and once γ converts into some other structure it never convert to another.



Austempering: Bainite cannot be produced by continuous cooling it is produced by Austempering. Austenite is quenched at a rate higher than CCT below the nose but above the martensite start line. This temp is maintained for a substantial period of time till transformation has entered the TTT diagram.



Hardenability: Hardenability is a case of martensite formation and it can be improved when martensite can be formed at slower cooling rates. This can be achieved by alloying. Alloying element occupies the substitutional site & create strain field in that area. For equilibrium to happen not only carbon but also the substitutional impurities has to jump to some vacancy site and this process takes time and TTT diagram shifted towards right.



Martempering (Step quenching)
 Sample is initially quenched into a bath maintained below the nose on TTT diagram but above the martensite start line. The sample is kept in medium for some period of time till the temp. becomes uniform throughout. The sample is quenched into another bath maintained at (optimal) room temp. Martempering decreases the probability of crack but does not completely eliminate it.

HEAT TREATMENT

- (1) Annealing $\rightarrow$ furnace cooling
 - (2) Normalizing $\leftarrow$ air quenching
 - (3) Hardening $\leftarrow$ medium (water/oil/air)
 - (4) Tempering $\leftarrow$ oil quenching
- (toughness to brittleness)

Full annealing: $30 - 200^\circ\text{C/hr}$

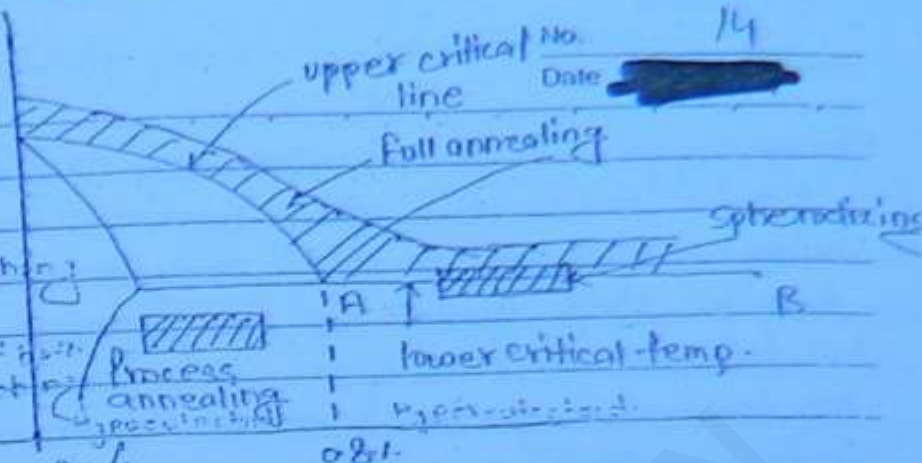
Hypoeutectoid steel samples are heated 50°C above the upper critical temp and hypereutectoid steel sample are heated 50°C above the lower critical temp. These sample are then cooled slowly in furnace. Full annealing results in coarse structure which are tough and ductile. It reduces hardness and brittleness of material.

Process annealing: microstructure of material will change only when T-T diagram comes into picture & if austenite appears. So in process annealing back stresses will be relieved by formation of new crystal but without any change in microstructure. It applies only for low carbon steel.

Spheroidise annealing: The objective of spheroidise annealing is to improve the machinability of medium and high carbon steels. These materials are taken to a temp. close to lower critical temp. and cooled extremely slowly in furnace which results in formation of spheroids and hence machinability improves. $(25-30^\circ\text{C/hr})$

Diffusion annealing (or homogenizing): The objective of this type of annealing is to make the chemical composition uniform specially after welding the structure. The sample is heated to 1150°C to enable to more and more diffusion. The sample is kept at this temp for around 6-8 hours and then cool slowly in furnace.

Higher the temperature more will be the diffusion.



(29)

with rapid cooling $\rightarrow$ fine grains are produced

with slow cooling $\rightarrow$ coarser grains are produced

Date

Normalizing: Sample is heated to a temp. at which austenite is stable. The sample is then quenched in air. Since the surface comes in contact with the cold air cooling will be rapid and hence fine grains will be produced over the surface. But towards the centre due to slower cooling rate grains will be coarser & coarser. An such structures are having hard surface and tough ^{core} which are most suitable for engg. application. Normalizing is considered as the final heat treatment process because hardening and tempering is meant only for a small section of material.

Hardening: Material is heated to a temp. at which austenite is stable and then it is quenched into some medium to produce martensite. Quenching medium

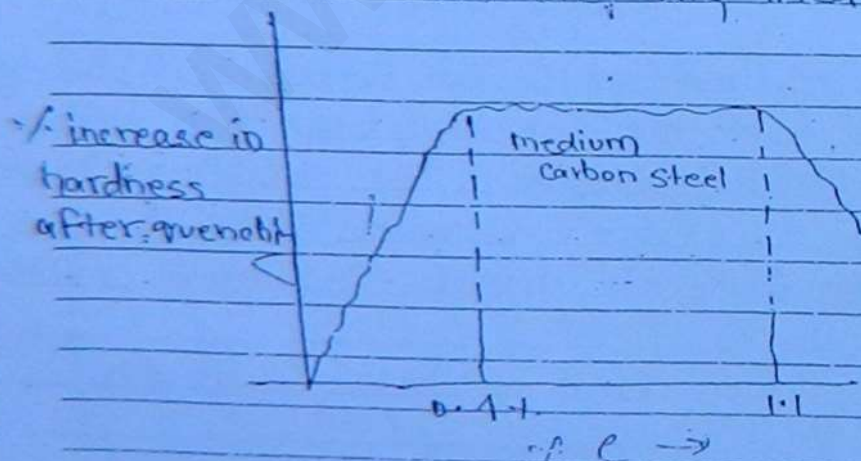
(i) water

(ii) Salt bath

(iii) oil

30

upon quenching the specimen into water a vapour blanket tends to form over the specimen. This normally not only decreases the heat transfer from the specimen but also leads to nonuniform cooling (because diff. thickness of vapour blanket). Salt bath $\downarrow$ the tendency of vapour blanket formation and uniform cooling is being provided by the oil bath. Since the cooling rate in oil baths are low so these bath are only used for Alloy steel.



Only eutectoid composition is responsible for producing martensite phase. Proeutectoid phases do not contribute to the hardening process. So only medium

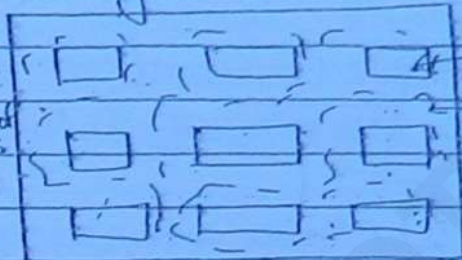
Carbon steel can be hardened not m.s. and high carbon steel.

Case hardening: It is the process of increasing the hardness of only surface by the process of diffusion of C and N. This increases the % of carbon and it approaches towards the eutectoid composition. Also both C & N produces strain fields on the surface.

(1) **Carburizing:** increasing the % of C

(A) **Pack carburizing:**

Although it is cheap, it is not possible to control the thickness of case hardening. Also the process cannot be automated. It takes long time.



m.s. sample

Mix of 50% charcoal

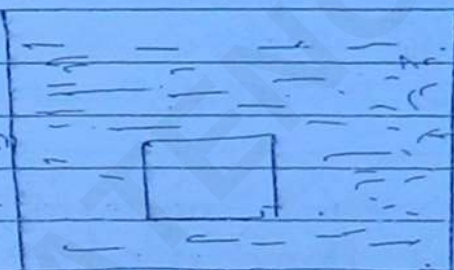
BaCO₃

CaCO₃

Heating temp: 950°C

(b) **Liquid Carburizing**

Dilute NaCN diffuses only Carbon
Conc. NaCN Along with other chemical diffuses both C & N atom.

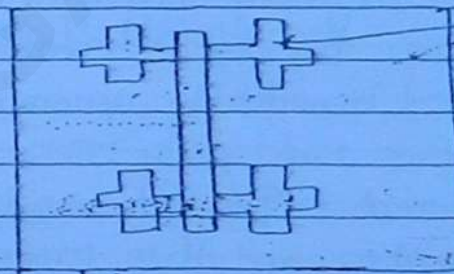


(dilute)

20% NaCN

Heating temp: 950°C

(c) **Gas carburizing**



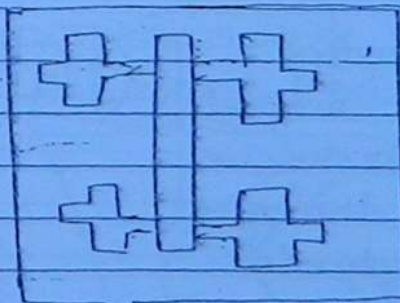
Samples are arranged in the form of Tree

Heating temp: 950°C

Hot CH₄

(2) **Nitriding:**

Nitride case are stronger than carbide case.

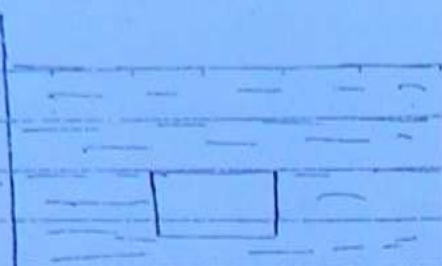


$N > CN > C$

temp: 500 - 650°C

NH₃

(c) Cyaniding:
It is the process of diffusing both C & N.



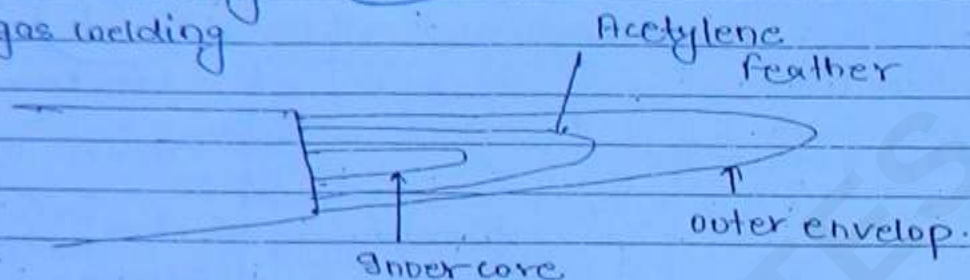
No.
Date

30% NaCN
NaCl
Na₂CO₃

temp: 250°C

(d) Flame hardening:
In gas welding

(32)

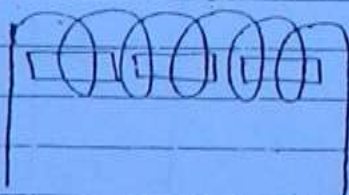


- 1) Carburizing flame 2900°C
- 2) Neutral flame 3150°C
- 3) oxidizing flame 3500°C

In oxyacetylene flame oxidized flames are the hottest and carburized flame emits a black smoke due to carbon. Generally oxidized flames are used in case hardening process. Medium carbon steel samples are heated and immediately quenched by using a spray of water for case hardening. In s. specimen carburized flames are used. This process is generally used to case harden steel parts and the process cannot be used to case harden thin section because there will be buckling.

(e) Induction Hardening:

It is the fastest method of case hardening technique. Samples are passed through induction coil and due to



oil Bath

development of eddy currents over

surface heat will be produced. Samples are immediately quenched in oil bath. Alloy steel with C-1 in medium C-steel range can be case hardened by this technique.

Date _____

The thickness of hardened layer can be controlled very precisely. Cranks, connecting rods, etc. are hardened by this process.

Tempering: Martensite by nature is extremely Brittle and the process of introducing toughness is called tempering.

(1) High temp. tempering:

Martensite is heated to a temp. of $500 - 650^{\circ}\text{C}$ and then cooled slowly in furnace. Submicroscopic form of cementite will combined together microscopic structure, coarser the structure, more tough the material will be. Sorbite is high temp. tempered product of martensite. Hardness $\rightarrow 350$

(2) medium temp. tempering: $300 - 500^{\circ}\text{C}$ ($350 - 500^{\circ}\text{C}$)

In the medium temp. tempering cementites will be on a finer level as compare to Sorbite. This microstructure is called troostite and used in making springs and dies.

(3) Low Temp. Tempering: $\sim 250^{\circ}\text{C}$

Martensite is heated at 250°C and cooled slowly to release internal stresses. this process is used specifically in making measuring tools and cutting tools.

33

CERAMICS:

Metal: Good conductor of heat & electricity

Generally form alloy.

At room temp they are solid.

Non-metal: - Bad conductor, Not form alloy, at room temp. gases.

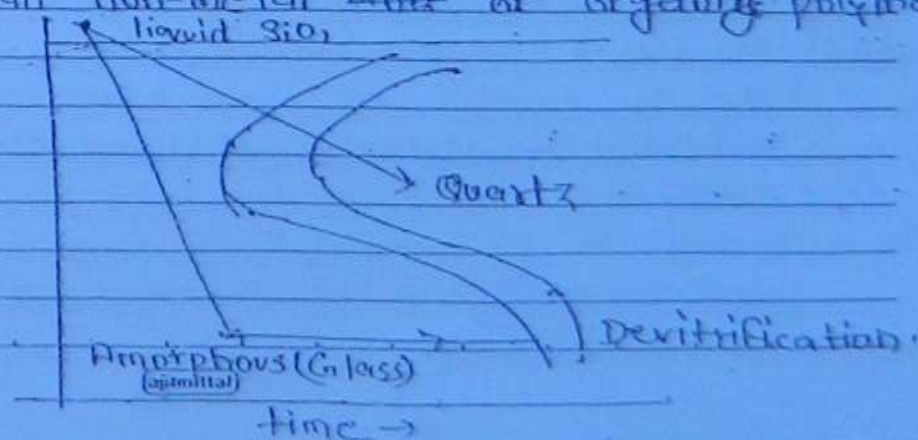
Whatever is not metal, non-metal and or organic polymer is called Ceramic.

Al_2O_3

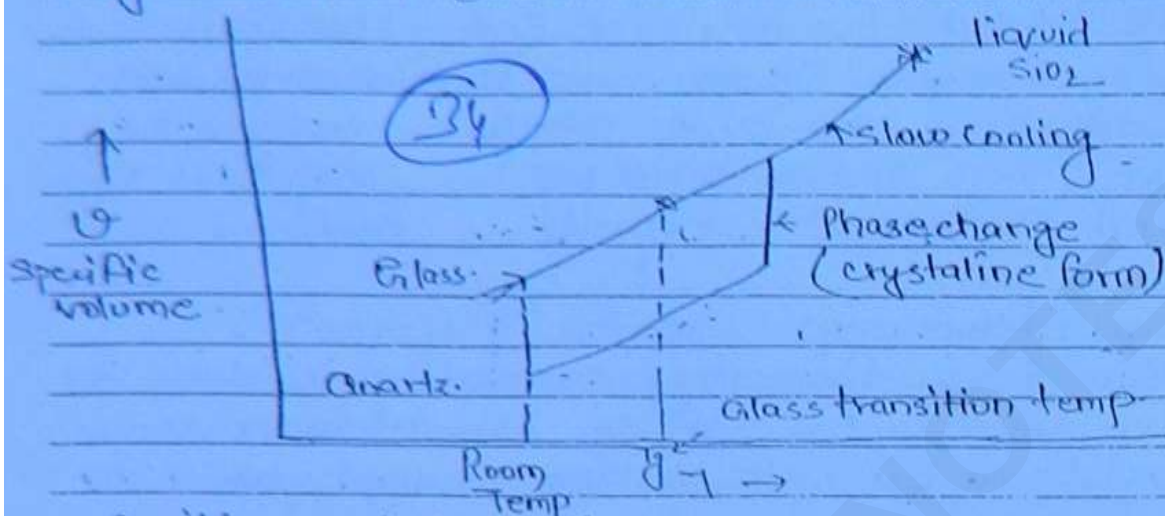
SiO_2

$\uparrow$

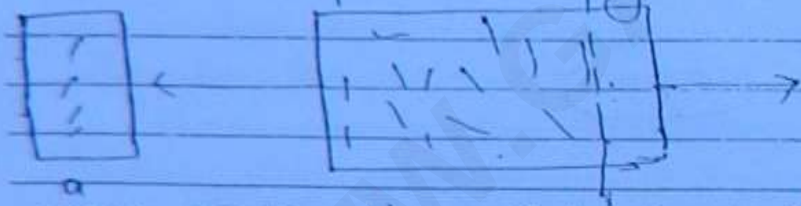
T



upon cooling liquid SiO_2 it will appear in the crystalline form called Quartz. upon cooling it rapidly the viscosity of liquid SiO_2 will keep on increasing and appears as solid without crystals. called glass. Glass is an unstable state and after some period of time it will convert into crystalline form called devitrification of glass.

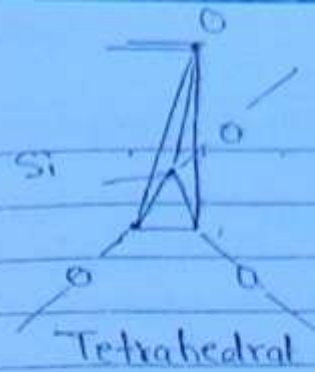


As it is seen in the figure upon slow cooling a vertical line will appear which indicate phase change. upon cooling rapidly the viscosity of liquid keeps on $\uparrow$ and at a particular temp. it is very difficult to decide whether it is liquid or solid this temp is called glass transition temp.



upon application of load whatever is the larger size crack will start $\uparrow$ in size and once it reaches a critical value the whole sample is bifurcated into 2 parts. larger is the size of sample greater is the probability of having large size cracks. so its strength will be low. So B. Ceramic strength is size dependent.

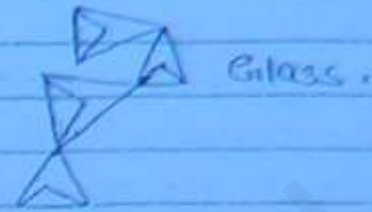
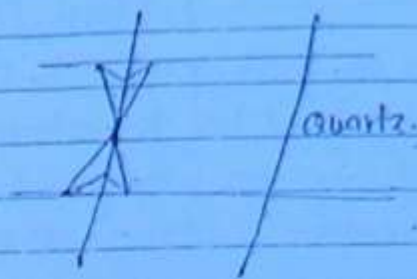
external cracks are 2 time stronger than internal cracks.



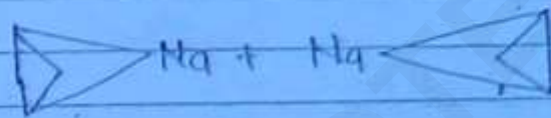
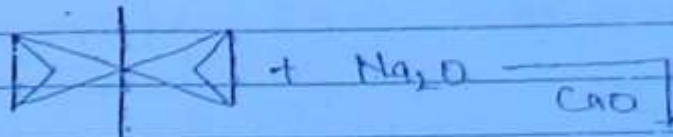
Systematic
Random connection of SiO₄ is called Quartz.
Random connection of SiO₄ is called glass.

No. 17

Date



(35)



Soda
Soda lime Glass.

long chain structure glass has very long processing time and due to which cost is very high. To break the long chain structure we react the glass with Na₂O & CaO. Na has single valency so the long chain structure break to form Soda lime Glass.

Toughening of Glass:

Toughening is a process of introducing compressive stresses in the surface of

Glass specimen for the purpose of

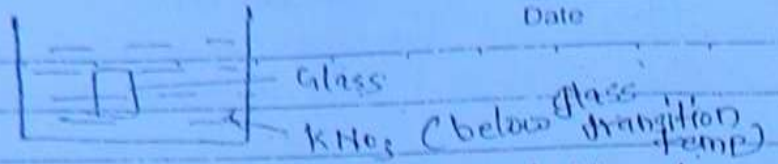
(1) Increase in the strength of Glass.

(2) In case glass breaks it breaks in large no. of small pieces with blunted edge.



(A) Air Quenching: Glass is heated to a temp. below glass transition temp. and then immediately quench into the stream of cold air. The surface of glass immediately come to the room temp. and will become rigid. but the core is still hot. once the core comes to the room temp. its specific volume will decrease and it will try to pull the surface towards the centre.

② Ion exchange:



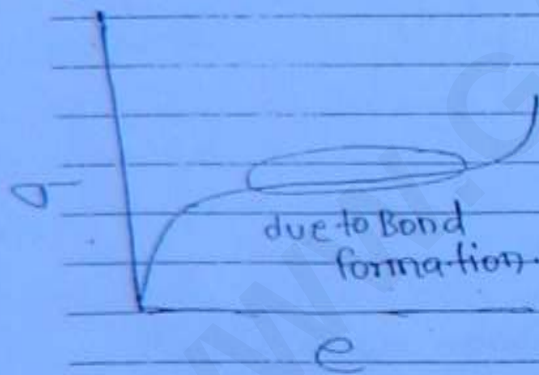
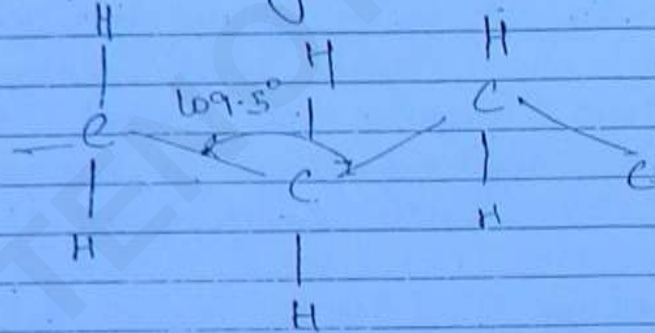
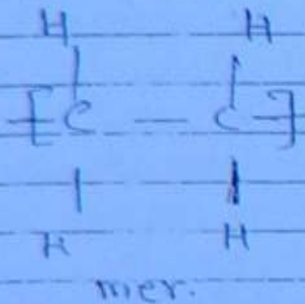
Soda lime glass is dipped in hot KNO₃ bath and Na atoms on the surface will be replaced by K atom. Since K is bigger in size surface will try to expand but core restricts its motion. (stresses will be of the order of 400 MPa and thickness of toughness layer is thin).

POLYMER:

(36)

Thermoplastic

Thermosetting — Cross linking of C atom:

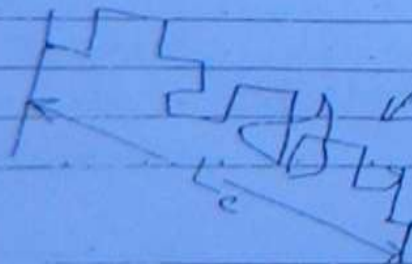


Conformation is the characteristic due to which C-C can take different 3-D shapes by maintaining the same bond angle.

Degree of Polymerization.

$$N = \frac{\text{Atomic weight of chain}}{\text{Atomic weight of one mer.}}$$

or No of mer connected.



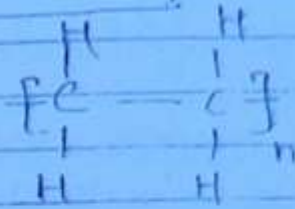
Theory of random walk

length of mer then (Thermoplastic)

$$[L_c = \sqrt{N}]$$

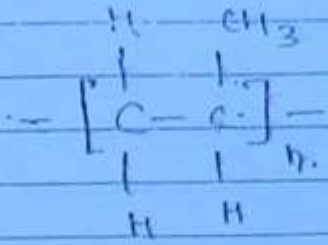
Fig 4:

(i)



Polyethylene

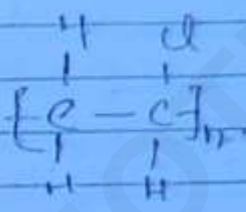
(ii)



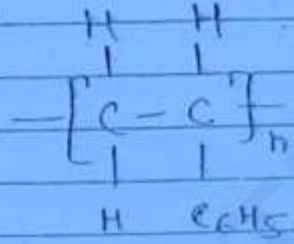
Polypropylene

(37)

(iii) P-V-C Polyvinyl chloride



(iv) Polystyrene



Thermosetting

- (i) Bakelite
- (ii) Nylon
- (iii) Epoxy

Composite: Metal, ceramic, polymer. When any of the two is mixed together to form the desired composition, objective is called composite.

CRYSTALLOGRAPHY

(1) Simple cube:

Cube crystal $\rightarrow$ Simple cube. $\rightarrow$ Body Centre cube. $\rightarrow$ Face centre cube.

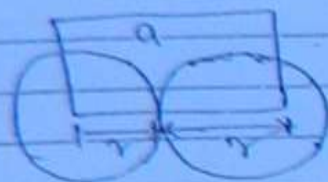
$$\text{effective atom per unit cell} = n = \frac{1 \times 8}{8} = 1.$$

$$\text{Atomic packing factor} = \frac{\text{Volume acquired by atom}}{\text{unit shell volume}}$$

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

(38)

$$a = 2r.$$



$$= \frac{1 \times \frac{4}{3} \pi r^3}{(2r)^3}$$

$$= 0.52$$

Co-ordination No : C.N. = 6.

(2) Body centre cubic structure: (B.C.C.)

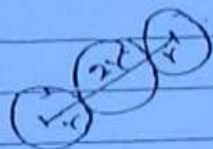
$$\text{effective atom per unit cell shell} \cdot n = \frac{1}{8} \times 8 + 1 = 2.$$

$$\text{Atomic packing factor} = \frac{2 \times \frac{4}{3} \pi r^3}{a^3}$$

$$\text{Now when } a \text{ become } \sqrt{(5r)^2 + a^2} = \sqrt{2} a.$$

$$\sqrt{2} a = 4r$$

$$a = \frac{4r}{\sqrt{2}}$$



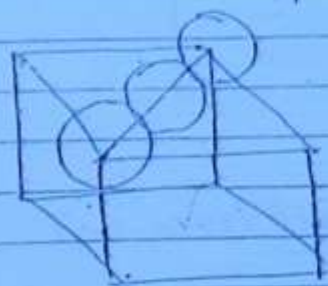
$$\text{A.P.F.} = \frac{2 \times \frac{4}{3} \pi r^3}{\left(\frac{4r}{\sqrt{2}}\right)^3}$$

$$= 0.678.$$

Co-ordination No : 8.

(iii) Face centred cube structure:

Effective atom per unit cell $n = \frac{1 \times 8}{8} + \frac{1 \times 6}{2} = 4$



$$4r = \sqrt{2}a$$

$$a = \frac{4}{\sqrt{2}} r$$

Atomic packing factor = $\frac{4 \times \frac{4}{3} \pi r^3}{a^3}$

(39)

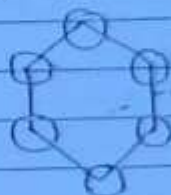
$$= \frac{4 \times \frac{4}{3} \pi r^3}{\left(\frac{4}{\sqrt{2}}\right)^3} = 0.74$$

Co-ordination No: 12

Atomic packing factor $\propto$ density

$$P_{fcc} > P_{bcc} > P_{sc}$$

Hexagonal unit shell:



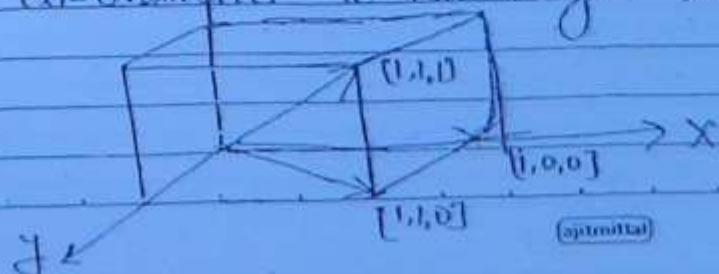
Effective atom per unit cell $n = \frac{1 \times 12}{6} + \frac{1 \times 2}{2} + 3 = 6$

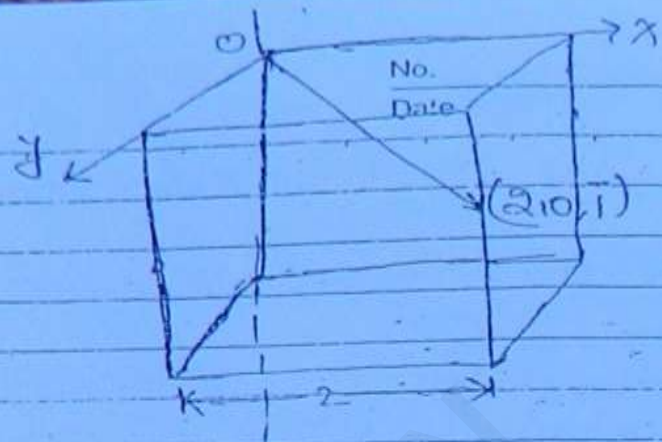
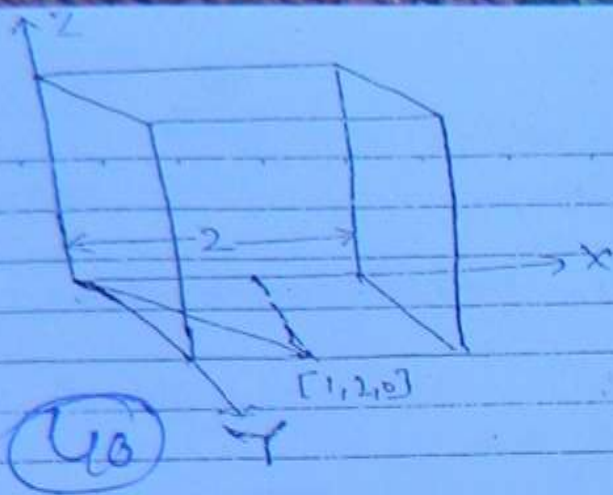
Atomic packing factor A.P.F. = 0.74

Co-ordination Number = 12

Crystal Directions: $[X, Y, Z]$

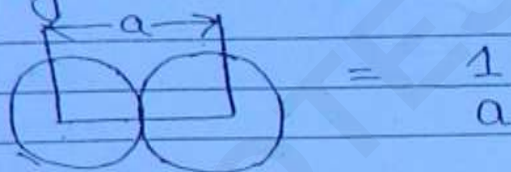
Within the bracket of crystal direction what ever is written is the 3-D co-ordinate and by joining these three co-ordinates to the origin we get crystal direction.





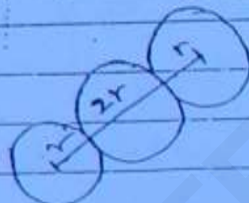
linear Density = $\frac{\text{No of atom in any direction (diameter)}}{\text{length of direction}}$

Simple cubic :



$$= \frac{1}{a}$$

B.C.C. :

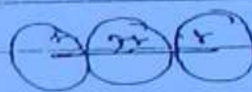


$$2r + r + r = 4r = 2d \text{ (2 dia)} \\ = 2$$

$$\sqrt{3}a$$

$$\text{linear density} = \frac{2}{\sqrt{3}a}$$

F.C.C. :



$$= 4r = 2d \text{ (2 dia)} \\ = 2$$

$$\frac{4}{\sqrt{2}a}$$

$$\text{linear density} : \frac{2}{\sqrt{2}a} = \frac{\sqrt{2}}{a}$$

91

Date:

No.
Date

THEORY OF METAL CUTTING

Primary Manufacturing
Process is manufacturing
costing.

↓
Manufacturing Science

↓
2ndly manufacturing process known as
metal cutting.

(42)

It depends upon material removal.

↓
Energy Intensive process → Surface Finish
→ Tolerances
→ Accuracy

Process should be best but economic because we
have to go beyond plastic deformation up to the fracture.

Material Removal Rate (MRR) = $V \cdot S \cdot t$
cutting speed ↑ ↑ ↑ depth of cut.
Feed

our Requirement:

MRR ↑

Surface Finish ↑

Power Consumption ↓

Tool-life ↑

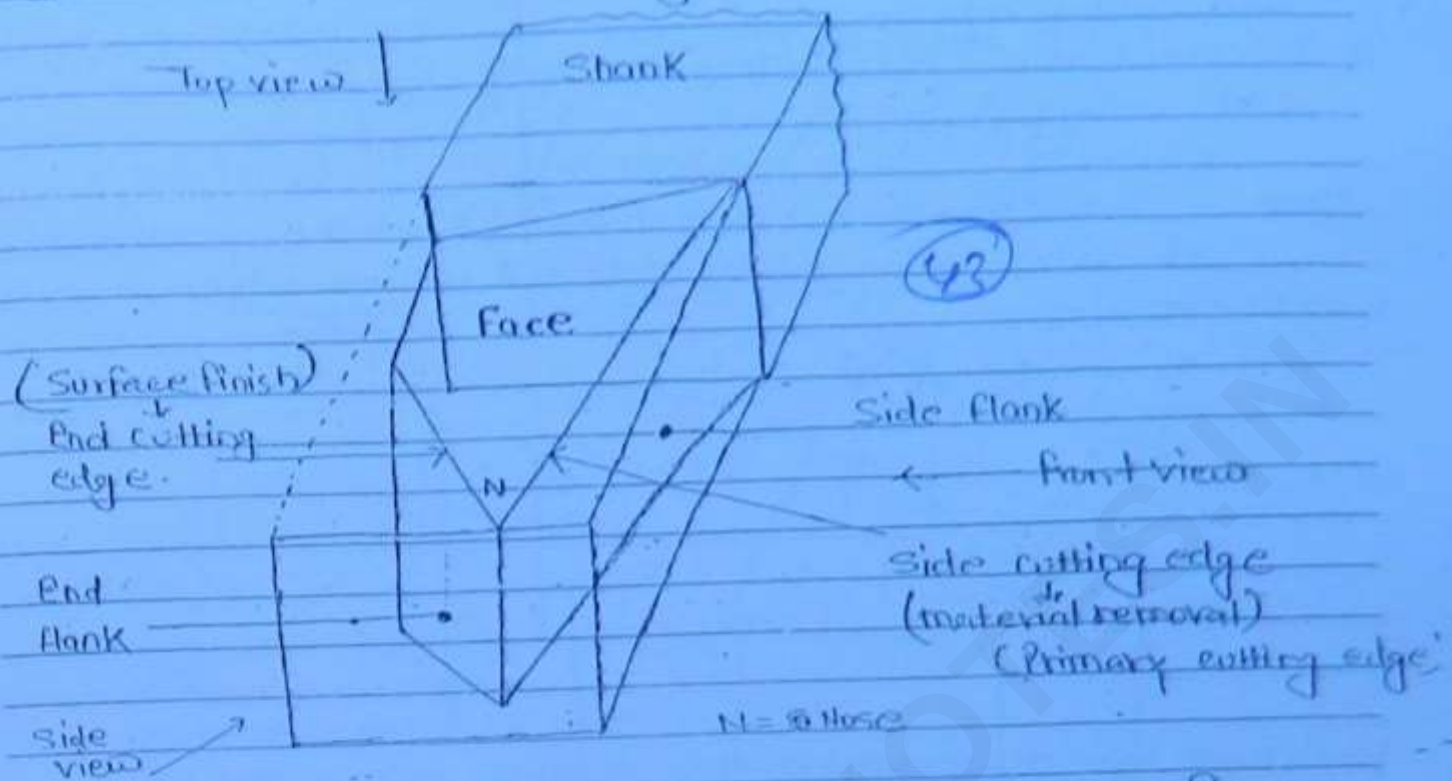
(1) Higher feed gives poor
Surface Finish.

(2) for Better Surface Finish.

Higher feed should be used.

	$V \uparrow$	$S \uparrow$	$t \uparrow$
MRR	✓	✓	✓
Surface Finish	✓	X	X
Power Consumption	X	X	X
Tool-life	X	X	X

Elements of Tool Geometry: →



- ① Entire portion after shank is called a cutting Point
- Single Point cutting tool has 2 cutting edge.
- Drill Bit has 4 cutting edge (2 Primary cutting edge)

Single Point tool → 1 Point, two edge, 3 areas

1 Point → Nose

two edge → Side cutting edge

End cutting edge

3 areas → Face

Side Flank

End Flank

All are made by Grinding

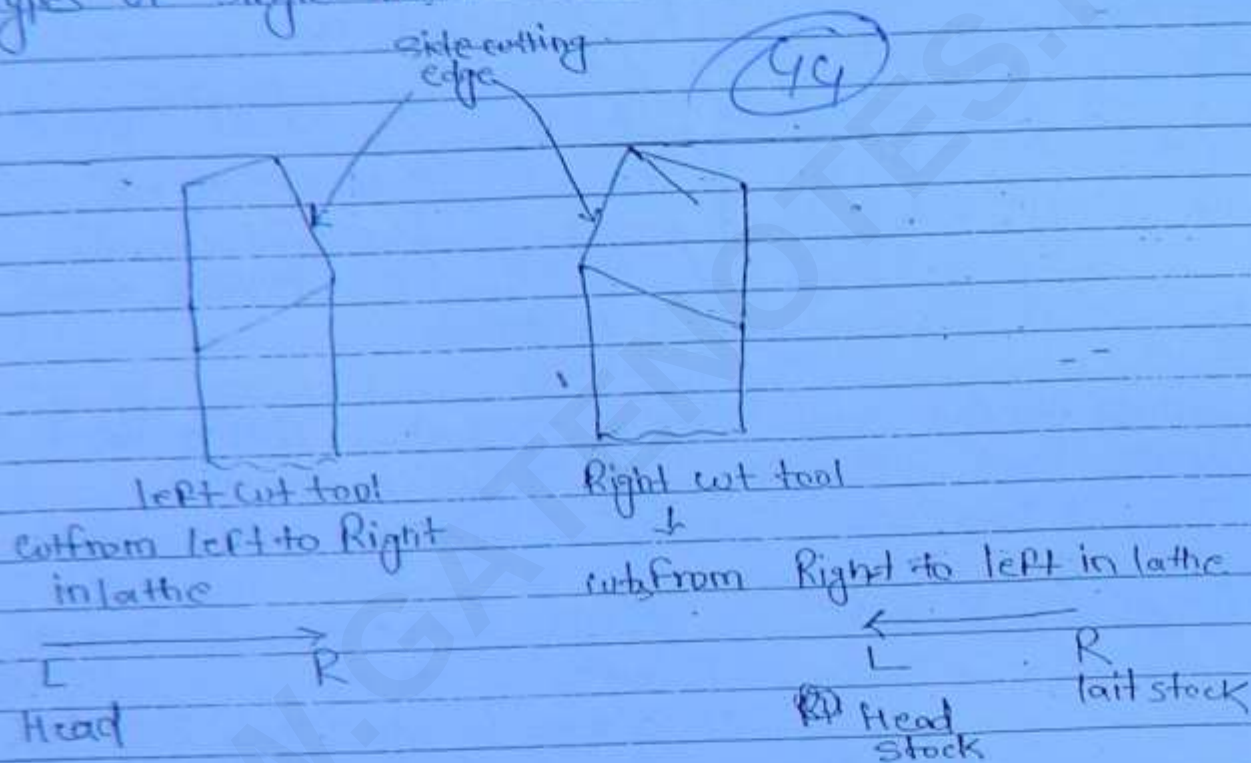
A Single Point tool consists of the following elements.

- ① Face — It denotes a surface on which the chip impinges and flows along.
- ② Flanks — they are the surfaces of the tool facing the work. They are of two type:
 - (1) Side Flank
 - (2) End Flank.
- ③ Cutting edges: They are of two types
 - (1) Side cutting edge
 - (2) End cutting edge.

- ① Intersection of Side Flank with rack face results in side cutting edge.
 ② Intersection of end Flank with rack face results in end cutting edge.

Nose: It is the ^{or} element of tool formed at the junction of side cutting edge and end cutting edge.

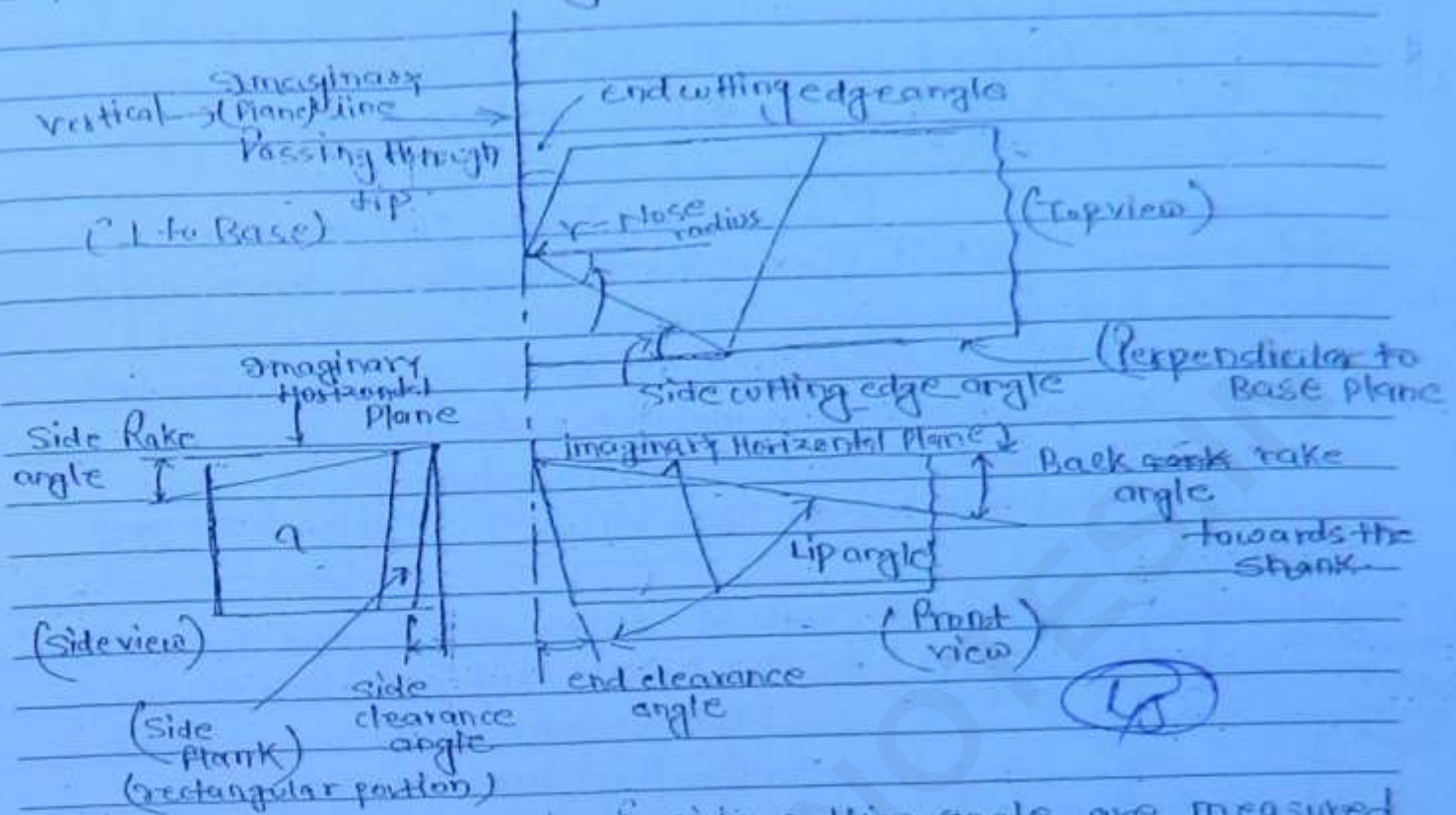
Types of single Point tools



Right cut tools have their side cutting edge on the side of the thumb when the right hand is placed on the tool with the first finger pointing towards the nose; they cut from Right to left (from tail stock to Head stock).

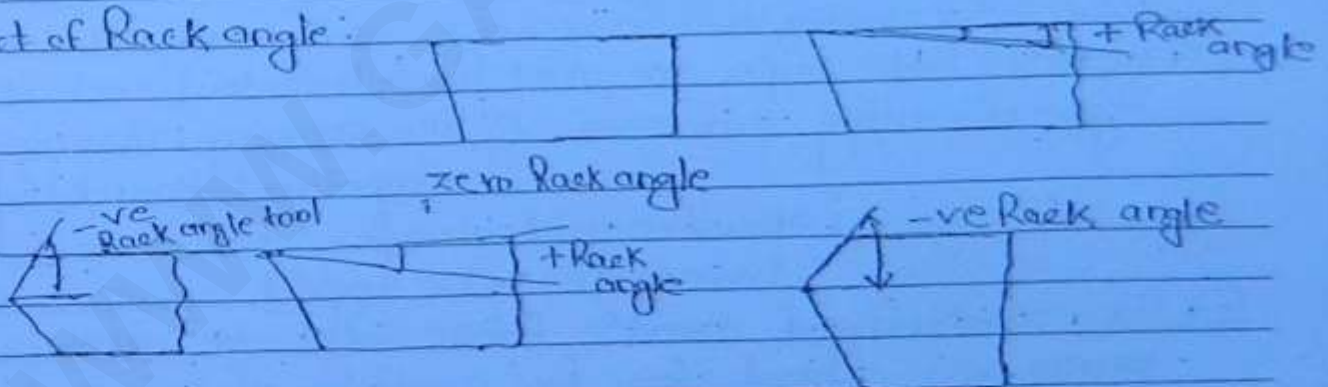
Left cut tools have their side cutting edge on the side of the thumb when the left hand is placed on the tool with the fingers pointing towards the nose. They cut from left to right (from Head stock to tail stock).

Effect of tool Geometry elements :



(End cutting edge angle & side cutting angle are measured with two mutually perpendicular plane which themselves are perpendicular to Base of tool.)

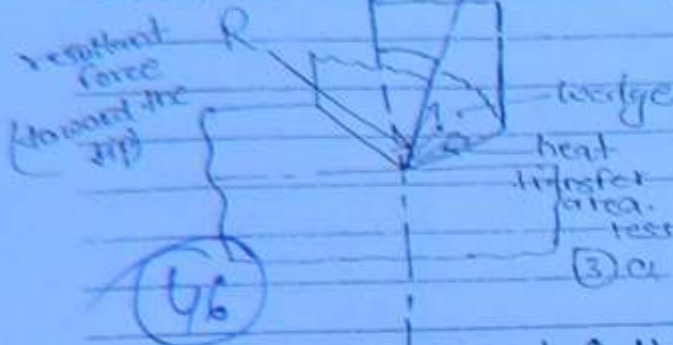
Effect of Rake angle :



$$\text{Back Rake angle} + \text{Lip angle} + \text{end clearance angle} = 90^\circ$$

(It is valid for all Back Rake angle)

Effects of Positive Rake angle:



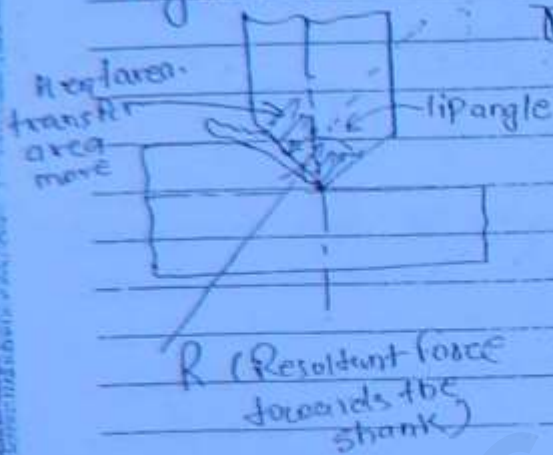
- (1) Tool life decreases
- (2) Work done less
forces are less
power consumption
- (3) A $\pm$ rake angle helps in chip formation.

(4) The rake angle, $\uparrow$, lip angle is reduces, sharper tool it can easily dig into the material.

(5) Work tool contact length is reduce

(6) Heat dissipation is less (7) chip tool interface temp more

Negative Rake:



(1) Tool life is more.

(2) Not help in chip formation
(compress the chip)

Cutting forces are more

work done more

power consumption more.

(3) Heat dissipation is more.

(4) less chip tool inter face temp.

(It reduces the diffusion wear.)

(5) Negative Rake angles are used for 'intermittent contact' type of cutting processes, (like shaping, planing, grinding, Bore grinding).

[Abrasive grit always have $-ve$ rake angle]

(6) For machining of hard & brittle solid $-ve$ rake angles are used. (ex. for machining of Grey cast iron).

(1) Positive Rake angles tool are best recommended for machining of soft & ductile material.

(2) They are recommended for use in continuous contact type cutting condition.

(3) Positive rake angle tool can give rise to excellent surface finish because with such tool the possibility is

of formation of build up edges minimise.

② Poor surface finish with -ve rake angle, [build up edges formation increases.]

(47)

⑤ Under the conditions of $\uparrow$ feed, for the same tool life, Rake angle must be decreased. but surface finish also decreases

⑥ ~~and~~

When discontinuous chip formation takes place, Negative rake angle tools are recommended because

(i) strength, (better tool life)

→ For achieving a specific surface finish the most imp. factor to be controlled → Cutting speed.

→ Consider the following statement

Strength of cutting tool depend on:

(i) Back rake (ii) Lip angle (iii) end clearance angle

~~→ Significance of Back rake angle, Lip angle, end clearance angle~~

→ Brass has zero rake angle ✓

→ Copper has negative rake angle ✓

→ Carbide tipped tools usually have negative rake angles ✓

Effect of clearance angle (Also known as Relief angle)

6-10 end r

- (1) Less angle, Higher Friction, poor Surface Finish.
- (2) Too large angle. Tip becomes weak & cutting edge will not be supported by material below it. So optimum value is desirable.

Side clearance angle (6-12° inside)

(78)

- (a) If the side clearance angle is too small then side cutting edge can't dig into work piece material properly.
- (b) Frictional rubbing results in increasing of power consumption with smaller clearance angle is identified.
- (c) optimum value of side clearance angle should be b/w 6-12°.
- (d) with radius tools relief angle must be decreased for higher tool life. (as no change in rake angle we want)
- (e) with radius tools clearance angles must be increased for min. power consumption.
- (f) At heavy feeds clearance angles must be decreased (This results in ↑ of lip angle & strengthen the tool.)
- (g) optimum value of end relief angle is 6-10°
- (h) larger the end relief angle lower will be the tool life, smaller the end relief angle more will be friction, heat generation, and power consumption.

Rake angle: Rake angle is the angle enclosed b/w radius passing through nose and tool face.

Relief angle: Relief angle is the angle b/w the cutting plane and tool flank.

Effect of tool Setting on Rake angle & clearance angle.

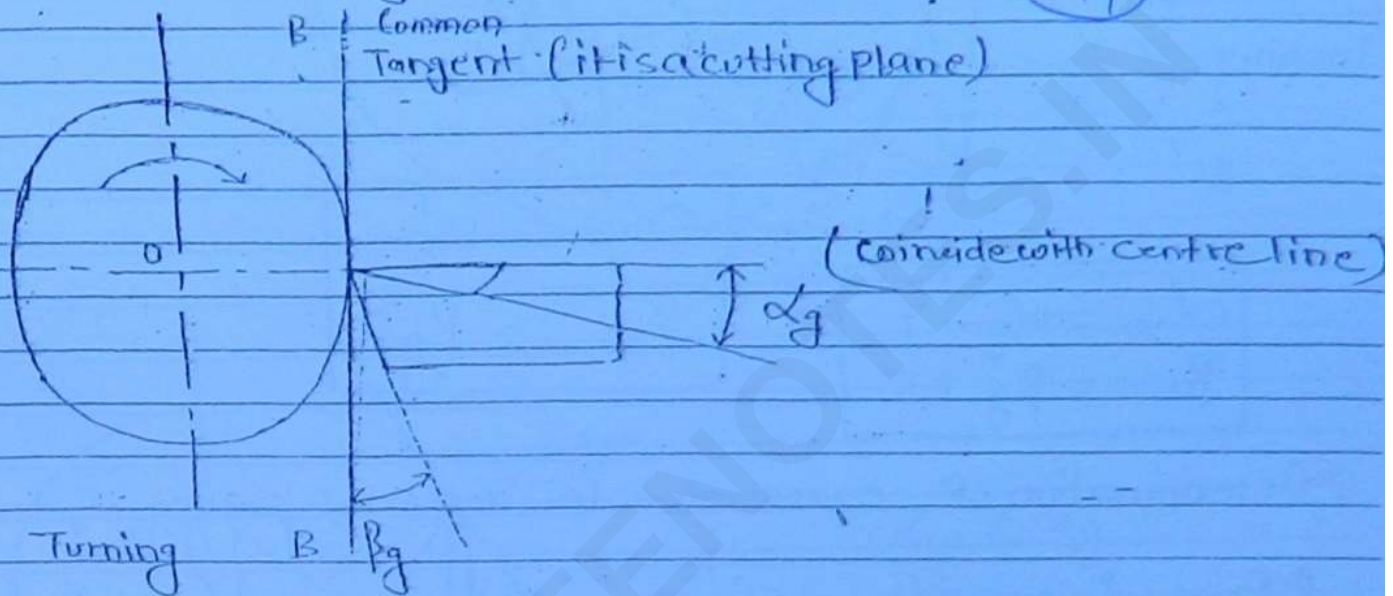
let: α_g : Rake angle ground on the tool

α_w : working Rake angle.

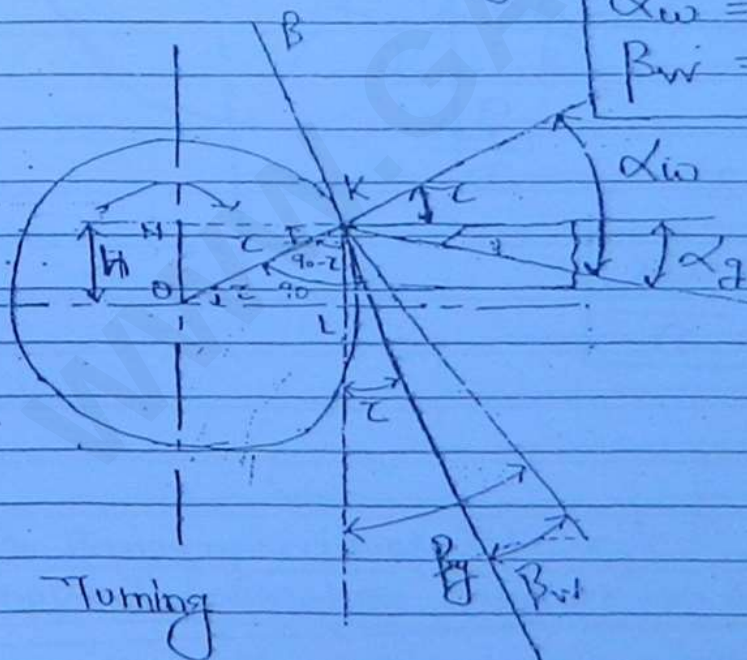
β_g : Relief angle ground on tool.

β_w : working Relief angle.

(49)



for this working angle = Ground angle.



$$\begin{aligned} \alpha_w &= \alpha_g \\ \beta_w &= \beta_g \end{aligned}$$

$$\alpha_w = \alpha_g + \theta$$

$$\beta_w = \beta_g - \theta$$

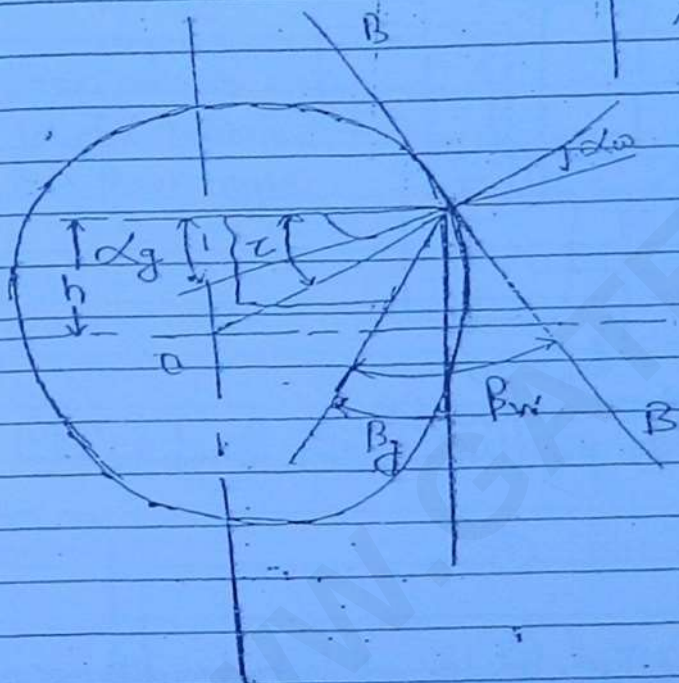
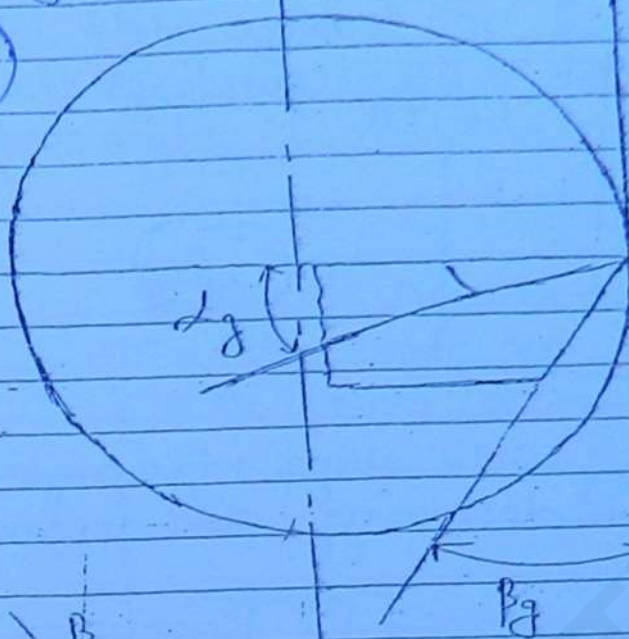
$$\begin{aligned} \alpha_w &> \alpha_g \\ \beta_w &< \beta_g \end{aligned}$$

OK is $\perp$ BB

B (Cutting Plane)
(Tangential Plane)

Case II: Boring operation

(57)



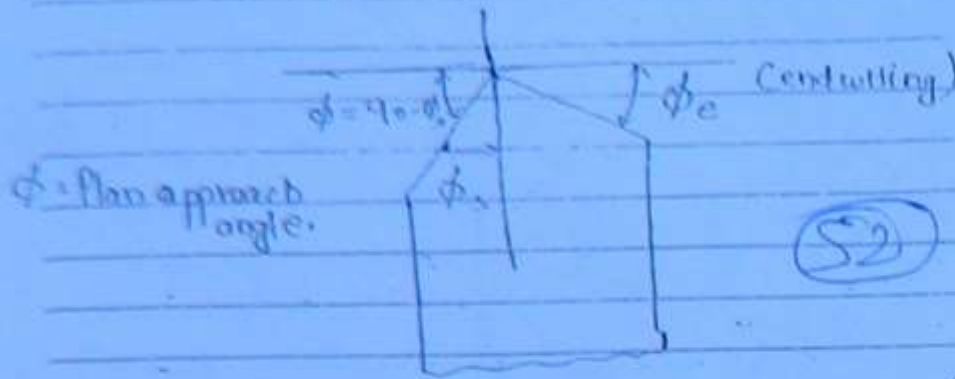
$$\alpha_w < \alpha_g$$

$$\beta_w > \beta_g$$

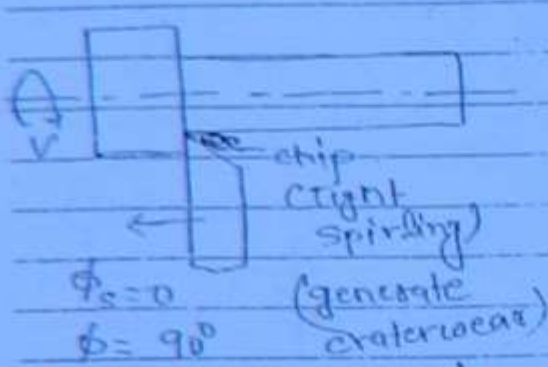
In Boring operations Rake angle & clearance angle will change in opposite direction compare to turning operation.

$$\sin \tau = \frac{2h}{d} \quad \text{will be same}$$

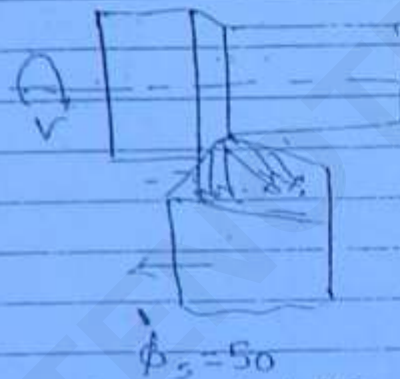
Effect of Side cutting edge angle (ϕ_s)



[Effect of increasing side cutting edge angle ϕ_s is Same as that of decreasing plan approach angle.]

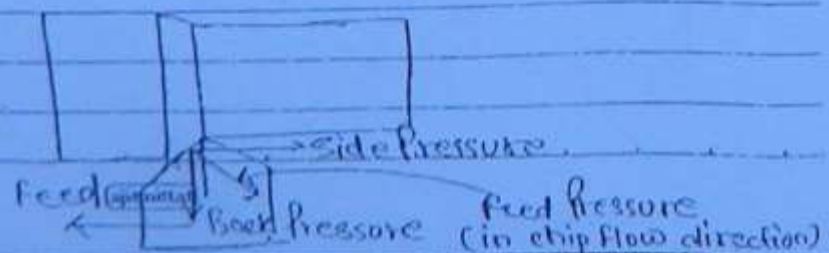
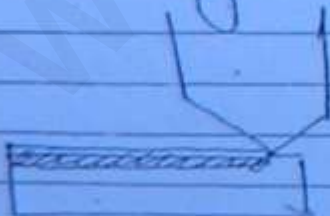


- ① ~~less~~ (less tool life)
- ② Heat dissipation less.
- Buildup edges may form
- Surface finish bad.



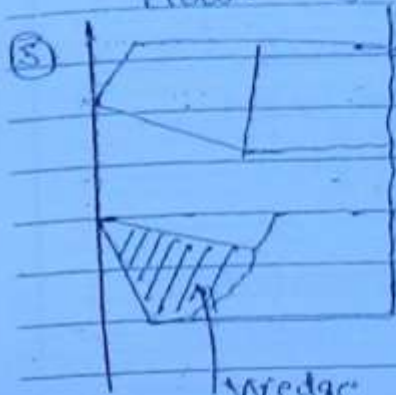
- ① more tool life
- ② Heat dissipation is much.

- ④ The provision of side cutting edge angle distributes stress and heat over a wider area, hence the tool life increases.
- ⑤ The provision of side cutting edge angle avoids momentary load coming into plan play, hence the tool life is more.



④ A gentle backpressure is created against the tool by the introduction of side cutting edge angle this back pressure keeps the slide tight against the lead screw. This prevents backlash from setting the vibration.

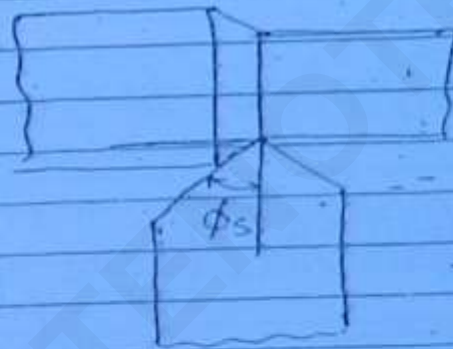
④ Side cutting edge angle Control the direction of chip flow.



Wedge
Gap shape
can seen only in blow
relief/clearance &
Back Rack angle

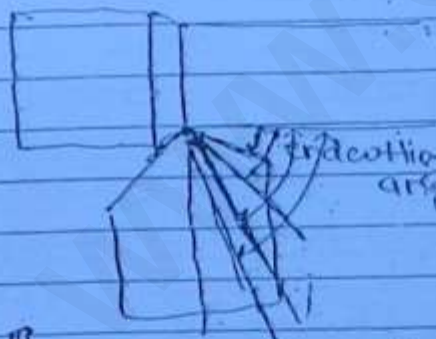
⑤ There is no influence of side cutting edge angle on cutting force and power consumption.

⑥



Greater values of side cutting edge angle results in vibrations.
too much large value, edge will rub with the work piece

Effect of End cutting edge angle



① To minimize the surface roughness (improve the surface finish)

② larger value of end cutting edge angle will results in decrease in the poor heat dissipation and less tool life.

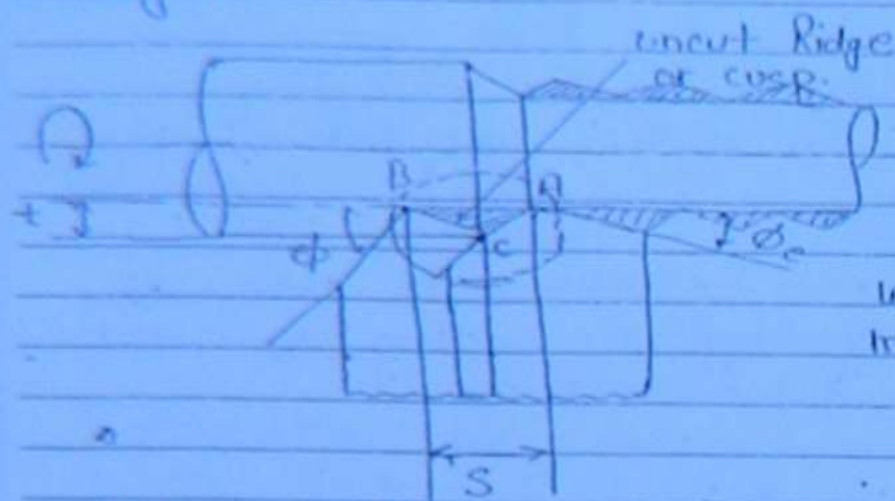
③ It has No influence on force &

As slenderness ratio increases, power consumption will be large for larger nose radius and vice versa.

Side cutting angle : vary from 60° to 80°

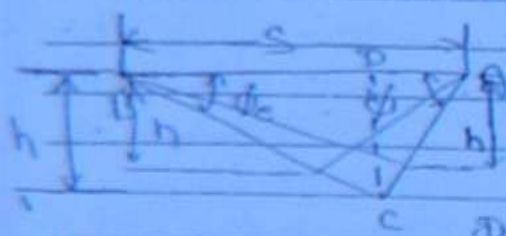
(30 machining of steel) with HSS.
(higher slenderness ratio) for l/d ratio upto 6 plan approach angle of 10 to 30° are used (higher nose radius)
when l/d ratio is more than 6 & upto 12 plan approach angle must be 40° . for l/d ratio $\phi = 80$ to 90°

Effect of side and end cutting edge angle on surface roughness



one revolution of work piece, nose radius moves from A to B.
AB = feed

Let $S = \text{Feed (mm/sec)}$



$h = \text{max height of surface roughness / irregularity}$

Draw $CD \perp AB$

From ΔBDC

$$\frac{BD}{DC} = \cot \phi_e$$

$$BD = h \cot \phi_e$$

From ΔADC

$$\frac{AD}{DC} = \cot \phi$$

$$AD = h \cot \phi$$

$$\text{But } S = BD + DA$$

$$= h \cot \phi_e + h \cot \phi$$

$$= h (\cot \phi_e + \cot \phi)$$

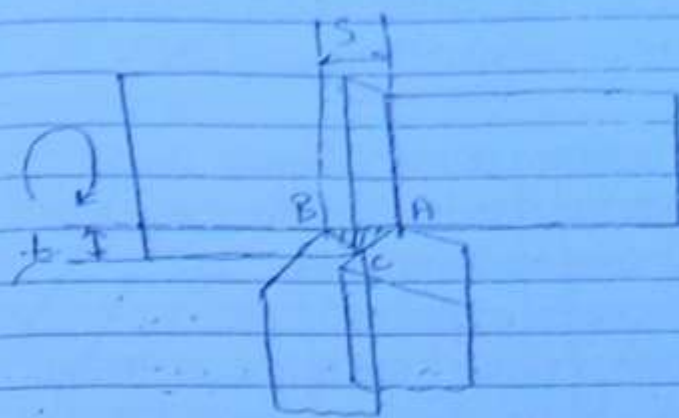
$$h = \frac{S}{(\cot \phi_e + \cot \phi)}$$

For better surface finishes ϕ_e must be small
 ϕ_s must be large (i.e. ϕ must be small)

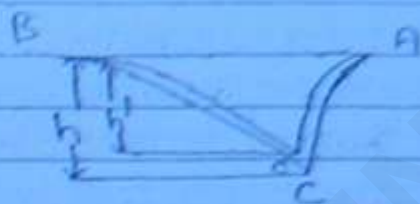
$$\text{or } h = \frac{S}{\cot \phi_e + \tan \phi_s}$$

$$h = \frac{S}{\cot \phi_e + \tan \phi_s}$$

Effect of Nose Radius



(SS)



With increased Nose radius, height of surface roughness decreases / Surface finish increases.

For larger Nose radius tools, clearance angle must be ~~decreased~~ ~~For better~~ ~~to~~ ~~reduce~~ power consumption.
 Increased

With larger Nose radii, clearance angle must be decrease (lip angle must be increased) for in order to have higher tool life.

Q: - For increasing the MRR without any constraints, what is the correct sequence to adjust the cutting parameter

① speed ② Feed, ③ depth of cut

Select the correct answer using following code

(A) 1-2-3

(B) 2-3-1

✓ (C) 3-2-1

(d) 1-3-2

Recommended values of tool Nose radius are

0.5 to 1.5 mm

~~(A) metal lathe~~ ~~(B) lathe~~ ~~(C) lathe~~ ~~(D) lathe~~

Tool Signature System:

A.S.A. (American Standard Association)

OR
orthogonal rake system.
Date
Continental system (Gierman)

2) Known as tool in hand system. (Tool is assumed ideal and not working against the work piece.)

① The tool is active and is assumed working against the work piece.

③ It is based on machine Reference Plane

② It is based on tool reference plane

③ It uses three reference plane.

③ O.R.S. uses three main reference plane

They are ① Base plane (Horizontal plane) and one auxiliary plane.

② Longitudinal plane (⊥ to Base plane) ① Base plane (Horizontal plane)

③ Transverse plane with ⊥ to both longitudinal and base plane.

② Cutting plane (which passes through principal cutting edge and ⊥ to base plane.)

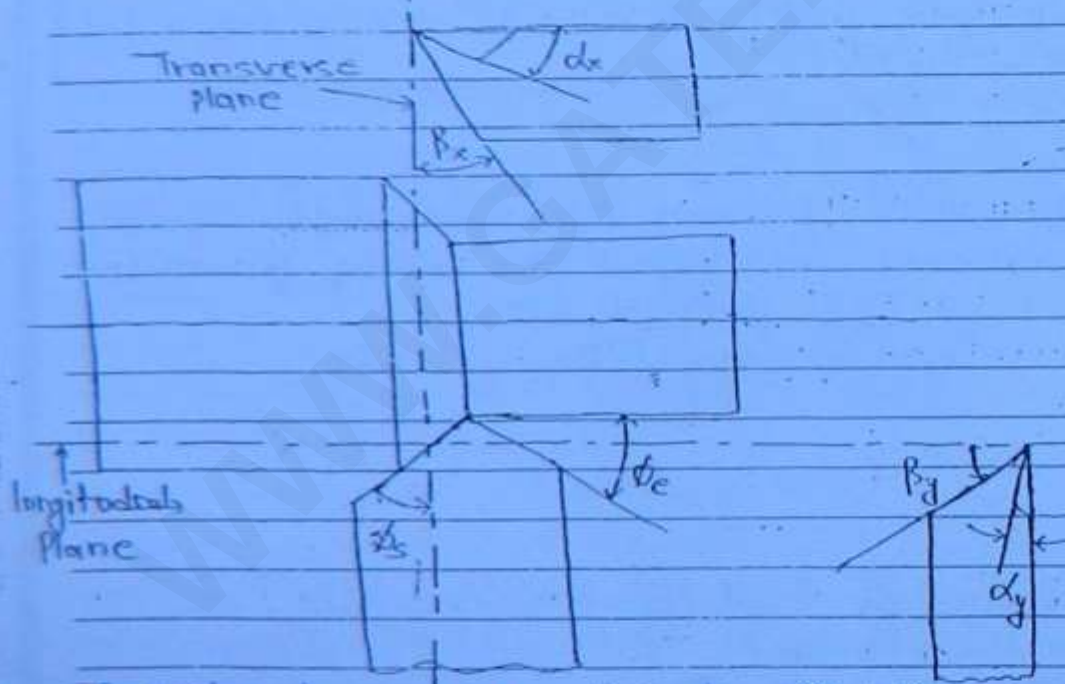
③ orthogonal plane (It is plane ⊥ to cutting plane and also to base plane)

④ Normal auxiliary plane which passes

through auxiliary cutting edge and ⊥ to base plane.

56

A.S.A. - -



Tool Signature according to A.S.A.

① Back Rake angle (α_y)

② Side Rake angle (α_x)

③ End clearance angle (β_y)

④ Side clearance angle (β_x)

⑤ End cutting edge angle (ϕ_e)

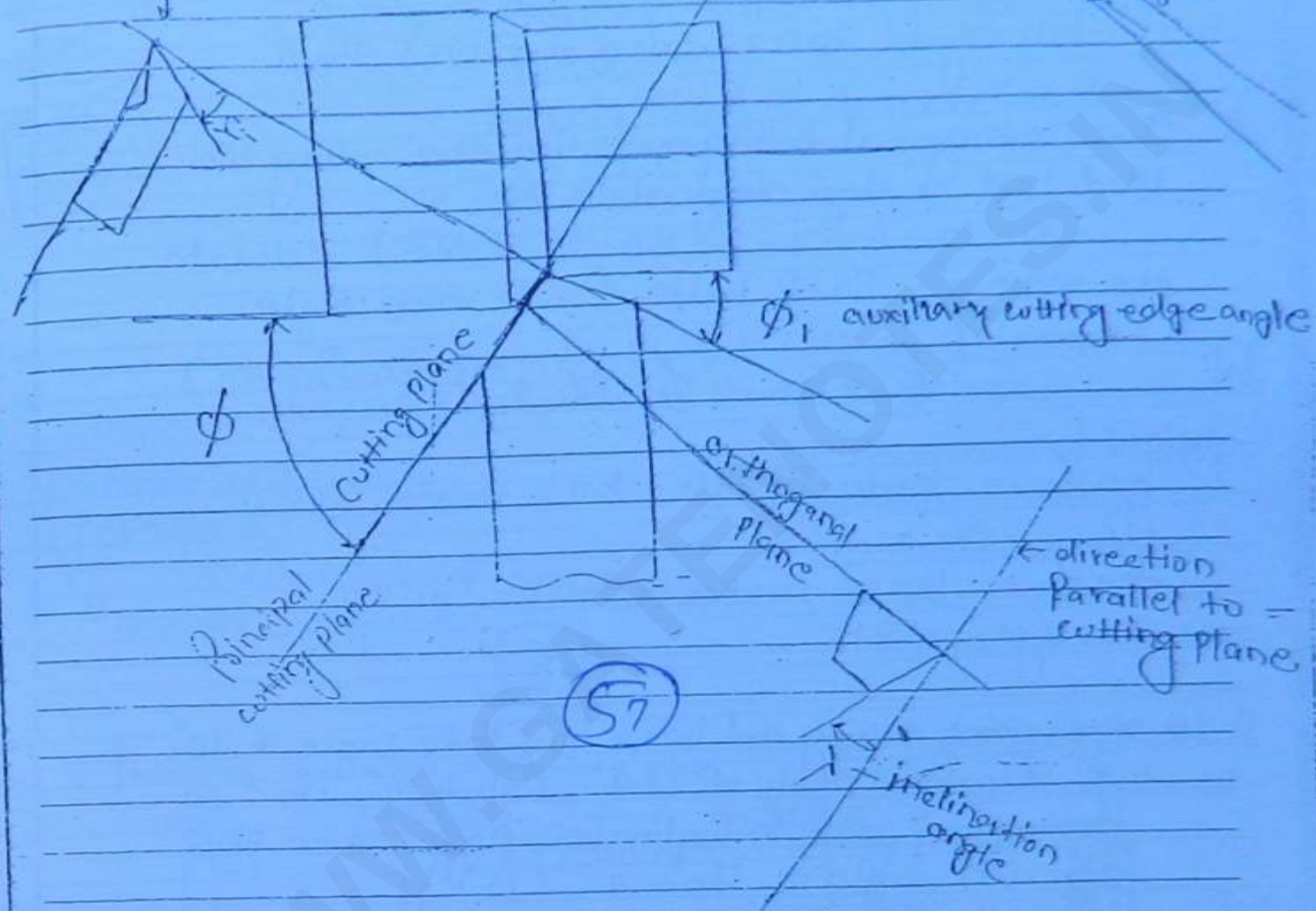
⑥ Side cutting edge angle (ϕ_s)

⑦ Nose Radius (R)

O.R.S. System.

No. 28
direction Date
Parallel to
orthogonal plane

Normal
Auxiliary plane



Tool Signature according to O.R.S. →

- ① Inclination angle λ
- ② orthogonal rake angle α_o
- ③ side relief angle γ
- ④ end relief angle γ_1
- ⑤ auxiliary cutting edge angle ϕ_1
- ⑥ Plan approach angle ϕ
- ⑦ Nose radius R

Relationship b/w ASA and ORS System

$$(i) \tan \alpha_o = \tan \alpha_y \cdot \cos \phi + \tan \alpha_x \cdot \sin \phi$$

$$(ii) \tan \lambda = \tan \alpha_y \cdot \sin \phi - \tan \alpha_x \cdot \cos \phi$$

$$(iii) \tan \alpha_x = \tan \alpha_o \cdot \sin \phi - \tan \lambda \cdot \cos \phi$$

$$(iv) \tan \alpha_y = \tan \alpha_o \cdot \cos \phi + \tan \lambda \cdot \sin \phi$$

Q. In an orthogonal cutting operation the cutting tool used had a degi designation of

0-10-6-7-8-80-1 (ORS) calculate the value of Back Rake & Side rake angle.

Sol: $\alpha_o = 10$ $\phi = 80$ $\lambda = 0$

$$\tan \alpha_x = \tan 10 \cdot \sin 80 - \tan 0 \cdot \cos 80$$

$$\alpha_x = 9^\circ 51'$$

$$\tan \alpha_y = \tan 10 \cdot \cos 80 + \tan 0 \cdot \sin 80$$

$$\alpha_y = 1^\circ 45'$$

(58)

Q. A single-point cutting tool has a back rake angle of 10° and side rake angle of 14° . Calculate its orthogonal rake & inclination angle when plan approach angle is 70° .

Sol:

$$\alpha_x = 10 \quad \alpha_y = 14$$

$$\phi = 70$$

$$\tan \alpha_o = \tan 14 \cdot \cos 70 + \tan 10 \cdot \sin 70$$

$$\alpha_o = 16^\circ 24'$$

$$\lambda = 4^\circ 36'$$

Q. In an orthogonal cutting a single point cutting tool has a side rake angle 12° and approach angle of 70° . Calculate the back rake angle when inclination angle is zero.

Sol.

$$\tan \lambda = \tan \alpha_s \cdot \sin \phi - \tan \alpha_n \cdot \cos \phi$$

$$\tan \lambda = \tan 0 = 0$$

$$\therefore \tan \alpha_s \cdot \sin \phi = \tan \alpha_n \cdot \cos \phi$$

(59)

Ans:
 49.25°

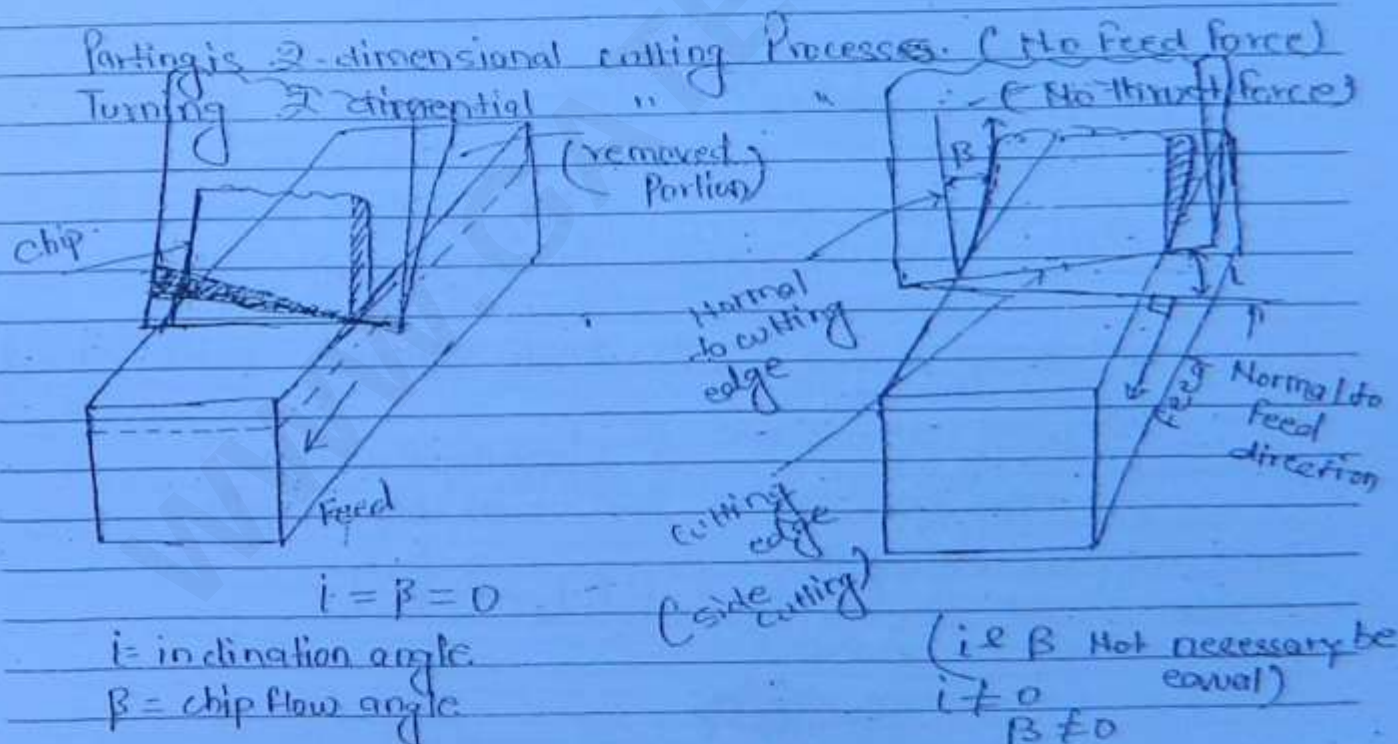
Classification of Metal cutting processes.

Tangential cutting force, axial feed force, Radial thrust force.

2-dimensional cutting
(orthogonal cutting)
(two force component)

3-dimensional cutting
(oblique cutting)
(3 force component)

Generally Tangential cutting force > axial feed force > Radial thrust force =



(i) cutting edge is inclined at right angle to the direction of feed.

(ii) cutting edge is inclined to at an angle i to the Normal drawn to the Feed direction

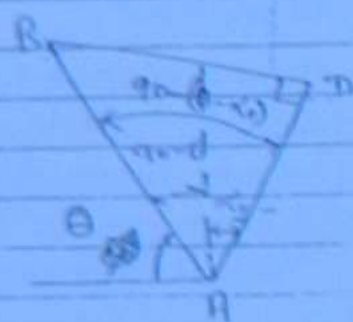
- (i) Tight spiral coiled chip is formed
 (ii) Heat and chip pressure are distributed over a smaller area
 (iii) Reduced tool life

- (iv) long spreading bell shaped chip is formed.
 (v) chip pressure & heat are distributed over wider area.
 (vi) Higher tool life.

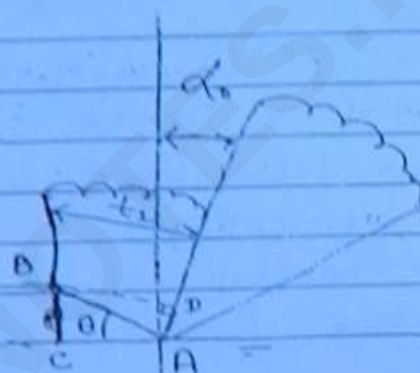
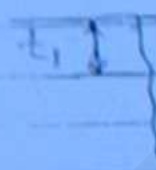
68

Ernst - Merchant theory Shear-angle determination.

Calculation valid for
orthogonal cutting only



$$BD = t_2$$



BD $\perp$ to tool face
 BC $\perp$ to work axis.

Let θ = Shear angle

Plane of

$\rightarrow$ AB = Shear plane

Primary plastic deformation

t_1 = uncut chip thickness.

t_2 = chip thickness.

(i) Volume remain constant

$$\gamma = \text{chip thickness ratio} = \frac{t_1}{t_2} = \frac{l_2}{l_1}$$

(ii) Width remain same
 $b_1 = b_2$

l_2 = length of chip

l_1 = uncut chip length.

(Side spread)

$$(l_1 t_1 = t_2 l_2)$$

In orthogonal cutting, No

side spread i.e. $b_1 = b_2$

~~result~~

~~or~~

$$\gamma = t_1 / l_2$$

due to permanent deformation $t_2 > t_1$

$$[\gamma < 1]$$

Always.

(approx)

efficient metal cutting process is removal of chip without must permanent deformation (i.e. less power consumption)
 [For minimum chip strain $\gamma = 1$ always.]

$$\gamma = \frac{t_1}{t_2} = \frac{BC}{BD}$$

from ΔBCA , $\frac{BC}{AB} = \sin \theta$ (6)

$$AB = \frac{BC}{\sin \theta} = \frac{t_1}{\sin \theta}$$

from ΔBDA , $\frac{BD}{AB} = \sin [90 - (\theta - \alpha_0)]$

$$AB = \frac{BD}{\cos(\theta - \alpha_0)} = \frac{t_2}{\cos(\theta - \alpha_0)}$$

equating AB

$$\frac{t_1}{\sin \theta} = \frac{t_2}{\cos \theta - \cos \alpha_0}$$

$$\left[\gamma = \frac{t_1}{t_2} = \frac{\sin \theta}{\cos(\theta - \alpha_0)} \right]$$

$\gamma (\cos \theta \cdot \cos \alpha_0 + \sin \theta \cdot \sin \alpha_0) = \sin \theta$
 divide both side by $\sin \theta$

$$\gamma (\cot \theta \cdot \cos \alpha_0 + \sin \alpha_0) = 1$$

$$\gamma \cot \theta \cos \alpha_0 = 1 - \gamma \sin \alpha_0$$

$$\cot \theta = \frac{1 - \gamma \sin \alpha_0}{\gamma \cos \alpha_0}$$

$$\tan \theta = \frac{\gamma \cos \alpha_0}{1 - \gamma \sin \alpha_0}$$

Note:

1. For min chip strain condition

$$\tan \theta = \frac{\cos \alpha_0}{1 - \sin \alpha_0}$$

2) when $\alpha_0 = 0$, shear angle corresponding to min chip strain can be calculated as given below.

$$\tan \theta = \frac{1}{1 - \sin 0} = \frac{1}{1} = 1$$

62

$$\theta = \frac{\pi}{4}$$

Velocity in orthogonal cutting

There are 3 types of velocity.

① Cutting velocity.

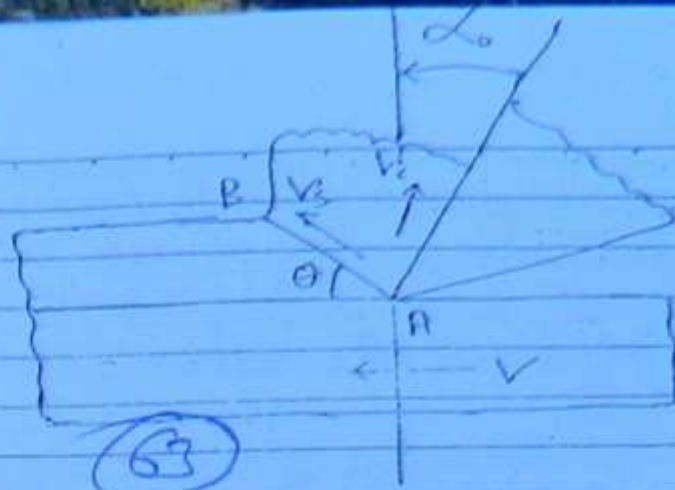
② chip velocity.

③ Shear velocity.

① Cutting velocity denotes the velocity of the tool related to the work piece & directed along the axis of the work. (V).

② Chip velocity (V_c) denotes the velocity of the chip relative to the tool and directed along the tool face.

③ Shear velocity (V_s) denotes the velocity of the chip relative to the work and directed along the shear plane.



(63)

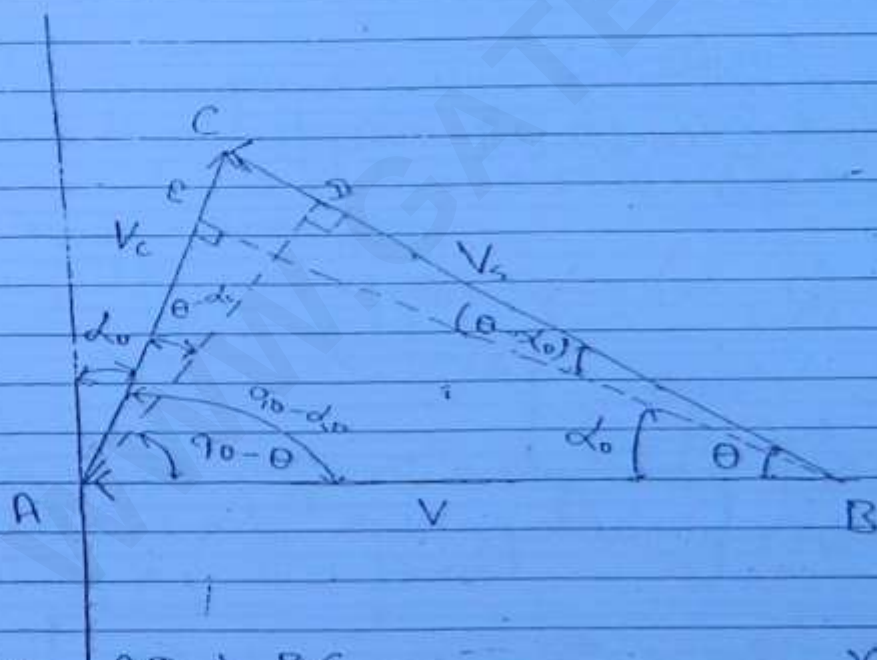
Total work done

= work towards cutting + total work done in shear + work against friction

$$= F_c V + F_s V_s + F V_c$$

$\uparrow$ cutting force $\uparrow$ shear force $\uparrow$ friction force

Assuming equilibrium, all the velocity will form polygon.



Draw $AD \perp BC$

Draw $BE \perp AC$

V_c can be directly calculated

Determination of V_s (In terms of V)

From $\triangle BEC$

$$BE = BC \cos(\theta - \alpha_0)$$

BC

$$BE = V_s \cos(\theta - \alpha_0) \quad \text{--- (1)}$$

From ΔBEG

$$\frac{BE}{AE} = \cos \alpha_0$$

$$BE = V \cos \alpha_0 \quad \text{--- (i)}$$

Equate (i) & (ii)

$$V_c \cos(\theta - \alpha_0) = V \cos \alpha_0$$

$$V_c = \frac{V \cos \alpha_0}{\cos(\theta - \alpha_0)}$$

Determination of V_c

Consider ΔADB

$$\frac{AD}{AB} = \sin \theta$$

$$AD = V \sin \theta \quad \text{--- (ii)}$$

Consider ΔADC

$$\frac{AD}{AC} = \cos(\theta - \alpha_0)$$

$$AD = V_c \cos(\theta - \alpha_0) \quad \text{--- (iv)}$$

Equate (iii) & (iv)

$$V_c \cos(\theta - \alpha_0) = V \sin \theta$$

$$V_c = \frac{V \sin \theta}{\cos(\theta - \alpha_0)}$$

or

$$V_c = V \cdot r$$

$$\vec{V}_s = \vec{V} + \vec{V}_c = \vec{V} + V \cdot r = (1+r)V$$

Q: During a metal cutting test under orthogonal condition it was found that the cutting speed was 165 m/min, rake angle of tool is 10° and shear plane angle is 19° . Calculate chip & shear velocity.

Sol:
$$V_c = \frac{165 \times \sin 19}{\cos (19 - 10)} = 54.35 \text{ m/s}$$

$$V_s = \frac{165 \times \cos 10}{\cos (19 - 10)} = 164.5 \text{ m/s}$$

(65)

Q: In orthogonal cutting with uncut chip thickness is .5 mm at a cutting speed of 2 m/sec. If the chip thickness is 0.75 mm find chip velocity.

Sol:
$$V_c = 2 \times \frac{.5}{.75} = 1.33 \text{ m/s}$$

Q: An orthogonal cutting operation is carried out under the following condition $V = 2 \text{ m/s}$, $t_1 = 0.5 \text{ mm}$, $t_2 = 0.6 \text{ mm}$. Find chip velocity along shear plane.

Sol:
$$V_s = \left(1 + \frac{.5}{.6}\right) \times 2 = 3.66 \text{ m/s}$$

Q: The rake angle of cutting tool is 15° (a) shear angle is 45° (a) cutting velocity 35 m/min find V_c along the tool face.

Sol:
$$V_c = \frac{35 \times \sin 45}{\cos (45 - 15)}$$

$$= \frac{35 \times \frac{1}{\sqrt{2}}}{\cos 30} = 28.5 \text{ m/sec}$$

Q. A medium C. Workpiece is turned on a lathe at 50 m/min speed, 0.8 mm/rev. & 1.5 mm depth of cut what is the rate of metal removal.

Sol: $MRR = V.S.f \cdot \text{mm}^3/\text{min}$
 $= 50 \times 1000 \times 0.8 \times 1.5 \text{ mm}^3/\text{min}$
 $(66) = 60000 \text{ mm}^3/\text{min}$

Note:

(Remaining portion is after geometry of drill bit)

Q. To Ascertain the machinability of different w/p material following data were obtain.

Work Material	Tool life (min)	Cutting speed (m/min)
Hardness: 8640 Steel	30 (hr)	120 (m)
200 BHN	12 (hr)	180 (m)
✓ 1020 Steel	44	210
115 BHN	20	240
4340 steel	40	60
400 BHN	20	90

Estimate the relative machinability By considering 1020 steel as standard and V_{90} as criteria.

Solution:

for 8640 steel

$$V_1 T_1^n = V_2 T_2^n$$

$$120 (30)^n = 180 (12)^n$$

$$\left(\frac{30}{12}\right)^n = \frac{180}{120}$$

$$(2.5)^n = 1.5$$

$$n \cdot \log 2.5 = \log 1.5$$

$$n = 0.4425$$

$$120 (30)^{0.44} = V_3 (90)^{0.44}$$

$$V_3|_{90} = 74.6 \text{ m/min.}$$

(machinability)
Rating index

$$MRI = \frac{74.6}{168.2} = 0.448$$

for 1020 steel.

$$210 (44)^n = 240 (20)^n$$

$$n = 0.31$$

$$210 (44)^{0.31} = V_3 (90)^{0.31}$$

$$\Rightarrow V_3|_{90} = 168.2 \text{ m/min.}$$

$$MRI = \frac{168.2}{168.2} = 1$$

for 4340 steel

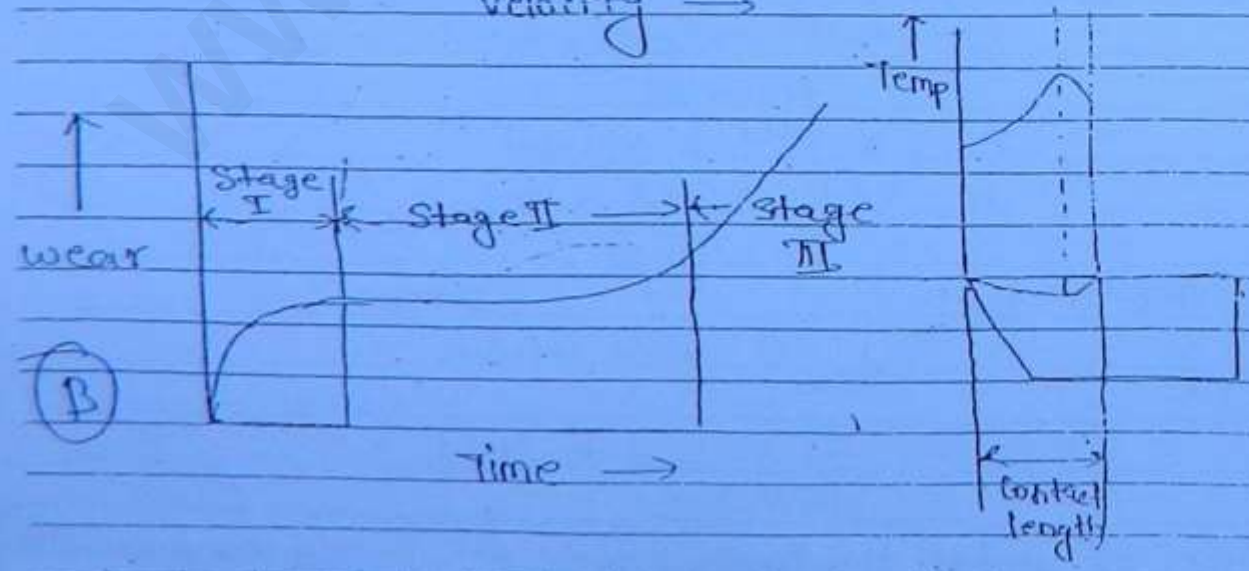
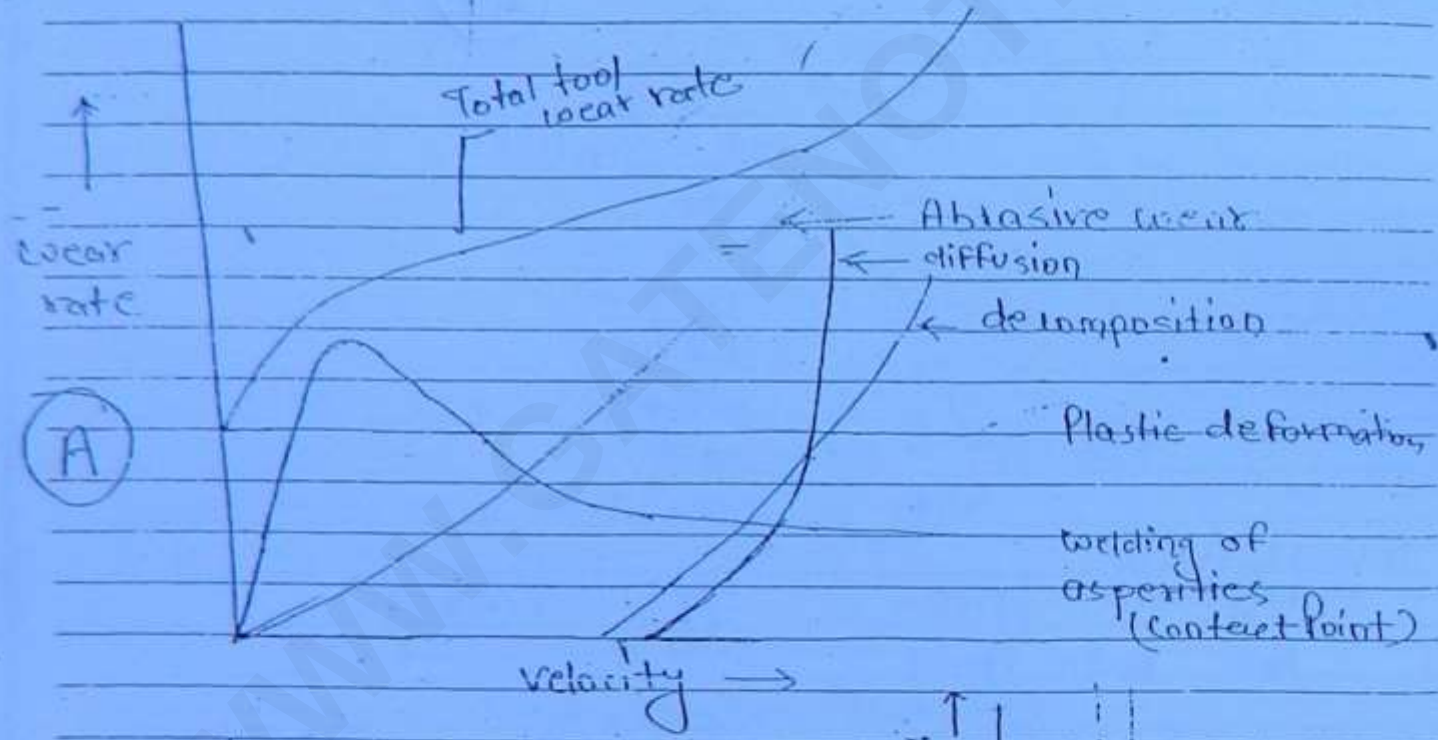
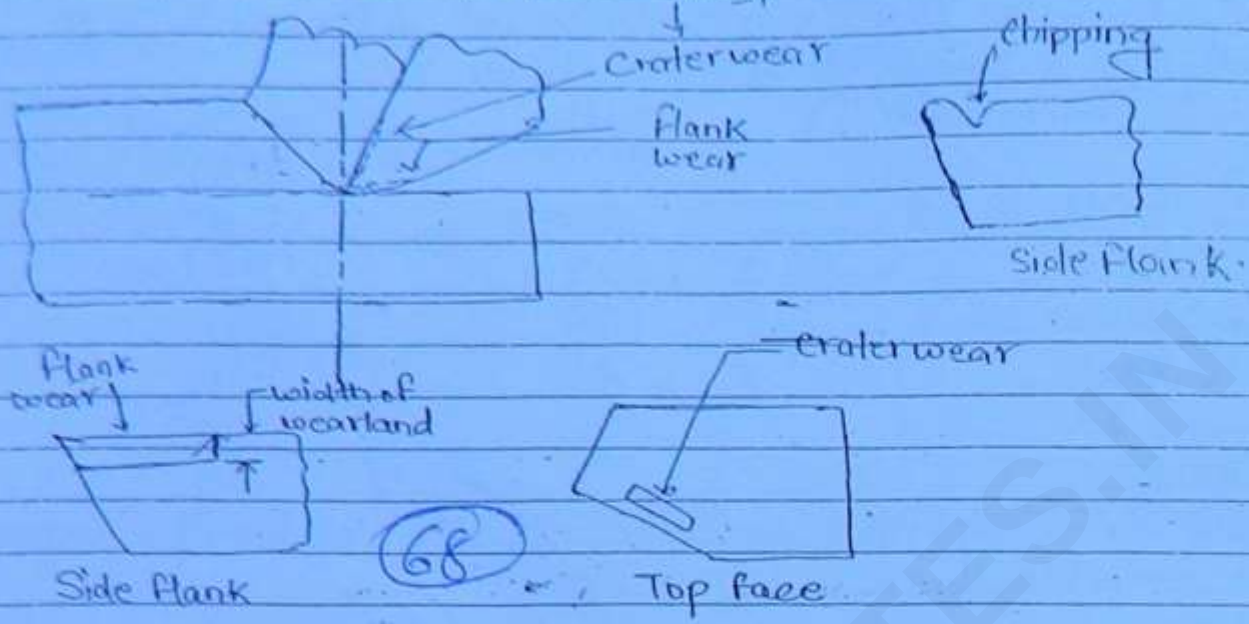
$$V_3|_{90} = 36.91 \text{ m/min.}$$

$$MRI = \frac{36.91}{168.2} = 0.219$$

Higher the index Hardness, lower will be the machinability Index.

(Optimal)

TOOL WEAR



Tool failure can be due to the following 3 reasons.

- ① Excessive forces
- ② Excessive temp.
- ③ Frictional influences and Impact of Hard particles.

In the first mode the tool wear occurs due to excessive clearance angle, machine vibration or due to machining of hard and brittle materials. This may start at the nose, the tool tip may break, the cutting edge may be crumbled (collapsing under compressive forces) leading to tool wear. Temp. failures.

Temp failure can be due to loss of sharpness of cutting edge by the tool material. Every tool material varies from one another in respect of the maximum temp. that it can withstand without undergoing softening.

69

Tool material

Highest temp which it can withstand without softening

- | | |
|---------------------|----------------|
| ① H.S.S. | 560 - 600°C |
| ② Cemented carbides | 800 - 950°C |
| ③ STELLITES | upto 1000°C |
| ④ Ceramic tools | 1200°C |
| ⑤ Diamond | 1500 to 1650°C |

Gradual wear at the tool point may occur in two different forms

① Flank wear

② Crater wear

① Flank wear: Flank wear starts at the cutting edge and progresses towards the side flank. It is found to occur at low feeds and during machining of hard and brittle materials.

② Crater wear: It is found on rake face. It usually starts away from the cutting edge and progresses towards the cutting edge. It is found to occur at feeds more than 0.15 mm/rev and during machining of ductile material. However the reason for crater wear formation with ductile materials is found to be diffusion.

diffusion facilitated by peak temp.

Crater wear is also frequently found with machining of hard and brittle materials however the reason for such crater wear is found to be abrasive effect of eroding hard particles. Following table gives permissible value of wear land width for different tool work combinations

Tool Material	Work material	Wear land width
H.S.S. 70	C.I.	1.5 mm - 2 mm
	Steel	0.6 mm - 1.0 mm
Cemented Carbide	C.I.	0.8 mm - 1.0 mm
	Steel	1.4 mm - 1.7 mm
Ceramic	C.I.	6 mm
	Steel	

Mechanism of tool wear

- ① Plastic deformation
- ② Diffusion
- ③ Abrasion
- ④ chemical decomposition
- ⑤ welding to contact points & tool chip

As shown in fig (A), the variation of total tool wear as a function of time is shown in fig (B)

This curve shows 3 significant regions.

→ Stage 1 is known as initial wear period. In this particular period initially wear rate is high due to fresh surfaces participating in sliding interaction.

Gradually the wear rate decreases.

→ Stage 2 is known as Steady State wear region. This is characterised by a gradual increase in wear rate or constant wear rate.

→ Stage 3 is known as rapid wear zone. It is characterised by a steep rise in wear rate. A decision regarding resharpening is usually taken in the beginning of this stage.

CUTTING TOOL MATERIALS

Properties:

Abrazion resistance

- (1) Toughness
- (2) Hardness
- (3) Red hardness
- (4) High young modulus/elastic modulus (HPPness)
- (5) good thermal conductivity
- (6) low coefficient of thermal expansion.
- (7) low coefficient of friction. — for conservation of Power
- (8) Anti chip welding properties:
 (No buildup edge) 7

Cutting tool materials and their characteristics:

- H.S.S. →
- (1) They are High C Steels alloyed with W, Cr, Mo, V.
 - (2) Alloying elements improve hardness and wear resistance.
 - (3) They are of 2 types
 - (A) Tungsten type.
 - (B) Mo type.

— out of the 2 varieties Mo type are cheaper and more tougher.

- (4) The main mode of wear is abrasion.

STAINLESS STEELS →

- (1) They are cast cobalt alloys.
- (2) They are not as tough as H.S.S.
- (3) They are sensitive to Shock loading.
- (4) They are available in the form of brazed tips to steel Shank
- (5) They have good wear resistance.
- (6) The main mode of wear is abrasion.

Cemented Carbide →

- (1) They have high hardness, high modulus of elasticity, low coefficient of thermal expansion & good thermal conductivity.
- (2) 3 types of Carbide tools are available
 - (1) Straight W carbide tool.
 - (2) Cubic carbides
 - (3) Coated carbides.

- (3) In the cubic carbides have the permissible cutting speed 2 to 3 times larger than the straight W carbide tool.

④ Coated Carbides increase resistance to crater wear and diffusion wear.

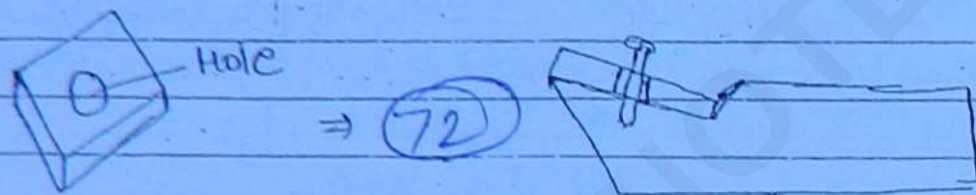
Coating materials on W Carbide $\rightarrow$ Titanium carbide
Tantalum carbide

Ceramics: ① They are made by powder metallurgy process.

② Composition consists of Aluminium oxide, magnesium oxide, MnO_2 , CrO_2 , Nickel oxide, Titanium oxide etc.

③ The additions to alumina improve grain structure & sintering properties.

④ Ceramic tools are available as indexable inserts.



⑤ They have high abrasion resistance and are harder than cemented carbide.

⑥ They have poor impact resistance.

⑦ They possess excellent anti-chip welding properties.

⑧ The main mode of wear is chipping.

Cubic Boron Nitride (CBN)

① They are made as indexable inserts. They have high hardness, high thermal conductivity, coupled with good tensile strength.

② The toughness & abrasion resistance of cubic boron nitride are excellent, hence they are used for machining of hardened steel, chilled cast iron, as well as high speed steel.

③ Both crater & flank wear are found to occur in their case.

Diamonds: ① extremely high in hardness, possess low coefficient of thermal expansion, high heat conductivity, poor resistance to shock.
② They are preferred for machining of abrasive non ferrous alloys like copper alloys, sink, alumina, mg. alloys, glasses, ceramics. (Brass)
↓ (silicate glasses are ceramics only) ⑦⑧

diamond is not recommended for machining of steel because at cutting temp more than 730°C diamond undergoes a lot of allotropic transformation of into graphite and hence becomes soft.

Favourable conditions and effects:

Discontinuous chips	Continuous chips	Continuous chips with Built-up-edges.
---------------------	------------------	---------------------------------------

① Machining of Brittle materials. ✓ ② Ductile material ✓ ③ Ductile material

like - C.I., Brass, castings
Titanium, ~~Be~~ Beryllium etc.

(74)

- | | | |
|--|--|---|
| ② low cutting speeds, ✓ | ② High cutting speed ✓ | ③ low cutting speed ✓ |
| ③ Small feed. | ③ large feed | ③ large feed ✓ |
| ④ Small Rake angle. ✓ | ④ large rake angle ✓ | ④ Small Rake angle ✓ |
| ⑤ Discontinuous chips are easier to dispose. | ⑤ chip disposal is difficult. (use chip Breaker) | ⑤ Chip disposal is difficult. |
| ⑥ Good surface finish. | ⑥ Poor surface finish. (if chip is not disposed earlier) | ⑥ Poor surface finish. |
| ⑦ Force variation is high. Strain energy in tool is more, hence tool life is less. | ⑦ Force variation is low. Steady force acts on tool. Strain energy in tool is less. tool life is more. | ⑦ cutting forces increase less tool life is more due to formation of BUE. |
| ⑧ Ineffective lubrication. high coefficient of friction. | ⑧ effective lubrication low coefficient of friction. | ⑧ Removed of BUE decrease tool life
⑧ Ineffective lubrication high coefficient of friction |

Built-up-edges - Salient features:

- ① When the frictional conditions on the tool face results in the compression of the contact layers, some layers may separate out from the bulk of the chip and such separated layers are called built-up edges.
- ② Built-up-edges are transition zones (they are unstable)
- ③ They are not homogeneous in structure
- ④ They differ from the metal being machined & the chip in respect of their structure
- ⑤ They are partly or completely destroyed due to the impact of hard particles flowing in the chip.
- ⑥ It is not considered harmful in roughing operations.
- ⑦ Variation in the height of BUE changes the tool geometry and also effect the accuracy of work piece.

ECONOMICS OF METAL CUTTING

Element of cost

(1) Nonproductive costs
(Loading, unloading, inspection etc.)
= $Z_1 \times \text{non-productive time/piece}$

= constant
(say 5 paise)

(2) Machining cost
depends upon
machining time

$$= Z_1 \times \text{machining time}$$

$$= Z_1 \times T_m$$

$$= \frac{Z_1 \times \pi D L}{1000 S} \times V^{-1}$$

(75)

Tooling cost

Tool change cost (3)

$$= Z_1 \times \text{No of tool failures} \times \text{Tool change time}$$

Tool Regrinding cost (4)

$$= Z_2 \times \text{No of Tool Failures}$$

$$= \frac{Z_2 \times \pi D L}{1000 S} \times \frac{V_0^{-1}}{c^{1/n}}$$

Notation: Z_1 = Direct labour cost & overhead cost Rs/min

Z_2 = Regrinding cost Rs/piece

D = Dia of work piece, mm

L = length of work piece, mm

V = cutting speed, m/min

N = Spindle Speed rev/min

TCT = Tool change time

T_m = Machining time — min.

$$= \frac{L}{S \times N} = \frac{L}{S \times \frac{1000 V}{\pi D}}$$

S = Feed in mm/Rev.

T_m = No of tool failure

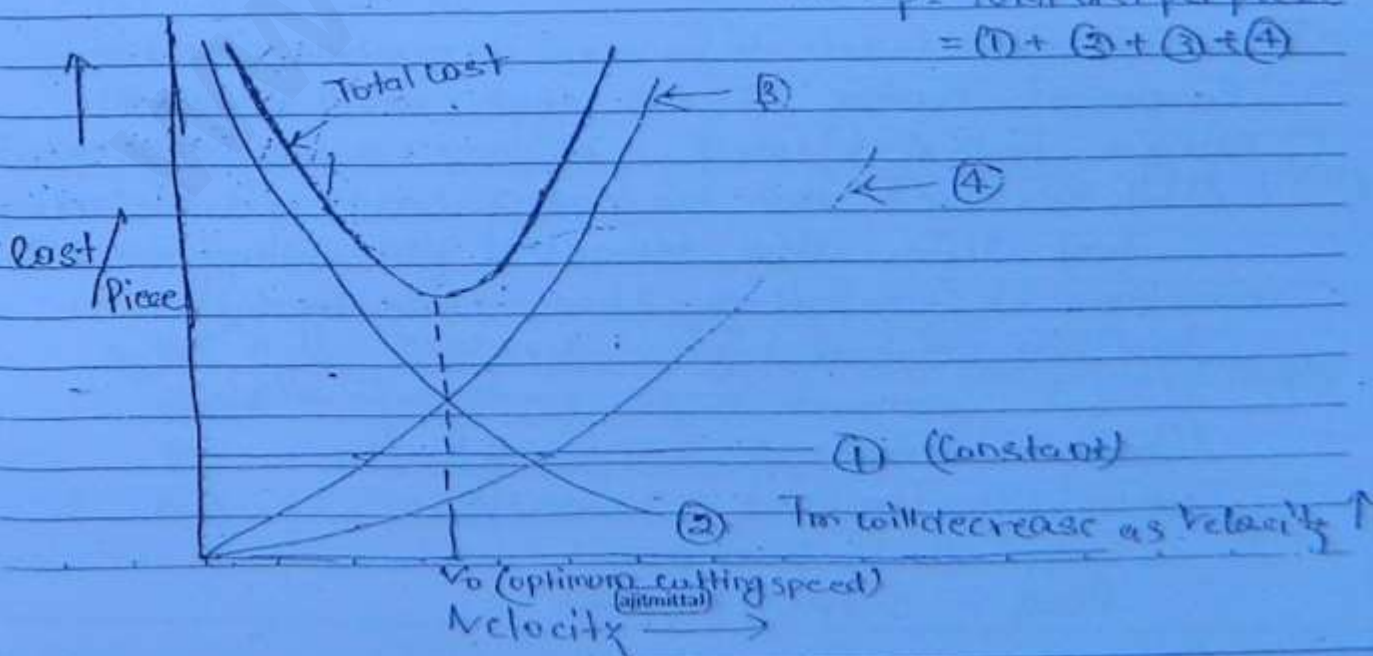
$$= \frac{\pi D L}{1000 V S} \times \left(\frac{V}{c}\right)^{1/n}$$

Tool life $\rightarrow T$

$$V T^n = C$$

$$T = \left(\frac{C}{V^n}\right)^{1/n}$$

Let C_p = Total cost per piece
= (1) + (3) + (3) + (4)



For calculation of optimum cutting speed corresponding to minimum total cost, $\left[\frac{dC}{dV} = 0 \right]$

$$V_{\text{optimum}} = \frac{C}{\left[\left(\frac{1}{n} - 1 \right) \left\{ T_{CT} + \frac{Z_2}{Z_1} \right\} \right]^{\frac{1}{n}}}$$

Compare with $V = \frac{C}{T^n}$ (Taylor's eqn)

Corresponding tool life $\left[T_{\text{opt}} = \left(\frac{1}{n} - 1 \right) \left\{ T_{CT} + \frac{Z_2}{Z_1} \right\} \right]$

Determination of V_{opt} for max. production rate
for max. production rate, regrinding cost is negligible i.e. $Z_2 = 0$

$$V_{\text{opt}} = \frac{C}{\left[\left(\frac{1}{n} - 1 \right) \left\{ T_{CT} \right\} \right]^{\frac{1}{n}}}$$

Corresponding tool life $\left[T_{\text{opt}} = \left[\left(\frac{1}{n} - 1 \right) (T_{CT}) \right]^{\frac{n}{n-1}} \right]$

Q. An automatic lathe is to be used to machine aluminium components having 75 mm length and 50 mm dia. using a depth of cut of 1.25 mm calculate the speed that minimized the machining cost and the corresponding tool life, also estimate the cutting speed for min. time of production. Assumed following data.
Tool life relationship is $V_T^{0.25} = 300$

labour + overhead rate = $Z_1 = 5 \text{ Rs/hr.}$

reconditioning cost = 0.25 Rs.

$T_{CT} = 5 \text{ min}$

feed = $0.2 \text{ mm/Rev. (optimal)}$

Sol: $V_{opt} = \frac{300}{\left[\left(\frac{1}{0.25} - 1 \right) \left\{ 5 + \frac{0.25}{\frac{5 \text{ Pa}}{60 \text{ min}}} \right\} \right]^{0.25}} = 135.6 \text{ m/min}$

$T_{opt} |_{\text{min cost}} = 24 \text{ min.}$

$N_{opt} |_{\text{material cost}} = 152.44 \text{ m/min.}$

(77)

Q1: The effects of setting a boring tool above centre height leads to: → Decrease in rake angle, clearance angle increase.

Q2: Soft material can not be economically ground due to:

(a) High temp. involve

(b) Grinding wheel glazing.

(c) Rapid wear of grinding wheel

(d) low work piece stiffness.

Q3: Primary force which is used in power consumption calculation is — Tangential cutting force.

Q4: Rearrange the following materials in the increasing order of difficulty in machining

(1) Titanium (2) mild steel (3) stainless steel

(4) Grey cast iron.

(a) 4-2-3-1.

(b) 4-2-1-3.

(c) 2-4-3-1.

(d) 2-4-1-3.

Q5: Single point cutting tool used in thread cutting should ideally have — Zero Rake angle.

Q6: Chip equivalent is increase by:

(a) Increase in side cutting edge angle.

(b) " " " Nose radius & side cutting edge angle.

(c) " " " Side cutting

(d) " " " Plane area of cut.

(e) " " " depth of cut.

- Q.7: CBN as hardness (i) ^{Slightly} more than HSS
 (ii) used for making cylinder blocks of air craft engine
 (iii) used for making optical glasses
 (iv) has a hardness comparable to diamond

78

Q.8: Predominant mode of wear in H.S.S. tools is
 — Abrasion.

Q.9: Notch wear is also called — Flank wear.

Q.10: Which of the following indicate better machinability:

(1) longer tool life (2) good surface finish.

(3) Smaller shear angle (4) Higher cutting forces

Q.11: Specific energy in grinding is more than that in turning for the same material removal rate because —

(1) High specific pressure exist in grinding

(2) Size effect of the larger contact area b/w wheel and work

(3) High cutting velocities

(4) large heat produce during grinding

Q.12: Consider the following forces acting on a finish turning tool and arrange them in the decreasing order of magnitudes.

(i) Feed force (ii) Thrust force (iii) cutting force

Ans: (iii) — (ii) — (i)

Q.13: Assertion: For high speed turning of C.T. piston, carbide tool bits are provided with chip breakers.

Reason: High speed turning may produce continuous chips, which must be broken into small length, which are otherwise difficult to handle.

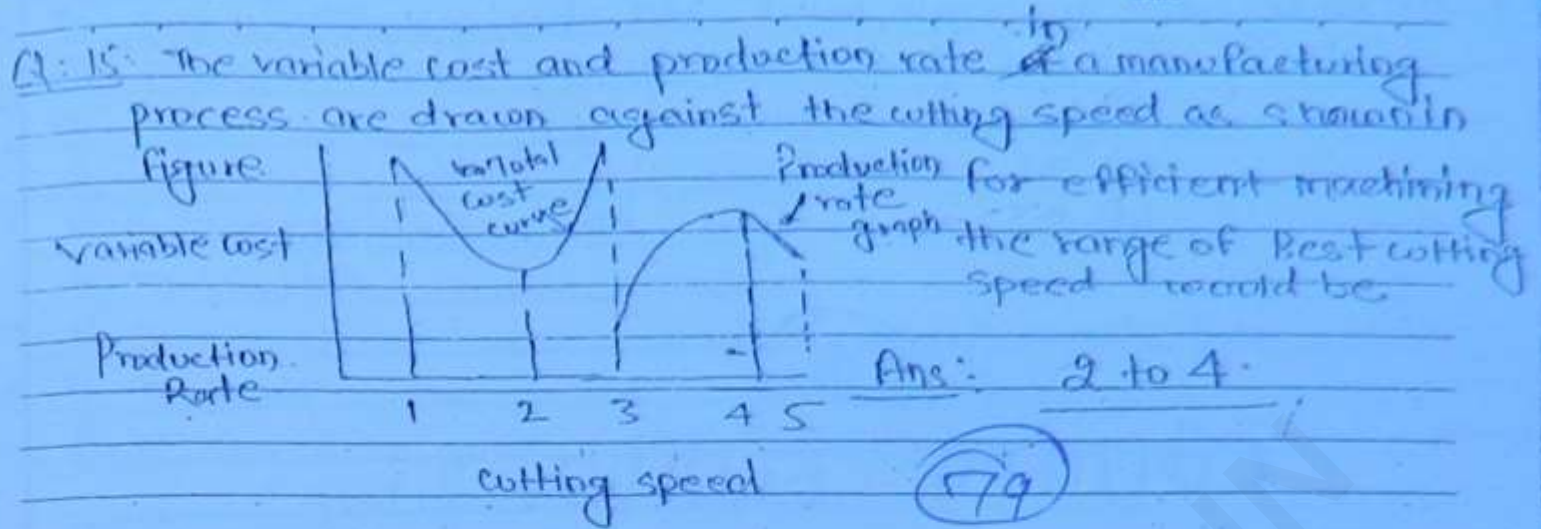
R — correct A — wrong

Q.14: A → Ceramic tools are used only for light, smooth, and continuous cuts at high speeds.

R → ceramics have high wear resistance & high temp. resistance.

B is Ans A & R are correct

R is not correct reasoning.



Q: 16: Which of the following sets of forces are encountered by a lathe parting tool while groove cutting

- (a) tangential, radial, axial
- (b) Radial, axial
- (c) tangential, Radial
- (d) tangential, axial

Q: 17: In a single point turning operation with a carbide tool the tool life exponent is 0.25, if the cutting speed is halved the tool life will ↑ by

$$V_1 T_1^n = V_2 T_2^n$$

$$V_1 (T_1)^{0.25} = \frac{1}{2} V_1 (T_2)^n$$

$$2 (T_1)^{0.25} = T_2^n$$

$$(16 T_1)^{0.25} = T_2^{0.25}$$

$$T_2 = 16 T_1$$

16 times

Q: 18: For Precision machining of Non ferrous alloys diamond is preferred because it has:

- (a) low coefficient of thermal expansion
- (b) high wear resistance
- (c) high Compression Strength
- (d) low fracture toughness

Q: 19: In a turning operation feed is doubled to increase the MRR to keep the same level of surface finish the nose radius of tool should be

- (a) made half
- (b) unchanged
- (c) doubled

- (d) made 4 times

$$h_{max} = \frac{S^2}{8r}$$

(optimal)

r = Nose radius

$$c = \frac{2^2 S^2}{8r} = \frac{4S^2}{8r \times 4}$$

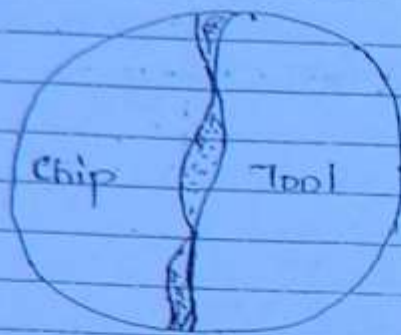
r should be 4x

Q: The radial force in a single point tool turning operation varies
blw

(A) 0.1 - 0.6 times
(B) 0.2 - 0.4 times
(C) 0.6 - 0.8 times
(D) 0.5 - 0.6 times

The main cutting force

CUTTING FLUIDS



Functions of cutting fluids:

- ① Reduces kinetic coefficient of friction due to formation of low shear strength solid.
- ② Forces ↓ Power consumption ↓.
- ③ Better surface finish.
- ④ Possibility for formation of BUE is minimized.
- ⑤ Tool life increases.
- ⑥ Machining accuracy of w/p increases.
- ⑦ chip tool interface temp decrease.
- ⑧ chips will get easily disposed.
- ⑨ m/c vibration will be minimized.

Types of cutting fluids:

- ① water based soluble oil → Best cooling
- ② Mineral oils → excellent cooling
- ③ Fatty oils (lard oils) → highly viscous
- ④ Blended oil (mineral + fatty oils)
- ⑤ oils with EP additives used in
extreme pressure
(S.I. 11)

Desirable Properties of cutting fluids:

- (1) Good thermal conductivity.
- (2) High film coefficient of film transfer.
- (3) Good lubricating properties. (low viscosity)
- (4) High flash point
- (5) It should be odourless.
- (6) It should be harmless to skin.
- (7) It should not cause corrosion in w/p or m/c part.
- (8) It should be transparent.
- (9) It should be good wettability, low surface tension.
(good spreading characteristics)
- (10) It should be non toxic.
- (11) It should be chemically stable.
- (12) It should be economical.

(8)

Comparison of cutting fluids:

(Qualitative bases)

Types of cutting fluid	Cooling Properties	Lubrication Property	Anti-chip welding Properties
Water	Excellent	Poor	Poor
Mineral oil	fairly good	Good	Fair
Partly oil	Fair	Excellent	Fair
EP cutting oil	Fair	Good	Excellent

Guidelines for selection of cutting fluids:

- (1) low speed shallow cuts require little cooling or lubrication.
- (2) A cutting fluid of considerable oiliness is required while machining tough metals at low speed or heavy cuts.
- (3) Shallow cuts at high speeds require good coolant.
- (4) Heavy cuts & high speed call for excellent cooling & lubricating properties.

low velocity cut	Shallow cut any fluid.	heavy cut. Excellent lubrication
High velocity cut	excellent cooling	Both

operation	Requirement	Recommended
Date		
① Turning	Selection of cutting fluid depends upon Velocity, Feed & depth of cut	Cutting fluid. Mineral oils or fatty oils are generally used. For light duty application, water soluble oils are sometime used for economy.
② Sawing	Requirements of Flushing of chips and prevention of adhesion of chips.	Water Soluble oil recommended
③ Thread cutting	cutting speed low, depth of cut is more ∴ main requirement is lubrication	Mineral oils with minor addition of lard oils.
④ Drilling, Boring, Reaming	Lubrication and cooling	Water Soluble oils.
⑤ Planing, shaping and slotting	→ (usually No cutting fluid Required)	← (tool gets cooled during return stroke.)
⑥ Milling	lubrication, cooling & Prevention of vibration.	Sulphurised mineral oil.
⑦ Grinding, Honing, lapping	Cooling is main, shallow depth.	Water Soluble oils

[chsastry@indiatimes.com]

No. _____
Date _____

Recommended cutting fluid on the bases of workpiece material:

w/p material

- Aluminium
- Copper & its alloys
- For carbon steels.

(83)

- Free cutting speed

- High Strength heat Resisting steels.

- Stainless steel

Pyrphoric material

- Magnesium
(It catches fire under metal cutting)

Recommended cutting fluid

Kerosene

Mineral oil blended with fatty oils are used.

oils with RP & additives for
brazing operation &
Mineral oil for other low
cutting speed operation.

Generally machined dry,
however under aggressive cutting
condition sulphurised mineral oil can be
used.

→ Sulphurised mineral oils are used.

→ For low speed machining operation
like tapping or Brazing mineral
oils are used.

For high speed machining operation
water soluble oils are used.

→ High speed cutting is prohibited
it is recommended only for low
machining operation.
When moderate speed machining is
taken up, we can go for mineral
oil.

[chsastry @india-times.com]

Unconventional m/c Process

unconventional: (i) Some form of energy is used to cut

(ii) No relative work-tool motion.

(iii) Unconventional m/c are not m/c tool i.e. Not a relative motion

(84)

(iv) little attention on tool geometry.

(v) So much of energy involve.

AB AEM: (i) used for hard and brittle material.

(ii) can be used for polishing operation.

Plasma: Plasma torch is made of copper.

Plasma gases: - H_2 , N_2 , He , Ar .

(ionisation of gases)

max temp in plasma $\rightarrow 16000^\circ C$

(Infinity resistance in plasma)

it is a rough machining operation.

Laser Beam $\rightarrow$ Cannot used for every ~~see~~ material.

Silver, Al can not be machined because

good reflectivity and heat transfer capacity.

Ultrasonic - MRR is low.

Machining $\rightarrow$ - Can machine conductive & Non conductive material

- used for making any kind of Holes.

[Bore grinding is conventional form of ultrasonic machining]

Electrochemical m/cing: Workpiece $\rightarrow$ anode

Tool $\rightarrow$ Cathode

electrolyte $\rightarrow$ NaCl (electroconductivity remains almost constant during electrolysis)

Extremely thin can be machined by this. Is because no pressure.

electrochemical grinding $\rightarrow$ Both abrasion & electrolysis.

EDM:

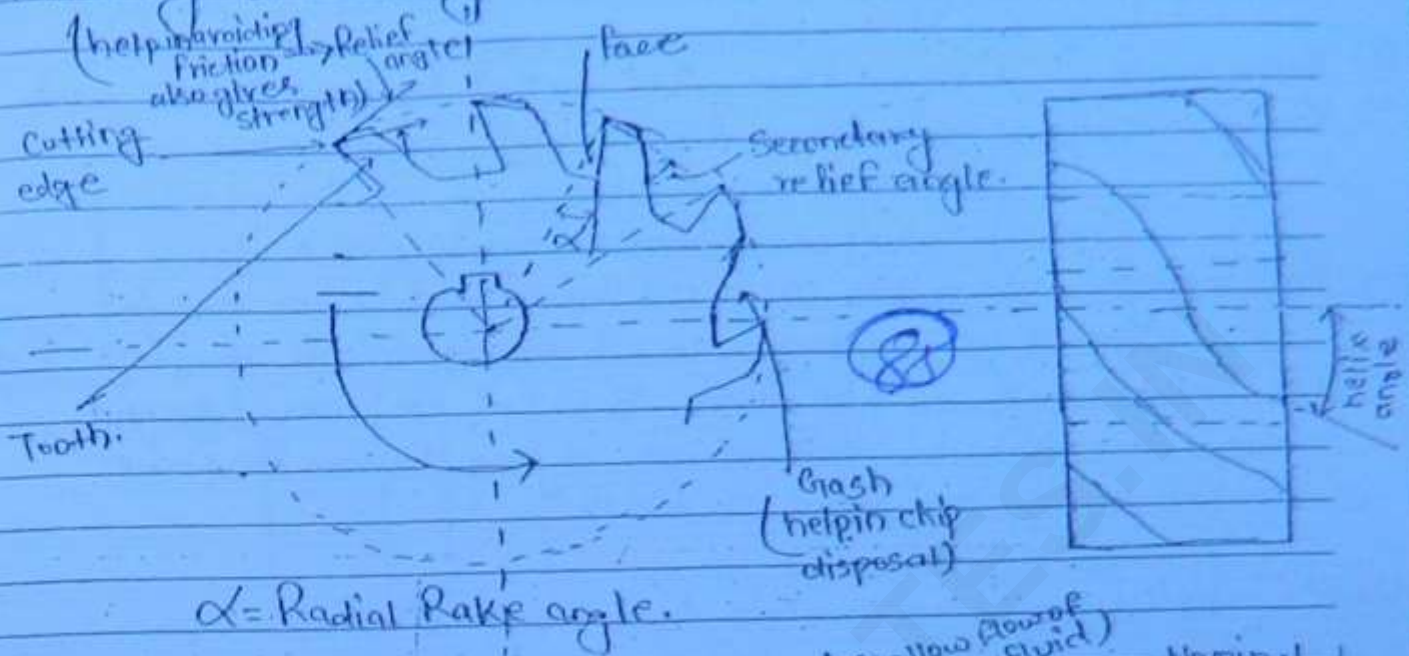
Initially dielectric fluids are insulator.

electrode will go under go wear.

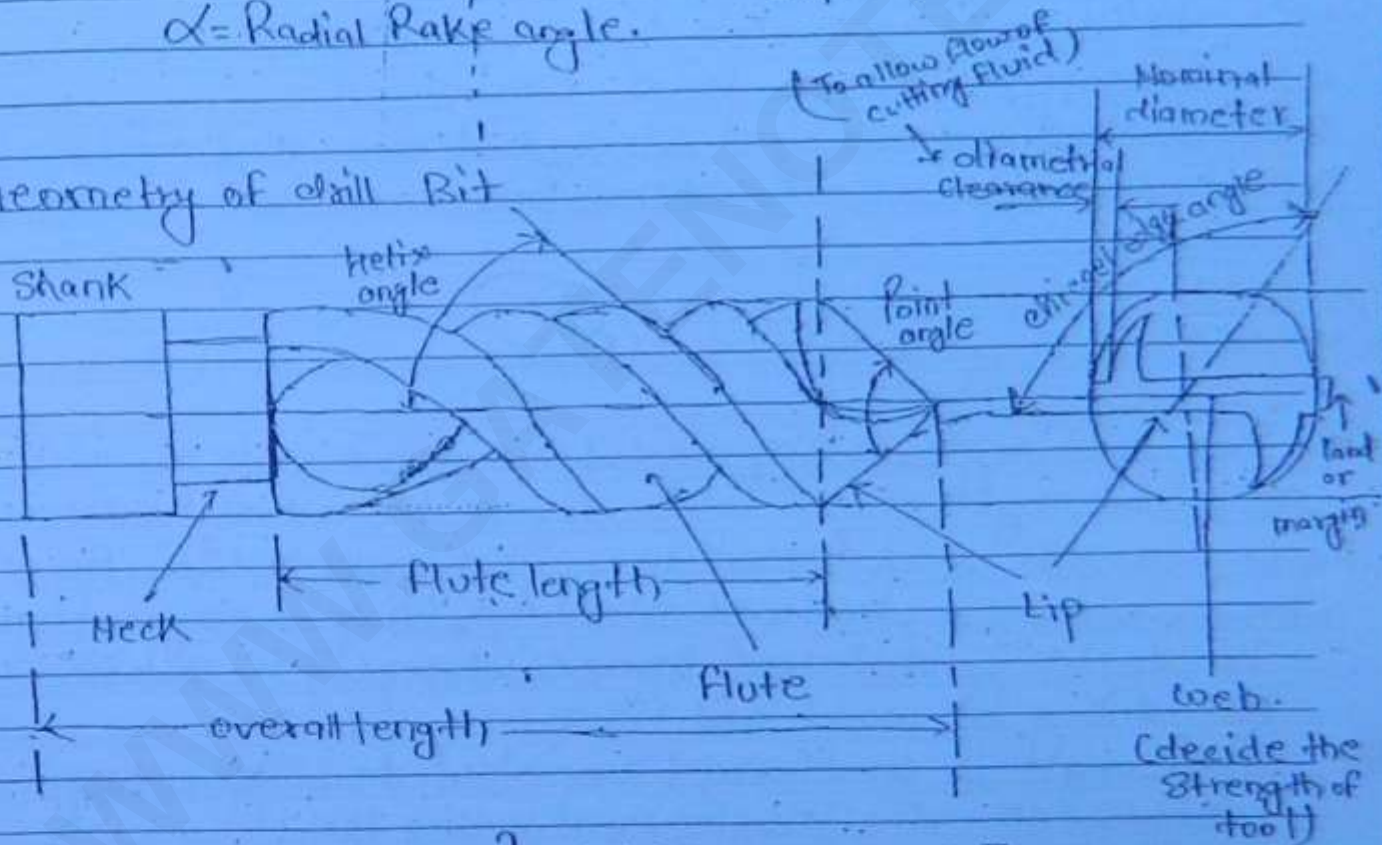
EDM $\rightarrow$ gives excellent surface finish. then EDM

EDM: $\rightarrow$ restricted for thick section.

Geometry of milling cutters:



Geometry of drill Bit



Smaller dia Shank Parallel Shank
 Larger dia Shank tapered Shank ($> \phi 12$) generally.

Flutes are made by twisting operation.
 (Bar is taken to the red hot condition and then twisted
 in a on its axis)

Geometry of milling cutter:

- ① Helix angle : It ranges from 20° to 30° for plane helical cutter.
- ② Back rake angle : varies from 10° to 20° . Larger values are preferred for machining of softer materials. Smaller values are preferred for machining of harder.
- ③ Relief angle : depend on w/p material & the cutter material.
ex: when H.S.S. cutter are used for m/cing of Steel & CI. the relief angle range from 5 to 10° whereas with the same cutter material for m/cing of non ferrous material the relief angle vary from 7 to 12° .

Note: Relief angle on Carbide tool will be of smaller value compare to those on H.S.S. cutters.

Width of land depends upon strength of the cutting point.
ex: the average value of width of land varies from 0.8 to 1.6 mm.

Geometry of drill Bit :

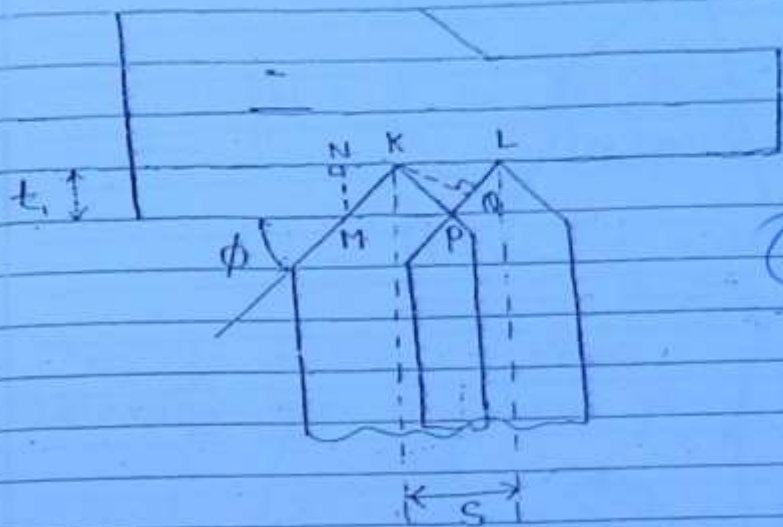
(86)

- ① The point angle is will selected based on the w/p material.
ex: Point angle = 116 to 118 degree for medium hard steel & cast iron. It is equal to 125° for hardened steel and its value ranges from 130 to 140° for Brass & Bronze, whereas it is just 60° for drilling of wood and Fiber.
- ② Point angle is considered equivalent to side cutting edge angle of a single point cutting tool.
- ③ Helix angle : This is equivalent to Back Rake angle of a single point cutting tool. its value ranges from 24 to 30° for most drills.
- ④ Chisel edge angle : It is the angle which the raised line at the dead centre makes with the cutting edge. Its value ranges from 120 to 135° .

Remaining Portion.

No. 43
Date

WIDTH OF UNCUT CHIP AND THICKNESS OF UNCUT CHIP.



(87)

let t = depth of cut.

width of uncut chip is defined as the distance b/w machined surface and the work measured along the cutting edge.

$MN \perp$ to NK

$$\text{width of uncut chip } KM = LP = b = \frac{t}{\sin \phi}$$

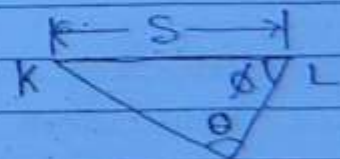
$\phi_c = 90^\circ$ Turning of Pipes.

Thickness of uncut chip — is defined as distance b/w the consecutive positions of the cutting edge measured in direction perpendicular to the cutting edge.

$KQ \perp$ to PL .

$$\text{uncut chip thickness} = t_1$$

$$t_1 = KQ = S \sin \phi$$



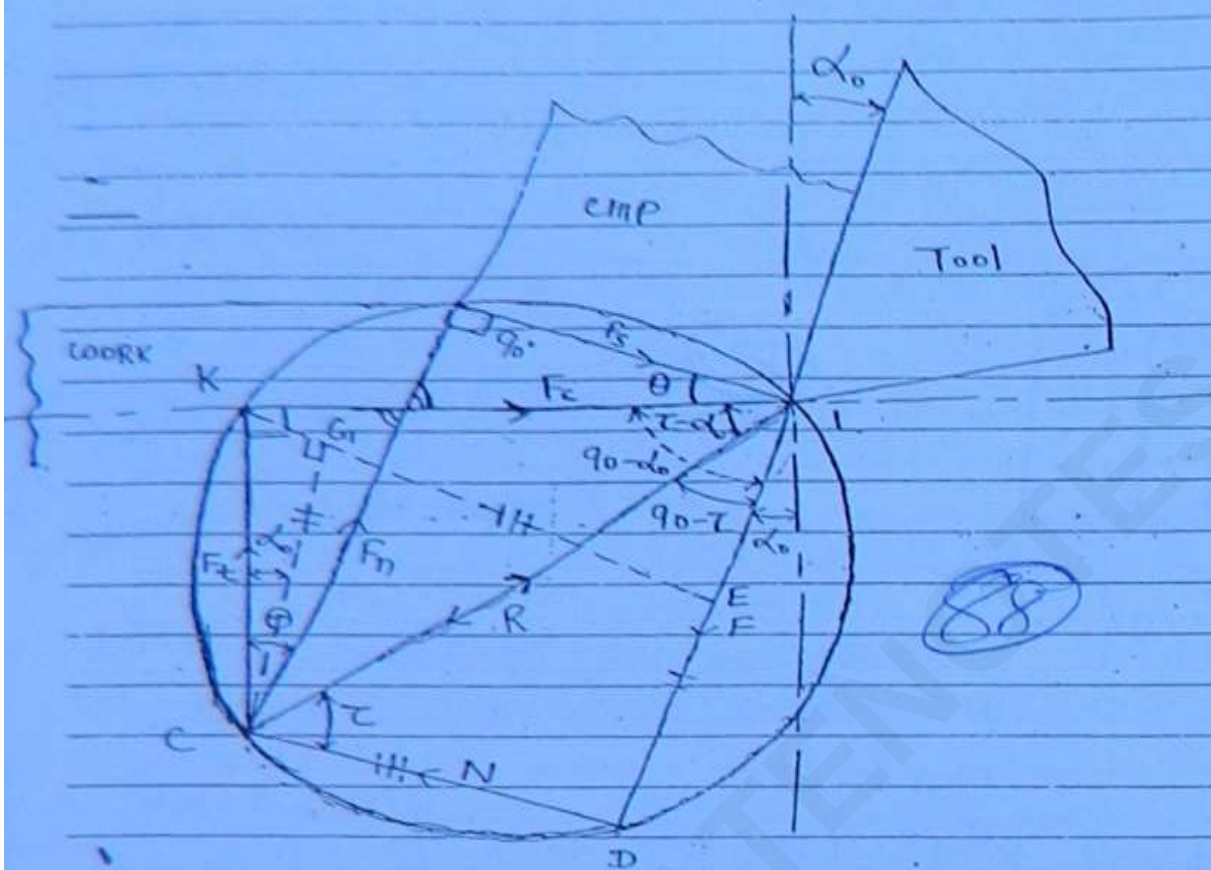
Note: In case of surface finishing operation performed with orthogonal tool, the uncut chip thickness can be taken as to depth of cut (shapping, planing, slotting).

FORCE RELATIONSHIP IN ORTHOGONAL CUTTING

No.

Date

CUTTING



Dia. of merchant circle is = Resultant force.

Secondary force. $\begin{cases} F_c \ \& \ F_f \Rightarrow \text{Cutting plane.} \\ F_s \ \& \ F_n \Rightarrow \text{Shear plane.} \\ F \ \& \ N \Rightarrow \text{Normal Plane.} \end{cases}$

Normal Reaction on tool face.

Determination of tool plane forces.

Draw line KE $\perp$ LD

Draw line CG $\perp$ KE.

$$(ED = GC)$$

$$F = LD = LE + ED$$

$$= F_c \cos(90 - \alpha_0) + GC$$

$$= F_c \cos(90 - \alpha_0) + F_f \cos \alpha_0$$

$$F = F_c \sin \alpha_0 + F_f \cos \alpha_0$$

$$N = CD = CE = KF - KN$$

$$= F_c \sin(90 - \alpha) - F_t \sin \alpha$$

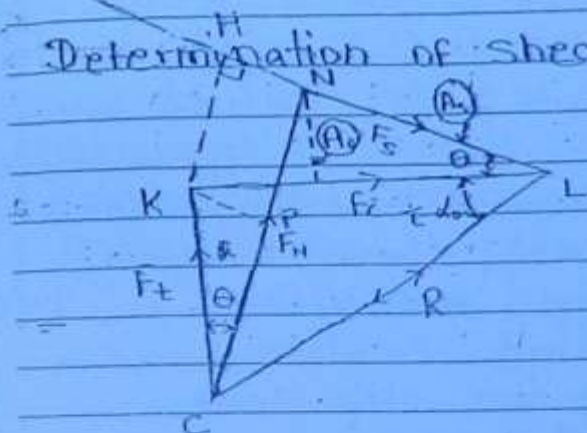
$$N = F_c \cos \alpha - F_t \sin \alpha$$

$$M = \frac{F}{N} = \frac{F_c \sin \alpha + F_t \cos \alpha}{F_c \cos \alpha - F_t \sin \alpha}$$

$$\tan \tau = \frac{F}{N} = M$$

(89)

Determination of shear plane forces



Draw $KH \perp LN$

Draw $KP \perp CN$

$$F_c = LN = HL - HN \quad (HN = KP)$$

$$= F_c \cos \theta - KP$$

$$F_c = F_c \cos \theta - F_t \sin \theta$$

$$F_n = NC = NP + PC$$

$$= KH + PC$$

$$F_n = F_c \sin \theta + F_t \cos \theta$$

let τ_s = Shear stress on shear plane

$$\tau_s = \frac{F_s}{A_s}$$

$$\tau_s = \frac{F_c \cos \theta - F_t \sin \theta}{(bt/\sin \theta)}$$

$$\frac{A_0}{A_s} = \sin \theta$$

$$A_s = \frac{A_0}{\sin \theta} = \frac{bt}{\sin \theta}$$

let σ_n = Normal stress on shear plane

$$\sigma_n = \frac{F_n}{A_s} = \frac{F_c \sin \theta + F_t \cos \theta}{(bt/\sin \theta)}$$

(Optimal)

Additional Results:

$$(i) \frac{F_c}{R} = \cos(\tau - \alpha_0)$$

$$(ii) \frac{F_s}{R} = \cos(\theta + \tau - \alpha_0)$$

$$(iii) \frac{F_c}{F_s} = \frac{-\cos(\tau - \alpha_0)}{\cos(\theta + \tau - \alpha_0)}$$

$$(iv) \frac{F_H}{F_s} = \tan(\theta + \tau - \alpha_0) \quad (96)$$

Note: when $\alpha_0 = 0$ then $\mu = \frac{F_H}{F_c} = 0.5$

Q: An orthogonal turning, the following data were obtained
 Rake angle $\alpha_0 = 15^\circ$ and V cutting speed 100 m/min.
 and uncut chip thickness $t_1 = 0.2$ mm, cutting force
 $F_c = 180$ kgf, feed force $= 60$ kgf. Calculate
 the shear angle, $\mu = ?$ cutting power, chip velocity,
 Shear force if the chip thickness $= 0.3$ mm.

Solve:

$$r = \frac{t_1}{t_2} = \frac{0.2}{0.3} = \frac{2}{3}$$

$$V_c = V \times r$$

$$= 100 \times \frac{2}{3} = 66.67 \text{ m/min.}$$

$$\mu = \frac{F_c \sin \alpha_0 + F_t \cos \alpha_0}{F_c \cos \alpha_0 - F_t \sin \alpha_0}$$

$$\mu = \frac{180 \sin 15 + 60 \cos 15}{180 \cos 15 - 60 \sin 15}$$

$$\mu = 0.67$$

$$\text{Cutting power} = \frac{F_c (\text{kgf}) \times (V) \text{ m/min}}{7500}$$

$$= 4 \text{ H.P.}$$

$$\tan \tau = \mu$$

$$\tau = \tan^{-1} \mu$$

$$(\tau = 23^\circ 26')$$

$$\tan \theta = \frac{r \cos \phi}{1 - r \sin \phi} = 37.51$$

$$F_s = \underset{\substack{\downarrow \\ 180}}{F_c} \cos \theta - \underset{\substack{\downarrow \\ 60}}{F_t} \sin \theta = 105.2$$

(9)

Q: During a metal cutting test and orthogonal condition it was found that the cutting force is $F_c = 1100 \text{ kgf}$ and F_t feed force is 102 kgf ; cutting speed 165 m/min . rake angle of tool is $\alpha_0 = 10^\circ$ and shear angle $\theta = 10^\circ$. calculate the work done in shearing the metal and also against the friction.

Sol: work done in shear = $F_s \times V_c$
 $= (F_c \cos \theta - F_t \sin \theta) \frac{V \cos \alpha_0}{\cos(\theta - \alpha_0)}$
 $= 1164.7 \text{ kgf/min.}$

work done against in friction = $F \times V_c$
 $= (F_c \sin \alpha_0 + F_t \cos \alpha_0) \frac{V \sin \theta}{\cos(\theta - \alpha_0)}$
 $= 6415.2 \text{ kgf/min.}$

Q: In orthogonal cutting test cutting force is $F_c = 900 \text{ N}$ and thrust force is $F_t = 600 \text{ N}$ find shear force if $\theta = 30^\circ$.

Sol:
 $F_s = 900 \cos 30 - 600 \sin 30$
 $F_s = 479.64 \text{ N}$ A

Merchant's 1st angle Relation:

(To establish a relation b/w friction angle, orthogonal rake angle and shear angle)

Assumption: (1) Shear will take place in such a direction in which energy required for shearing is minimum.

(2) Shear stress is max. on shear plane and it remain constant.

from Merchant circle diagram:

$$F_c = F_s \frac{\cos(\tau - \alpha_o)}{\cos(\theta + \tau - \alpha_o)} \quad (92)$$

$$= \tau_s A_s \frac{\cos(\tau - \alpha_o)}{\cos(\theta + \tau - \alpha_o)}$$

$$F_c = \frac{(\tau_s \cdot b t_1 \cos(\tau - \alpha_o))}{\sin \theta \cos(\theta + \tau - \alpha_o)}$$

Here it is assumed to be

constant because of it

it is not valid for metal

and not give same result

as per theory has given.

$$\frac{dF_c}{d\theta} = \tau_s b t_1 \cos(\tau - \alpha_o) \frac{d}{d\theta} \left[\frac{1}{\sin \theta \cos(\theta + \tau - \alpha_o)} \right]$$

$$\cos(2\theta + \tau - \alpha_o) = 0$$

$$2\theta + \tau - \alpha_o = \frac{\pi}{2}$$

This formula is not acceptable for metals valid only for synthetic plastics.

$$\theta = \frac{\pi}{4} - \frac{\tau}{2} + \frac{\alpha_o}{2}$$

MERCHANT'S MODIFIED SHEAR ANGLE RELATION:

According to investigation of Higgin Bothams.

$$\tau_s = \tau_o + K \sqrt{F_n} = \tau_o + K \left\{ \frac{F_n}{A_s} \right\}$$

Constant for any given metal

$$\tau_s = \tau_o + K \left\{ \frac{F_s \tan(\theta + \tau - \alpha_o)}{A_s} \right\}$$

$$\tau_s = \tau_o + K \left\{ \tau_s \tan(\theta + \tau - \alpha_o) \right\}$$

(optimal)

$$\tau_s [1 - K \tan(\theta + \tau - \alpha_0)] = \tau_0$$

No.

46

Date

$$\tau_s = \frac{\tau_0}{[1 - K \tan(\theta + \tau - \alpha_0)]}$$

Now relation from Merchant's 1st angle relation

$$F_c = \frac{\tau_0}{1 - K \tan(\theta + \tau - \alpha_0)} \times A_s \times \frac{\cos(\tau - \alpha_0)}{\cos(\theta + \tau - \alpha_0)}$$

$$\frac{dF_c}{d\theta} = 0$$

(92)

$$\cos(2\theta + \tau - \alpha_0) = K \sin(2\theta + \tau - \alpha_0)$$

$$\begin{aligned} \cot(2\theta + \tau - \alpha_0) &= K \\ \text{or} \\ 2\theta + \tau - \alpha_0 &= \cot^{-1}(K) \end{aligned}$$

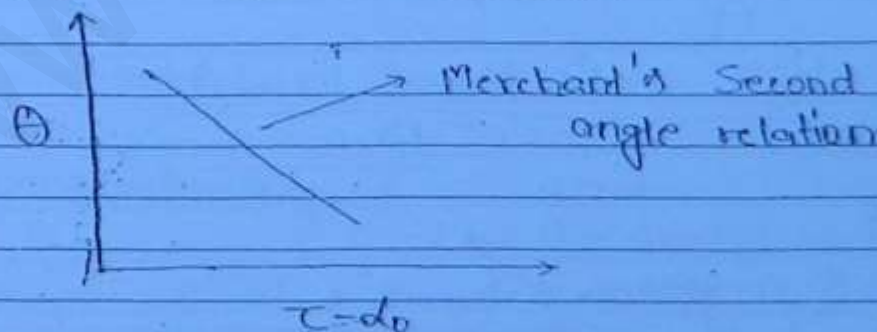
It is now valid for
metals:

machining constant unit will be in
degree.

* The value of machining constant ranges from $69^\circ - 80^\circ$ in case of steel.

* Machining constant is a property of work material, it is unaffected by cutting conditions, however cold working and grain size refinement result in increasing of machining constant.

$$2\theta + \tau - \alpha_0 = \text{Constant}$$



From this graph when $(\tau - \alpha_0) \downarrow \Rightarrow \theta \uparrow$

$$F_s = \tau_s A_s = \frac{\tau_s \times b \times t_1}{\sin \theta}$$

By of this Power consumption ↓.

Q. In a typical metal cutting operation a cutting tool of -1 Rake angle is 10° was used. It was observed that the Shear angle θ is 20° . Find out the Friction angle τ .

Sol.

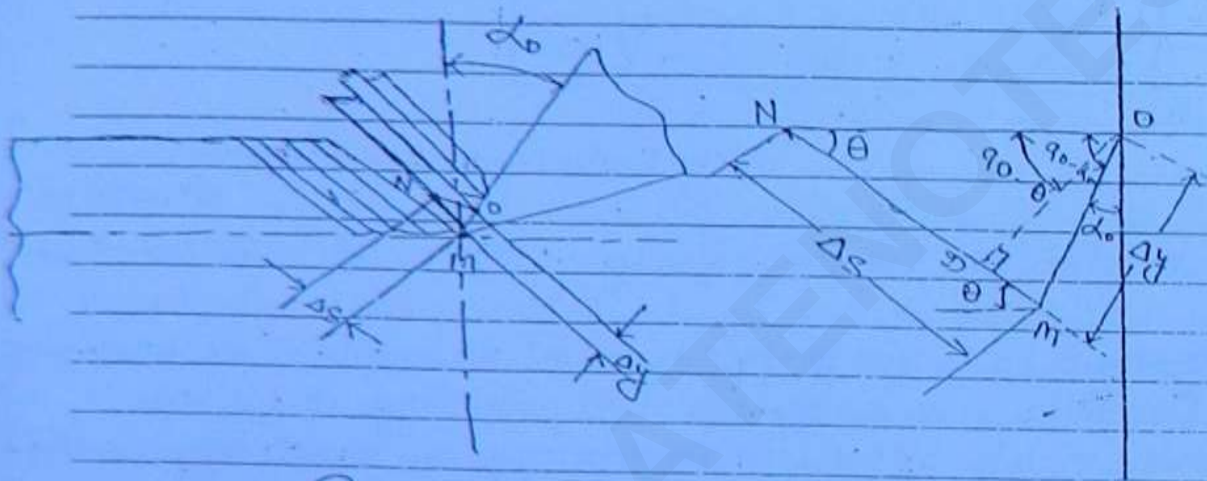
$$2\theta + \tau - \alpha_0 = \frac{\pi}{2}$$

$$2 \times 20 + \tau - 10 = 90$$

$$\tau = 60^\circ$$

(99)

Shear Strain calculation: A chip is considered to be consisting be a plate like element of thickness Δy and displaced through distance Δs relative to each other.



$$\epsilon = \frac{\Delta s}{\Delta y}$$

$$\epsilon = \frac{\Delta s}{\Delta y} = \frac{NM}{OM} = \frac{NO + OM}{OM} = \frac{NO}{OM} + \frac{OM}{OM}$$

$$|\epsilon = \cot \theta + \tan(\theta - \alpha_0)|$$

$$= \frac{1}{\tan \theta} + \frac{\tan \theta - \tan \alpha_0}{1 + \tan \theta \cdot \tan \alpha_0}$$

$$\epsilon = \frac{1 + \tan \theta \cdot \tan \alpha_0 + \tan^2 \theta - \tan \theta \cdot \tan \alpha_0}{\tan \theta + \tan^2 \theta \cdot \tan \alpha_0}$$

$$\epsilon = \frac{1 + \tan^2 \theta}{\tan \theta + \tan^2 \theta \cdot \tan \alpha_0}$$

$$\epsilon = \frac{\sec^2 \theta}{\tan \theta + \tan^2 \theta \cdot \tan \alpha_0}$$

$$\epsilon = \frac{\sec^2 \theta \cdot \sin \alpha \cdot \sec \theta + \sin^2 \theta \cdot \sec^2 \theta \cdot \tan \alpha}{\sin \alpha \cdot \sec \theta + \sin^2 \theta \cdot \tan \alpha}$$

$$\epsilon = \frac{1}{\sin \alpha \cdot \cos \alpha + \sin^2 \theta \cdot \tan \alpha}$$

$$\boxed{\epsilon = \frac{\cos \alpha}{\sin \alpha \cdot \cos (\theta - \alpha)}} \quad (98)$$

Shear strain is defined as the deformation per unit length of two mutually previously mutually orthogonal sides.

Prove that:

$$\epsilon = \text{Shear strain} = \frac{k^2 - 2k \sin \alpha + 1}{k \cos \alpha}$$

where k is called chip reduction coeff.

Sol: $k = \frac{1}{\text{chip thickness ratio}} = \frac{1}{r}$

$$\tan \theta = \frac{r \cos \alpha}{1 - r \sin \alpha}$$

divide numerator and denominator with r

$$\tan \theta = \frac{\cos \alpha}{k - \sin \alpha}$$

Now shear strain

$$\epsilon = \cot \theta + \tan(\theta - \alpha)$$

$$= \frac{1}{\tan \theta} + \frac{\tan \theta - \tan \alpha}{1 + \tan \theta \cdot \tan \alpha}$$

$$\epsilon = \frac{k - \sin \alpha}{\cos \alpha} + \frac{\cos \alpha - \sin \alpha}{k - \sin \alpha} \cdot \frac{\sin \alpha}{\cos \alpha}$$

$$= \frac{k - \sin \alpha}{\cos \alpha} + \frac{\cos^2 \alpha - \sin^2 \alpha}{(k - \sin \alpha) \cos \alpha}$$

$$\epsilon = \frac{k - \sin \alpha}{\cos \alpha} + \frac{\cos^2 \alpha - \sin^2 \alpha}{(k - \sin \alpha) \cos \alpha}$$

$$= \frac{k - \sin \alpha}{\cos \alpha} + \frac{\cos^2 \alpha - \sin^2 \alpha}{(k - \sin \alpha) \cos \alpha}$$

$$= \frac{K - \sin \alpha_0}{\cos \alpha_0} + \frac{\cos^2 \alpha_0 - \sin \alpha_0 (K - \sin \alpha_0)}{(K - \sin \alpha_0) \cos \alpha_0 + \cos \alpha_0 \sin \alpha_0}$$

$$= \frac{1}{\cos \alpha_0} \left[\frac{(K - \sin \alpha_0)^2 + (K - \sin \alpha_0) \sin \alpha_0 + \cos^2 \alpha_0 - \sin \alpha_0 (K - \sin \alpha_0)}{(K - \sin \alpha_0) + \sin \alpha_0} \right]$$

$$= \frac{1}{\cos \alpha_0} \left[\frac{K^2 + \sin^2 \alpha_0 - 2K \sin \alpha_0 + \cos^2 \alpha_0}{K} \right]$$

$$\therefore \boxed{\epsilon = \frac{K^2 - 2K \sin \alpha_0 + 1}{K \cos \alpha_0}}$$

Q. Prove $F_c = 2 \tau_s b t_1 \cos \theta$ IF $2\theta + \tau - \alpha_0 = \frac{\pi}{2}$ (96)

Solution:

$$2\theta + \tau - \alpha_0 = \frac{\pi}{2}$$

$$\tau - \alpha_0 = \frac{\pi}{2} - 2\theta$$

$$F_c = \frac{\cos(\tau - \alpha_0)}{\cos(\theta + \tau - \alpha_0)} F_s$$

$$F_c = \frac{\cos\left(\frac{\pi}{2} - 2\theta\right)}{\cos\left(\theta + \frac{\pi}{2} - 2\theta\right)} F_s$$

$$F_c = \frac{\sin 2\theta}{\sin \theta} \times \frac{\tau_s b t_1}{\sin \theta}$$

$$= \frac{2 \sin \theta \cdot \cos \theta \cdot \tau_s b t_1}{\sin \theta \cdot \sin \theta}$$

$$\boxed{F_c = 2 \cos \theta \cdot \tau_s b t_1}$$

Q: In an orthogonal cutting the following observation is made
 depth of cut = 0.25 mm, chip thickness ratio is $0.45 = r$
 and width of cut 4 mm, cutting velocity is 40 m/min. Cutting
 force component parallel to cutting velocity vector 1150 N (F_c)
 cutting force component normal to cutting velocity vector is
 140 N (F_t). rake angle of tool is 18° . Determine
 the resultant cutting force, cutting power, shear angle,
 friction angle, and force component parallel to shear plane.

Sol:
$$\mu = \frac{F_c \sin \alpha_0 + F_t \cos \alpha_0}{F_c \cos \alpha_0 - F_t \sin \alpha_0}$$

$$\mu = 0.46$$

$$\tau = \tan^{-1}(\mu) = 25$$

$$\tan \theta = \frac{r \cos \alpha_0}{1 - r \sin \alpha_0}$$

$$\theta = \tan^{-1} \left(\frac{0.45 \cos 18}{1 - 0.45 \sin 18} \right)$$

$$\theta = 26^\circ 25'$$

$$R = \sqrt{F_c^2 + F_t^2} = 1152.490 \text{ N.}$$

$$P = F_c \times V = 1150 \times 40 = 46000 \text{ Nm/min.}$$

$$[P = 766.66 \text{ W}]$$

$$F_s/R = \cos(\theta + \tau - \alpha_0) = \cos(26^\circ 25' + 24.70 - 18)$$

Q: During turning of a plain Carbon Steel a rod of 16 mm dia.
 is machined by a carbide tool designated as
 0-0-10-8-15-7-0 at speed of 400 rpm and
 feed of (s) = 0.32 mm and 4 mm depth of cut the following
 observation are available: tangential component of
 cutting force $F_c = 1200 \text{ N}$, and axial component of cutting
 force is $F_t = 800 \text{ N}$, chip thickness is 0.8 mm.
 determine the values of (1) Friction force & Normal force
 at chip tool interface.

(2) Shear strength of work material

(3) cutting power in kw.

Sol:

$$\alpha_0 = 0$$

$$N = F_c \cos \alpha_0 - F_t \sin \alpha_0$$

$$N = 1200 \text{ N.}$$

$$F = F_c \sin \alpha_0 + F_t \cos \alpha_0 = 800 \text{ N.}$$

$$\tan \theta = \frac{r \cos \alpha_0}{1 - r \sin \alpha_0}$$

No.
Date

$$\tan \theta = r \Rightarrow \theta = \tan^{-1} r$$

$$t_1 = 0.32 \times \sin 75^\circ$$

$$t_1 = 0.30$$

$$t_2 = 0.8$$

$$r = 0.8 / 0.8 = 0.88$$

(98)

$$b = \frac{t_1}{\sin \theta}$$

$$= 4 / \sin \theta$$

$$= 4.14$$

$$\theta = \tan^{-1} (0.88) = 21.125^\circ$$

$$T_c = \frac{1200 \cos 21.125^\circ - 800 \sin 21.125^\circ}{4.14 \times 0.30 / \sin 21.125^\circ}$$

$$T_c = 831.03 \Rightarrow [T_c = 241.53]$$

$$1.24 / 0.36$$

- Q. Mild steel is being machined at a cutting speed of 200 m/min with tool having a rake angle of 10° . The width of cut and uncut chip thickness are 2 mm and 0.2 mm respectively. if avg. value of coefficient of friction $\mu = 0.5$ and the shear stress of work material is 400 N/mm² (τ_s) determine
- Shear angle
 - Cutting & thrust component of the machining force

Sol: $\tan \theta = \frac{r \cos \alpha_0}{1 - r \sin \alpha_0}$

$$2\theta + \tau - \alpha_0 = 90^\circ$$

$$2\theta + 26.56^\circ - 10^\circ = 90^\circ$$

$$\theta = 36.72^\circ$$

$$F_c = R \cos (\tau - \alpha_0)$$

$$F_t = R \cos (\theta + \tau - \alpha_0)$$

$$F_c = 2 \tau_s b t_1 \cot \theta$$

$$= 2 \times 400 \times 2 \times 2 \times \cot 36.7^\circ$$

$$[F_c = 429.3 \text{ N}]$$

$$F_t = F_c \tan (\tau - \alpha_0)$$

$$F_c$$

$$F_t = 429.3 \tan (26.56^\circ - 10^\circ)$$

$$429.3$$

$$[F_t = 124.653 \text{ N}]$$

TOOL LIFE

Tool life is defined as the time elapsed b/w two successive re-sharpening.

Q: How to identify when the tool life is lost: →

- (1) Surface Roughness increases.
- (2) Machining accuracy decreases.
- (3) Force, workdone, power consumption increases.
- (4) Machine vibration increases.
- (5) Heat dissipation decreases.
- (6) Tool chip interface temperature increases.
- (7) M.R.R. decreases.
- (8) Contact b/w w.p & tool increases leading to rise in Friction.

Effect of various parameter on tool life: →

(1) Effect of type of cutting:

Continuous contact cutting — ~~tool~~ tool life ↑
Intermittent contact cutting — Tool life ↓

(2) Effect of workpiece material:

Pearlite
Sorbite
Troostite
Bainite
Martensite ↓
Tool life in ↓ order.

(3) Effect of tool material:

H.S.S.
Carbides
Ceramics
Cemented oxide CBN
Diamond Cubic Boron Nitride
Tool life ↑
Hardness increases

(4) Effect of cutting Fluids: (Schaubroch equation)

$$T \cdot V^n = C$$

T → Tool life
 V → Tool chip Interface temp.
 n → exponent depends upon Material used.
 C → Initial value

⑤ Effect of tool geometry

$\uparrow \phi_s$
 $\uparrow \phi_c$
 $\uparrow \alpha_y$
 $\uparrow \alpha_x$

Tool life

$\uparrow$ beyond the
 $\uparrow$ Permissible
 $\uparrow$

$\downarrow$
 $\downarrow$
 $\downarrow$
 $\downarrow$

within the recommended range these elements will improve tool life, however larger values will result in decrease in tool life.

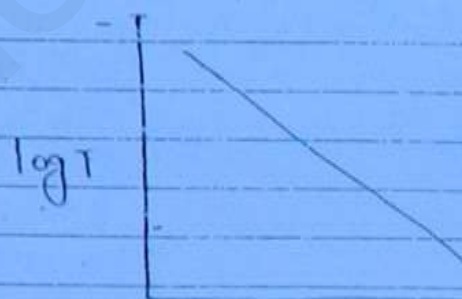
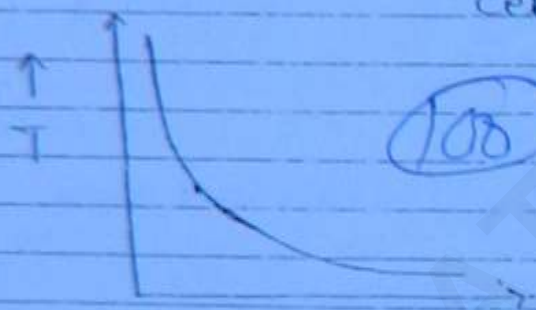
Taylor's Tool life equation:

$$V \times T^n = \text{Constant}$$

$\downarrow$ m/min $\searrow$ min (Tool life)

$$V_1 T_1^n = V_2 T_2^n$$

Value of n	For	H.S.S. $\rightarrow$	0.1 — 0.15
		Carbide tools $\rightarrow$	0.2 — 0.4
		Ceramic tools $\rightarrow$	0.4 — 0.6



$$\log V + n \log T = \log C = c'$$

$\log c$

Q: Determine the % change in cutting speed which is required to give a 60% reduction in tool life. the tool life eqⁿ may be taken as $V T^{0.2} = C$

$$V_1 T_1^n = V_2 T_2^n$$

$$V_1 T_1^{0.2} = V_2 T_2^{0.2}$$

$$V_1 (T_1)^{0.2} = V_2 (0.4 T_1)^{0.2}$$

$$\frac{V_1}{V_2} = \left(\frac{0.4 T_1}{T_1} \right)^{0.2}$$

$$V_2 = 1.20 V_1$$

$\therefore$ Increase in cutting ^(optimal) speed = 20%.

Q: The following data were calculated while turning a work piece on lathe. $V = \text{cutting speed} = 25 \text{ m/min}$.

$$S = 0.3 \text{ mm/rev}$$

$$\text{depth of cut } t = 2 \text{ mm}$$

$$T = 100 \text{ min}$$

$$\text{tool life eqn: } VT^{12} S^7 t^3 = C$$

if cutting speed, feed and depth of cut were increased by 25% each and also collectively what will be their effect on tool life.

Sol: $VT^{12} S^7 t^3 = C = 23.02$

Effect of 25% $\uparrow$ in V Effect of 25% $\uparrow$ in S Effect of 25% $\uparrow$ in t Effect of 25% $\uparrow$ in $V, S \& t$

$$T = \left[\frac{23.02}{(1.25V)(S)^7 t^3} \right]^{1/12} \quad T = \left[\frac{23.02}{V(1.25S)^7 t^3} \right]^{1/12} \quad T = \left[\frac{23.02}{VS^7 (1.25t)^3} \right]^{1/12} \quad T = \left[\frac{23.02}{(1.25V)(1.25S)^7 (1.25t)^3} \right]^{1/12}$$

$$T = 15.57 \text{ min}$$

$$T = 24.20 \text{ min}$$

$$T = 57.10 \text{ min}$$

$$T = 2.42 \text{ min}$$

Imp Note: Cutting speed V has highest effect on tool life. Lowest effect on tool life is due to depth of cut.

$V \uparrow$ direction of increasing effect on tool life.
Feed $\leftarrow S$
 t

(10)

Note: Highest effect on tool life, which component parameter has highest value of exponent.
lowest effect on tool life, which parameter has lowest value of exponent.

Q: The results of machining steel with two grade material are

Tool grade	Taylor's Component	cutting speed/min tool life
A	.20	100
B	.25	120

What are the standard tool life equation for these two material

Ans: $100 T^{.20} = C$ $120 T^{.25} = C$

Q: In a drilling operation under a given condition the tool life was found decreases from 20 min $\rightarrow$ 5 min due to an increase in drill speed from 200 rpm to 400 rpm. What will be the tool life under the same condition if drilling speed is 300 rpm.

Sol:

$$\frac{V_1}{V_2} = \left(\frac{T_1}{T_2} \right)^n$$

$$\frac{200/1000}{400/1000} = \left(\frac{20}{5} \right)^n$$

$$\left(\frac{1}{2} \right) = \left(\frac{1}{2} \right)^{2n}$$

$$n = \frac{1}{2}$$

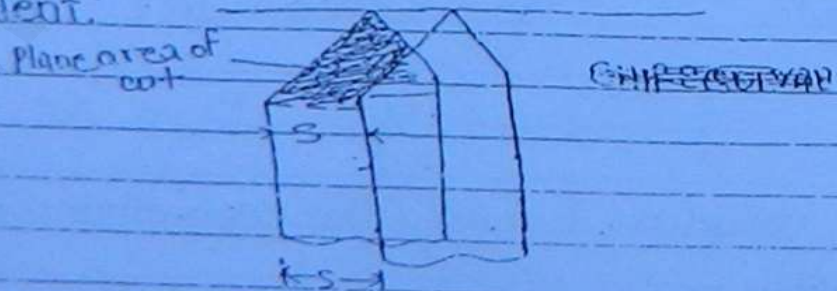
$$V_1 T_1^n = C \quad \text{or } C$$

$$\frac{200}{300} = \left(\frac{T_3}{20} \right)^{1/2}$$

$$6667 = \left(\frac{T_3}{20} \right)^{1/2}$$

$$T_3 = 8.889 \text{ min}$$

chip equivalent:



chip equivalent: $\frac{\text{Engaged length} \times \text{Cutting edge}}{\text{Plane area of cut (uncut chip area)}}$

Equivalent chip thickness = $1/a$

chip equivalent can be increased by decreasing the plane area of cut.

103

MACHINABILITY: Machinability is defined as the ease with which a material can be machined.

Machinability criteria -

- (1) Surface finish criteria: Higher the surface finish better the machinability.
- (2) Tool life criteria: Higher the tool life better the machinability.
- (3) Material Removal criteria: large volume material removal denotes better machinability.
- (4) Power consumption criteria: less power consumption denotes better machinability.
- (5) Machinability rating index: "It is defined as the ratio of the cutting speed for 60 min tool life for a test material to the cutting speed for 60 min tool life on a standard material."

$$MRT = \text{mle}^{\text{ing}} \text{ rating index} = \frac{V_{60}^t}{V_{60}^s}$$

where V_{60}^t is cutting speed for 60 min tool life of a test material and

V_{60}^s is cutting speed for 60 min tool life of a standard material.

- * Free cutting steel is used as standard reference material in the calculation of machinability material index rating.
- * Free cutting steel is steel containing minor additions of Sulphur, Selenium and phosphorus (0.01-0.02%).

104

CASTING

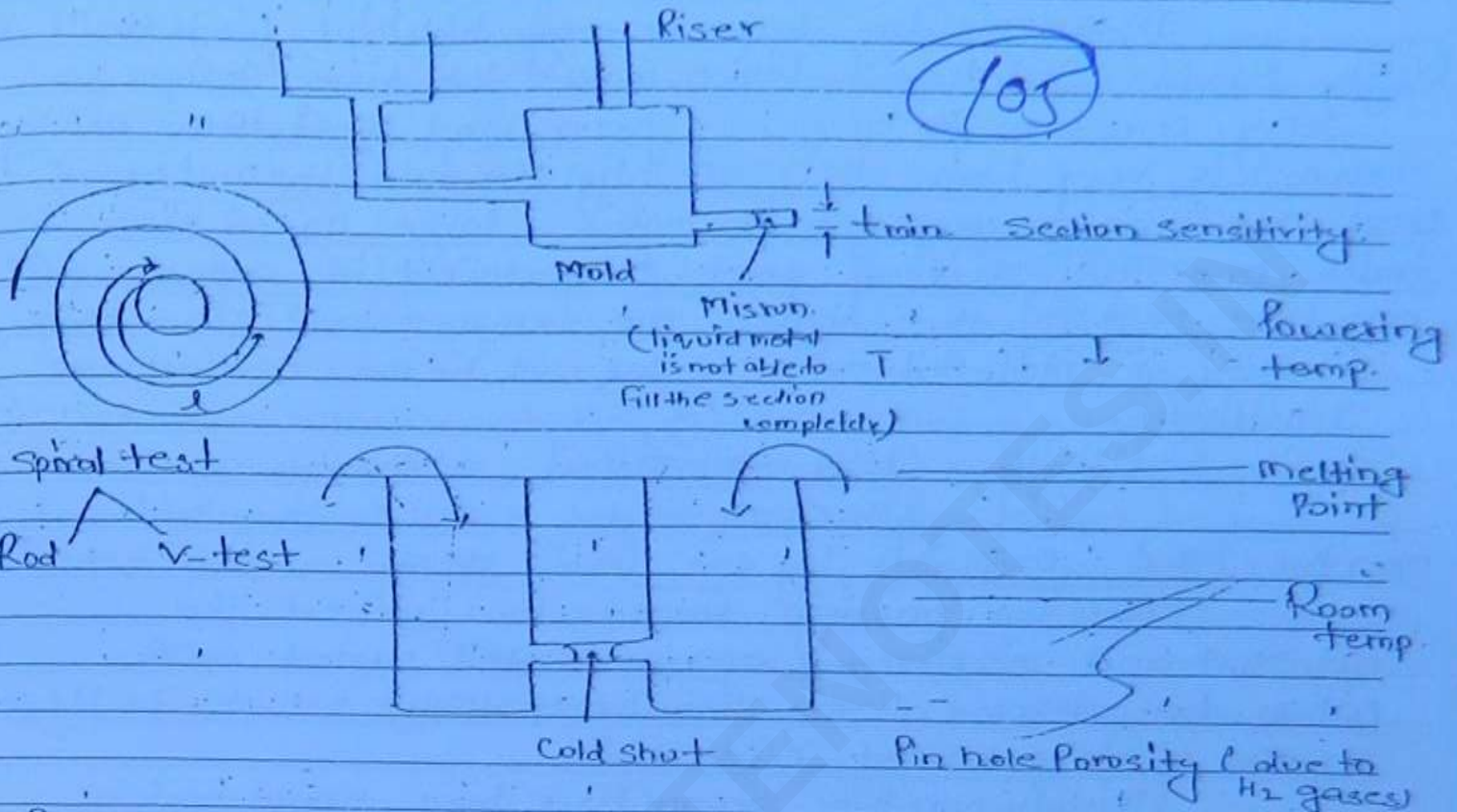
No. 52

Date

Cast

Mold

Pattern



Pattern is the replica of part being produced and it is used to create mold cavity. When either mold or pattern is destroyed after every cast is being produced, it is called expendable mold or pattern. When same mold or pattern is reused again and again it is called permanent mold or pattern. From the pouring temp. liquid metal undergoes 3 stages of shrinkages.

- (1) From the pouring temp. to the liquid at the melting point.
- (2) Shrinkage during phase change.
- (3) Solid from the melting point to solid at the room temp.

First two stages of shrinkages are compensated by riser and to compensate the third stage of shrinkage allowances are given over the pattern.

Shrinkage allowances are always given in terms of linear unit. i.e. mm/100mm (per cent).

So, riser design should be such that material in the

riser should solidify after casting. The second function of riser is to show that whether the casting is full or not.

If the pouring temp is very high it leads to large liquid shrinkages which makes the riser design very complex. In case of green sand mold if the pouring temp. is very high, H_2O disintegrate into H_2 and O_2 and as H_2 is coming out it leaves large no. of fine holes over the casted part. This defect is called pin hole porosity. But higher the temp. more will be the fluidity of material and better will be the section sensitivity.

Section sensitivity: It is the smallest thickness section, attached to the main casting that can be filled completely by the liquid metal.

When the pouring temp is low, defect like cold shut and misrun will appear in the casted part.

When two streams of the liquid metal are not able to fused together it is called cold shut.

Fluidity can be quantified by a spiral test. This spiral cavity is kept in the horizontal plane and liquid metal is poured through the centre. The length, liquid metal covers in the mold cavity before solidification is a measure of its fluidity. When the cross section area of the ~~spiral~~ spiral cavity is constant it is called Rod test and when the cross section area varies it is called V-test.

In case of grey cast iron, free carbon discharged from the casting and due to lower density of graphite casting expands after solidification. So Negative shrinkage allowance is given over the pattern of to mold grey cast iron.

Types of Patterns:

- (i) loose pattern: It is made in one piece, usually from wood, and is used for castings numbering upto 100.
- (ii) Gated pattern: This is one or more than one loose pattern with attached gates and runners. It is set on a follow board which helps easy removal of the pattern after the mould has been assembled prepared.

Pattern allowances:

- 1) Shrinkage allowance.
- 2) Machining allowance: Cast generally does not produce accurate products so some allowance has to be kept for machining.
- 3) Draft allowance:



$$\alpha = \frac{1}{2} \text{ to } 2^\circ$$

(107)

Taper is provided over the pattern for its easy removal.

- 4) Distortion allowance: While casting heavy work pieces distortion may appear when the temp is near melting point. This compensation is provided in the pattern itself.

Allowances for various metals

Material	Shrinkage allowance	Machining allowance For dimensions	
		0-30 cm	30-60 cm
Cast iron	$1/96 = 0.01041$	2.5 mm	4.0 mm
Cast Steel (low carbon)	$1/48 = 0.02083$	3 mm	4.5 mm
Aluminium	$3/192 = 0.015625$	1.5 mm	3 mm
Bronze	$3/192 = 0.015625$	1.5 mm	3 mm
Brass	$1/48 = 0.02083$	1.5 mm	3 mm

Decreasing order of shrinkage allowance

Cast Steel (low carbon) = Brass > Aluminium = Bronze > Cast iron.

Decreasing order of machining allowance

Cast Steel (low carbon) > Cast iron > Aluminium = Brass = Bronze.

(iii) Match plate pattern: This pattern is made in two halves mounted on both sides of a wooden or metal match plate. The match plate is accurately placed b/w the cope and the drag flasks by means of locating pins for small castings. Several patterns can be mounted on the same match plate.

(iv) Cope and drag pattern: Cope and drag halves of a split pattern are separately mounted on two match plates. Thus the cope and drag flasks are made separately and brought together to produce the complete mould.

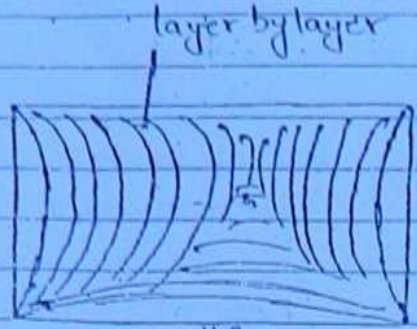
(v) Sweep pattern: Moulded of wood. It is used to generate surfaces of revolution in large castings & to prepare moulds out of a paste like material. Sweep refers to the section that rotates about an edge to yield circular section.

(vi) Skeleton pattern: This consists of a simple ^(sprung) wooden frame outlining the shape of the casting. It is used to guide the moulder in hand-shaping the mould and for large castings having

Types of Solidification:

(1) Skin forming:

This type of solidification appears either in case of pure materials or alloys having eutectoid composition. Solidification



front will appear over the surface and it will proceed towards the centre. All the shrinkages will be accumulated at the centre which can be compensated by riser.

Because the surface temp is lower than the pouring metal temp, metal solidifies at surface.

As long as shrinkage can be predicted, there is no problem because by proper riser design it can be neutralised.

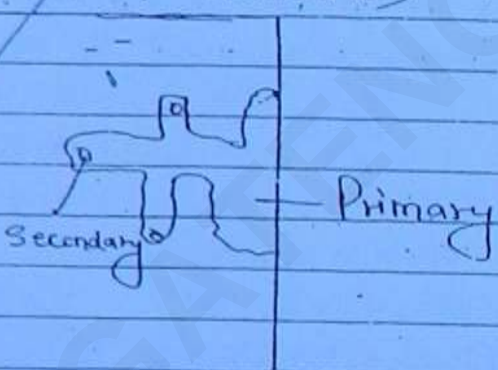
(2) Dendritic growth:

Tree like

Solid (Secondary dendrite)

108

Solid Primary dendrite



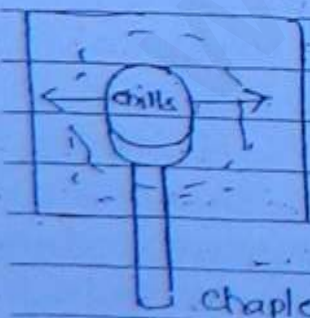
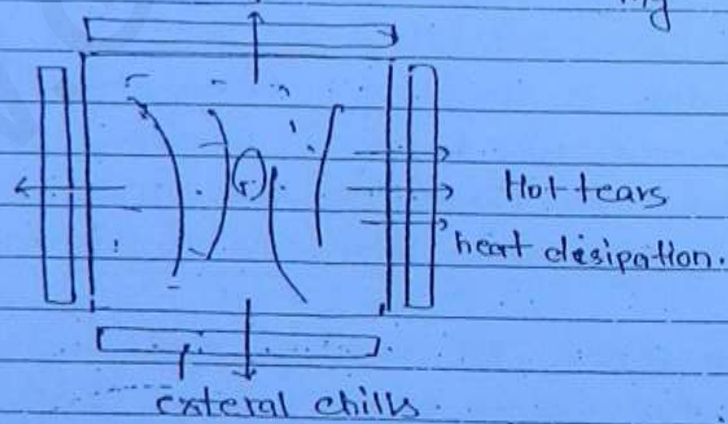
Catalyst

Na - For Al.

Mg - For cast iron

(i) Inoculation

(ii) Chills



internal chills

caibib

This type of Solidification appears when the ^{cast} alloy ~~is~~ ^{exhibits} ~~is~~ ^{primary} dendrite zone. As soon as the liquid metal comes in contact with the mold wall solidification will start called primary dendrite. Solid will start also nucleate somewhere in the liquid region called secondary dendrite. Thousands of such secondary dendrite will appear in the liquid region. The region where primary and secondary dendrite meets there will be microvoids which can not be compensated by the riser. This problem can be taken care of by two methods.

1. Innoculation: Innoculants are catalyst when added to the liquid metal it retards the formation of secondary dendrite. So the directional solidification is achieved by decelerating the solidification rate. Solidification (In single direction)

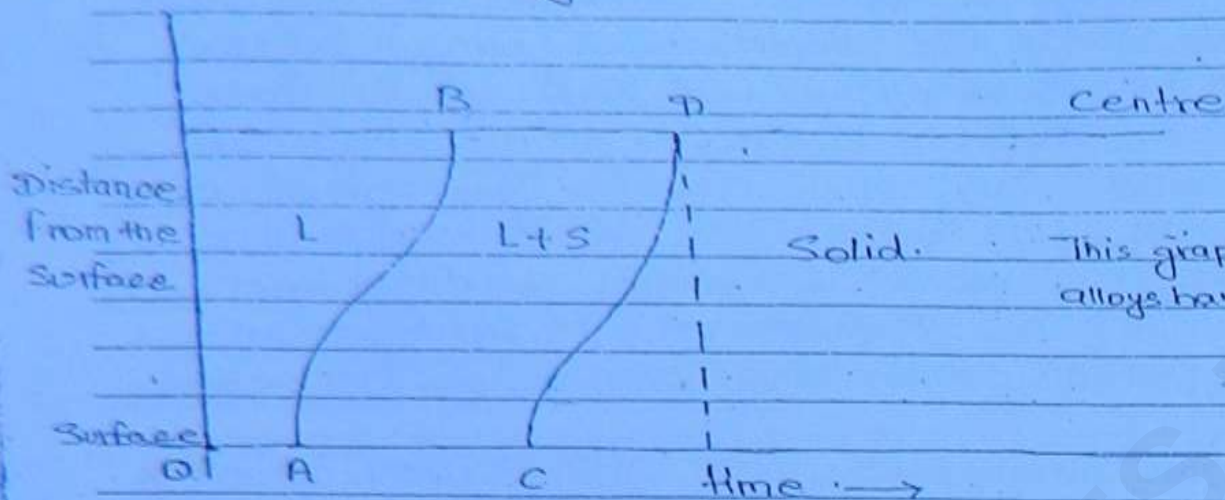
2: Chills: Directional Solidification can be achieved by accelerating Solidification rate. In case of external chill, pieces of the same material are kept all around the mold cavity. Due to the rapid heat transfer, Solidification Front will move towards centre not giving any chance for the secondary dendrites to form. Chills should be dry to avoid any blow hole or gas hole. Every Solidification Front will have some residual stress associated with it. When two oppositely moving Solidification Front meet at the centre and when the ^{Practically} combined stress goes beyond the fracture limit, tear will appear in the material. This metallurgical defect is called HOT TEAR.

In case of complex or large casting internal chills are used. Internal chills are supported by chaplets. Both internal chill and chaplet should be highly pure and the pouring temp should be such that the both chill and chaplet diffuses with the metal. Undiffused chillers are biggest defect in casting.

Chills, chaplets and padding are used in directional solidification.

10. Horizontally

Centre line Feeding Resistance (CFR)

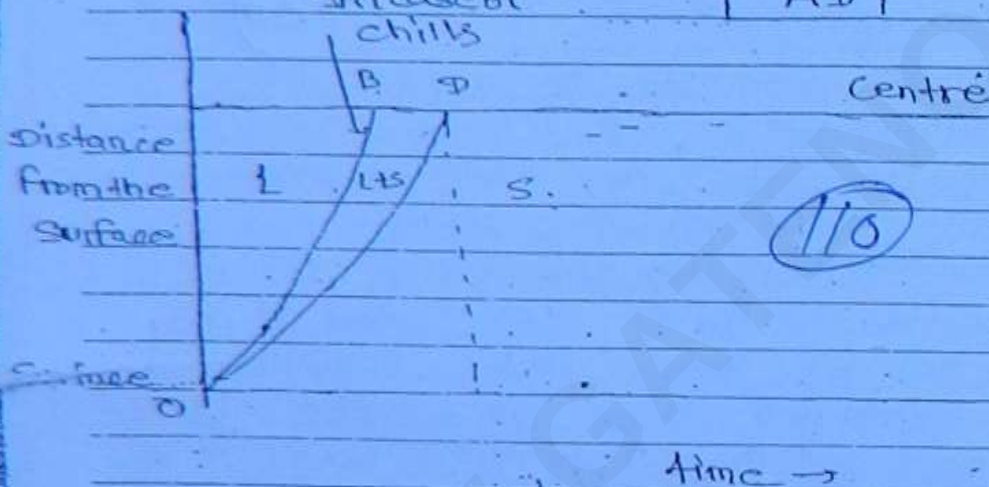


This graph is plotted for the alloys having mushy zone

$$CFR = \frac{BD}{AD}$$

At B First Solid Front reached to the centre and at D complete casting is solidify at centre.

In case of chills



110

CFR is the time required to solidify the centre to the total time required to solidify the entire casting. CFR indicates how much difficulty liquid metal will have to transfer from riser to compensate the liquid shrinkage. It's value should be low for better casting. For skin forming CR CFR value will be zero.

(It is called green because it is freshly prepared.)
Green Sand mold.

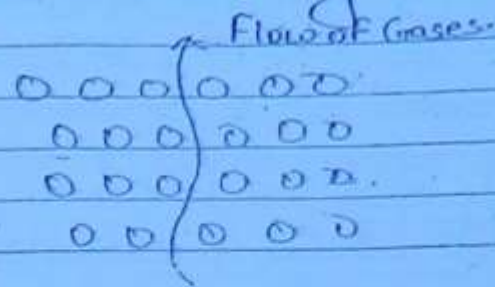
70 - 85% Sand.

10 - 20% clay clay

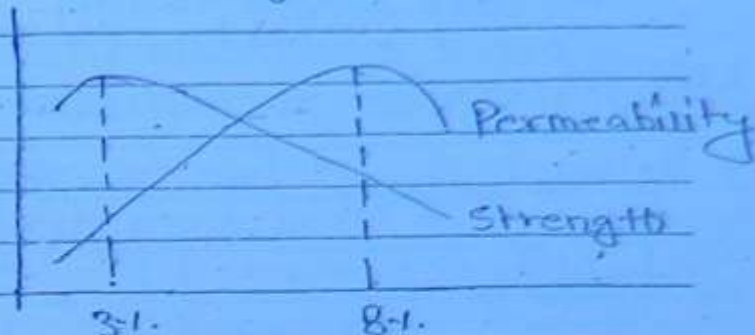
3 - 6% water.

1 - 8% Additives

① Permeability



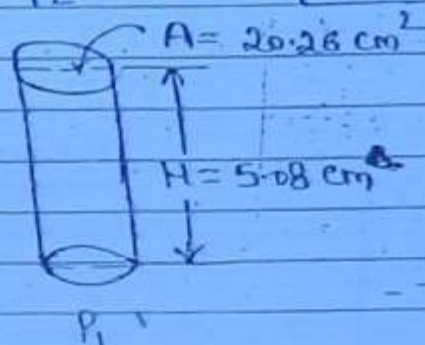
② Strength



Permeability No: $(PN) = \frac{V H}{P A T}$

Time

(11)



$P = P_1 - P_2 = 10 \text{ g/cm}^2$

$PN = \frac{3007}{T \leftarrow \text{Sec}}$

Permeability is the gas flow rate through the specimen under a specified pressure difference across it.

When the water content in the sand is low, sand voids will be filled with smaller size sand particles. By increasing the water content, smaller particles also combined together which increases the size of void and hence permeability. Once the water content increases beyond a certain value, it starts accumulating in the sand void and hence decreasing the permeability. Larger the size of void although permeability is higher but the strength will be lower.

if there are rubbing b/w the sand and mold wall then chances of cracks appearing in the wall is more.

(3) Collapsibility: It is the property of the sand mold

no resistance will be offered by the wall when the mold is contracting. It is due to which it does not offer resistance during contraction of solid metal.

Additives like wood flour (Bura) when it comes in contact with liquid metal it burns producing some extra clearance b/w solid metal and mold wall. But in case of grey cast iron loam sands are used because there is flexibility in the sand to expand

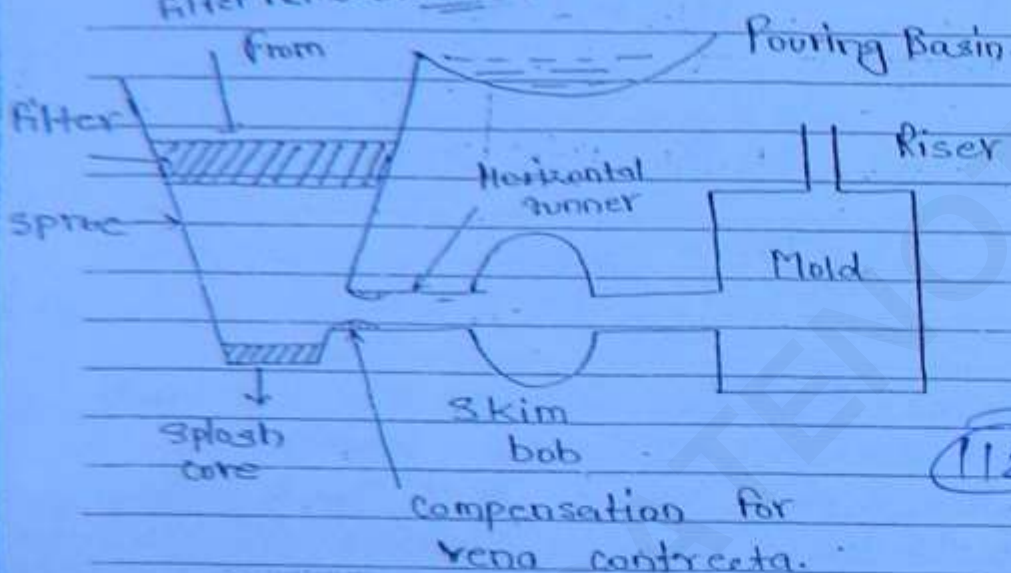
loam sand — ^{upto 12% water} 50% silt & 50% sand

(4) Flowability: It is the property of sand to flow and take the shape of pattern upon ramming.

(5) Refractoriness: It is the property of a sand due to which it remains solid at elevated temperature.

Components of a Gating system

Filter removes dross & sand



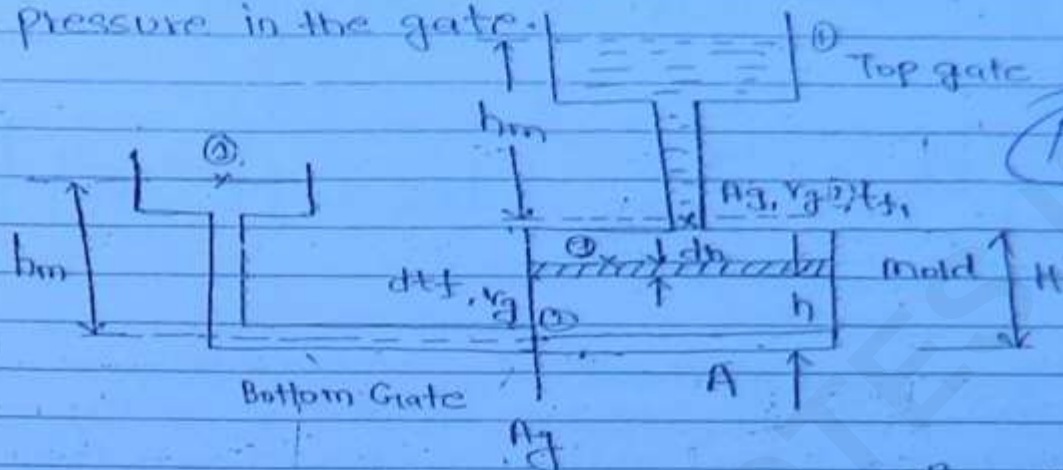
Friction material used in ABS (Anti-lock Braking System) is made of P.T. - ceramic powder metallurgy.

112

Initially the liquid metal, stored into the pouring basin to arrest the turbulence otherwise sand will be mixed with the liquid metal to produce fayalite ($FeSiO_2$). Since this material is very hard and brittle it leads to abrasion wear on the cutting tool. A ceramic filter made by powder metallurgy is kept in the sprue to filter out impurities from the liquid metal. A splash core is kept at the bottom of sprue to avoid further sand erosion. At the entry of the horizontal runner a compensation for vena contracta will be provided otherwise due to eddy current formation vacuum will be created and air gases through the sand void will be trapped in the liquid metal. Skim bob is being provided just before the liquid metal.

otherwise ~~flow~~ in the direction of flow pressure $\propto \frac{1}{\rho g}$ No. 56
Date

enters into the mold cavity so that heavier impurity settled down and lighter impurity float in the bob cross section area of the horizontal runner increases increases in the forward direction to maintain uniform atm. pressure in the gate.



for top gating:

$$A_g v_g t_{11} = AH$$

$$v_g = \sqrt{2gh_m}$$

$$t_{11} = \frac{AH}{A_g \sqrt{2gh_m}}$$

for Bottom gating system

for a small time dt , Volume of metal entering the mold is raising the level by dh .

$$A_g v_g dt = A dh$$

$$h_m = \frac{P_2}{\rho g} + \frac{v_g^2}{2g} \quad \text{--- (1)}$$

P_2 is not zero, it is higher than the atmospheric pressure.

Applying Bernoulli's eqn blw (2) & (3)

Applying Bernoulli equation blw (1) & (2)

$P_1 = \text{gauge} = 0$

$v_1 \approx 0$ (very large tank)

$$\frac{P_2}{\rho g} + \frac{v_2^2}{2g} = \frac{P_1}{\rho g} + \frac{v_1^2}{2g} + h$$

$$\frac{P_2}{\rho g} = h$$

$v_1 = v_2$
because of the constant area of mold

$$V_g^2 = 2g(h_m - h)$$

$$\int_0^{t_2} dt = \int_0^H \frac{A}{A_g} \frac{dh}{\sqrt{2g(h_m - h)}}$$

114

$$t_{f_2} = \frac{2A}{A_g \sqrt{2g}} \left[\sqrt{h_m} - \sqrt{h_m - H} \right]$$

In the top gating system there will be turbulence, but lesser time will be consumed to fill the casting as compared to the bottom gating system. Top gating systems are used in the cases where the casting is very large or alloys having large mushy zone.

Q: Determine the time to fill the casting of dimensions $50 \times 25 \times 15 \text{ cm}^3$ cube by top and bottom gating system if area of gate is 5 cm^2 and manometric height available in pouring basin is 15 cm .

Sol: $t_{f_1} = \frac{AH}{A_g \sqrt{2gh_m}} = \frac{50 \times 25 \times 15}{5 \times \sqrt{2 \times 9.81 \times 15}}$

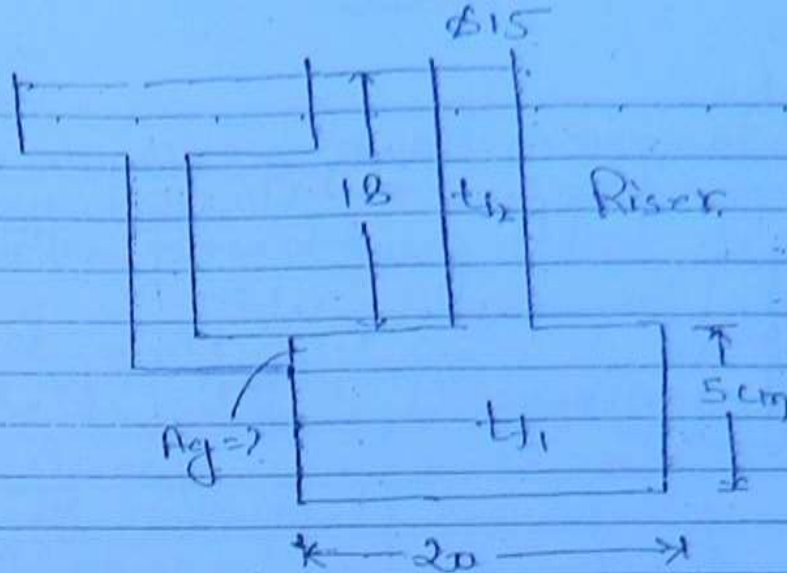
$$t_{f_1} = \frac{25 \times 50 \times 15}{5 \times \sqrt{2 \times 9.81 \times 15}} = 21.85 \text{ sec.}$$

$$t_{f_2} = \frac{2 \times 25 \times 50}{5 \times \sqrt{2 \times 9.81}} \left[\sqrt{15} - \sqrt{15 - 15} \right] = 43.7 \text{ sec}$$

$t_{f_2} > t_{f_1}$ always,

If $h_m = H$ then $t_{f_2} = 2t_{f_1}$

Q:



115

Given that = total time to fill the riser = 10 sec. = t .

$A_g = ?$

$$t_{f1} = \frac{AH}{\sqrt{2gh_m} \times A_g} = \frac{20 \times 20 \times 5}{A_g \times \sqrt{2 \times 981 \times 18}} = \frac{10.6425}{A_g}$$

$$t_{f2} = \frac{2A}{A_g \sqrt{2g}} \left[\sqrt{h_m} - \sqrt{h_m - H} \right]$$

$$= \frac{2 \times \frac{\pi (15)^2}{4}}{A_g \times \sqrt{2 \times 981}} \left[\sqrt{18} - \sqrt{18 - 18} \right]$$

$H = 18$ for Bottom gating system

$$= \frac{5.083}{A_g}$$

$$t_{f1} + t_{f2} = 10 = \frac{5.083 \times 60}{A_g} + \frac{10.6425 \times 60}{A_g}$$

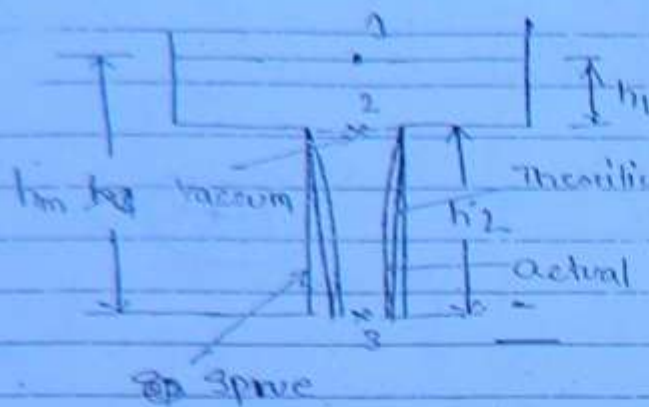
$$= \frac{2 \times \frac{\pi (15)^2}{4}}{A_g \sqrt{2 \times 981}} \left[\sqrt{18} - \sqrt{18 - 18} \right] = \frac{33.8523}{A_g}$$

Given that

$$t_{f1} + t_{f2} = 10 = \frac{10.6425}{A_g} + \frac{33.8523}{A_g}$$

$$\boxed{A_g = 4.44918 \text{ cm}^2}$$

Aspiration Effect.

Applying Bernoulli's eqⁿ b/w (2) and (3)Taking (3) as reference $z_3 = 0$

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

 P_3 : atm pressure $P_2 = -ve$ $V_1 = V_3$ (in same cross section area (by continuity eqⁿ))

If the cross sectional area of sprue is constant vacuum will form at point 2, as shown in fig. and as a result of that atm. air will be trapped in the liquid metal through sand voids. This phenomenon is called aspiration effect.

$$\frac{V_2^2}{2g} + h_2 = \frac{V_3^2}{2g} \quad \begin{matrix} V_3 \text{ is more compared to } V_2 \text{ due to} \\ \text{less cross section} \end{matrix}$$

$$A_2 V_2 = A_3 V_3$$

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

 R = area ratio

$$R^2 \left(\frac{V_3^2}{2g} \right) + h_2 = \frac{V_3^2}{2g}$$

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

$$V_3^2 = 2gh_1 \quad [\text{Bernoulli's eqⁿ b/w (3) \& (1)}]$$

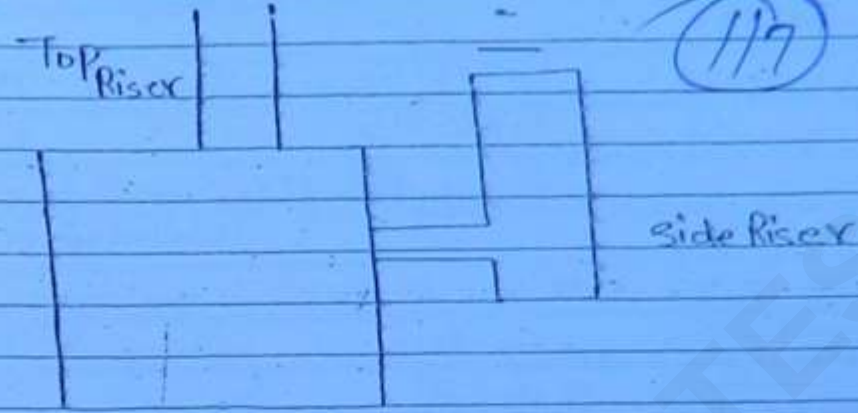
$$\frac{h_2}{h_1} = 1 - R^2$$

$$R^2 = 1 - \frac{h_2}{h_1}$$

$$R = \sqrt{h_1/h_2}$$

Theoretically the cross section area of the sprue should decrease linearly but to avoid the boundary layer separation curve is given to the decreasing cross section.

RISER DESIGN

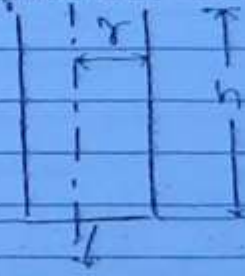


for casting and riser
Solidification time $t \propto \left(\frac{V}{A}\right)^2$
Through which heat transfer takes place
Surface area of riser $\left(\frac{V}{A}\right)_{\text{riser}} \rightarrow \left(\frac{V}{A}\right)_{\text{casting}}$

$V_r = 3 \times \text{shrinkage}$ (Initially we take to start the neck designing)

Q: Determine the dimensions of top and side cylindrical risers for casting aluminium cube of 15 cm. Consider the volume shrinkage during solidification to be 6.5%.

Sol: Top Riser



$$V = \pi r^2 h$$

$$A = \pi r^2 + 2\pi r h$$

$$h = \frac{V}{\pi r^2}$$

This area is not included in the calculation because from top riser through this no heat transfer taking place

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

$$\frac{dA}{dr} = 0$$

$$r = \left(\frac{V}{\pi}\right)^{\frac{1}{3}} \quad (\text{optimal})$$

$$h = \frac{V}{\pi \left(\frac{V}{\pi}\right)^{\frac{2}{3}}} = \left(\frac{V}{\pi}\right)^{\frac{1}{3}}$$

$$\left[r = \left(\frac{V}{\pi} \right)^{1/3} = h \right]$$

For optimum Riser $r = h$.

$$\left(\frac{V}{A} \right)_r = \frac{\pi r^3}{3\pi r^2} = \frac{r}{3} \quad (118)$$

$$\left(\frac{V}{A} \right)_{\text{casting}} = \frac{15 \times 15 \times 15}{5 \times 15 \times 15} = 3$$

No heat transfer from top side

only five sides are included top side is excluded in calculation.

$$V_r = \pi r^3 = 3 \times 6.5 (15)^3 = 3 \times \text{volume shrinkage of casting}$$

100

$$r = 5.9 \text{ cm.}$$

$$\left(\frac{V}{A} \right)_r = 1.98 < \left(\frac{V}{A} \right)_c$$

This indicates that riser will solidify prior to casting. So the riser design is not correct. At least riser should solidify along with casting. So

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

$$\frac{r}{3} \geq 3 \Rightarrow [r = h \geq 9]$$

Correct riser design.

(ii) For side Riser

$$V = \pi r^2 h$$

$$A = 2\pi r^2 + 2\pi r h$$

$$h = \frac{V}{\pi r^2}$$

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

$$A = 2\pi r^2 + 2\pi V$$

r .

$$\frac{dA}{dr} = 0$$

$$\frac{d}{dr} \left(2\pi r^2 + \frac{2V}{r} \right) = 0$$

$$2\pi \cdot 2r + 2V(-1)r^{-2} = 0$$

$$4\pi r - \frac{2V}{r^2} = 0$$

$$4\pi r^3 - 2V = 0$$

$$\left[r = \left(\frac{V}{2\pi} \right)^{1/3} \right]$$

$$h = \frac{V}{(\pi r^2)} = \frac{V}{\pi \cdot \left(\frac{V}{2\pi} \right)^{2/3}} = \frac{V}{\pi \cdot \frac{V^{2/3}}{(2)^{2/3} (\pi)^{2/3}}} = \frac{V}{\pi \cdot \frac{V^{2/3}}{(2)^{2/3} (\pi)^{2/3}}}$$

$$h = \frac{V}{\pi \cdot \frac{V^{2/3}}{(2)^{2/3} (\pi)^{2/3}}}$$

$$h = \frac{V}{\pi \cdot \frac{V^{2/3}}{(2)^{2/3} (\pi)^{2/3}}} = \frac{V}{\pi \cdot \frac{V^{2/3}}{(2)^{2/3} (\pi)^{2/3}}}$$

$$\left[\begin{array}{l} r > 7.5 \\ h > 15 \end{array} \right]$$

$$h = \frac{(2)^{2/3} \cdot \left(\frac{V}{\pi} \right)^{1/3}}{1} = \frac{2}{2^{2/3}} \left(\frac{V}{\pi} \right)^{1/3} = 2 \left(\frac{V}{2\pi} \right)^{1/3}$$

$$h = 2r$$

$$\left(\frac{V}{A} \right)_r = \frac{2\pi r^3}{2\pi r^2 + 2\pi r(2r)} = \frac{2\pi r^3}{6\pi r^2} = \frac{2r}{6} = \frac{r}{3}$$

$$\left(\frac{V}{A} \right)_c = \frac{15 \times 15 \times 15}{6 \times 15 \times 15} = 2.5$$

3 times shrinkage

$$V_r = 2\pi r^3 = 3 \times 6.5 \times (15)^3$$

100

$$r = 4.7138 \text{ cm.}$$

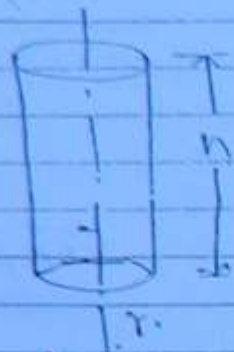
$$\left(\frac{V}{A} \right)_r = \frac{r}{3} = 1.57128 \leq \left(\frac{V}{A} \right)_c$$

This indicates that riser will solidify prior to casting. so the riser design is not correct. At least riser should solidify along with casting so, $\left(\frac{V}{A} \right)_r > \left(\frac{V}{A} \right)_c$ $r/3 > 2.5 \Rightarrow r > 7.5$
 $h > 2r = 2 \times 7.5 = 15$

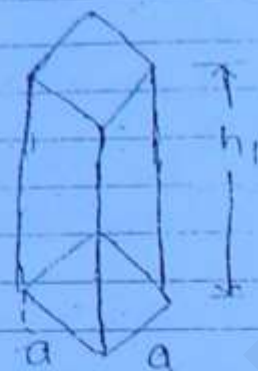
Q: Compare the solidification time of two optimum side risers of the same volume when one has a cylindrical shape and the other is of square parallelepiped.

Q. IAS 2008.

Side Riser:



120



$\pi r^2 h = a^2 h_1$ (Same volume)
cylindrical

$h = 2r$

$\left(\frac{V}{A}\right)_c = \frac{r}{3}$

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

$\frac{t_c}{t_s} = \frac{(r/3)^2}{(a/6)^2}$

$= \frac{r^2/9}{a^2/36} = \frac{r^2/9}{a^2/36}$

$= \frac{36r^2}{9a^2} = \frac{4r^2}{a^2}$

$\pi r^2 \times 2r = a^3$

$2\pi r^3 = a^3$

$a^3 = 2\pi r^3$

$a = \sqrt[3]{2\pi r^3}$

$a = r \sqrt[3]{2\pi}$

$\frac{t_c}{t_s} = \frac{4r^2}{a^2}$

$= \frac{4r^2}{(r \sqrt[3]{2\pi})^2}$

$= \frac{4}{(\sqrt[3]{2\pi})^2}$

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

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

$\frac{t_c}{t_s} = 1.174$

Square

$V = a^2 h_1$

$A = 2a^2 + 4ah_1$

$h_1 = V/a^2$

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

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

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

$\frac{dA}{da} = 0$

$\frac{d}{da} (2a^2 + 4 \frac{V}{a}) = 0$

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

$4a^3 - 4V = 0$

$a^3 = V$

$a = \sqrt[3]{V}$

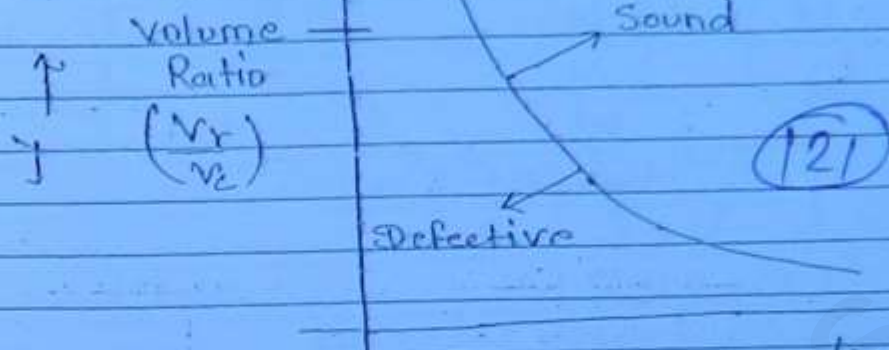
$h_1 = \frac{V}{a^2} = \frac{V}{V^{2/3}} = V^{1/3}$

$a = h_1 = \sqrt[3]{V}$

$\left(\frac{V}{A}\right)_s = \frac{a^2 \times a}{2a^2 + 4a \times a} = \frac{a^3}{6a^2} = \frac{a}{6}$

$\left(\frac{V}{A}\right)_s = \frac{a}{6}$

Caines curve
(used for designing the riser made of steel)



$$\text{freezing ratio } (X) = \frac{(V/A)_r}{(V/A)_c}$$

$$X = \frac{a}{(y-b)} + C$$

a, b, C is Freezing constant / caines constant.

Q. IES-2004 (a) b)

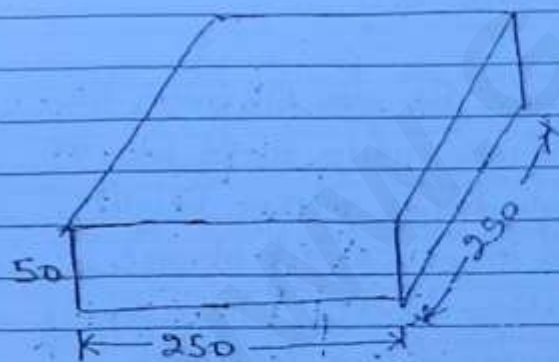
given $\Rightarrow h = d = ?$
Side Riser.

Steel Riser design.

Given $a = 0.1$

$b = 0.03$

$C = 1.00$



$$V_i = \pi r^2 h = 2\pi r^3$$

$$A = 2\pi r^2 + 2\pi r h$$

$$\left(\frac{V}{A}\right)_r = \frac{r}{3}$$

$$\left(\frac{V}{A}\right)_c = \frac{250 \times 250 \times 50}{4 \times 50 \times 250 + 2 \times 250 \times 250} = 17.8571$$

$$X = \frac{r/3}{17.8571}$$

$$X = \frac{r}{53.571}$$

(ajitmital)

$$y = \frac{V_p}{V_c} = \frac{2\pi r^3}{50 \times 250 \times 250}$$

$$y = 2.0106 \times 10^{-6} r^3$$

$$x = \frac{a}{y-b}$$

(122)

$$r = \frac{0.1}{53.571 - 2.0106 \times 10^{-6} r^3 - 0.03} + 1$$

$$r = \frac{0.1 \times 53.571}{2.0106 \times 10^{-6} r^3 - 0.03} + 53.571$$

$$2.0106 \times 10^{-6} r^4 - 0.03 r = 0.1 \times 53.571 + 53.571 (2.0106 \times 10^{-6} r^3 - 0.03)$$

~~64 mm~~
 $r = 64 \text{ mm}$
 5 mm

$$2.0106 \times 10^{-6} r^4 - 0.03 r = 5.3571 + 1.077 \times 10^{-4} r^3 - 1.607$$

$$2.0106 \times 10^{-6} r^4 - 1.077 \times 10^{-4} r^3 - 0.03 r - 3.74997 = 0$$

Putting $r=64$

$$33.7322 - 28.2329 - 1.92 - 3.74997$$

$$= 33.7322 - 33.9028 \approx 0$$

Q: Chvorinov and Caine gave rules for solidification time and freezing into ratio for a riser. Using these rules or otherwise find the size of a cylindrical riser of height to diameter ratio as one for a steel casting of size $250 \times 250 \times 50 \text{ mm}^3$ when the casting is fed horizontally and riser is a side one. Thickness of the casting is 50 mm . For steel $a = 0.1$, $b = 0.03$ and $c = 1$. Consider it as a long bar of cross section 250×50 .

Gate: 2007

No. 61
Date

Q: 74

Cube

$\downarrow$
 l

$$V_c = l^3$$

$$A = 6l^2$$

Sph sphere

$\downarrow$
 r

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

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

(123)

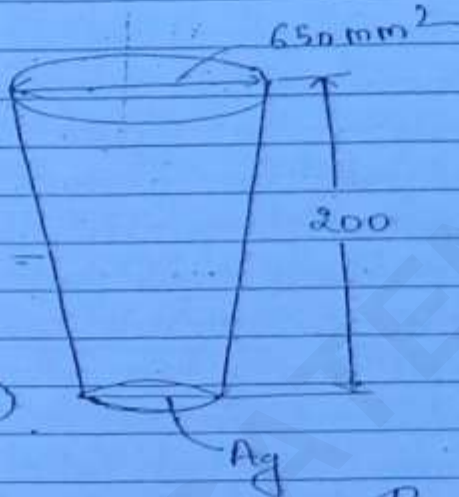
$$\frac{t_c}{t_s} = \frac{(V/A)_c}{(V/A)_s} = \left(\frac{A_s}{A_c}\right)^2 = \left(\frac{4\pi r^2}{6l^2}\right)^2$$

$$= \left(\frac{4\pi}{6}\right)^2 \left(\frac{r^2}{l^2}\right)^2 = \left(\frac{4\pi}{6}\right)^2 \left(\frac{r}{l}\right)^4$$

Gate: 2007

Q: 84

(1)



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

$$g = 10^4 \text{ mm/s}^2$$

$$Q = A_1 V_1$$

$$6.5 \times 10^5 = 650 \times V_1$$

$$\frac{6.5 \times 10^5}{650} = V_1$$

$$V_1 = 1000 \text{ mm/s}$$

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + Z_2$$

$$\frac{(1000)^2}{2g} + 200 = \frac{V_2^2}{2g} + 0$$

$$\frac{(1000)^2}{2} + 200 \times g = \frac{V_2^2}{2}$$

$$\Rightarrow V_2 = 2236 \text{ mm/s}$$

$$Q = A_2 V_2$$

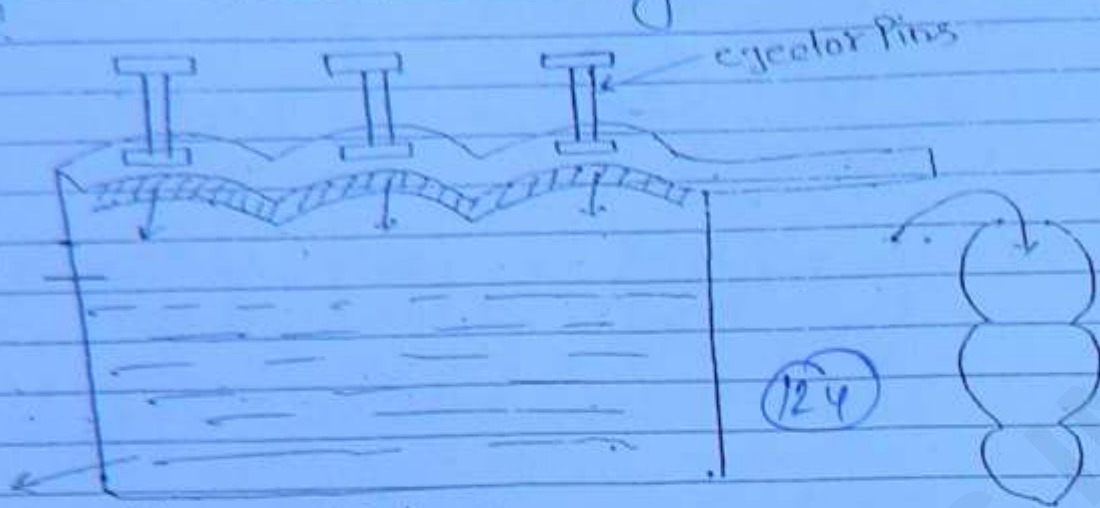
$$Q/A$$

$$\frac{6.5 \times 10^5}{2236} = A_2 = \frac{Q}{V_2} = A_2 = 290.7 \text{ mm}$$

$$A_2 = 290.7 \text{ mm}$$

(april 2012)

Shell Molding



Sand + additive + Alcohol

If water is used then temperature should be high.

Very good dimensional tolerances can be achieved by shell molding but the parts needs to be symmetric. Also

irregular shape can not be produce by this method. Pattern is made up of permanent material like cast iron.

~~Ejector~~ Ejector pins are provided over pattern to remove the shell. From the pattern. Pattern is heated an around 250°C then it is clamped over a box which contains Sand, additives and alcohol and no water. Box is inverted and sand is allow to fall over the hot pattern. depending upon the lead time some thickness of shell will appear over the pattern. Pattern is unclamped from the box and baked

in an oven at around 300°C . Alcohol burns and due to localized heating sand becomes strong. By hitting the ejector pins into the ground shell is taken out. Two or three such shell

are joint together with the help of thermosetting plastic or clamps. and liquid metal is poured into the mould cavity. After Solidification shell is broken to get the product.

Investment Casting: Steel turbine blade : ECM Process

Gas turbine " : Investment

very big " " " : Silicon Nitrogen

Silicon / Aluminium oxygen

(optional)

Silicon tool, pin copy routing lattice

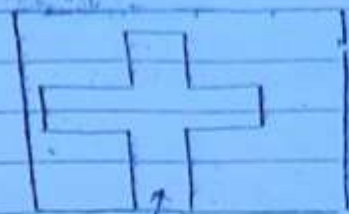
Material of CD — ABS

No.

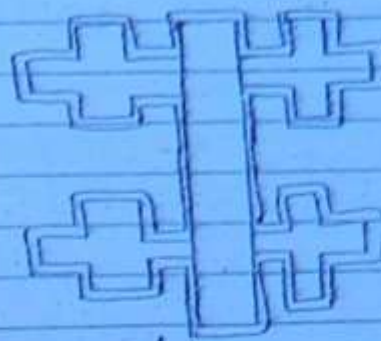
62

Acrylo Butadiene Styrene

Date



Wax — lost wax
Hg — Mercast.



Sand + additives + water.

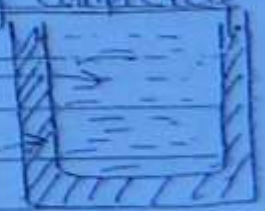
125

Not only complex, but very good dimensional accuracy can be produced by investment casting. Jet engine blades are being produced by this method. Wax is injected into the die to make the pattern. A No. of these patterns are joined together to form a pattern tree. This pattern tree is dipped into alcohol to remove dirt, grease etc. This pattern tree is then dipped into a ^{Slurry containing Sand, wax, Additives} slurry and after taking out the pattern is dried. By repeating this procedure for certain No. of times, a thickness of shell ~~ap~~ will appear over the pattern. Pattern is heated to remove wax from it the shell is then fired in the furnace at 1100°C . This ensure complete removal of wax and also gives strength to the shell. after taking out from the furnace liquid metal is poured into the cavity when it is still hot. This avoids shell catching moisture from the surrounding.

Slush Casting: Jewellery, statues, lamp bases etc are produced by this process. liquid metal is filled in the die and before it gets solidify completely excess metal & material is being removed.

Excess material

Solidify material



Blow Molding: Material in the semi viscous form is kept inside the die and by blowing the air material take the shape of die. Plastic bottles, bulbs etc are produced by this method.

CO₂ Molding: 3-4-1. Na₂SiO₃ (Sodium Silicate)
water glass.

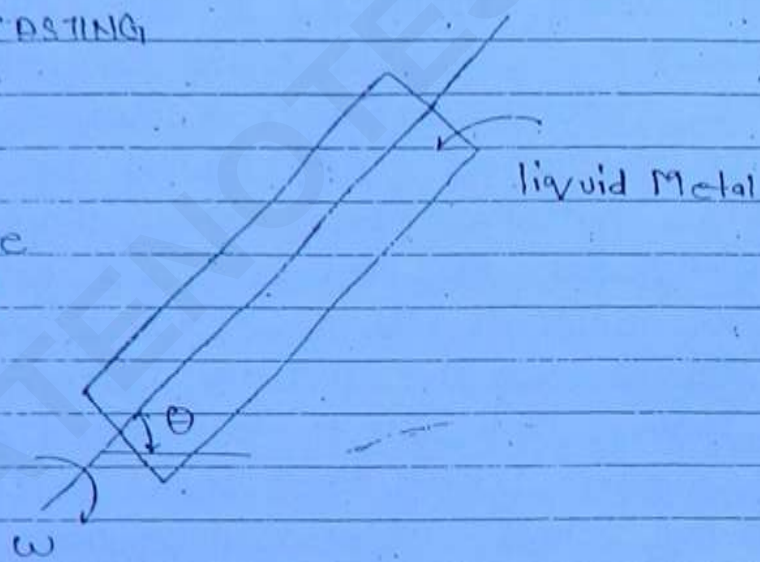
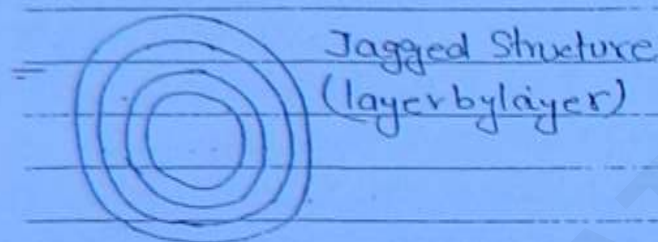


Harder the mold surface better dimensionally accurate products can be casted. While preparing the sand mold Sodium Silicate is added into the sand and CO₂ is then passed through the mold cavity. CO₂ by reacting with water glass produces very hard material. But Harder the mold surface lesser will be the collapsibility.

126

CENTRIFUGAL CASTING

(1) True centrifugal casting:

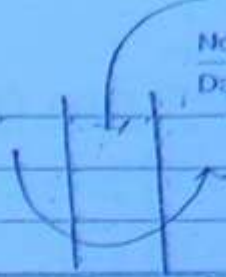


The mold is in the form of pipe with flanges is to be held in chuck of a lathe which is inclined from the horizontal. Liquid metal is poured through the centre and inclination is given so that the liquid metal covers the entire working length of the mold cavity.

So it produces jagged structure. Casted product will be denser due to centrifugal pressure. Since liquid metal is coming in contact with metallic molds this produces rapid cooling hence the fine grain structure. Since no riser, runner, cores etc are used in casting so % yield is as high as 95%.

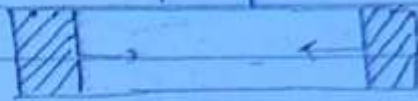
% yield: Percentage yield is defined as the weight of the final product to the weight of the total material poured in the mould cavity.

Semi centrifugal Casting:



mold is kept in the horizontal plane & is

$$F = mr\omega^2$$



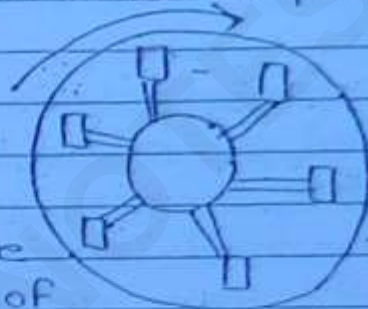
rotated about the vertical

axis. Liquid metal is poured through the centre. After outer region of the mold will be filled by centrifugal action but towards centre mold will be primarily filled by gravity.

After solidification central portion has to be removed.

-1. yield and speed of rotation is lower as compare to true centrifugal casting.

(128)



Centrifuging:

Even non symmetric products can be produced by this method. No. of

molds are placed on the periphery of a drum which is connected to the central space through individual turner. Drum is

rotated in the horizontal plane and by the centrifugal pressure

the casting will appear to be dense. -1. yield in this case

is very low and the major application of the process

is in making patterns for investment casting.

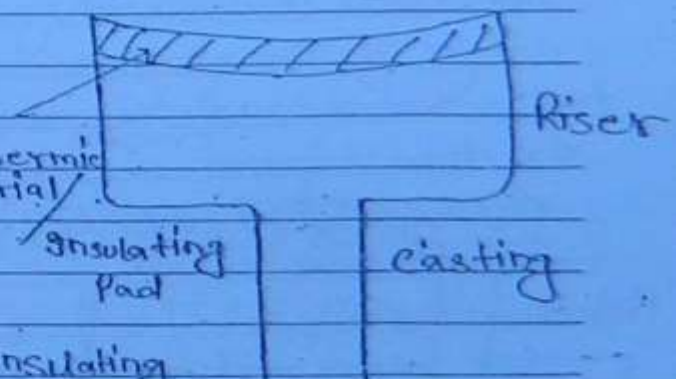
Steel Casting

Steel can be casted either with the help of insulated material or exothermic material or compound.

After filling the mold completely insulating material is kept at the top of riser which decreases the heat transfer and in the riser

material will remain liquid for longer period of time.

When exothermic material is placed at the top of riser, material in the riser again liquifies which eliminates the shrinkage completely.



DIE CASTING

No.

Date

Gravity die casting

Pressure die casting

Die steel
C.I.
Copper
Graphite
Aluminium

In die casting mold is made up of some permanent materials which can be reused again and again. Following are the characteristics of die casting.

① Production rate will be very high (around 150 casts per hour)

② Very good section sensitivity and complex geometry can be casted.

③ Strong products due to development of fine grain structure.

④ Very good dimensional tolerances.

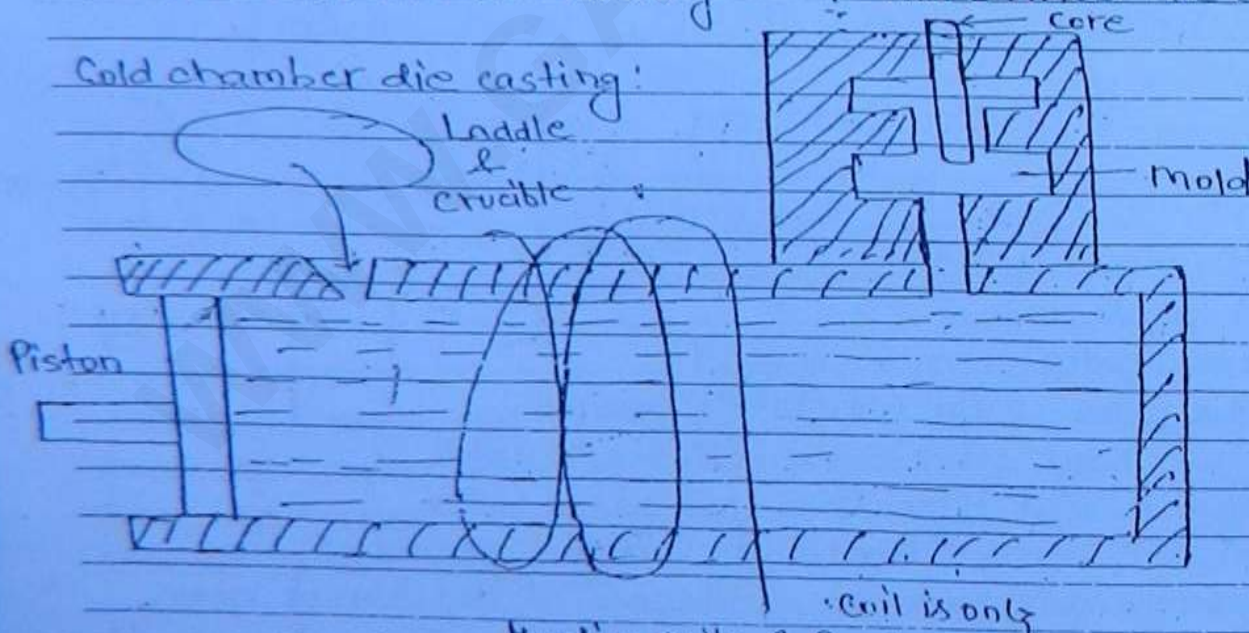
⑤ Although it produces good surface finish but after repeated use some mold contamination will take place. So after some interval of time mold are cleaned by abrasive jet machining.

⑥ Since permeability of these mold will be zero. So once the air/gases are trapped it will produce blow holes and gas holes.

Pressure die casting

Hot chamber die casting

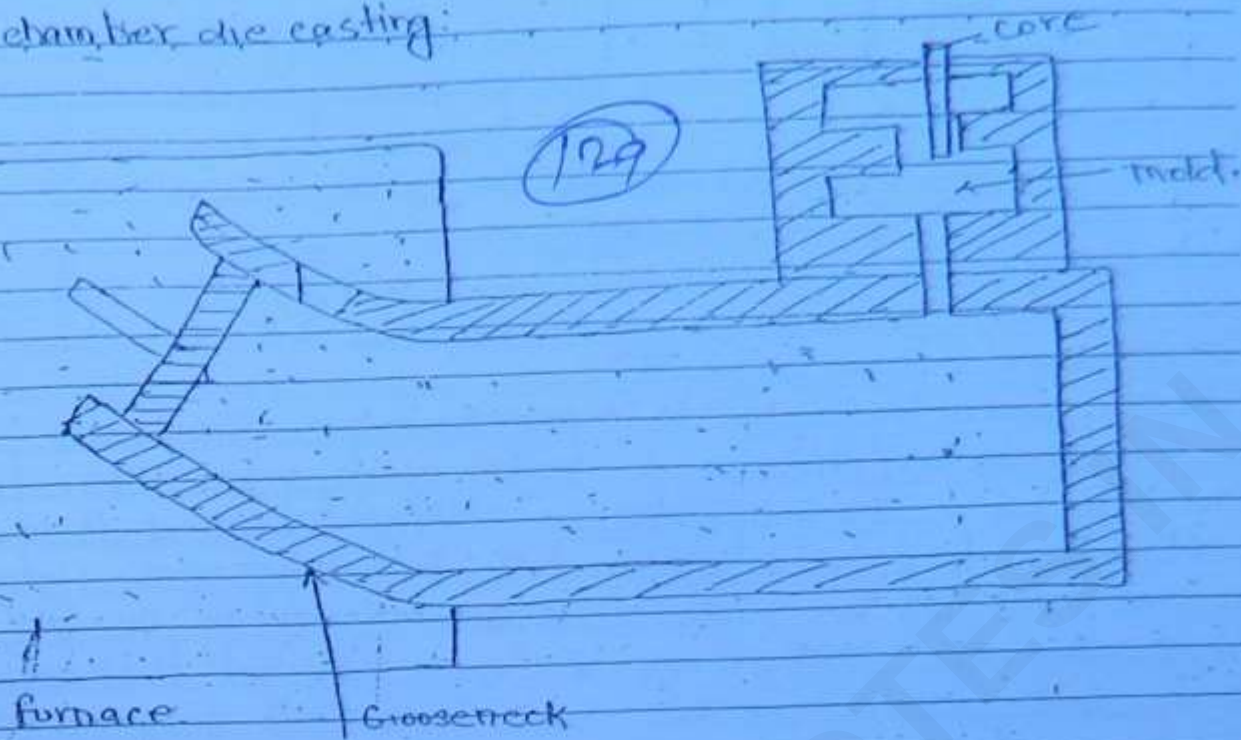
Cold chamber die casting



Heating coil (for injection molding)

Injection molding: From ladle & crucible or through some opening. Solid plastic pieces are brought to the cylinder and through piston, particles move further in the

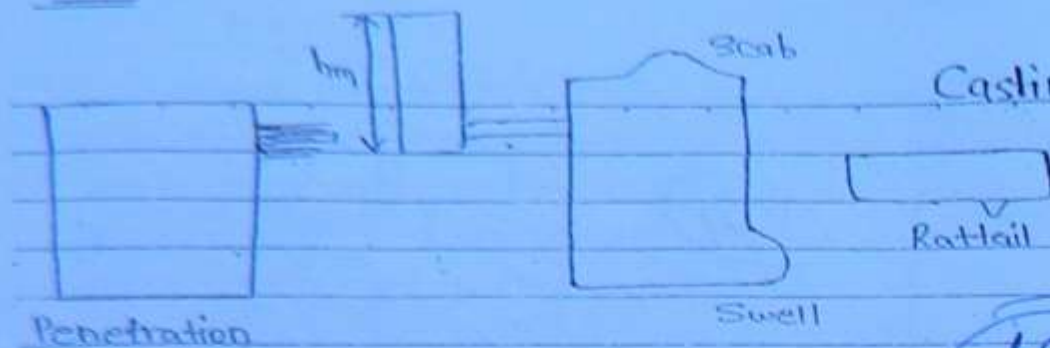
Hot chamber die casting:



In cold chamber die casting process furnace and mold are separate and liquid metal is brought to the mold cavity with the help of ladle & crucible. In hot chamber die casting process furnace is an integral part of mold cavity. In cold chamber die casting process since hot metal comes in contact with the atm. oxides will form and ^{good} castings will can not be produce. if atm. gases trapped it leads to blow holes & gas holes. In hot chamber die casting piston and a major portion of the cylinder is dipped into the hot metal and liquid metal never comes in contact with atm. This produces very high quality products but only those material can be casted which has lower melting point and which does not react with piston & cylinder material. Although Aluminium is having lower melting point but it absorbs iron from the cylinder material and iron and Aluminium is not a desirable impurity. so these materials are not casted by hot chamber die casting process.

cylinder and converts into semisolid from through the heat addition by the heater rounded on to the periphery of the cylinder. and then pour into the mold cavity by further piston movement. (optimal)

Casting Defects



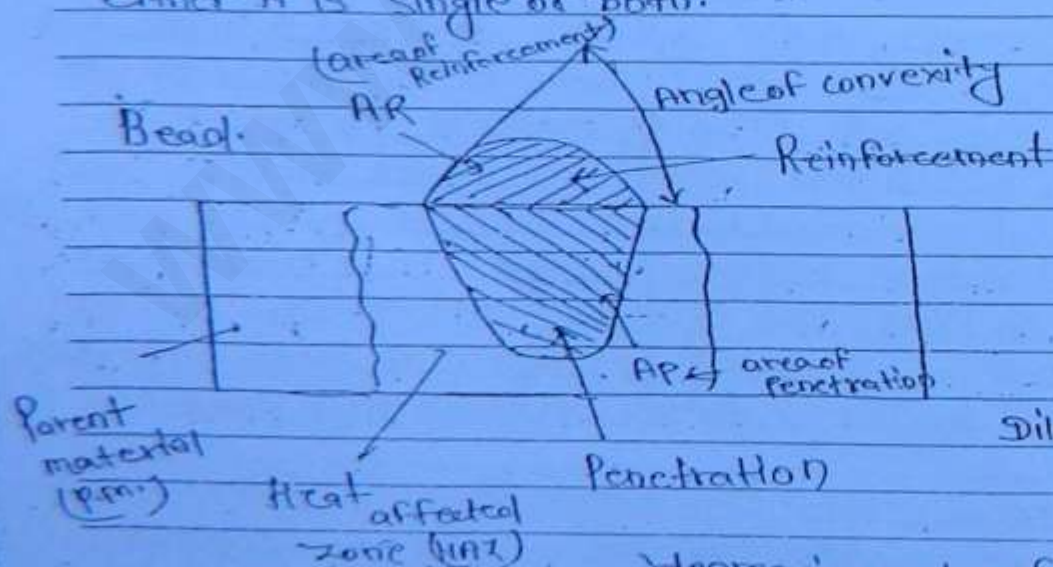
130

In the sand

If the sand is loose due to improper mixture, liquid will penetrate into the sand region called penetration. Due to improper ramming if the strength of sand is low in certain regions, due to hydrostatic pressure of the liquid metal sand will be replaced in some region by liquid metal. When this defect appears over the wall it is called Swell. And when it is on the top surface it is known as Scab. and in thin section when it appears in the bottom it is called ~~rat~~ rattail.

WELDING

It is joining of two similar or dissimilar material with or without the application of heat and pressure either it is single or both.



$$\text{Dilution} = \frac{AP}{AP + AR} \times 100$$

Decreasing order of strength
Bead > P.M. > HAZ

Classification:

- i) Arc
- ii) Gas
- iii) Resistance
- iv) Thermit

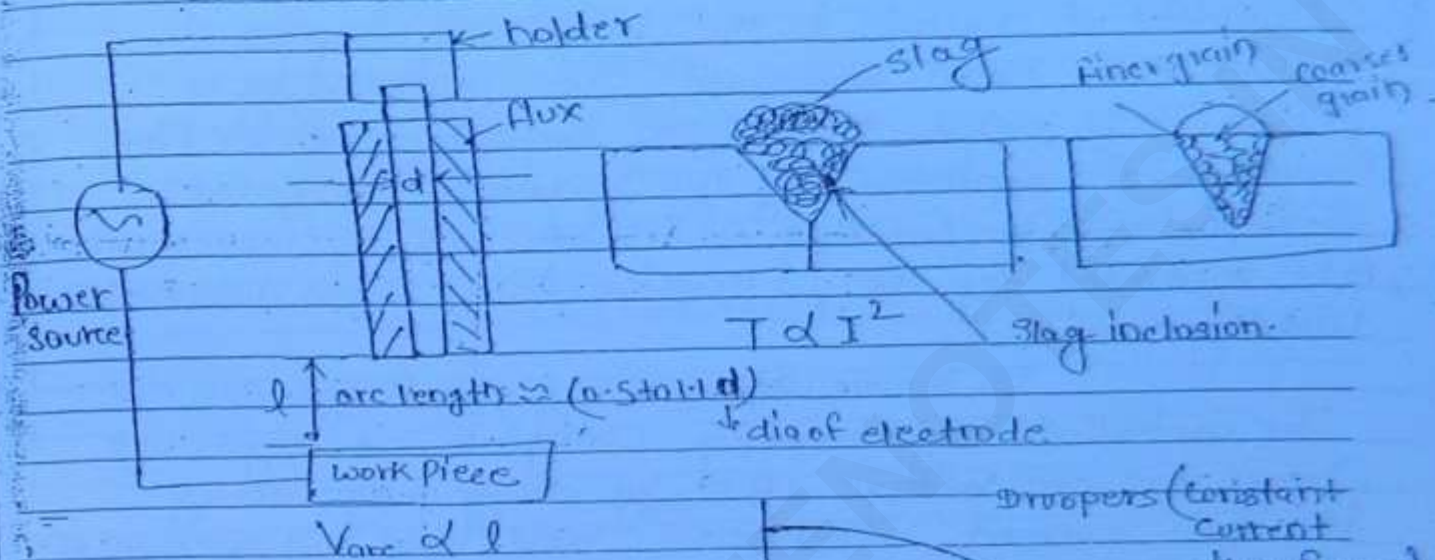
- iv) Solid state
- v) Radiant
- vi) Allied process

131

Arc welding

① Shielded metal arc welding (SMAW)

Stick electrode.



Initially there are being created b/w electrode wire and w/p and flux by taking energy from the spark also liquifies and a mixture of flux & molten

metal is deposited in the groove. Since flux is having lower density as compare to liquid metal it comes up over the surface and gets deposited as slag coating. This flux is having 3 functions to perform:-

- (i) It gives alloys to the bead making it even more stronger than the parent metal.
 - (ii) It supports the heat treatment of the bead and it produces the coarse structure at the centre and in the outward direction grains becomes finer and finer.
 - (iii) It protects the bead from the attack of atm gases.
- The molten pool temp. is proportional to

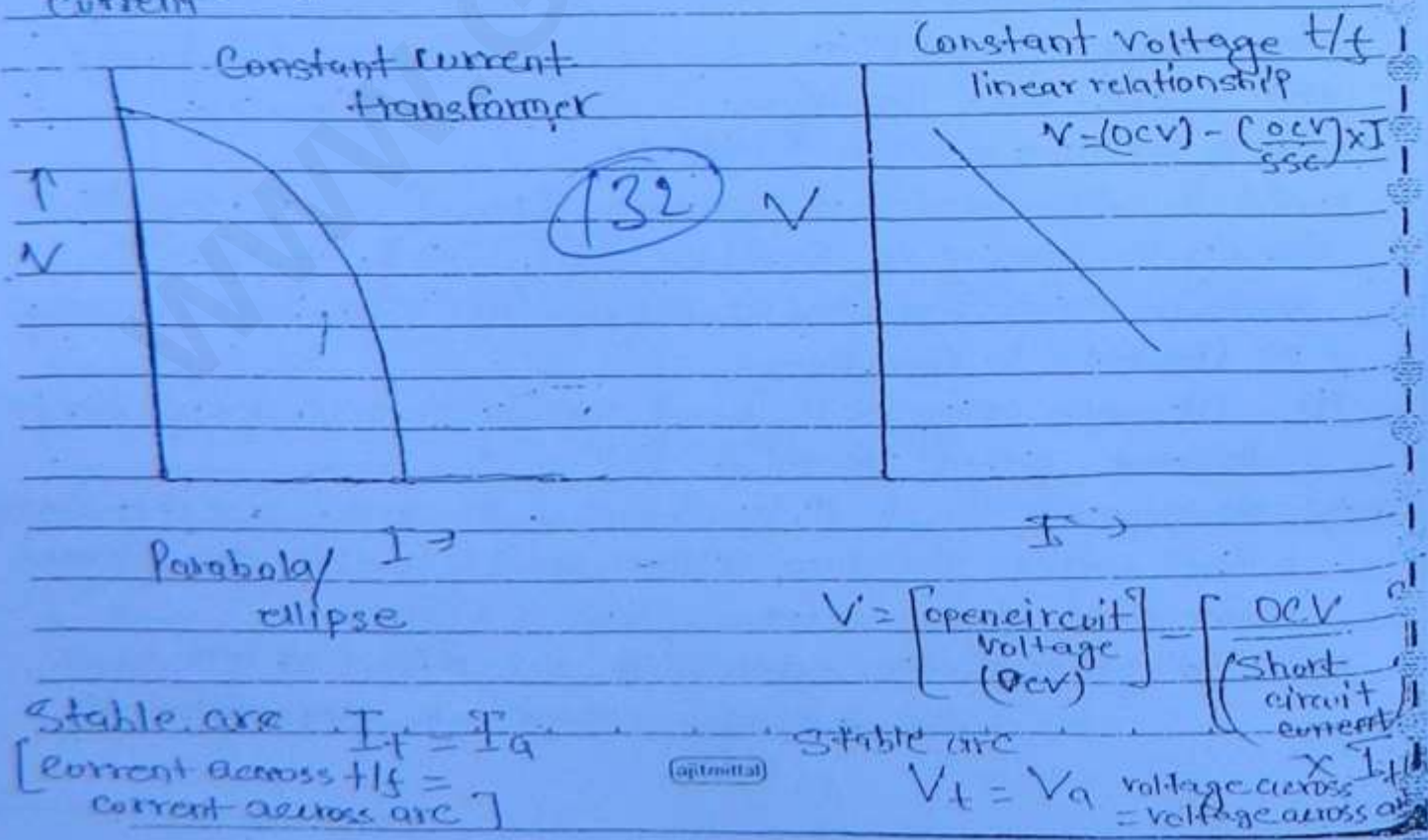
current and when the cooling is performed at lower current settings molten pool temp will be lower. and as the slag is trying to come out liquid material will be solidified and a portion of slag will be trapped within bead this defect is called slag inclusion.

There are two movements of electrodes:

- 1: Feeding of electrode towards the molten pool.
- 2: Movement of electrode in the longitudinal direction.

When both these movements are controlled by a person it is called manual arc welding; when the first movement is controlled by the machine it is called Semiautomatic welding and when both the movements are controlled by the machine it is called automatic welding process.

In manual arc welding, arc length can not be controlled very precisely. Change in arc length will change the arc voltage and by change in arc voltage if arc current changes weld bead will have no. of defects. So Droppers (or constant current transformers) are used in manual arc welding and as it can be seen in the fig. that for a considerable change in arc voltage there is insignificant change in arc current.



Q: The arc length current voltage characteristic is given by the eqn. $V = 24 + 4l$ where l is arc length in millimeter. The static Volt amp. characteristic of a power source can be approximated by a straight line with $OCV = 80V$ and short circuit current of $600A$. determine the optimum arc length for maximum power.

Sol: Constant voltage transfer.

$$OCV = 80V.$$

$$V = 24 + 4l$$

$$SCC = 600A.$$

$$V_t = OCV - \left(\frac{OCV}{SCC} \right) I.$$

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

(133)

$$V_t = V \text{ (for stable arc)}$$

$$80 - \left(\frac{80}{600} \right) I = 24 + 4l.$$

$$-\left(\frac{80}{600} \right) I = -56 + 4l$$

$$\frac{8}{60} I = 56 - 4l.$$

$$I = \frac{60(56 - 4l)}{8}$$

$$\text{Power} = VI = (24 + 4l)(56 - 4l) \frac{60}{8}$$

$$\frac{dP}{dl} = 0 \Rightarrow \frac{d}{dl} (24 + 4l)(56 - 4l) \frac{60}{8} = 0$$

$$\frac{d}{dl} 60 \times \frac{1}{8} (6 + l)(14 - l) = 0$$

$$\frac{d}{dl} 120 (6 + l)(14 - l) = 0$$

$$\frac{d}{dl} 120 (84 + 14l - 6l - l^2) = 0$$

$$\frac{d}{dl} 120 (84 + 8l - l^2) = 0$$

$$8 - 2l = 0$$

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

Q. The static volt amp. characteristic of a power source is given by the following eqn. $I^2 = -500(V-80)$

(a) If the arc characteristics can be represented by $I = 23(V-18)$ determine the power of stable arc.

(b) if arc length voltage are related by expression $V = 20 + 4.5l$ determine the ^{optimum} arc length for ^{maximum} optimum power.

Sol.

(a) $I_f = I_a$

$I^2 = -500(V-80)$

$I = 23(V-18)$

$(23(V-18))^2 = -500(V-80)$

$529(V^2 - 36V + 324) = -500V + 40000$

$V = 25.1, 9.9$

with 9.9, I is -ve.

$\therefore V = 25.1$

$I = 23(25.1-18)$

$I = 23 \times 7.1 = 163.3$

$P = V \times I = 25.1 \times 163.3 = 4098.33 = 4.098 \text{ kW}$

(b) $V = 20 + 4.5l$

$I^2 = -500(20 + 4.5l - 80)$

$I^2 = 500(80 - 20 - 4.5l)$

$I^2 = 500(60 - 4.5l)$

$I = \sqrt{500(60 - 4.5l)}$

$P = V \times I = (20 + 4.5l) \sqrt{500(60 - 4.5l)}$

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

$l = 7.4 \text{ mm}$

Q: The voltage length characteristic of DC arc is given by
 $V = 20 + 4l$

where l is arc length in mm during a welding operation
 it is expected that the arc length will vary b/w 4 to 6mm
 and current will vary b/w 450 A to 550 A. Assuming a
 linear power source characteristic determine ocv and
 SCC.

Sol. $V = ocv - \left(\frac{ocv}{SCC}\right) I$ Power will remain constant
 $P = VI$

at 4mm, $V_1 = 20 + 4 \times 4 = 36 \text{ V}$

at 6mm $V_2 = 20 + 4 \times 6 = 44 \text{ V}$

$I_1 = 450 \text{ A}$

$I_2 = 550 \text{ A}$

$I \uparrow V \downarrow$
 at 4mm, $V = 36$
 $I = 550$
 at 6mm, $V = 44$
 $I = 450$

~~$V_1 = ocv - \left(\frac{ocv}{SCC}\right) I_1$~~

135

$$36 = ocv - \frac{ocv}{SCC} \times 450 \quad \text{--- (i)}$$

$$44 = ocv - \frac{ocv}{SCC} \times 550 \quad \text{--- (ii)}$$

$$36 = ocv \left[1 - \frac{1}{SCC} \right] \times 450$$

$$44 = ocv \left[1 - \frac{1}{SCC} \right] \times 550$$

$$\frac{36}{44} = \frac{\left(1 - \frac{1}{SCC}\right) \times 9}{\left(1 - \frac{1}{SCC}\right) \times 11}$$

$ocv = 80 \text{ V}$
$SCC = 1000 \text{ A}$

$36 = ocv \left(1 - \frac{550}{1000}\right)$
 $ocv = 80 \text{ V}$

$V_1 = ocv - \left(\frac{ocv}{SCC}\right) I_1$

$36 = ocv - \left(\frac{ocv}{SCC}\right) \times 550 \Rightarrow 36 = ocv \left(1 - \frac{550}{SCC}\right) \quad \text{--- (i)}$

$V_2 = ocv - \left(\frac{ocv}{SCC}\right) I_2 \Rightarrow 44 = ocv \left(1 - \frac{450}{SCC}\right) \quad \text{--- (ii)}$

D. I. (ii) $\frac{9 \times 36}{11 \times 44} = \frac{\left(1 - \frac{550}{SCC}\right)}{\left(1 - \frac{450}{SCC}\right)}$

$\frac{9}{11} = \frac{SCC - 550}{SCC - 450} \Rightarrow 9SCC - 9 \times 450 = 11SCC - 11 \times 550$

$\frac{11 \times 550 - 9 \times 450}{2} = SCC \Rightarrow SCC = 1000 \text{ A}$

Duty Cycle

It is the time period in successive 10 min interval during which current can be drawn from the transformer after that there has to be compulsory Brake.

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

↓
duty cycle

ex: $400A \rightarrow 60\%$
for drawing $400A$ current ~~can~~ transfer ~~can~~ can run 6 min continuously after that 4 min compulsory Brake.

Ex: $400A \rightarrow 60\%$

Suppose $600A$ has to draw.

$$(400)^2 \times 0.6 = (600)^2 D_1$$

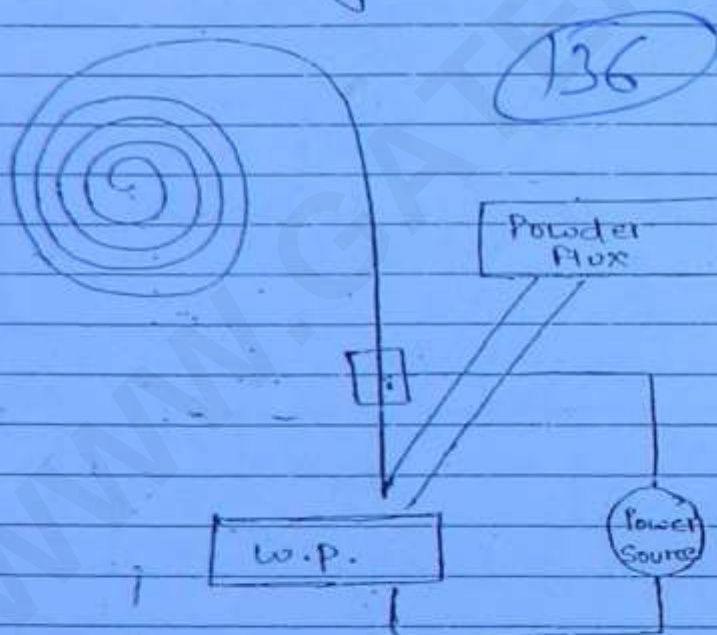
$D_1 = 26\% \leftarrow$ every 2.6 min, compulsory Brake of 7.4 min.

like: $200A$ has to draw

$$(400)^2 \times 0.6 = (200)^2 D_2$$

$D_2 = 240\% \leftarrow$ can be run continuously

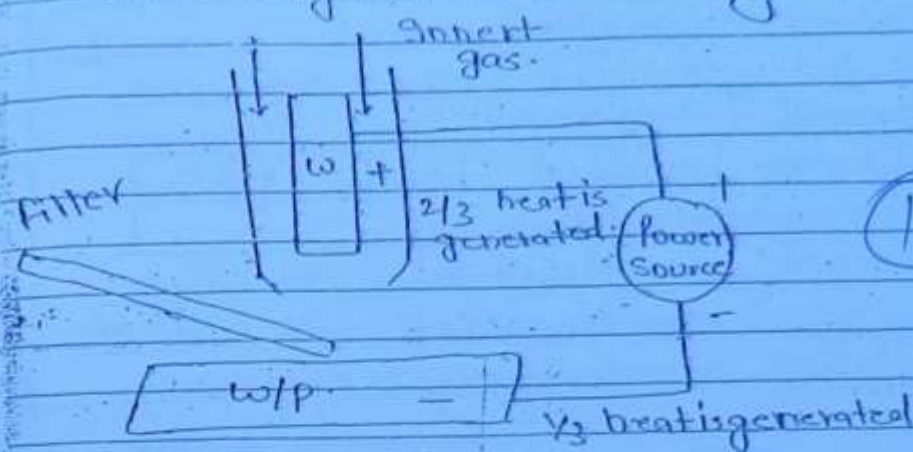
Submerged arc welding: (SAW):



It is the semiautomatic version of SMAW process. Using SMAW long welds can not be performed and at the point of Joint there will be welding defects like slag inclusion. In SAW process electrode is in the form of spool of copper coated wire and powder flux is kept in a separate container. Arc is maintained within the pool of powder flux so the defect, like spatter is completely eliminated.

Wire is Copper coated to increase the conductivity so that a proper arc can be maintained b/w electrode and w/p.
(Temp = 7000°C in all arc welding process)

Gas Tungsten Arc Welding (GTAW) / Tungsten Inert Gas welding (TIG)



Peeling / ~~etc~~ cathodic cleaning

Gas metal arc welding (GMAW) / Metal inert gas welding (MIG)

In GTAW Arc is being produced b/w Non consumable tungsten electrode & workpiece. A separate

filler rod is used to deposit the material over the workpiece.

But in GMAW process a non consumable electrode is replaced by copper coated spool of wire. When shielding is provided by CO_2 the process is known as Gas Metal Active

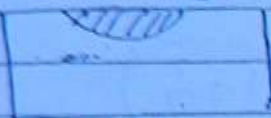
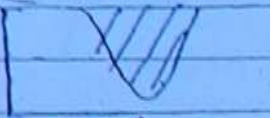
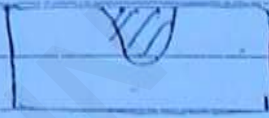
(GMA) welding. The process was invented primarily to weld alloys of

Aluminium & Magnesium. Al, when it is exposed to atmosphere it forms a layer of aluminium oxide which is a ceramic. To

weld aluminium work piece should be given -ve polarity &

electrode positive. As the -ve electrodes ^{are} coming out from the

fresh
w/p. oxide layer peels off and a fresh aluminium comes in contact with the arc. this phenomenon is called cathodic cleaning. from wherever electrons are coming out $\frac{1}{3}^{th}$ heat will be generated & where electrons are bombarding $\frac{2}{3}^{rd}$ heat will be generated.

	(electrode positive) Deep (Reverse Polarity)	(electrode negative) DCEN (Straight polarity)	AC
(1) Penetration			
	$\frac{1}{3}^{rd}$ heat w/p. $\frac{2}{3}^{rd}$ electrode Shallow penetration	$\frac{2}{3}^{rd}$ w/p $\frac{1}{3}^{rd}$ electrode deep	50-1. w/p 50-1. w/p electrode Medium.

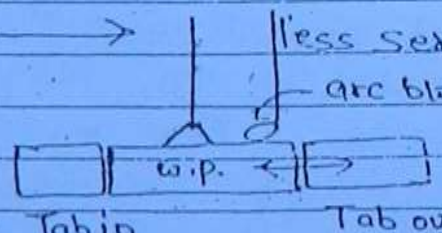
(2) Metal deposition Rate	High	low	Medium
---------------------------	------	-----	--------

(3) Thickness of Material to be welded	low [TiG, -ve polarity lower current setting ex: Joining Razer Blades]	High.	medium.
--	---	-------	---------

(4) Cathodic cleaning	Good	NIL	Partial.
-----------------------	------	-----	----------

(5) Maintaining Stable short arc	← Possible →	Not Possible (due to polarity changes)
----------------------------------	--------------	---

(6) Arc Blow	← Serious →	less serious.
--------------	-------------	---------------

(with DC Bare electrode)
Arc blow is ~~more~~ much serious)


Arc Blow: Due to fixed polarity in D.C. welding magnetic lines form in the w/p. when the weld welding is performed at the centre. Since magnetic lines will

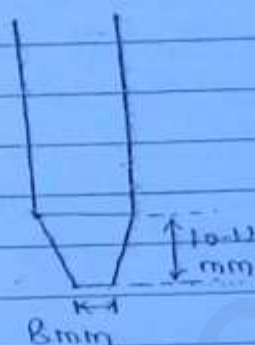
be equally distributed, arc will be straight. But while welding near the edges since most of the magnetic lines will be concentrated in the workpiece arc will deflect towards the magnetic lines. This phenomenon is called arc blow which produces severe spatter. To avoid this phenomenon metal plates are kept at the entry and at the exit so that magnetic line continuous. These plates also eliminates the end defects and are called tab ins and tab outs.

Arc Blow phenomenon becomes very serious in case of DC welding with bare electrodes. Sometime in AC also arc blow phenomenon will appear if there is improper earthing or large piece of iron is kept near the welding site.

139

Electrode preparation in GTAW:

DCen



dcep



AC

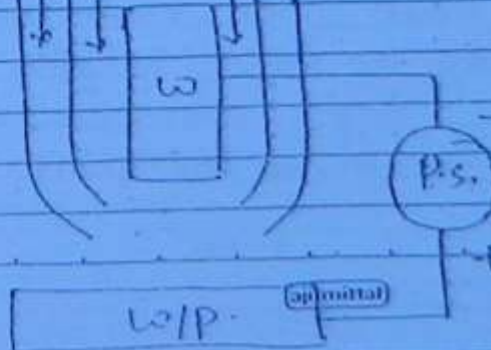


When electrode is given negative polarity its tip is grinded to a point to concentrate the flow of electrons. This produces deeper penetration. If electrode is given positive polarity its dia. at the tip should be increased to minimize the electrode erosion.

Plasma arc welding (PAW)

Ar/Hc

Plasma arc (H₂)



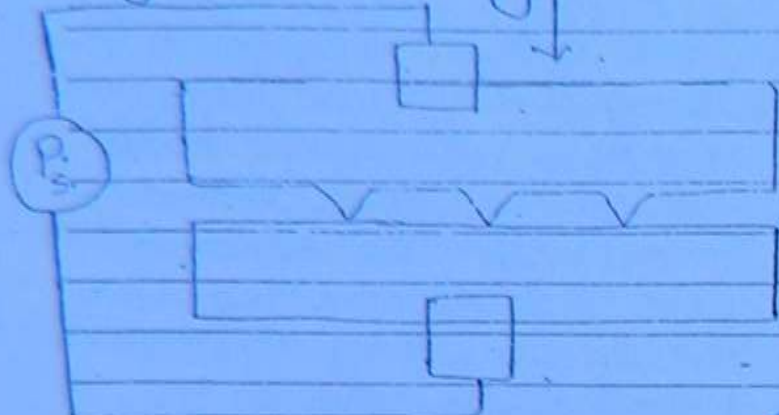
Plasma arc temp
= 55000°C
but for welding
= 20000°C.

Faster the process lesser will be the HAZ.

No.

Date

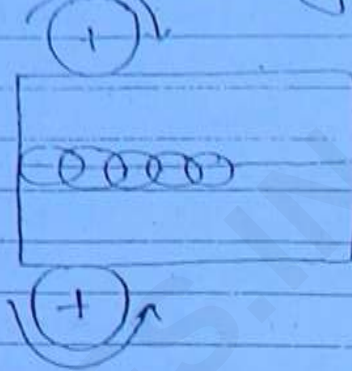
Projection welding:



Embossing

140

Seam welding

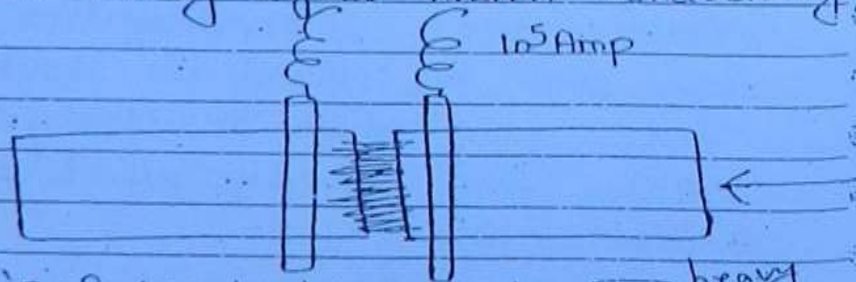


In seam welding leakproof welds are being made. In this process electrodes are in the form of rollers which produces overlapping Spot welds. In projection welding No of spots are being made in one setup. Projections are made in the sheet by embossing process and when the current is passed through the conductor material near the projection will become ~~the~~ soft. At a certain point of time current is stopped and pressure is increased and the projection collapses in the form of spots. During projection collapse the sheet which is having projection tends to be hotter.

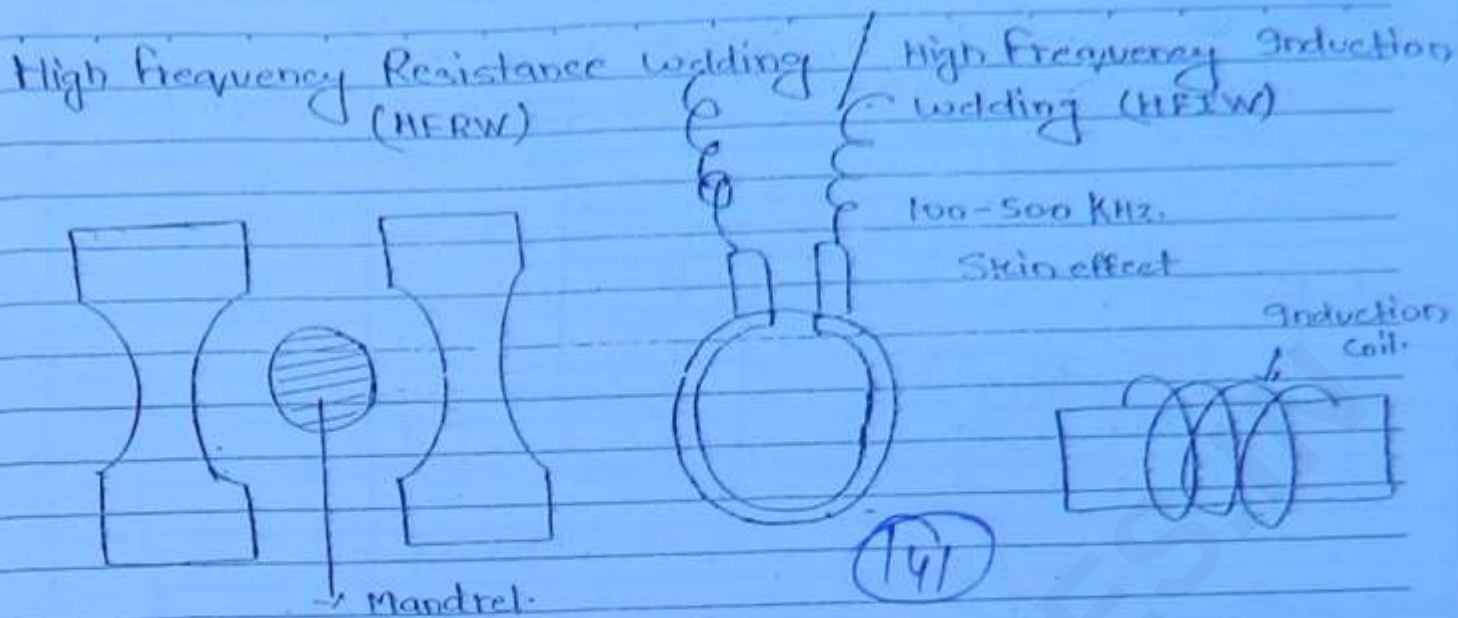
So projections are provided in the sheets which is thicker or the sheet which is having higher thermal conductivity.

Flash Butt Welding.

Process is primarily used to join railway tracks. Two

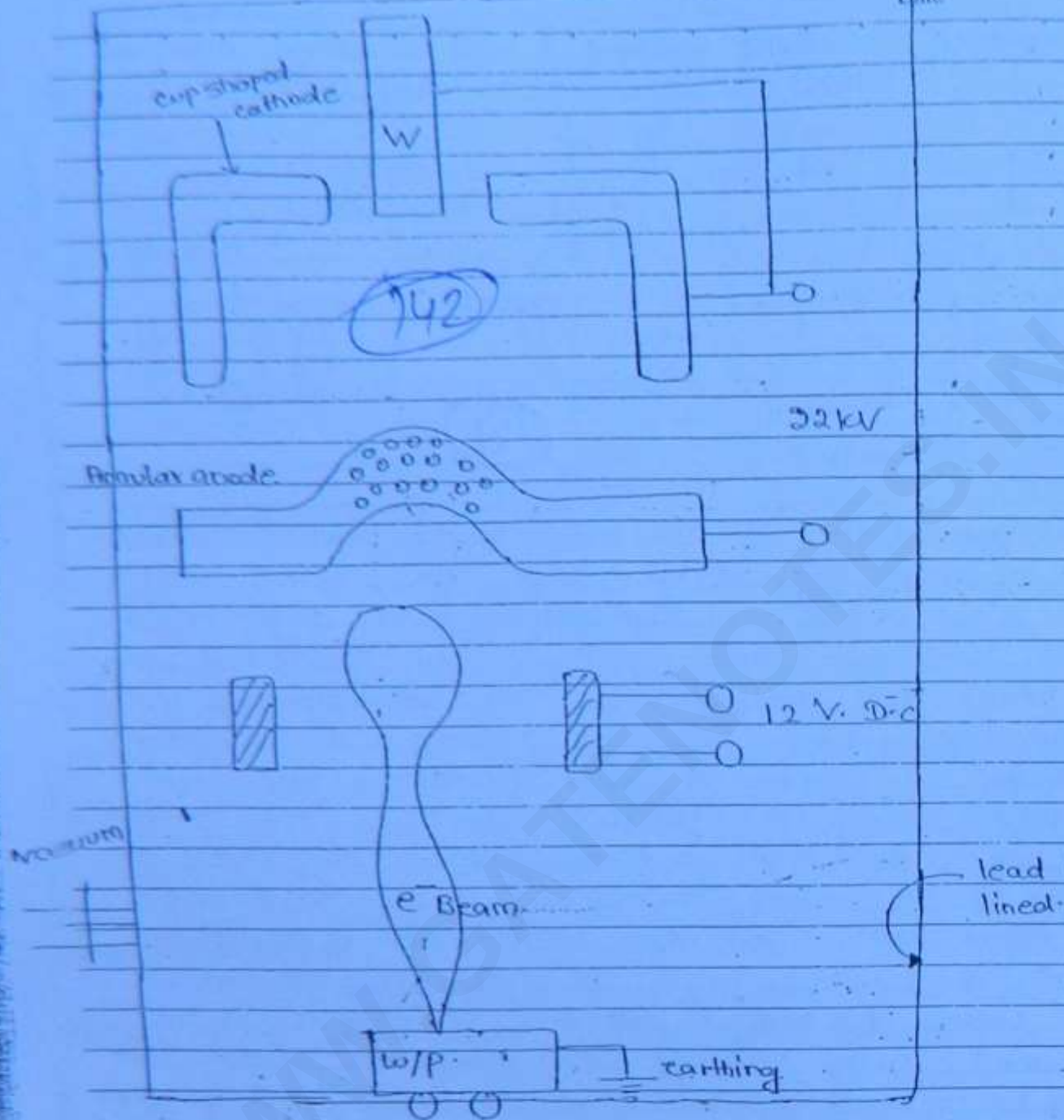


pieces are held in a pair of conductors and a ~~very~~ heavy current is passed through ~~to~~ them. When the work pieces are brought closed to each other flash will be produced this not only washes away the oxide But also makes the material soft near the edges. Current is stopped and axial pressure is increased to make the joint.



Different types of steel pipes are made by this process. Material is cut into strips and with the help of ~~conv~~ concave wall it is bended in the form of pipe. ~~A mandrel is used~~ with the help of mandrel bending is done exactly in the cylindrical way. Just before pipe enters into the rolls conductors are placed on each edge and high frequency current is passed through to them. A phenomena called skin effect appears due to which current flow through the path of least inductance (air gap) rather than least resistance, i.e. through the air gap b/w the edges. This makes the material near the edges soft. and when the pressure is applied by the rolls there will be a joint. In HFRW since conductors are coming in contact with the material it will be consumed after welding some kilometers of pipe so it has to be replaced by a new pair. In HFIRW conductors are replaced by induction coil which heats the edges by the development of eddy current.

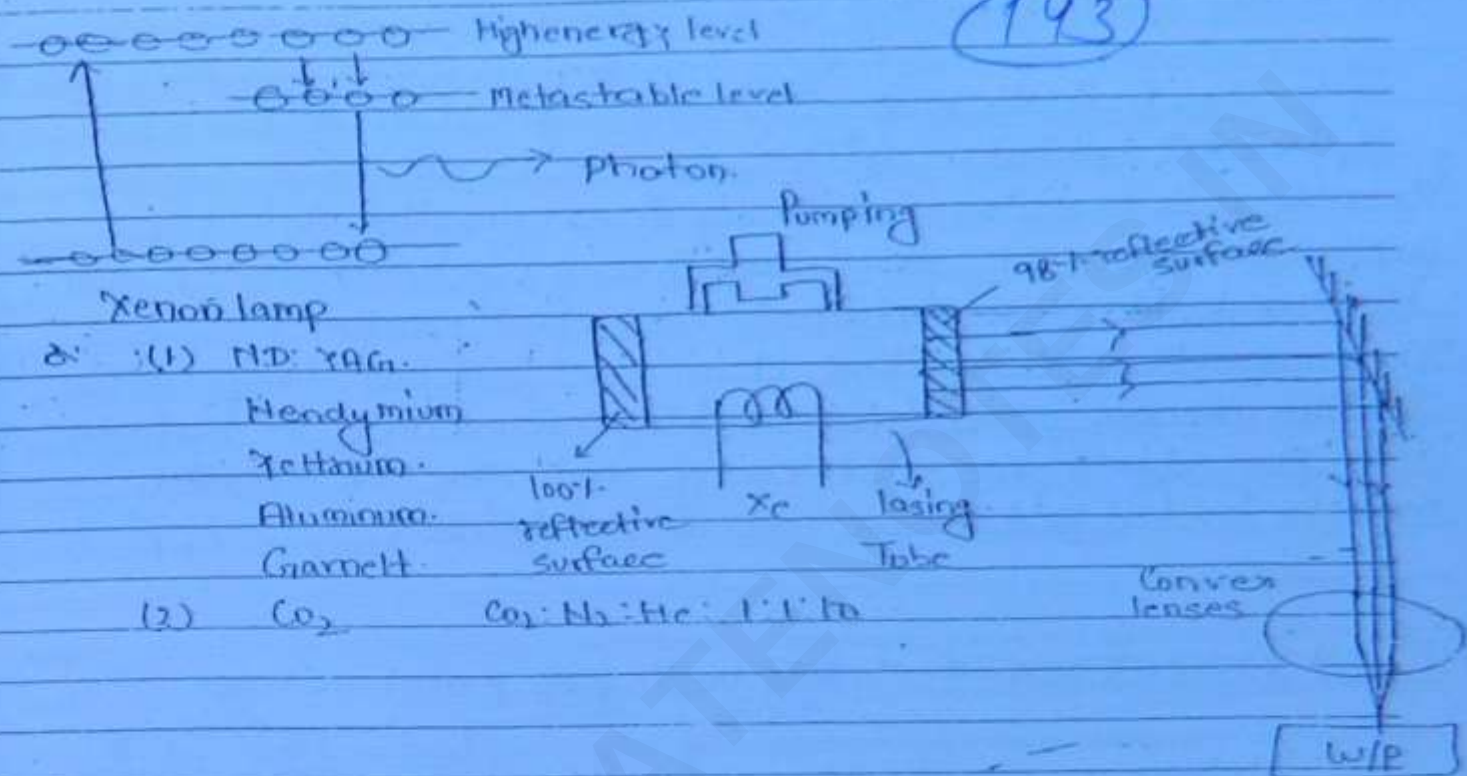
Plastics and other soft material pipes are made by extrusion. steel pipes are made by resistance welding and pipes of brittle material are made by centrifugal casting.



are converged to a beam by electric magnetic field in its path. entire assembly is kept inside a chamber and vacuum is maintained in it. otherwise high energy electrons will bombard the air particles & lose their energy. When high energy hit the workpiece X rays will be produced and to absorb these X-rays inside surface of chamber is lead lined. Electron beam welding produces almost ideal weld i.e. deep penetration & almost insignificant HAZ. Dr.

major application of the process is in space industries i.e. welding superalloys, titanium, S.S.

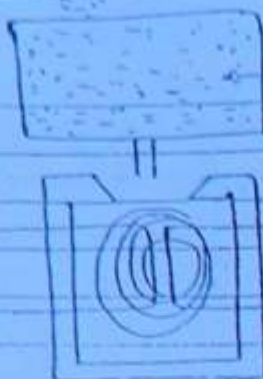
Laser Beam welding



atoms are pumped from the ground level by using Xe lamp. From the high energy level atoms come automatically to metastable state and once there is sufficient population inversion atoms come to the ground level by emitting a bundle of energy called photon. One side of lasing tube there is 98% reflecting lens which means that unless photons are coming in the horizontal direction they will not be allowed to come out. Since the photons are moving back and forth in the lasing tube most of its energy has to be carried away by cooling agent. So efficiency of laser is very low. LBW is even more versatile than EBW because materials can be joint in air, through a transparent medium and also profile welding can be achieved very easily. The major application of the process is in Radio engineering and electronics.

(c) Thermit Welding:

144

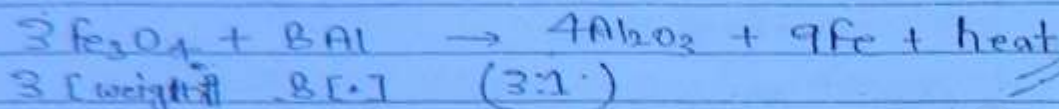


No. _____
Thermit date _____

Fe_3O_4 & Al

3:1 Ratio

weight
basis



The process is used to join railway tracks on site. A mold is prepared around the track and over it in a box thermit mixture is placed. Reaction is started using a fire cracker and since it is an exothermic reaction it will be self sustaining. Within a few minutes steel turns to boil automatically. The material is poured into the mold cavity and after solidification mold is broken and excess material is grinded.

Allied Processes: $\leftarrow$ No ~~melting~~ melting of parent material

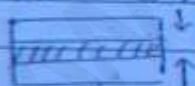
Soldering

< 450°C

Emery Paper

ZnCl_2

Pb - Sn



Brazing

> 450°C

1st Grinding
2nd then CCl₄

Borex

Brass and

Ag - Cu - Zn - Cd

Joining tip of single
point cutting tool

Temp:

Surface
Cleaning:

Flux:

Material:

Adhesive bonding $\rightarrow$ Joining by thermosetting plastic

In allied processes parent metal is not heated.

The surface to be joint is initially cleaned and then the Flux is deposited over the surface. It is for the purpose of dissolving the oxide present over the surface and also to protect the surface from further oxidation. The material to be deposited is liquify and fluid metal flows between the workpiece by capillary action. By increasing the thickness of deposited

layer Initially the strength of joint increases but when thickness increases beyond a certain value the joint strength will decrease.

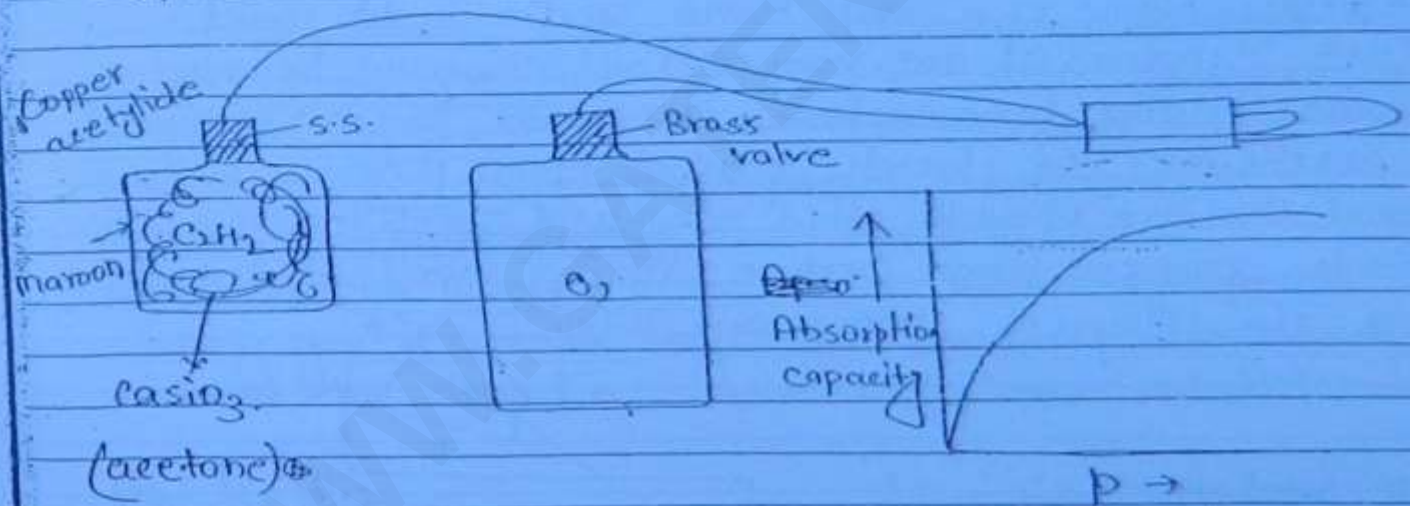
- Thermal spraying - Cladding
Primarily used to repair sick rolls.

In rolling mills, roll erosion gradually takes place due to diffusion. Since rolls are expensive it has to be repaired by these two processes. In thermal spraying a plasma torch is used to liquify the material and by using compressed inert gases it is sprayed over another material. In cladding operation electrode is in the form of a thin sheet and by using SAW or GMAW process it is deposited over the roll material.

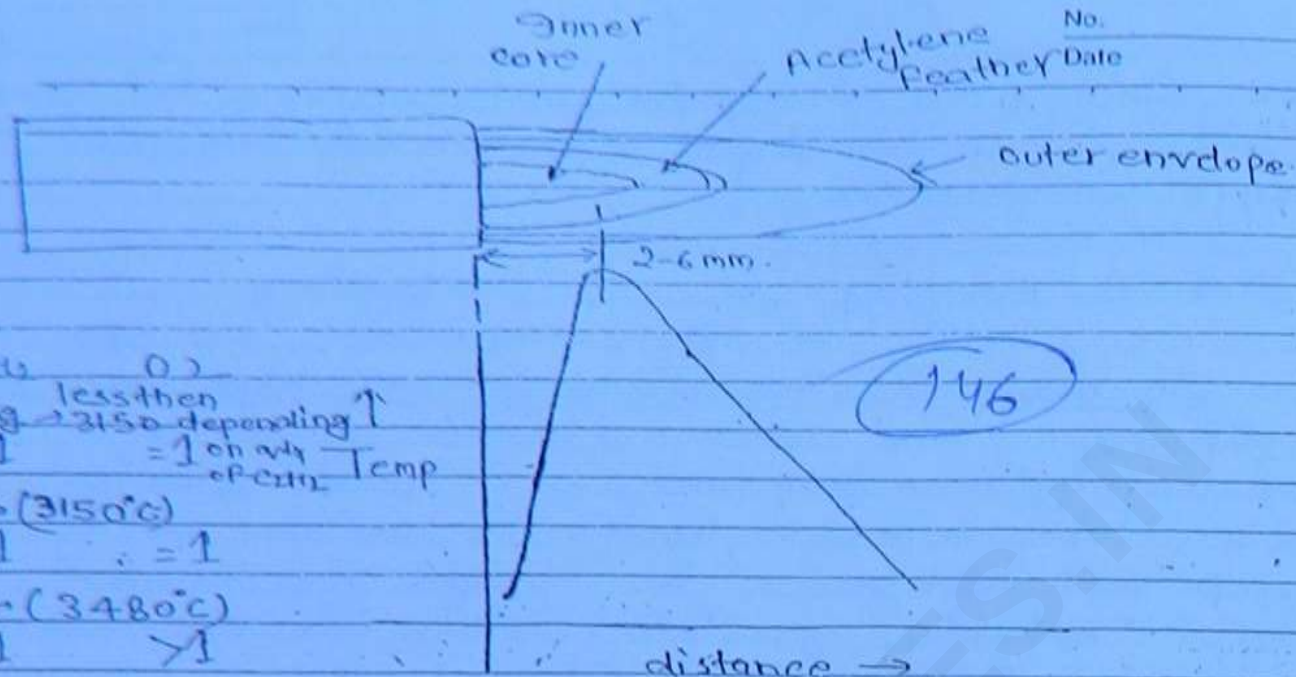
electrode is given +ve polarity

GIAS WELDING:

(145)



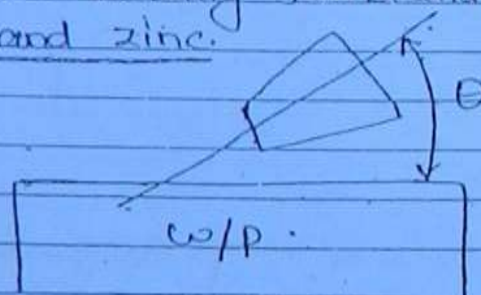
C_2H_2 is a very dangerous gas because it can explode under its own weight. Ac- C_2H_2 is absorbed in acetone. C_2H_2 cylinder is initially filled with a spongy like material like $CaSiO_3$. C_2H_2 is acetone is absorbed by Calcium silicate. C_2H_2 is then absorbed by acetone. The absorbing capacity of acetone $\uparrow$ with pressure. Stainless steel valves are used with C_2H_2 cylinder because C_2H_2 after reacting with copper produces Copper acetylide which is explosive.



In carburising flame there are 3 region and by increasing the % of O_2 , acetylene feather gradually disappear.

Carburising flame is silent flame and is used to weld.

Cast irons & C.I. are very difficult to weld because while welding free carbons comes out and this produces cracks over the bead. Neutral flame produces hissing sound and are used to weld structural steels or low carbon steels. Oxidized flame produce roaring sound and are used to weld alloys of copper and zinc.



Thickness	θ
$t \leq 1$	20°
1-3	30°
3-5	40°
5-7	50°
7-10	60°
10-15	70°
> 15	80°

Al cannot be cut because Al_2O_3 has 4 to 5 times higher melting point than Al.

Gas cutting: [only those materials are being cut, whose oxides have much more lower melting temp than the parent metal like Fe.]

Material is heated along the side to a kindling temp. (It is the temp at which rapid oxidation of material takes place). After that oxygen flow is suddenly increased and metal oxide melts out along the direction of movement of cutting torch.

Gas cutting is an oxidation process and not a melting process. Iron coming out from continuous casting machine will be cut by simple flow of O_2 gas because the temp above is already above the kindling temp. the process is called lance cutting.

(147)

Types of Fluxes:

- (1) Cellulosic :
- | | |
|--------------|-----------|
| 20 - 60% | TiO_2 |
| 10 - 20% | Cellulose |
| 15 - 30% | Quartz |
| 30 - 100 ppm | H |
- if H is present in the flux
H combines together to produce H_2 gas. Since it is an exothermic reaction

deeper penetration will be produced. But as the hydrogen is coming out it leaves large no of fine holes over the surface of bead the defect is called hydrogen embrittlement.

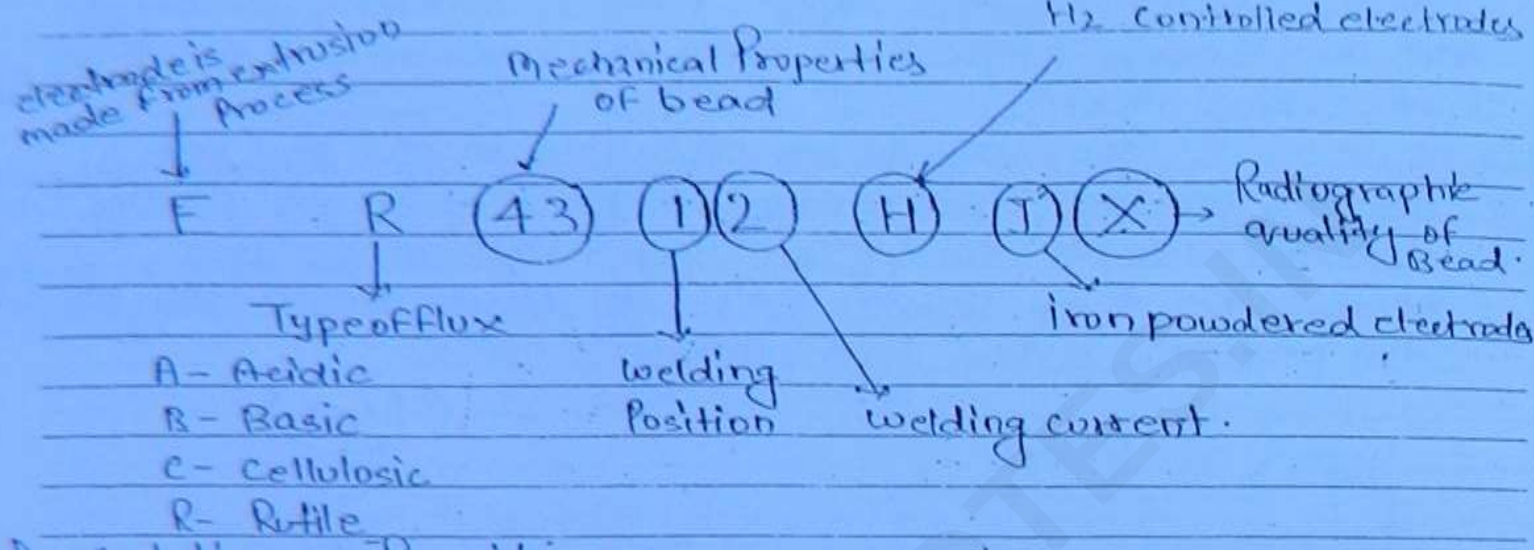
- (2) Rutile :
- | | |
|----------|-----------------|
| 40 - 60% | Natural TiO_2 |
| 15 - 20% | Quartz |
| 0 - 15% | Carbonates |
- (General Purpose electrode)

- (3) Acidic ^{coating} : Fe_3O_4 , MnO_2 , Quartz, Silicates
Very high H content ✓

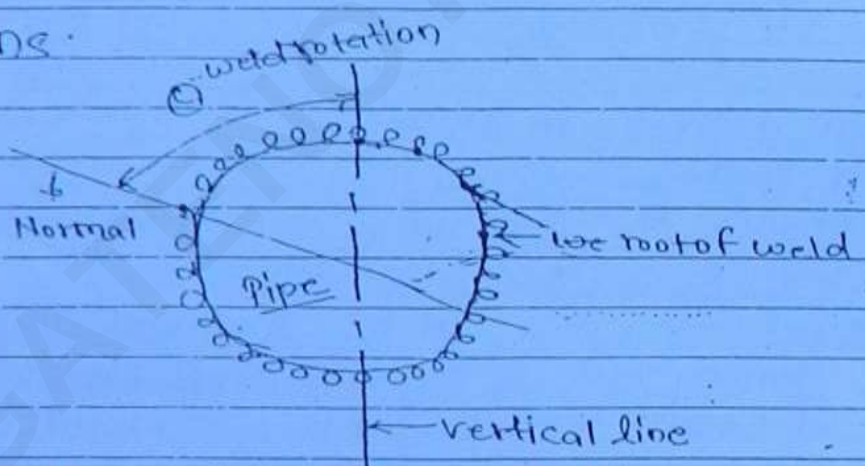
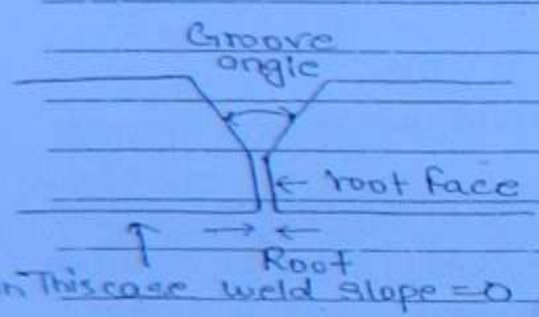
- (4) Basic coating →
- | | |
|----------|-----------|
| 40 - 50% | $CaCO_3$ |
| 20 - 40% | Fluorspar |
| | Feldspar |
| 0 - 5% | Quartz |
- Due to the presence of $CaCO_3$ flux is having a tendency to absorb moisture from the atm. So these electrodes has to be baked in an oven before used.

ISO: Designation of Electrodes

148



Welding Positions



The angle that the root of weld makes with the horizontal is called **weld slope**. By drawing Normal to the bead the angle this makes with the normal is called **weld rotation**.

Position	Symbol	Weld Slope	Weld Rotation
Flat	F	0 - 5°	0 - 10
Horizontal	H	0 - 5°	30 - 90
vertical up	V	80 - 90°	0 - 180
Down hand	D	80 - 90°	0 - 180
Overhead	O	0 - 15°	115 - 180

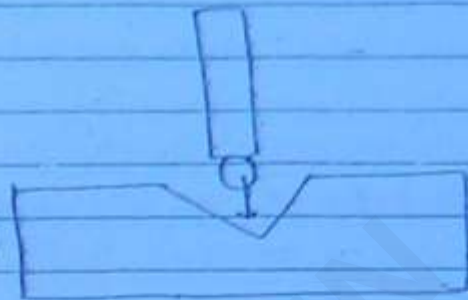
Electrode will be given - repolarity and we select higher current.

(optimal)

In overhead welding electrode should be given -ve polarity and current setting should be higher.

Forces in Metal transfer:

(i) Gravity: Gravity is a detaching force but in case of overhead welding it will be an attaching force.



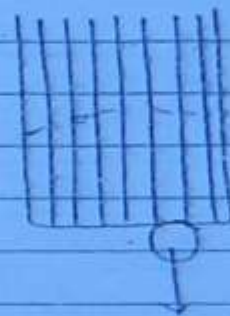
(149)

(ii) Surface tension: This force is always being an attaching force.

(iii) Drag force: Drag will appear between the flow of shielding gases and the liquid metal and it will always try to detached the molten droplet from the tip of electrode.

(iv) Electromagnetic pinch force (Lorentz force): $\propto I^2$

Electrode can be considered as made up of many parallel conductors and when current flows in the same direction an attractive force will develop. This will try to detach the molten droplet so higher is the current setting finer will be the droplet size coming out of the electrode.



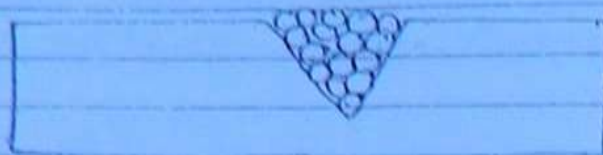
1:- Short circuit transfer and dip transfer.

Short circuit transfer appears when the current settings are low. There will be periodic bridging b/w electrode and ^{the} molten pool. This type of metal transfer may produce slag inclusion in the bead. This dip transfer appears in electroslag and electrode gas welding.

③ Globular transfer:

This transfer appears at a slightly higher current setting and the detachment primarily takes place by gravity.

Groove will be filled drop by drop. Density of bead will be low in this case.

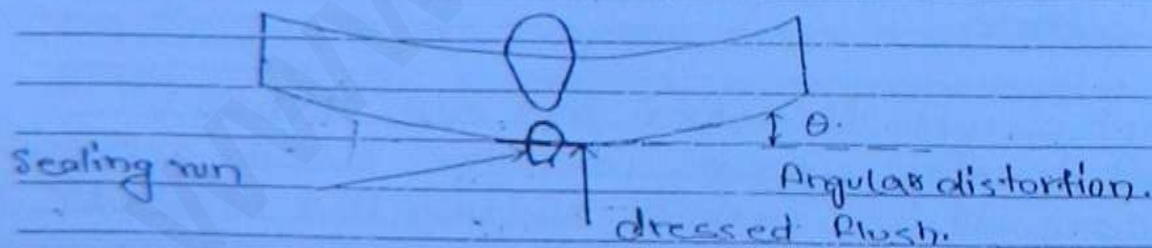
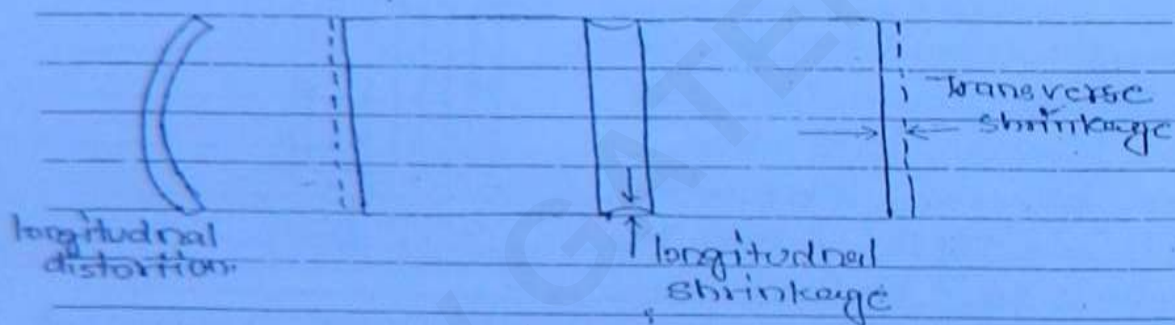


④ Spray transfer: Spray transfer appears at much higher current settings and dense bead appears as a result of that.

⑤ Repelled transfer: This type of metal transfer takes place during arc blows.

WELDING DEFECTS.

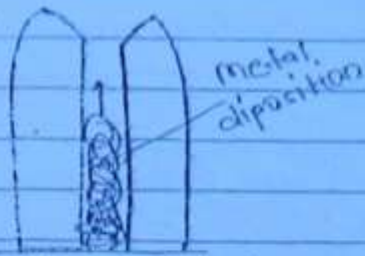
150



Due to the thermal stresses distortion appears in the weldments. Angular distortion will be significant and cannot be ignored.

This distortion can be neutralized to a great degree by depositing a small amount of material on the opposite face. Called Sealing run. This also.

closes the root gap. Reinforcement of the sealing too is generally not desirable so it is grinded and the process is called dressed flush.



Due to improper control of temp in electrode by welding thick plate will be heated in the upper region. Called Rotational distortion.

(157)

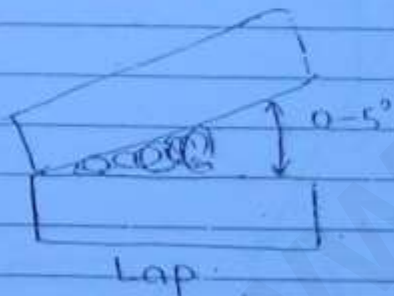
Rotational distortion.

Types of Joints

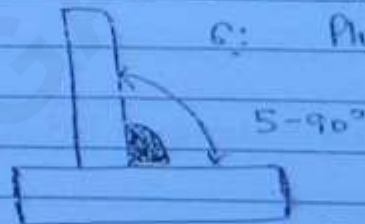
- 1: Lap weld.
- 2: Butt weld
- 3: Edge
- 4: T-joint.
- 5: Corner
- 6: cruciform.

Types of weld:

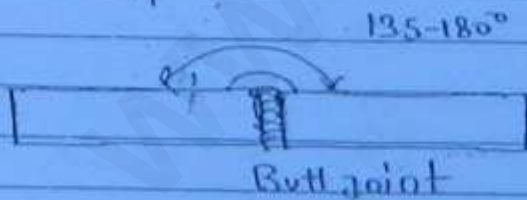
- 1: Fillet
- 2: Groove weld.
- 3: Spot
- 4: Seam
- 5: Surfacing
- 6: Plug.



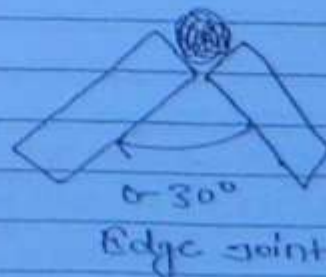
Lap



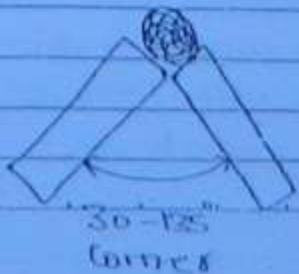
T-Joints



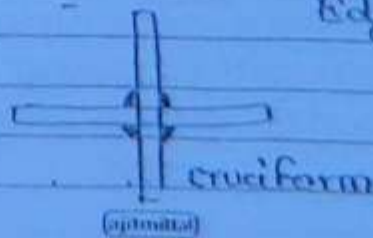
Butt joint



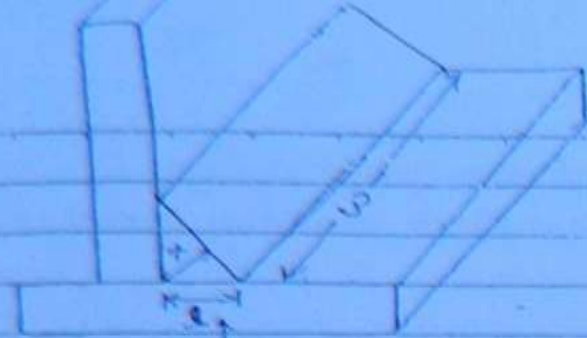
Edge joint



Corner



(optimal)



$$x = l \cos 45^\circ$$

$$A = (\cos 45^\circ) w$$

Fillet weld always fails in shear through min cross-section area.

leg length
to fillet weld.

Groove weld: edges are being prepared around the plates and then the material is deposited.

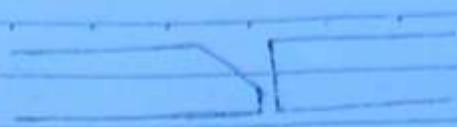
Plug weld:



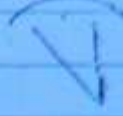
By using intense source of heat when penetration extends in another material, it is called plug weld.

WELDING SYMBOLS:

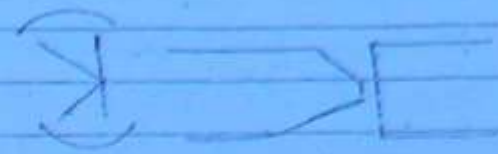
	No edge of Preparation	Symbol.
Square Butt.		
V-Butt		
V-Butt with Sealing Run with dressed flush		
Spot		
Seam		
Fillet		
Double V-Butt.		



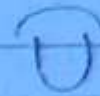
Single Bevel



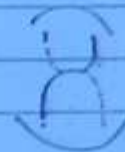
Double Bevel



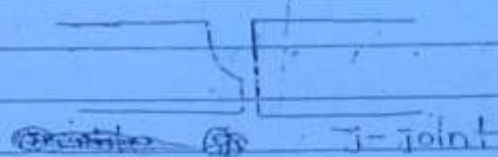
U-joint



Double U-joint



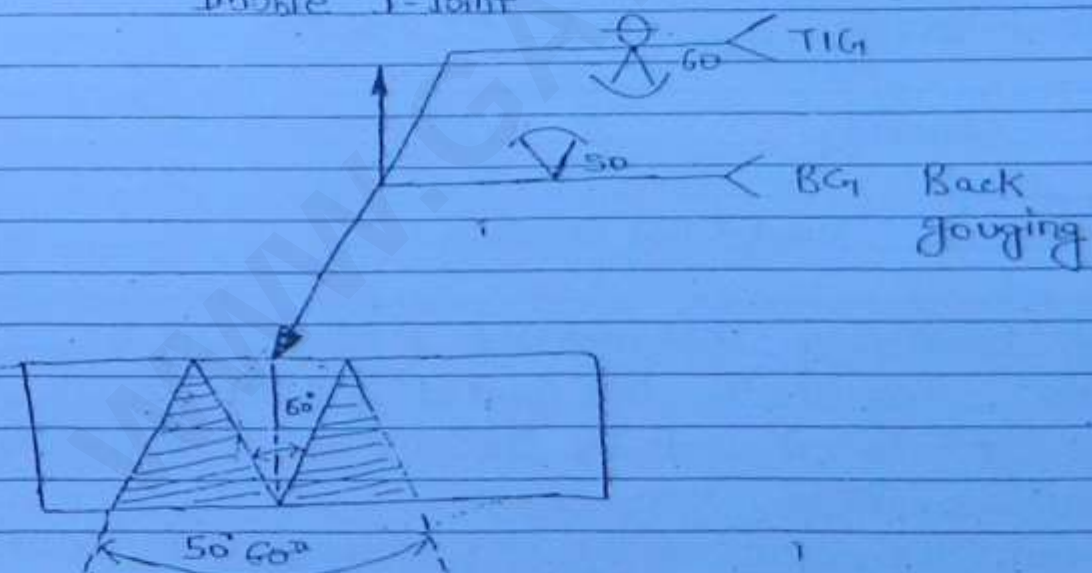
153



J-joint



Double J-Joint



Back gouging is a process of removing already deposited material. Information given ^{below} the line refers to the same side of arrow and information given above the line refers to the other side of arrow. In the above example there was 50 degree V on the opposite side of arrow but due to some

1. deposited metal was removed and a 60 degree V was prepared on the opposite face towards the arrow. The welding was performed by TIG and to minimise angular distortion, sealing run was performed and its reinforcement was dressed. Flushed. The entire procedure was done on site. ~~At the site~~

(Flag denotes the process done at site)

[The processes above the flag, all processes are done on site]

154

METAL FORMING

Cold working $\leq 0.4 T_m < \text{melting point}$

Warm working $0.4 \text{ to } 0.6 T_m$

Hot working $\geq 0.6 T_m$

characteristics of Cold & Hot working

- ① Due to work hardening, cold worked product will be stronger as compared to hot worked product.
- ② Due to the formation of oxide on the surface, surface finish in hot working will be very poor.
- ③ Due to shrinkages in the hot working, dimensional accuracy will be better in cold working.
- ④ To form hard and brittle materials, hot working is being performed due to lower mean flow stresses.
- ⑤ Due to excessive cold working, internal cracks may appear in the material.

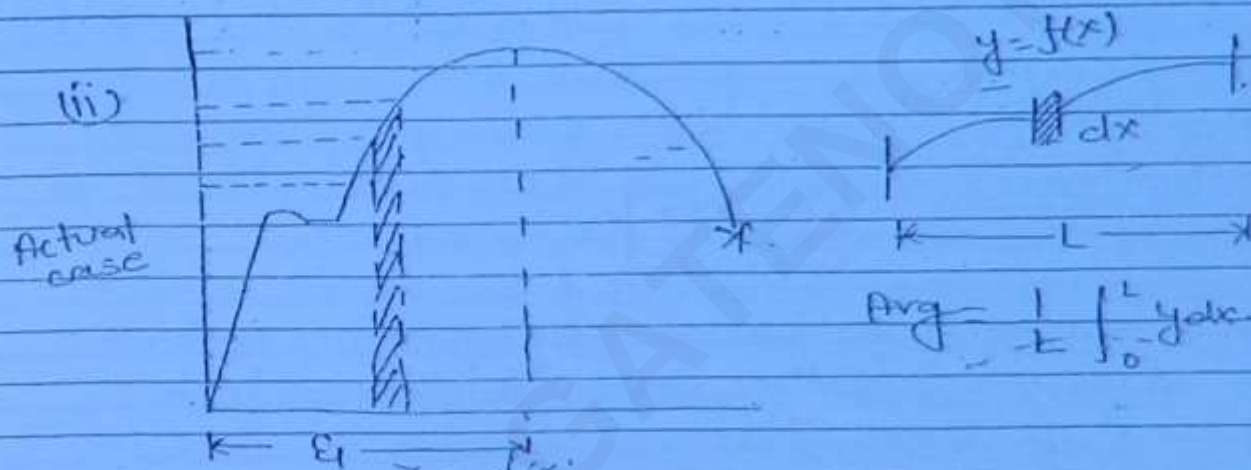
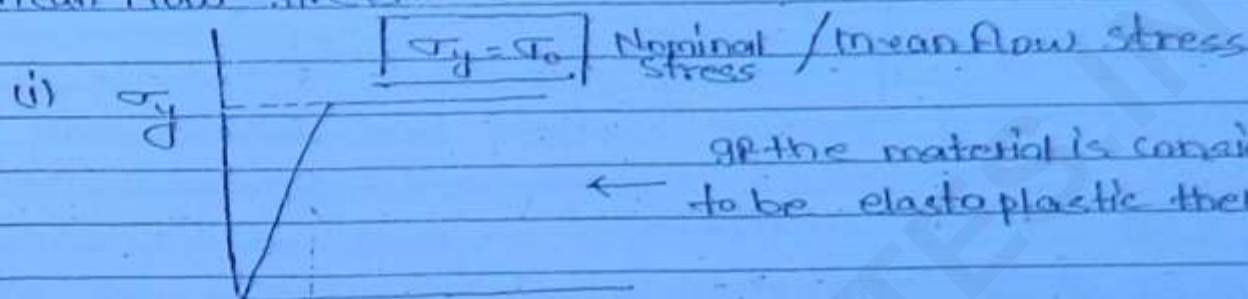
~~Plane strain - Von Mises.~~

Plane Strain - Von Mises.

Plane Stress - Tresca.

$$\sigma_1 - \sigma_2 = 2k \quad \text{yield strength in shear.}$$

Mean Flow Stress.



$$\sigma_y = K \epsilon^n \quad \leftarrow \text{Hollomon eqn.}$$

σ_y : True stress
 K : Strength coefficient
 ϵ : true strain
 n : work hardening exponent

$$\sigma_0 = \sigma_{fm} = \frac{1}{\epsilon_1} \int_0^{\epsilon_1} \sigma_y \cdot d\epsilon$$

$$\sigma_{fm} = \frac{1}{\epsilon_1} \int_0^{\epsilon_1} K \epsilon^n d\epsilon$$

$$= \frac{1}{\epsilon_1} \left[\frac{K \epsilon^{n+1}}{n+1} \right]_0^{\epsilon_1}$$

$$\sigma_0 = \sigma_{fm} = \frac{K \epsilon_1^n}{n+1} \quad \text{Mean Flow Stress.}$$

Plane strain - von mises

$$(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2 = 6k'^2$$

uniaxial tensile

$$2\sigma_0^2 = 6k'^2$$

$$k' = \frac{\sigma_0}{\sqrt{3}}$$

186

Plane stress - Tresca

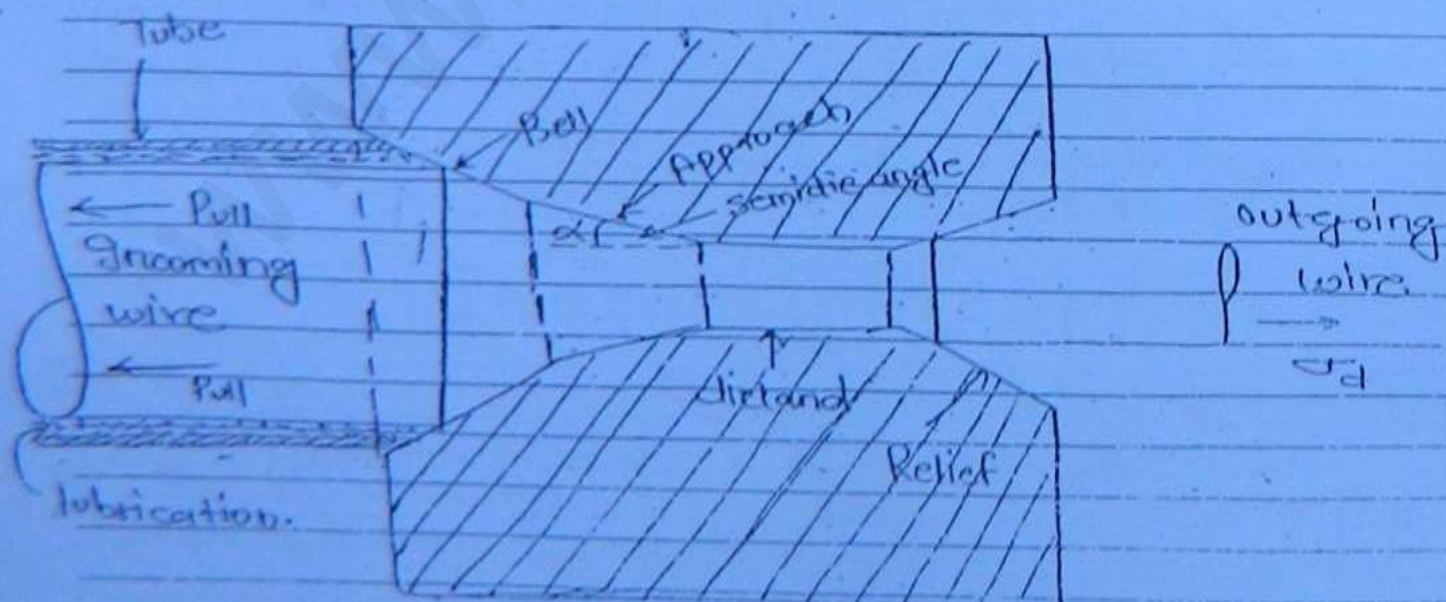
$$[(\sigma_1 - \sigma_2)^2 - 4k'^2][(\sigma_2 - \sigma_3)^2 - 4k'^2][(\sigma_3 - \sigma_1)^2 - 4k'^2] = 0$$

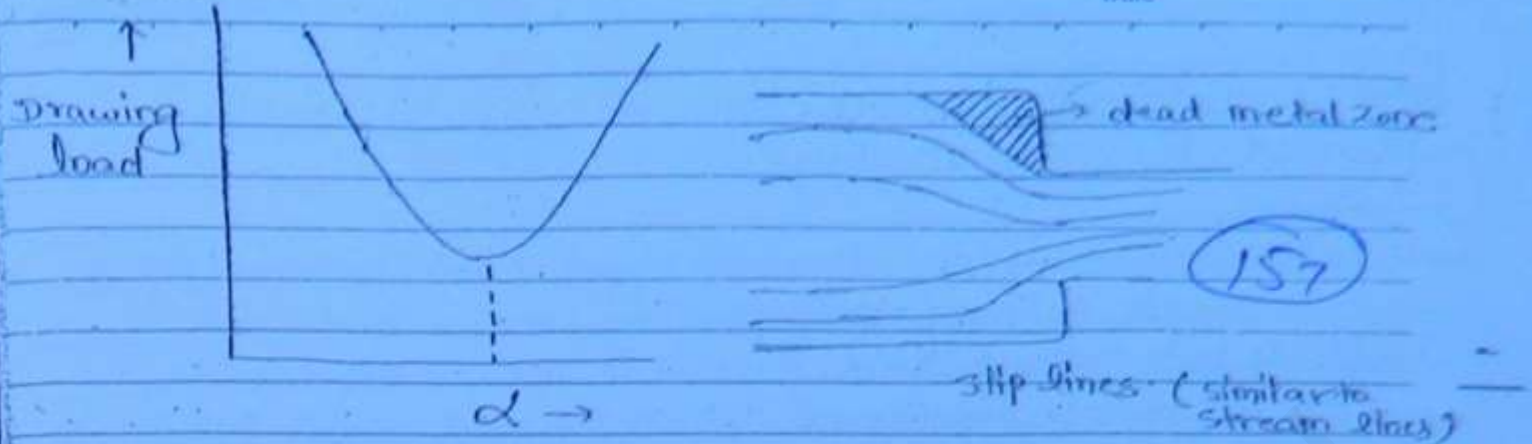
for uniaxial flow

$$k' = \frac{\sigma_0}{2}$$

Many metal forming operation when metal flow is restricted in one direction it is the case of a plane strain otherwise it is plane stress.

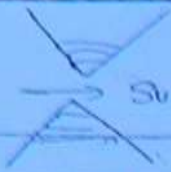
WIRE DRAWING





To start the wire drawing process, incoming wire is given a ~~bend~~ bend to remove the oxide layer from it. Wire is then dipped into lubricant. Liquid lubricants like soap solution, oil etc. produces bright finish, but solid lubricants like soap powder, aluminum powder, graphite etc. produces dull surface but heavy reductions can be given. Back pull is given to the incoming wire to keep it straight although by providing the back pull drawing pressure increases but die life increases ^(otherwise wire will get Bell surface of die and damage it) wire enters into the bell section of die through a tube. The purpose of this tube is pressurized lubrication. oil etc. as soon as the lubricant hits the die surface and it loses all its momentum which converts into pressure and this pressure enable the lubricant to enter into the deformation zone. Deformation of material takes place in the approach section. By increasing the semi die angle, the contact length b/w material and die decreases this decreases the energy require to overcome the friction hence drawing pressure decreases. Similar to stream lines in fluid flow, there are slip lines in metal flow and at any point of time metal flow will be tangential to slip line. When the semi die angle $\uparrow$, beyond a certain value there will be some region in the deformation zone will not be covered by slip line. So this material will not flow and it is called dead metal zone. It creates obstruction in the normal metal flow this $\uparrow$ the drawing load.

Dead metal zone improves the surface finish. Although by providing the die land drawing



Sudden change in die

No.

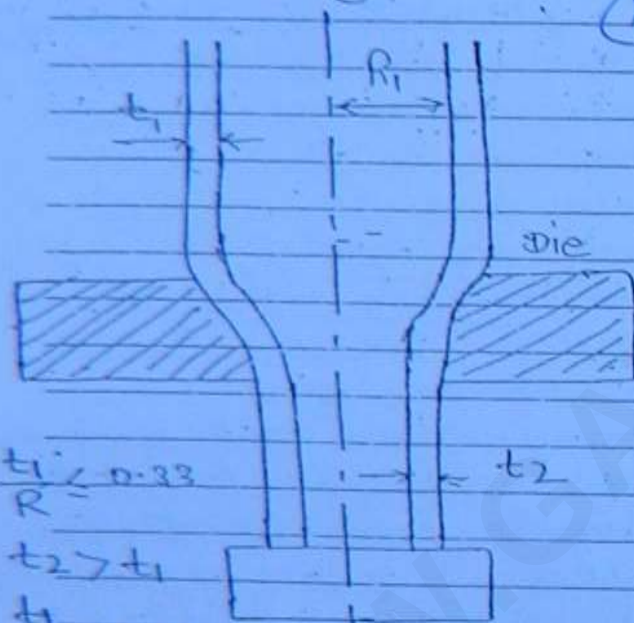
Date

load requirement increases but die land has to be provided for die stability.

If Breaking of oxide layer from the material is improper, during deformation, these oxide will percolate down and settle at the centre creating metallurgical weakness which produces central Burst or center line cracking.

Tube Drawing:

158

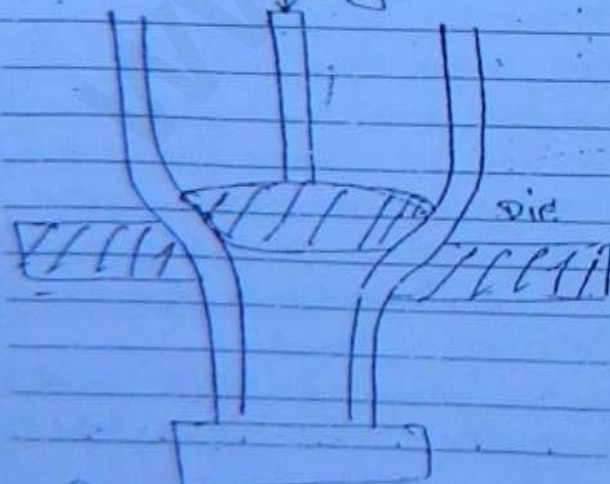


$$\frac{t_1}{R} \leq 0.33$$

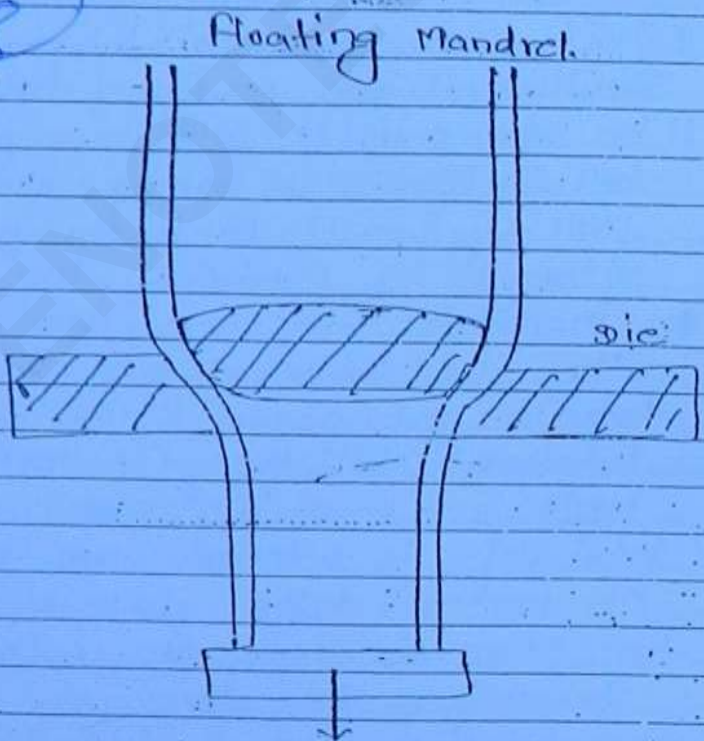
$$t_2 > t_1$$

$$\frac{t_1}{R} > 0.33$$

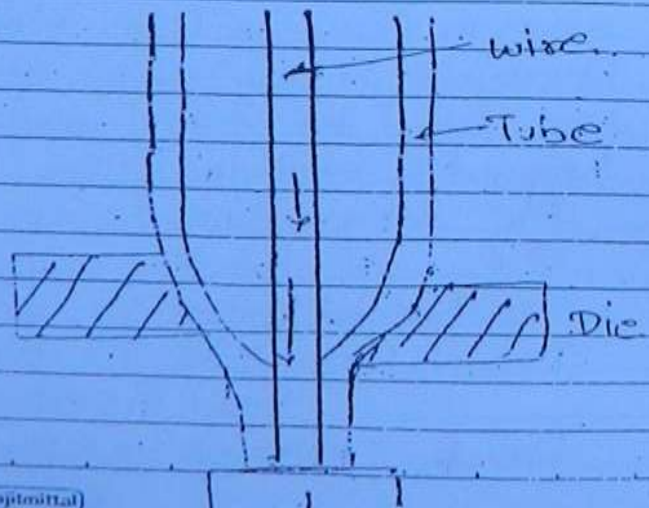
$t_2 < t_1$ Tube sinking



Fixed Mandrel



Floating Mandrel

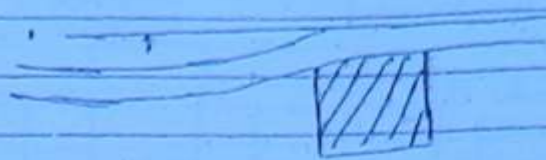


Optimal

with moving mandrel



No. 81
Date



159

~~Tube~~ In tube sinking since there is uncontrolled deformation at the inside surface neither the surface finish will be better nor there will be dimensional control of the outgoing tube. Tube drawing with floating mandrel, since there is the controlled deformation at the inside surface surface finish will be better but there is no dimensional control. Dimensional control can better be achieved in case of fixed mandrel and by increasing the load on the mandrel outgoing tube thickness can be decreased. Energy required in drawing operation is summation of energy required in plastic deformation and energy required in overcoming the friction. Tube drawing with moving mandrel, the wire dia is equal to the inside dia of outgoing tube. On the interface b/w die and material frictional will act in the backward direction but on the interface b/w wire and material, since tube is moving in the backward direction ^(initially wire velocity is greater than tube velocity) relative to wire, friction will act in the forward direction. This oppositely acting friction force will cancel each other hence lesser energy will be consumed in overcoming the friction. So max reductions can be given to the material when tube is drawn with moving mandrel. As soon as the drawing load becomes equal to the nominal stress σ_{UTS} wire will start breaking in the forward direction and that is the condition of drawing limit.

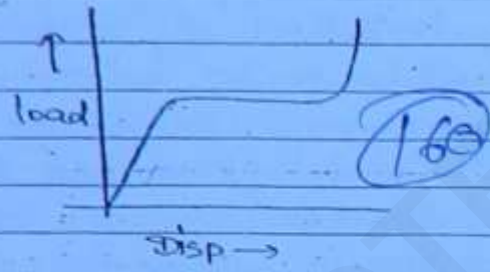
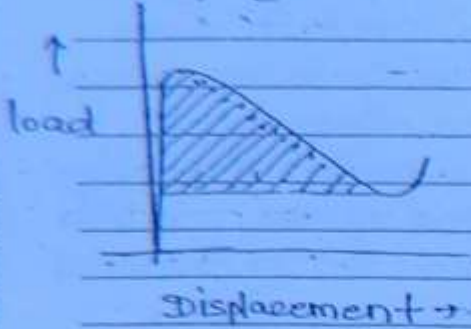
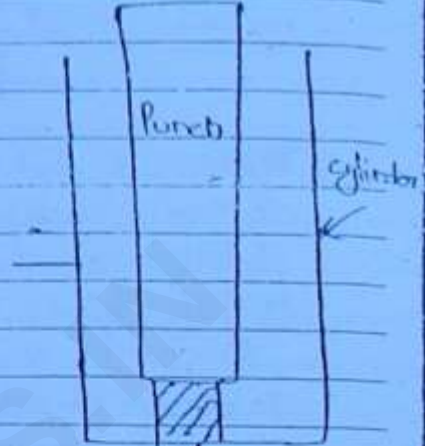
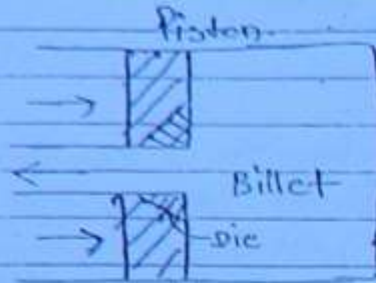
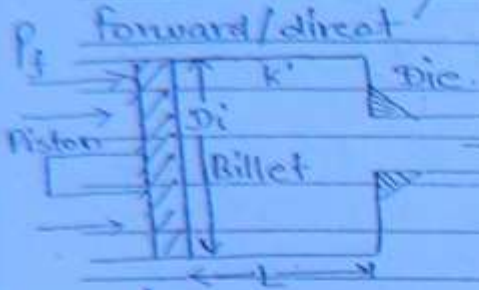
Extrusion:

$$P_f \times \frac{\pi}{4} d^2 = k' \times \pi d L$$

$$P_f = \frac{4k' L}{d}$$

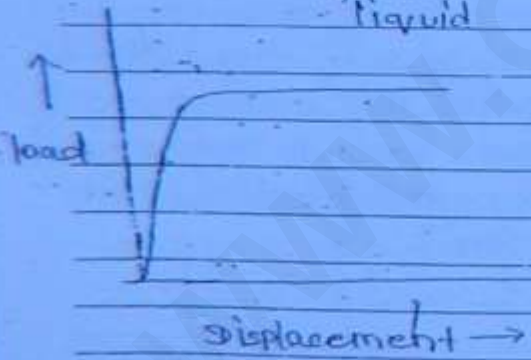
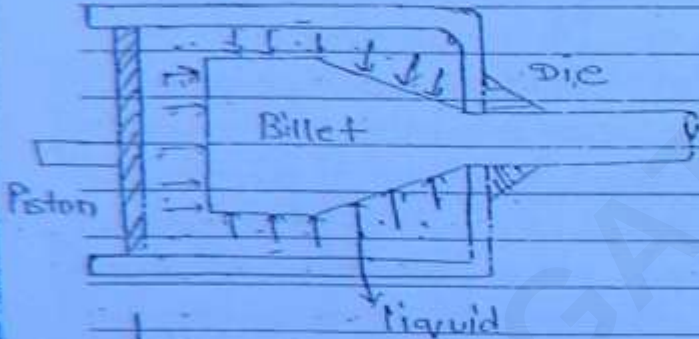
Reverse/Backward

Impact extrusion



Collapsible tube

Hydrostatic



In forward extrusion, extruded material moves in the same direction as that of piston. But in the backward extrusion, extruded material moves in the opposite direction as that of piston. In forward extrusion, since billet friction with die also appears, so larger extrusion pressures are required in the process. By increasing the hydrostatic pressure, ductility of the material increases. So in case of hydrostatic extrusion, brittle materials are extruded. High quality product will be produced by hydrostatic extrusion. In impact extrusion,

a heavy punch is allowed to fall over a soft material and due to impact load, metal will flow in the clearance b/w punch and cylinder. Collapsible tubes are made by this method.

Due to the metallurgical weakness at the centre, cracks appear in different fashion, called pipe, tail pipe or fish tailing.

Johnson Formula: $\sigma_d = \sigma_0 (a + b \ln R)$

σ_0 = nominal stress

a, b = Johnson's Constant

R = Extrusion Ratio = $\frac{A_{\text{initial}}}{A_{\text{final}}}$

(161)

Q18S-2003: Backward extrusion $a = 0.8$, $b = 1.5$

$K = 750 \text{ mPa}$, $n = 0.15$

$d_i = 40 \text{ mm}$, $d_f = 15 \text{ mm}$, $l_i = 100 \text{ mm}$

find (i) $R = ?$ (ii) $e = ?$ (iii) $\epsilon = ?$ (iv) $\text{load} = ?$

Sol. $\sigma_0 = \sigma_{\text{fm}} = \frac{K \epsilon^n}{n+1}$, $e = \frac{l_f - l_i}{l_i} = \frac{l_f}{l_i} - 1$

$$\frac{\pi d_i^2 l_i}{4} = \frac{\pi d_f^2 l_f}{4}$$

$$(40)^2 \times 100 = (15)^2 \times l_f$$

$$l_f = 711.11 \text{ mm}$$

$$e = \frac{711.11}{100} - 1$$

$$e = 6.11$$

$$\epsilon = \ln(e+1)$$

$$\epsilon = \ln(6.11+1) = \ln(7.11)$$

$$\epsilon = 1.9616$$

$$\sigma_0 = \frac{750 \times (1.9616)^{0.15}}{0.15+1}$$

$$\sigma_0 = 721.53 \text{ mPa}$$

$$\sigma_d = \sigma_0 (a + b \ln R)$$

$$= 721.53 (0.8 + 1.5 \ln \frac{(40)^2}{(15)^2}) = 787.53$$

$$(2700.30 \text{ mPa})$$

$$\therefore \text{load} = \sigma_d \times \frac{\pi (d_i^2 - d_f^2)}{4}$$

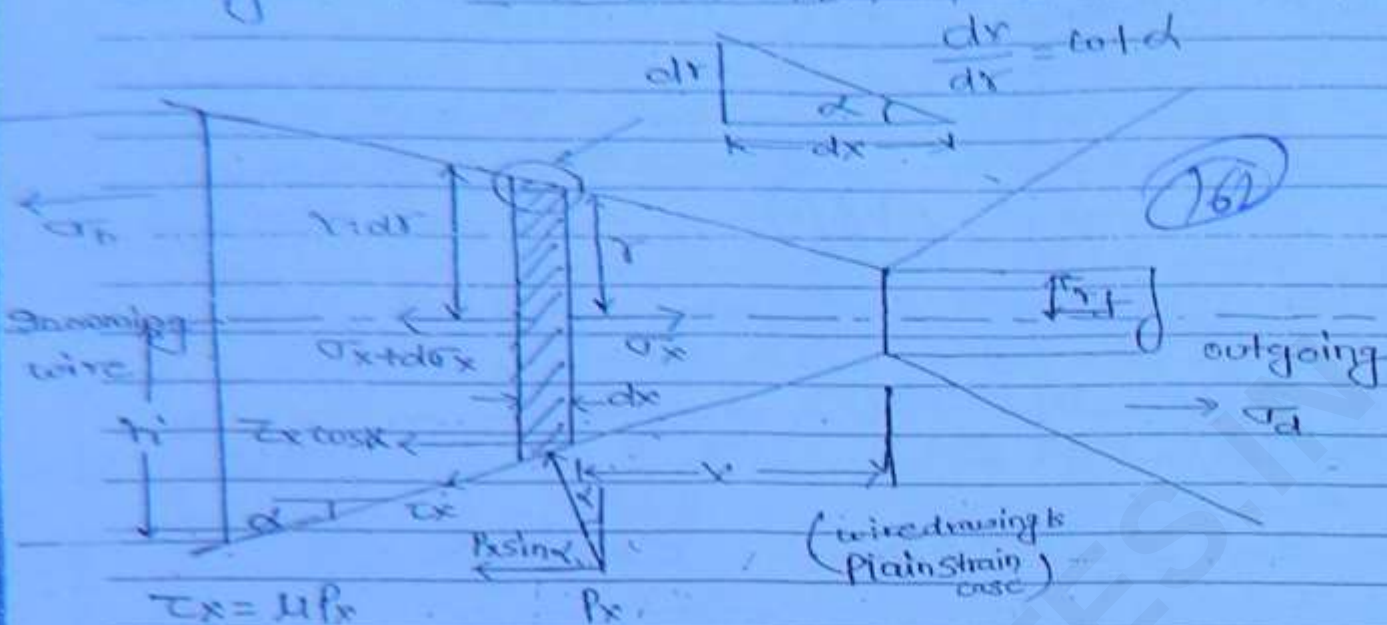
$$= 787.533 \times \frac{\pi [(40)^2 - (15)^2]}{4}$$

$$(9.91 \text{ MN})$$

$$= 2700.3 \times \frac{\pi}{4} \times [(40)^2 - (15)^2]$$

$$= 9.91 \text{ MN}$$

Analysis: Slab method:



$$(\sigma_x + d\sigma_x) \pi (r + dr)^2 - \sigma_x \pi r^2 + \tau_x \cos \alpha \cdot (2\pi r dr \cos \alpha) + p_x \sin \alpha (2\pi r \cdot dx \cos \alpha) = 0$$

after

~~expanding~~ + expanding and neglecting the higher order term and dividing by $r^2 dr$ we get

$$\frac{d\sigma_x}{dr} + \frac{2\sigma_x}{r} + \frac{2\tau_x}{r} \frac{dx}{dr} + \frac{2p_x}{r} \tan \alpha \cdot \frac{dx}{dr} = 0$$

$$\tau_x = \mu p_x$$

$$\frac{d\sigma_x}{dr} + \frac{2\sigma_x}{r} + \frac{2\mu p_x \cdot \cot \alpha}{r} + \frac{2p_x}{r} = 0$$

$$\text{let } [\mu \cot \alpha = \beta] \text{ (constant)}$$

$$\frac{d\sigma_x}{dr} + \frac{2\sigma_x}{r} + \frac{2\beta p_x}{r} + \frac{2p_x}{r} = 0$$

Assuming that σ_x and p_x are the principal stresses

$$\sigma_1 - \sigma_2 = 2k'$$

$$\therefore \sigma_x + p_x = 2k'$$

(p_x is compressive)

$$\frac{d\sigma_x}{dr} + \frac{2(\bar{\sigma}_r')}{r} + \frac{2B(\bar{\sigma}_r' - \sigma_x)}{r} = 0 \quad \text{--- (1)}$$

$$\frac{d\sigma_x}{dr} = -\frac{2}{r} [\bar{\sigma}_r' + B(\bar{\sigma}_r' - \sigma_x)]$$

$$\int \frac{d\sigma_x}{[\bar{\sigma}_r' + B(\bar{\sigma}_r' - \sigma_x)]} = \int -\frac{2}{r} dr \quad (163)$$

$$-\frac{1}{B} \ln [\bar{\sigma}_r' + B(\bar{\sigma}_r' - \sigma_x)] = -2 \ln r + C_1$$

$$\frac{1}{B} \ln [\bar{\sigma}_r' + B(\bar{\sigma}_r' - \sigma_x)] = 2 \ln r + C_2$$

$$\ln [\bar{\sigma}_r' + B(\bar{\sigma}_r' - \sigma_x)] = 2B \ln r + C_2$$

Boundary condition at $r = r_i$, $\sigma_x = \sigma_b$.

$$\ln [\bar{\sigma}_r' + B(\bar{\sigma}_r' - \sigma_b)] = 2B \ln r_i + C_2$$

$$\ln [\bar{\sigma}_r' + B(\bar{\sigma}_r' - \sigma_b)] - 2B \ln r_i = C_2$$

$$C_2 = \ln \left[\frac{\bar{\sigma}_r' + B(\bar{\sigma}_r' - \sigma_b)}{(r_i)^{2B}} \right]$$

$$\therefore \ln [\bar{\sigma}_r' + B(\bar{\sigma}_r' - \sigma_x)] - 2B \ln r$$

$$= \ln \left[\frac{\bar{\sigma}_r' + B(\bar{\sigma}_r' - \sigma_b)}{(r_i)^{2B}} \right]$$

$$\Rightarrow \ln \left[\frac{\bar{\sigma}_r' + B(\bar{\sigma}_r' - \sigma_x)}{(r)^{2B}} \right] = \ln \left[\frac{\bar{\sigma}_r' + B(\bar{\sigma}_r' - \sigma_b)}{(r_i)^{2B}} \right]$$

$$\frac{\bar{\sigma}_r' + B(\bar{\sigma}_r' - \sigma_x)}{\bar{\sigma}_r' + B(\bar{\sigma}_r' - \sigma_b)} = \left(\frac{r}{r_i} \right)^{2B}$$

$$\text{at } r = r_f, \sigma_x = \sigma_d$$

$$\sigma_d = \bar{\sigma}_r' \left(\frac{1+B}{B} \right) \left[1 - \left(\frac{r_f}{r_i} \right)^{2B} \right] + \sigma_b \left(\frac{r_f}{r_i} \right)^{2B}$$

and $\sigma_r = 0$

let $\mu = 0$, and case is plane stress although drawing is plane strain case.

Plane Stress	$k' = \frac{\sigma_0}{2}$	$\sigma_1 - \sigma_2 = 2k'$	$\sigma_1 - \sigma_2 = \sigma_0$
Plane strain	$k' = \frac{\sigma_0}{\sqrt{3}}$	$\sigma_1 - \sigma_2 = 1.15(\sigma_0)$	

Put them into eqn (1)

we get $\frac{d\sigma_r}{dr} + \frac{2(2k')}{r} = 0$

$$\int d\sigma_r = \int -\frac{2 \cdot (2k')}{r} \cdot dr$$

Boundary condition at $r=r_i$, $\sigma_r = 0$
at $r=r_f$, $\sigma_r = \sigma_d$

$$\sigma_d = (2k') \ln \left[\frac{r_i^2}{r_f^2} \right]$$

or $\sigma_d = (2k') \ln \left[\frac{\pi r_i^2}{\pi r_f^2} \right]$

$$k' = \frac{\sigma_0}{2} \text{ (Plane stress)}$$

$$\sigma_d = \sigma_0 \ln \left[\frac{A_i}{A_f} \right]$$

for maximum reduction.

$$\sigma_d = \sigma_0$$

$$1 = \ln \left[\frac{A_i}{A_f} \right]$$

$$\therefore \frac{A_i}{A_f} = e$$

$$\therefore \text{reduction in area} = \frac{A_i - A_f}{A_i} \times 100$$

$$= \left(1 - \frac{A_f}{A_i} \right) \times 100$$

$$= \left(1 - \frac{1}{e} \right) \times 100 = 63\%$$

Q: A rod of ~~6.25~~ 6.25 mm in dia is drawn into wire of 5.6 mm diameter. The semi die angle is 10.1° . Coefficient of friction is $\mu = 0.04$, nominal stress is 35 mpa, Calculate the drawing stress and max. reduction that can be given to the material in this situation. (165)

Sol:

$$B = \mu \cot \alpha = 0.04 \cot 10.1 = 0.2245$$

$$\sigma_d = \frac{2K'}{\sqrt{3}} \left(\frac{1+B}{B} \right) \left[1 - \left(\frac{r_f}{r_i} \right)^{2B} \right] + \sigma_b \left(\frac{r_f}{r_i} \right)^{2B}$$

Plain strain case

$$\sigma_d = \frac{2\sigma_0}{\sqrt{3}} \left(\frac{1+B}{B} \right) \left[1 - \left(\frac{r_f}{r_i} \right)^{2B} \right]$$

$$\sigma_b = 0 \text{ (Not given)}$$

$$\sigma_d = \frac{2 \times 35}{\sqrt{3}} \left[\frac{1+0.2245}{0.2245} \right] \left[1 - \left(\frac{2.8}{3.125} \right)^{2 \times 0.2245} \right]$$

$$\sigma_d = 10.605 \text{ mpa}$$

$$\sigma_d = \frac{2\sigma_0}{\sqrt{3}} \left(\frac{1+B}{B} \right) \left[1 - \left(\frac{r_f}{r_i} \right)^{2B} \right]$$

for max reduction $\sigma_d = \sigma_n$

$$1 = \frac{2}{\sqrt{3}} \left(\frac{1+0.2245}{0.2245} \right) \left[1 - \left(\frac{r_f}{3.125} \right)^{2 \times 0.2245} \right]$$

$$r_f = 2.1262 \text{ mm}$$

$$\% \text{ reduction} = \frac{A_i - A_f}{A_i} \times 100$$

$$= \frac{\frac{\pi}{4} (6.25)^2 - \frac{\pi}{4} (4.25)^2}{\frac{\pi}{4} (6.25)^2} \times 100$$

$$= 0.5371 \times 100$$

$$= 53.71\% \text{ reduction}$$

Q. Determine the drawing stress to produce 20% reduction in diameter of 10 mm of stainless steel. The flow curve equation of steel is $\sigma_f = 1300 \epsilon^{0.3}$. Consider the die angle to be 12° and coefficient of friction 0.09.

sol:

$$d_i = 10 \text{ mm} \quad d_f = 8 \text{ mm} \quad \sigma_f = 1300 \epsilon^{0.3}$$

$$2\alpha = 12^\circ \Rightarrow \alpha = 6^\circ \quad \mu = 0.09$$

$$\sigma_0 = \sigma_{fm} = \frac{k \epsilon^n}{n+1}$$

(166)

$$\epsilon = \ln \cdot \frac{l_f}{l_i} = \frac{\pi d_i^2 l_i}{4} = \frac{\pi d_f^2 l_f}{4}$$

$$\epsilon = \ln \left[\frac{d_i^2}{d_f^2} \right] = \ln \left(\frac{10}{8} \right)^2$$

$$\epsilon = 0.44628$$

$$\sigma_0 = \frac{1300 \times (0.44628)^{0.3}}{1+0.3}$$

$$= 785.022 \text{ MPa}$$

Plain strain case: $\rightarrow$

$$\sigma_d = \frac{2}{\sqrt{3}} \sigma_0 \left(\frac{1+B}{B} \right) \left[1 - \left(\frac{r_f}{r_i} \right)^{2B} \right]$$

comp

$$B = \mu \cot \alpha = 0.09 \times 10 + 6 = 0.856$$

$$\sigma_d = \frac{2}{\sqrt{3}} \times 785.022 \left(\frac{1+0.856}{0.856} \right) \left[1 - \left(\frac{4}{5} \right)^{1.7125} \right]$$

$$\sigma_d = 624.23 \text{ MPa} \quad \underline{\underline{A_5}}$$

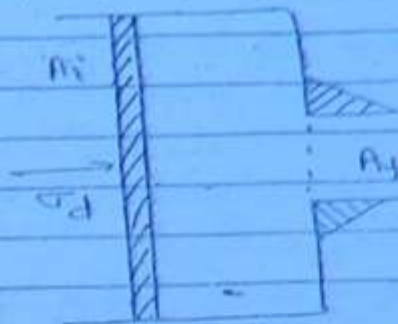
Extrusion:

$$\sigma_d = 2K' \left(\frac{1+\beta}{\beta} \right) \left[\left(\frac{y_i}{y_f} \right)^{2\beta} - 1 \right]$$

$$\sigma_d = 2K' \left(\frac{1+\beta}{\beta} \right) \left[\left(\frac{A_i}{A_f} \right)^{\beta} - 1 \right]$$

$$\sigma_d = 2K' \left(\frac{1+\beta}{\beta} \right) (R^{\beta} - 1)$$

R = Extrusion Ratio.



167

Q: An alloy is extruded from 150 mm dia to 50 mm dia by a forward extrusion process. If Billet is 380 mm long, mean flow pressure is 250 MPa, semicircle angle 60° and coefficient of friction is 0.1. Determine the extrusion load.

Sol: $\sigma_d = 2K' \left(\frac{1+\beta}{\beta} \right) \left[\left(\frac{A_i}{A_f} \right)^{\beta} - 1 \right]$

$$K' = \frac{\sigma_0}{\sqrt{3}}$$

$$\sigma_d = \frac{2 \times \sigma_0}{\sqrt{3}} \left(\frac{1 + \frac{1}{\sqrt{3}}}{\frac{1}{\sqrt{3}}} \right) \left[(9)^{0.0573} - 1 \right]$$

$$= \frac{2 \times 250}{\sqrt{3}} \left(\frac{1 + 0.0573}{0.0573} \right) \left[9^{0.0573} - 1 \right]$$

$$\sigma_d = 715 \text{ MPa}$$

$$P_t = 4K'L$$

$$K' = \frac{\sigma_0}{\sqrt{3}}$$

$$P_t = \frac{4 \times \sigma_0 \times L}{\sqrt{3}}$$

$$P_t = \frac{4 \times 250 \times 380}{150 \times \sqrt{3}} = 1462.62 \text{ MPa}$$

$$P_t = 1462 \text{ MPa}$$

$$\text{Punch Pressure } P_r = (\sigma_d + P_t) = 715 + 1462 = 2177 \text{ MPa}$$

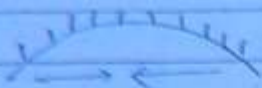
$$\text{load} = P_r \times \frac{\pi}{4} \times d_i^2$$

$$= \frac{2177 \times \pi \times (150)^2}{4}$$

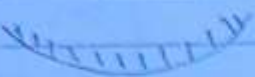
$$= 38.47 \text{ MN}$$

(optimal)

FORGING

Edging 

Edging is performed by concave pair of dies and upon forging metal moves towards the centre. This increases the size of work/stock.

Fullering 

Fullering is performed by convex pair of dies, in which materials moves away from the centre and this decreases the size of stock.

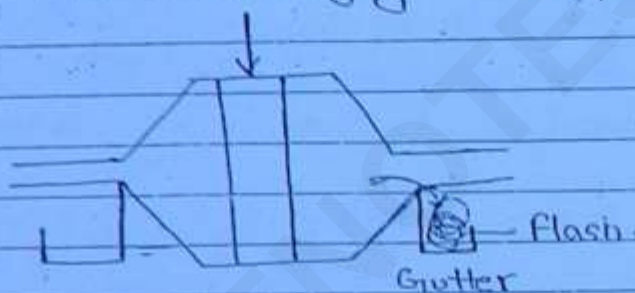
Forging

168

open die forging

closed die forging

Impression die forging

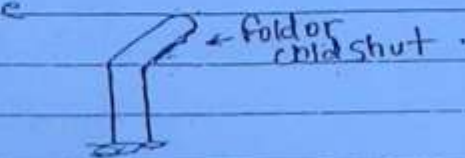
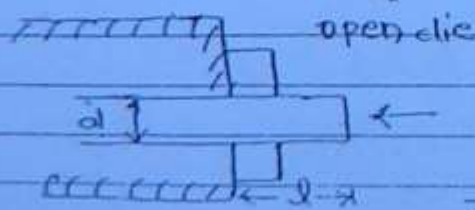


In open die forging work is kept in a die and hammer comes in contact with the material. This produces improper finish and after forging operation top surface of the work material has to be machined.

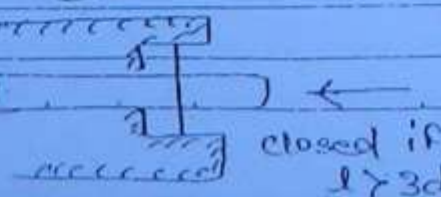
In closed die forging operation work is kept b/w top and bottom dies and hammer comes in contact with top die. Gutters are connected with the bottom die and extra material during the forging operation settles down in these Gutters. This Flash has to be removed by Abrasive jet machining.

In impression die forging a calculated amount of material is kept b/w the dies. No Gutters are required in lower die and in the process not only there is a proper material utilization but also good finish is being produced.

Upsetting:



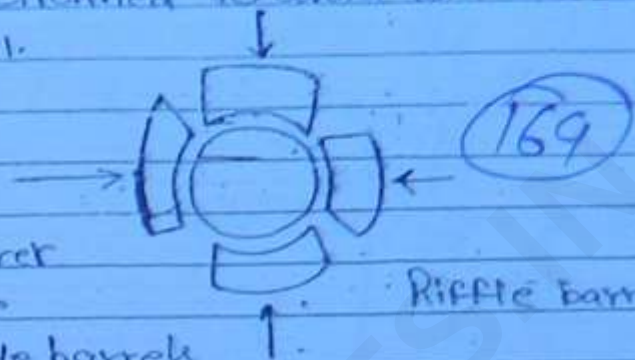
(april 2014)



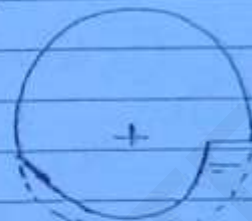
upsetting is forging a portion of work and the process is used to make bolt heads if overhanging length is more than $3d$ or when the hexagonal head has to be ~~made~~ made closed die upsetting is performed to avoid fold and cold shut in the work material.

Swaging:

work is held b/w dies and repeated impacts over the die metal flows in the longitudinal direction. Riffle barrels are being produce by this method. by flowing the material over a tapered mandrel.



Roll Forging:



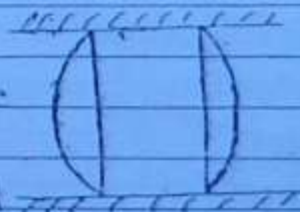
Also made by investment casting. Railway wheels are made by roll forging operation. 3 rolls are placed in a horizontal plane 120° apart. When sudden change in

radius comes in contact with the work metal will flow in the die cavities.

Forging defect:

Barreling

This defect appears in the hot forging. The contact surface b/w the work and

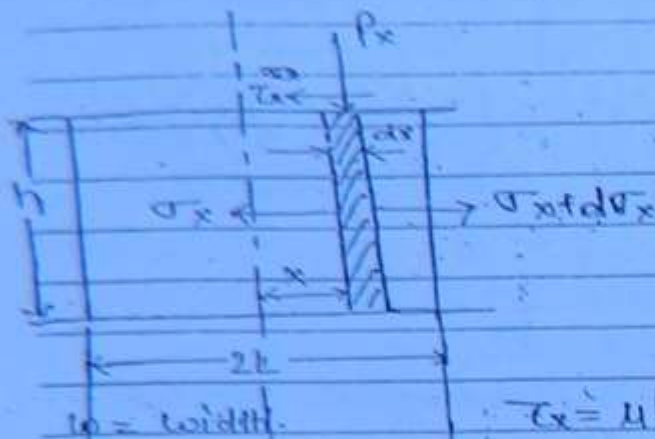


the dies will exhibit higher flow stresses due to lower temp. But at the centre material flow will be more due to lower flow stresses. This produces barreling.

Analysis: forging b/w Rectangular flat die.

Slab method:

170



$$(\sigma_x + d\sigma_x)wh - \sigma_x wh - 2\tau_x w \cdot dx = 0$$

$$\sigma_x wh + d\sigma_x wh - \sigma_x wh - 2\tau_x w dx = 0$$

$$d\sigma_x wh = 2\tau_x w dx$$

$$d\sigma_x = \frac{2\tau_x}{h} dx$$

$$\tau_x = \mu P_x$$

Assuming that σ_x and P_x are the principal stresses

$$\sigma_x + P_x = 2k' \quad \text{--- (1)}$$

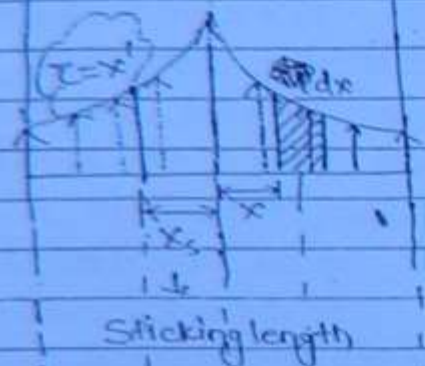
(P_x is compressive)

diff. (1)

$$d\sigma_x + dP_x = 0$$

$$\therefore -dP_x = \frac{2\mu P_x}{h} dx \quad \text{--- (A)}$$

$$\int \frac{dP_x}{P_x} = \int -\frac{2\mu}{h} dx$$



Sticking length

$$\ln P_x = -\frac{2\mu x}{h} + C$$



linear (upto sticking)
exponential (slipping)

$$x=L, \sigma_x=0, \therefore P_x = 2k'$$

$$\ln \log 2k' = -\frac{2\mu L}{h} + C$$

$$C = \ln \log 2k' + \frac{2\mu L}{h}$$

$$P_x = 2k' e^{\frac{2\mu(L-x)}{h}} \quad \text{--- (2)}$$

No sticking take place

$$\text{load} = 2 \left[\int_0^L P_x \cdot w dx \right]$$

$$\text{Avg. die pressure} = \frac{\text{load}}{2L \times w}$$

(ajitmittal)

For sticking $\tau = k' = \mu P_x$
at $x = x_s$, $\mu P_x = k'$
 $P_x = \frac{k'}{\mu}$

(171)

Putting above values on equation (2)

$$\frac{k'}{\mu} = \frac{2k'}{h} \cdot e^{\frac{2\mu}{h}(L-x_s)}$$

$$1 = e^{\frac{2\mu}{h}(L-x_s)}$$

Coefficient of friction is property of two mating parts and temp.
as temp $\uparrow$ $\mu \uparrow$

$$x_s = L - \frac{h}{2\mu} \ln\left(\frac{1}{2\mu}\right)$$

Sticking

$$\tau = k'$$

$$\int dP_x = - \int \frac{2k'}{h} dx \quad \text{From A.}$$

$$P_x = - \frac{2k'}{h} x + C_2$$

Boundary condition at $x = x_s$ $P_x = \frac{k'}{\mu}$

$$P_{x_2} = \frac{k'}{\mu} + \frac{2k'}{h}(x_s - x)$$

$$\text{Load} = 2 \left[\int_0^{x_s} P_{x_2} w dx + \int_{x_s}^L P_{x_1} w dx \right]$$

All the forging calculations are done on the final dimension.
The dimension which does not change is width.

Q. IEs: 5(c): 2005:

$$24 \times 24 \times 150 \text{ mm}^3$$

$$6 \times 6 \times 150 \text{ mm}^3$$

$$\mu = 0.05 \quad \sigma_0 = 7 \text{ mPa}$$

$$h = 6 \text{ mm}$$

$$2L = 96 \text{ mm} \Rightarrow L = 48 \text{ mm}$$

$$w = 150 \text{ mm}$$

$$x_s = 48 - \frac{6}{2 \times 0.05} \ln\left(\frac{1}{2 \times 0.05}\right) = -ve \therefore \text{No sliding}$$

(optimal) No slip.

$$\text{Load} = 2 \int_0^{48} (2k') e^{\frac{24}{H} (48-x)} w \cdot dx$$

$$k' = \frac{\sigma_0}{\sqrt{3}} \quad \text{Plain strain case}$$

(172)

$$= 2 \int_0^{48} \frac{2 \times \sigma_0}{\sqrt{3}} e^{\frac{2 \times 0.05}{6} (48-x)} \times 150 \, dx$$

$$= 2 \int_0^{48} \frac{2 \times 7}{\sqrt{3}} e^{\frac{2 \times 0.05}{6} (48-x)} \times 150 \, dx$$

$$= 2424.87 \int_0^{48} e^{(0.0166)(48-x)} \, dx$$

$$= 2424.87 \int_0^{48} (e^{0.8 - 0.0166x}) \, dx$$

$$= 2424.87 \left[\int_0^{48} e^{0.8} e^{-0.0166x} \, dx \right]$$

$$= 2424.87 \int_0^{48} \frac{e^{0.8}}{e^{0.0166x}} \, dx$$

$$= 2424.87 \times e^{0.8} \int_0^{48} \frac{1}{e^{0.0166x}} \, dx$$

$$= 2424.87 \times e^{0.8} \left[-\frac{1}{0.0166} e^{-0.0166x} \right]_0^{48}$$

$$= 2424.87 \times e^{0.8} \left[\frac{-0.0166}{e^{0.0166x}} \right]_0^{48}$$

$$= 2424.87 \times e^{0.8} \left[\frac{-0.0166}{e^{0.0166 \times 48}} + \frac{0.0166}{e^0} \right]$$

$$= 396.64 \left[0.0166 - 0.0166 e^{-0.8} \right]$$

$$= 0.17 \, \text{MN}$$

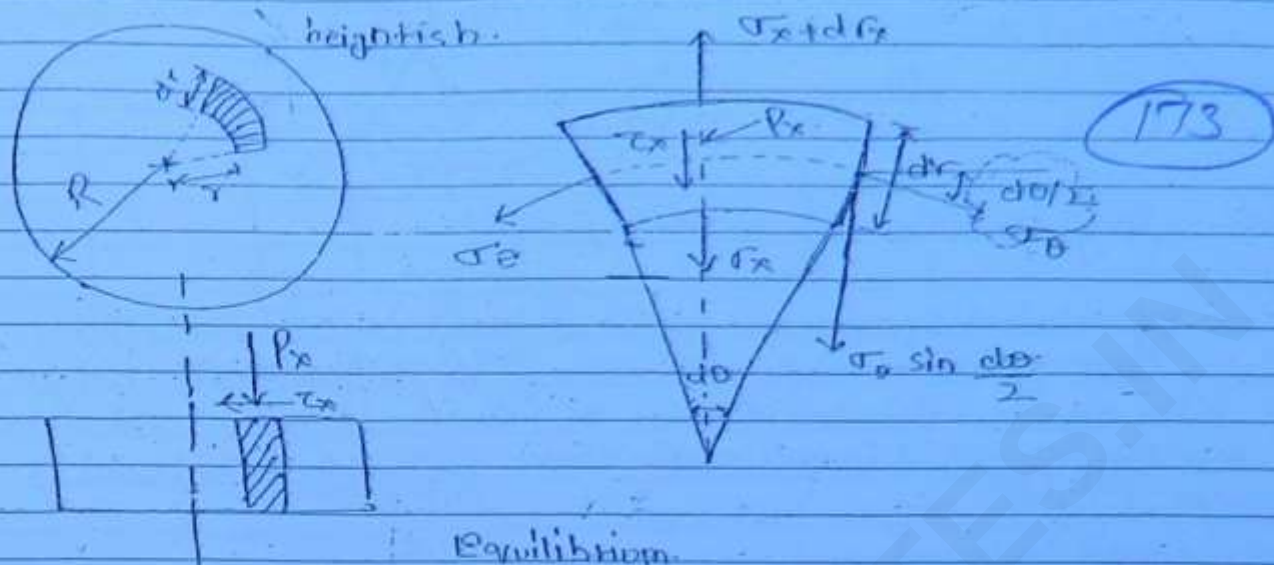
Second case $\mu = 0.25$

$$x_s = 39.6 \, \text{mm}$$

$$\text{Load} = 2 \left[\int_0^{39.6} \frac{k'}{\mu} + \frac{2k'}{H} (39.6-x) \right] w \, dx + \int_{39.6}^{48} \frac{2k'}{H} e^{\frac{24}{H} (48-x)} w \, dx$$

$$= 0.539 \, \text{MN}$$

② Forging in the circular Billet: (Plane stress case)



$$(\sigma_r + d\sigma_r) (r + dr) d\theta h - \sigma_r \cdot r d\theta h - 2 \tau_x r d\theta \cdot dr$$

$$- 2 \sigma_\theta \sin \frac{d\theta}{2} \cdot dr \cdot h = 0$$

$$\left(\sin \frac{d\theta}{2} = \frac{d\theta}{2} \right)$$

After solving and neglecting higher order term, by dividing by $(h r dr)$

$$\frac{d\sigma_r}{dr} + \frac{\sigma_r - \sigma_\theta}{r} - \frac{2\tau_x}{h} = 0$$

ϵ_θ = circumferential strain

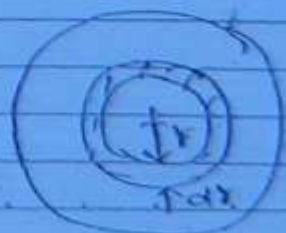
$$= \frac{(r + dr) d\theta - r d\theta}{r d\theta} = \frac{dr}{r} = \epsilon_r \quad (\text{radial strain})$$

$$\therefore \sigma_\theta = \sigma_r$$

$$\therefore \frac{d\sigma_r}{dr} = \frac{2\tau_x}{h}$$

$$P_r = 2kl e^{\frac{2\mu}{h}(R-r)}$$

$$P_r = \frac{kl}{h} + \frac{2kl}{h} (R - r) \quad (\text{applied})$$



$$R_s = R \cdot \frac{h}{2H} \ln\left(\frac{V_i}{V_f}\right)$$

$$\text{load} = \int_0^R P_r (2\pi r) dr$$

(174)

$$\text{Avg. die pressure} = \text{load} / \pi r^2$$

Q. A cylindrical specimen made of steel is 150 mm in dia and 100 mm high. It is forced to a flat height of 50 mm if coefficient of friction is 0.2. Calculate the forging load if the flow curve eqn of the material is

$$\sigma_f = 1030 \epsilon^{0.17}$$

Sol. for wire drawing/extrusion $\epsilon = \ln\left(\frac{l_f}{l_i}\right)$

for forging $\epsilon = \ln\left(\frac{h_i}{h_f}\right)$

$$\epsilon = \ln\left(\frac{100}{50}\right) = 0.6931$$

$$\sigma_f = \sigma_0 = \frac{1030 \epsilon^{0.17}}{1.17} = \frac{1030 \times (0.6931)^{0.17}}{1.17} = 827.15 \text{ MPa}$$

$$\frac{\pi}{4} D_i^2 h_i = \frac{\pi}{4} D_f^2 h_f$$

$$D_f = 212 \text{ mm}$$

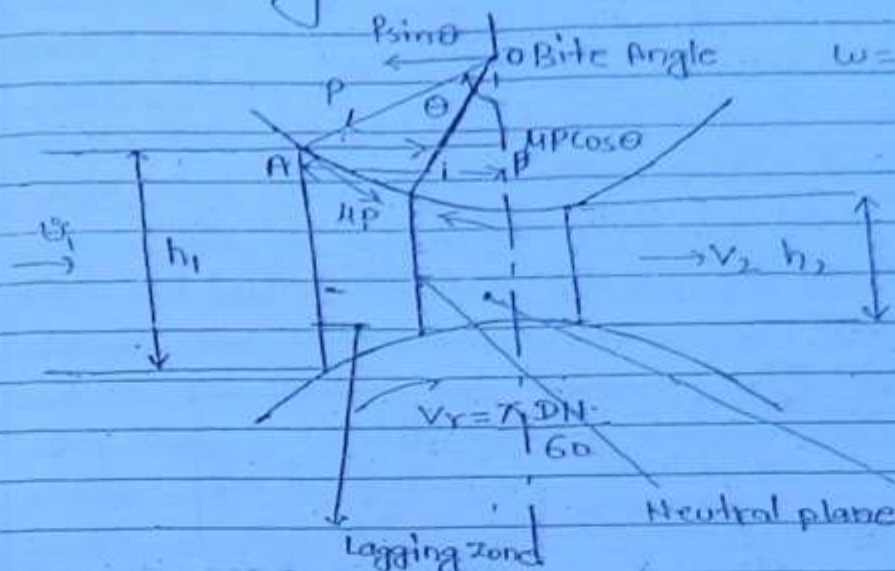
$$R = \frac{D_f}{2} = 106 \text{ mm}$$

$$\text{load} = \int_0^{106} \sigma_0 e^{\frac{2\mu}{h} (106-r)} \cdot 2\pi r \cdot dr = 39.6 \text{ MN}$$

(Plain stress case)

Rolling

Date



$w = \text{width of plate}$

(175)

Leading zone

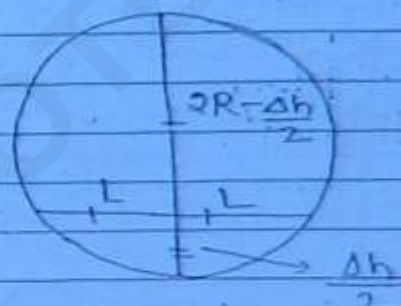
Forward slip
 $= \frac{V_2 - V_r}{V_r} \times 100$

Backward slip
 $= \frac{V_r - V_1}{V_r} \times 100$

Roll separating force

$$= \frac{\text{Self entry}}{M \cos \theta} \geq P \sin \theta$$

$$\boxed{\tan \theta \leq \mu}$$



$$\Delta h = h_1 - h_2$$

$$L^2 = \left(2R - \frac{\Delta h}{2}\right) \left(\frac{\Delta h}{2}\right)$$

$$\boxed{L = \sqrt{R \Delta h}}$$

Approximate Rolling load

$$F = \sigma_0 (Lw)$$

$$\text{Power} = F \times V_r$$

in ΔOAB

$$\tan \theta = \frac{AB}{OB} = \frac{L}{R - \frac{\Delta h}{2}}$$

$L = \text{Roll strip constant}$
 Contact length

$$\mu = \frac{\sqrt{R \Delta h}}{R}$$

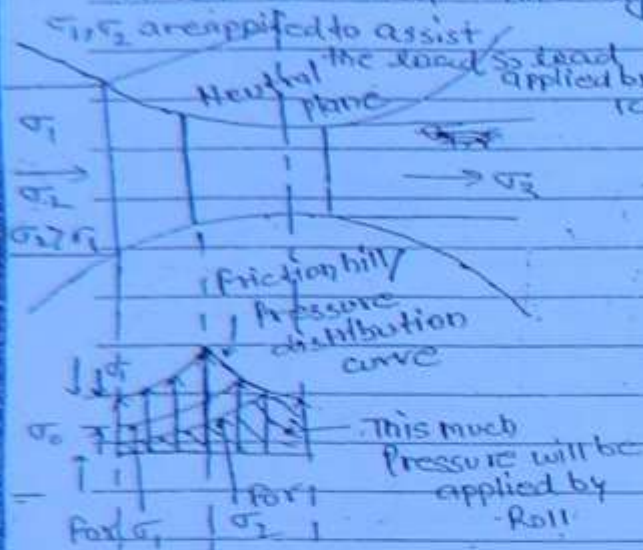
$$\equiv \frac{\Delta h}{R}$$

$$\boxed{\Delta h = \mu^2 R}$$

Rolling is a process of decreasing the cross section area of incoming plate. There exist a plane in the deformation zone where the roll velocity is equal to the velocity of material called Neutral plane. Before this neutral plane, Backward slip exists in the material.

(optimal)

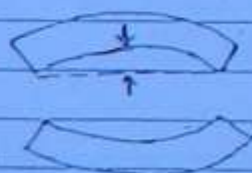
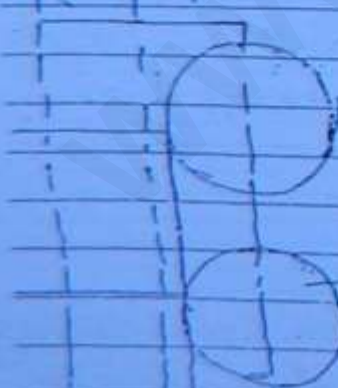
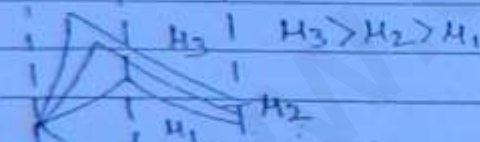
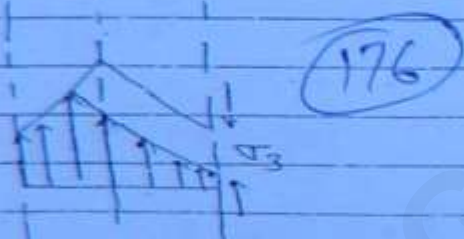
Since material is moving in the backward direction relative to Roll friction will be acting in the forward direction. Beyond neutral plane material velocity will be larger than the roll velocity so the friction will be acting in the backward direction. P is the load applied by the roll to deform the material and similar load will be applied by material to the rolls and this load will try to bend the rolls and it is called Roll Separating force. Angle made by the deformed material at the centre of roll is called Bite angle.



Rolling limit
 $\alpha_n = \text{Angle of nip}$
 $= 2\mu$

Beyond the condition of self entry reductions can be given to the material. By applying stress at the entry. But it can be seen from the friction hill that by increasing the stress at the entry, neutral plane shifts towards right the movement of neutral plane coincide over the vertical axis. Roll will slip over the material without any deformation. This is called Rolling limit and Bite angle at rolling limit is called angle of nip.

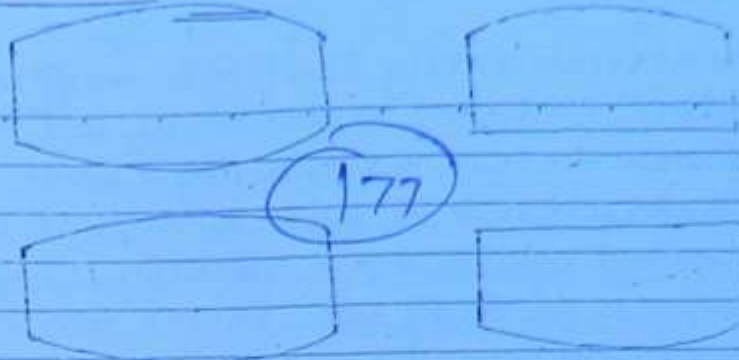
By increasing the coefficient of friction more reduction can be given to the material.



As it can be seen from the friction hill that smaller is the size of rolls less will be the power consumed in rolling operation. But Roll separating force is sufficient to bend the rolls. As a result of that cross section of the rolled material will not be uniform.

Friction decreasing

(optimal)

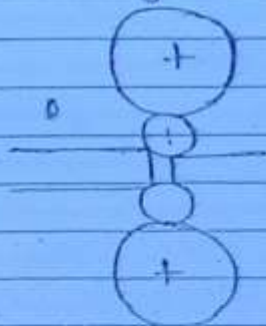


within the elastic limit.

material
Head Field Steel

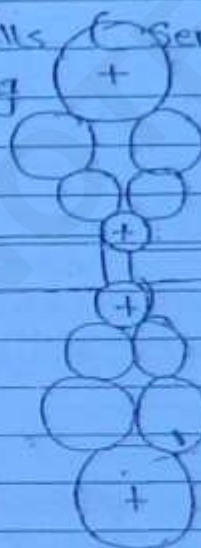
Corresponding to a particular Δh value camber is provided in the rolls and when the metal comes into contact with the roll, roll surface becomes exactly flat. Deformations of the camber rolls are within the elastic limit. The camber rolls are designed for mass production only because any change in material and Δh value different sets of camber will be used.

② 4-high Mills



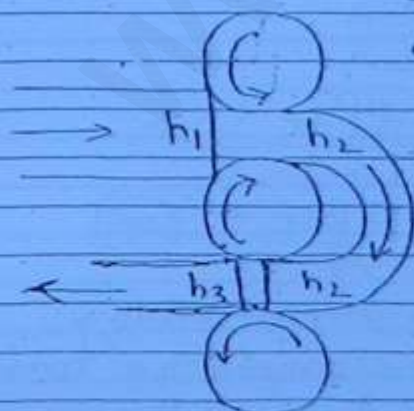
cluster mills (Sendzimer)

dia increasing
in outward
direction.



In 4 high mill power is given to the smaller roll and larger rolls are used for Backup. 4 high mills are not versatile because any change in Δh value since max roll separating force will appear at the Neutral plane Backup rolls may not be able to provide the support. In such cases cluster mills are used.

3-high mill



In 3-high mills all the rolls are same size and two stage reduction can be given by using 3 roll thus saving the cost of one roll.

$$h_1 > h_2 > h_3$$

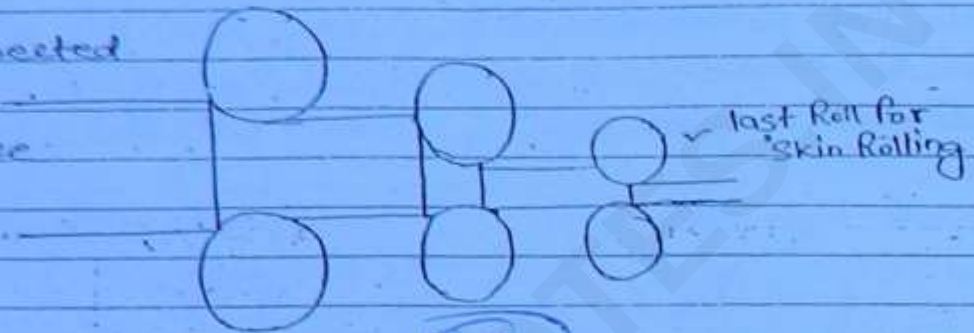
Planetary mill



Since there is a rolling limit for every material, this limit is increased in planetary mill by giving reduction to the material by a no. of pair of rolls. As a result of that a thick plate can be converted into a thick sheet in single stage. Power is given to the larger rolls and smaller rolls are connected on its periphery with individual axle.

Tandem Mill

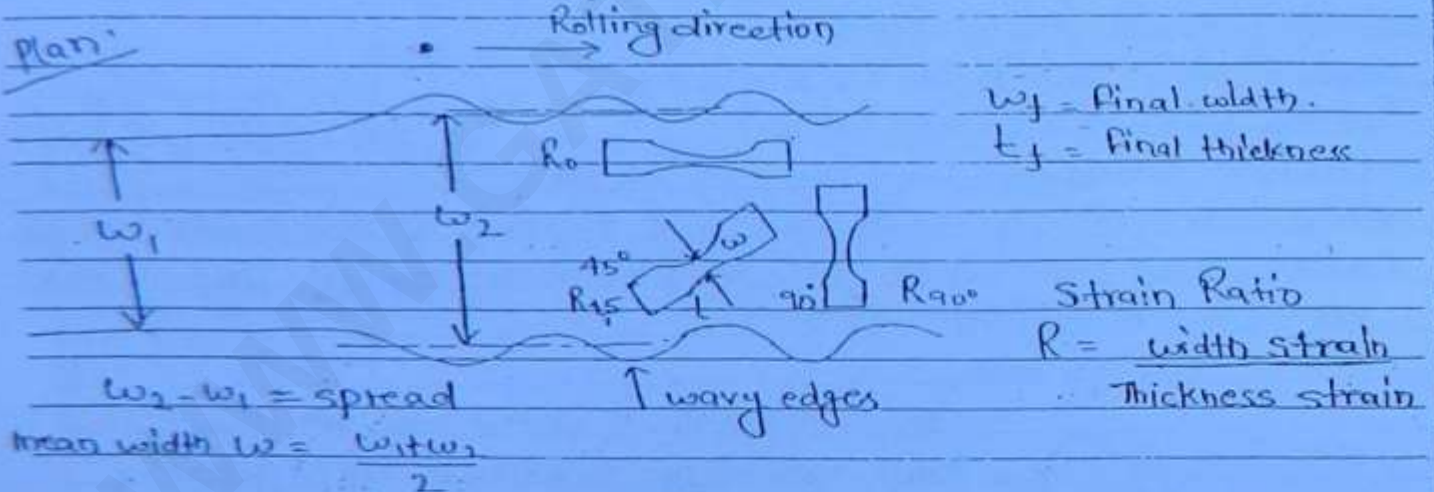
Pair of rolls are connected in series and the reduction takes place in stages.



178

Defects in Rollings

Due to metallurgical weakness centre line of the sheet may fracture after rolling operation called Crocodile crack.



Normal Anisotropy $\bar{R} = \frac{R_0 + 2R_{45} + R_{90}}{4}$

Planar Anisotropy $\Delta R = \frac{R_0 - 2R_{45} + R_{90}}{2}$

Wavy edges in the rolling and earing in deep drawing appears due to planar anisotropy and cannot be avoided because it is the property of material. Larger is the normal anisotropy, more will be the formability of material and larger reduction can be (optimal) given.

Gate 04:

Q: 32:

$$h_1 = 25 \text{ mm}$$

$$h_2 = 20 \text{ mm}$$

$$R = 300 \text{ mm}$$

$$M = 10 \text{ rpm}$$

$$l = \sqrt{R \Delta h} = \sqrt{300 \times (25 - 20)} \\ = \sqrt{300 \times 5} = 38.7 \text{ mm}$$

Gate: 06:

Q: 39:

$$h_1 = 4 \text{ mm}$$

$$R = 150 \text{ mm}$$

$$\mu = 0.1$$

$$h_2 = ?$$

$$\Delta h = \mu^2 R$$

$$h_1 - h_2 = (0.1)^2 \times 150$$

$$h_1 - h_2$$

$$h_2 = h_1 - (0.1)^2 \times 150 = 2.5$$

179

Gate: 07:

$$D_i = 200 \text{ mm}$$

$$(B1) \quad h_i = 60 \text{ mm}$$

$$D_f = 400 \text{ mm}$$

$$\varepsilon = \ln \left(\frac{h_i}{h_f} \right)$$

$$\frac{\pi D_i^2 h_i}{4} = \frac{\pi D_f^2 h_f}{4}$$

$$(200)^2 \times 60 = h_f (400)^2$$

$$\varepsilon = \ln \left(\frac{60}{15} \right) = 1.38$$

(B2)

$$h_1 = 16 \text{ mm}$$

$$h_2 = 10 \text{ mm}$$

$$R = 200 \text{ mm}$$

$$\theta =$$

$$\Delta h = \mu^2 R$$

$$6 = \mu^2 \times 200$$

$$\mu^2 = 0.1732$$

$$\theta = \tan^{-1} \mu = 9.826^\circ$$

Gate: 08: (Q3):

$$\ln E_{cm}$$

$$MRR =$$

chemical equivalent

$$\frac{eI}{F \rho}$$

$eI \leftarrow \text{current}$

$F \rho \leftarrow \text{density}$

$$96500$$

$$e = \frac{\text{At. wt.}}{\text{valency}}$$

$$\frac{1}{e} = \sum_{i=1}^n \frac{h_i \times \text{val.}}{\text{At. wt.}}$$

(Q3) $\rightarrow$

$$Fe$$

$$P$$

$$\rho = 6000 \text{ kg/m}^3$$

$$\text{At. wt. } 56$$

$$24$$

$$F = 96500$$

$$\text{val. } 2$$

$$4$$

$$MRR = 50 \text{ mm}^3/\text{s}$$

$$I = 2000 \text{ A}$$

$$2 \times P + (100 - x) \cdot Fe$$

(optimal)

$$\frac{1}{e} = \frac{x}{100} \times \frac{4}{24} + \frac{(100-x)}{100} \times \frac{2}{56}$$

$$50 \times 10^{-9} = e \times 2000$$

$$96500 \times 6000$$

Grade: 94%

$$h_1 = 20 \text{ mm}$$

$$w = 100 \text{ mm}$$

$$h_2 = 18 \text{ mm}$$

$$R = 250 \text{ mm}$$

$$N = 10 \text{ rpm}$$

$$\sigma_0 = 300 \text{ MPa}$$

$$P = ? = 175 \text{ kW}$$

$$P = \sigma_0 \times (L \times w)$$

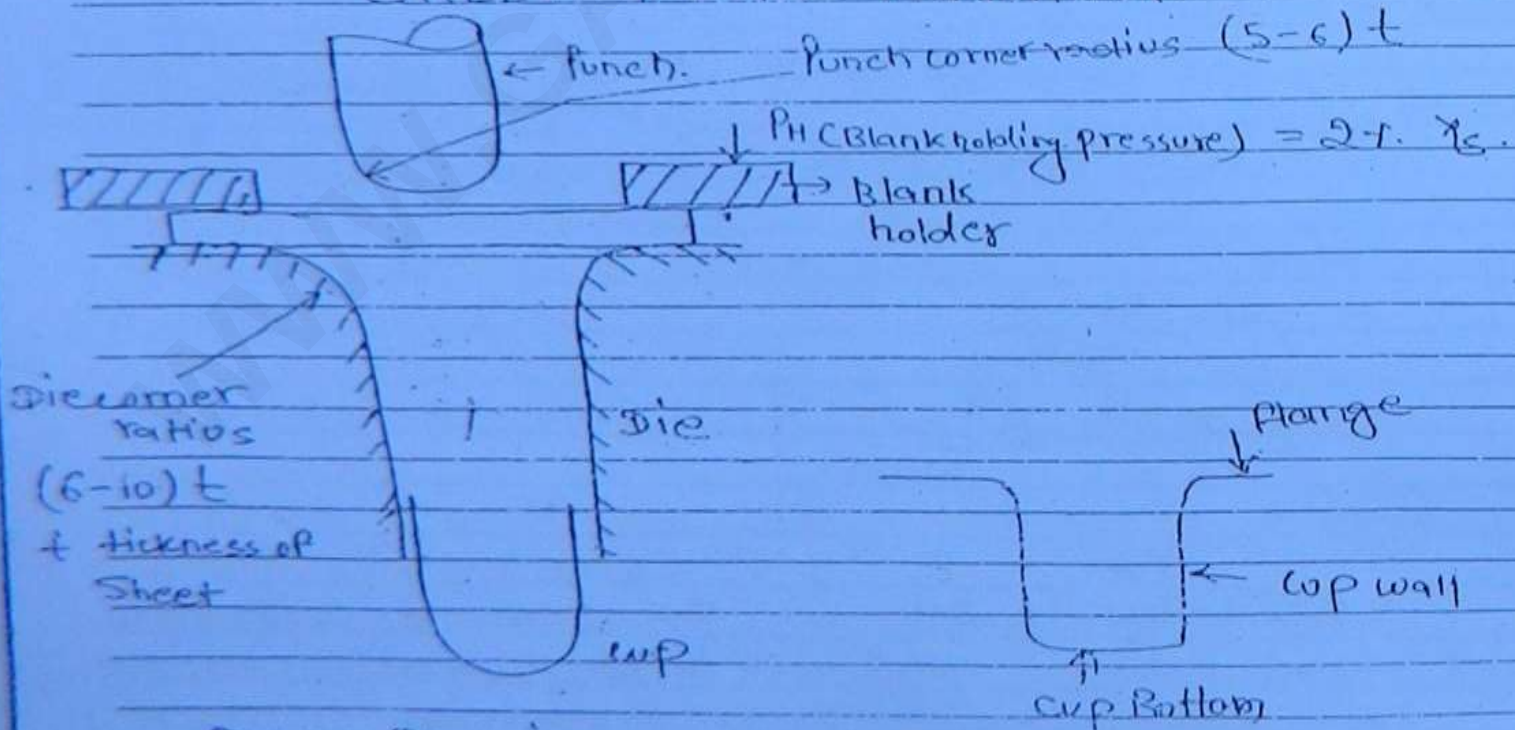
$$L = \sqrt{R \Delta h}$$

$$= \sqrt{250 \times 2} = \sqrt{500} = 22.3606 \text{ mm}$$

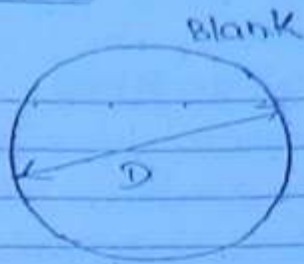
$$P = 300 \times 22.3606 \times 100$$

180

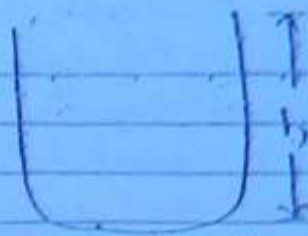
SHEET METAL FORMING



Deep Drawing



Blank



No.

92

Date

Sheet thickness

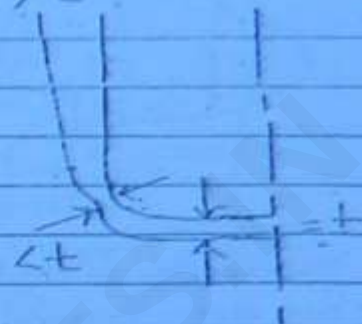
Radius of Punch



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

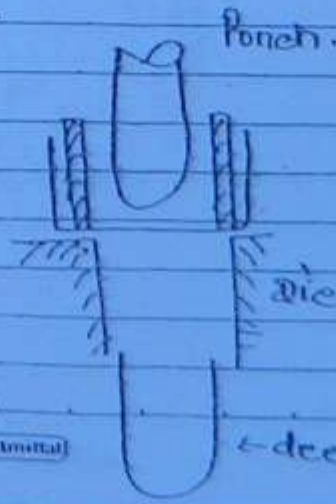
$$\frac{D}{d} = \text{Draw Ratio}$$

$$\frac{D_{\max}}{d} = \text{limiting draw Ratio}$$



When a circular blank is converted into a cup shaped component by applying pressure of punch called deep drawing operation. Circumferential compressive and radial tensile stresses appears in the flange region. Uniaxial tension appears in the wall region. Due to compressive hoop stresses thickness of sheet in the wall increases and since max load appears at the cup bottom Necking appears in the material. By increasing the size of Blank larger will be the punch load and more will be the extent of necking at the cup bottom. Once the thickness in the neck region reaches at a particular value fracture appears in the cup. Max dia of Blank that can be drawn safely in the deep drawing operation without any fracture is called limiting draw ratio (LDR) which is the property of material. LDR for Aluminium is around 1.8 to 1.9 and for steel it is around 2.2.

$$\text{Drawing Ratio} = \frac{D}{d}$$



Punch.

Die

Redrawing

(optimal)

deeper cup.

Wrinkles appear due to improper blank holding force and can be eliminated by increasing the blank holding pressure.

No.

Date

Buckers appears in case of hemispherical punch.

Redrawing is a process of drawing already drawn cup. And the process is used to achieve higher draw ratios. When the redrawing process is performed near LDR step rings will appear. To avoid this the draw ratio b/w stages should decrease.

Ironing



Thickness of the drawn cup can be made uniform by decreasing the clearance b/w punch and die.

The process is called Ironing. In this process

Plastic deformation of material takes place over the walls and when it is excessive the defect called burrishing will appear.

Draw marks appear due to improper finish of the die.

Orange peel defects appears where excessive deformation of material takes place i.e. punch corner region due to coarse grain structure of work material. Remedy: have a fine grain structure.

Heavy scratches over the wall appears due to appearance of yield point phenomena.

Fracture in the drawn cup appears when either draw ratio exceeds LDR or when blank holding force is high.

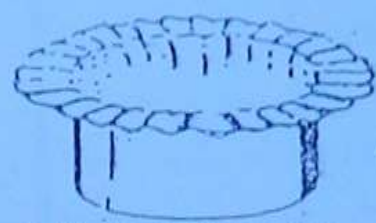
11, 12, 14: earing appears due to anisotropy value ΔR .

Due to non symmetric placement of work over the die miss-strike appears.

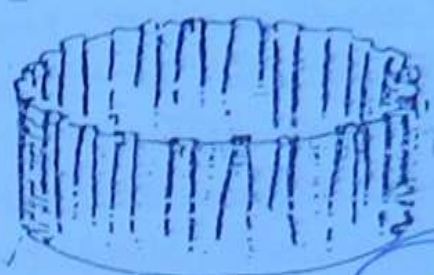
182

DEFECTS IN DEEP DRAWING

Defects in Deep Drawing



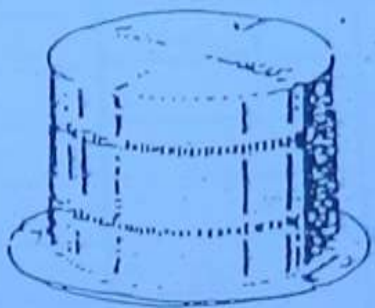
1. FLANGE WRINGES



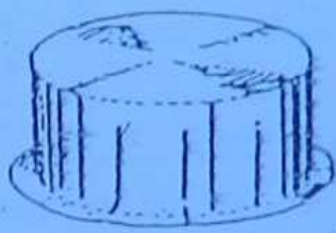
2. WALL WRINKLES



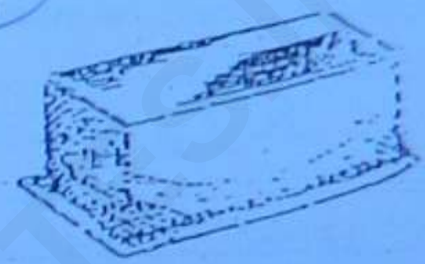
3. PUCKERS



4. STEP RINGS



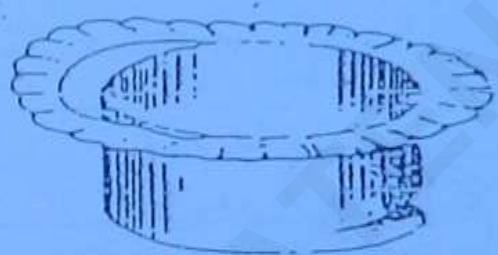
5. DRAW MARKS



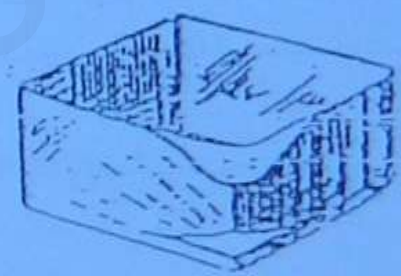
6. ORANGE PEEL



7. SCRATCHES



8. FRACTURED AND BOTTOM



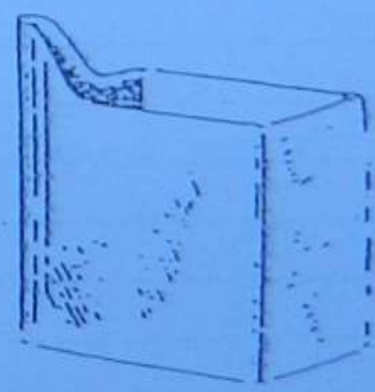
9. CORNER FRACTURE



10. EARING



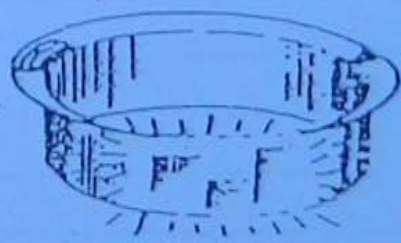
11. MISS-STRIKE



12. TOOL EARS



13. DIRECTIONAL EARING



14. BURNISHING

184

Q: A cylindrical cup is drawn from a 2 mm thick sheet. The cup sheet have dia of 15 mm and a height of 40 mm. The reduction ratio in the 1st draw and subsequent draws are 40% and 15% respectively determine the blank size and no of draws necessary

Sol: $d = 15 \text{ mm}$, $h = 40 \text{ mm}$.

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

185

$$D = 51.2 \text{ mm}$$

1st
40% and then 15%
↓
Draw ratio = $\frac{5 D}{d} = \frac{51.2}{15} = 3.41$

$$\frac{D}{d_1} \times \frac{d_1}{d_2} \times \frac{d_2}{d_3} \times \dots = 3.41$$

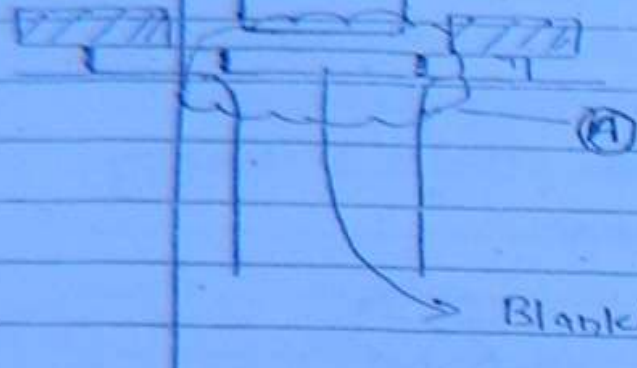
let there are n stages

$$\frac{D}{0.6 D} \times \frac{d_1}{0.85 d_1} \times \dots = 3.41$$

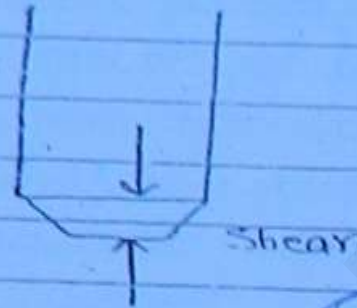
$$\frac{1}{0.6} \times \left(\frac{1}{0.85} \right)^{n-1} = 3.41$$

$$n = 5.4$$

$$\therefore \text{total No of draws / stages} = 6$$



Punch corner radius low



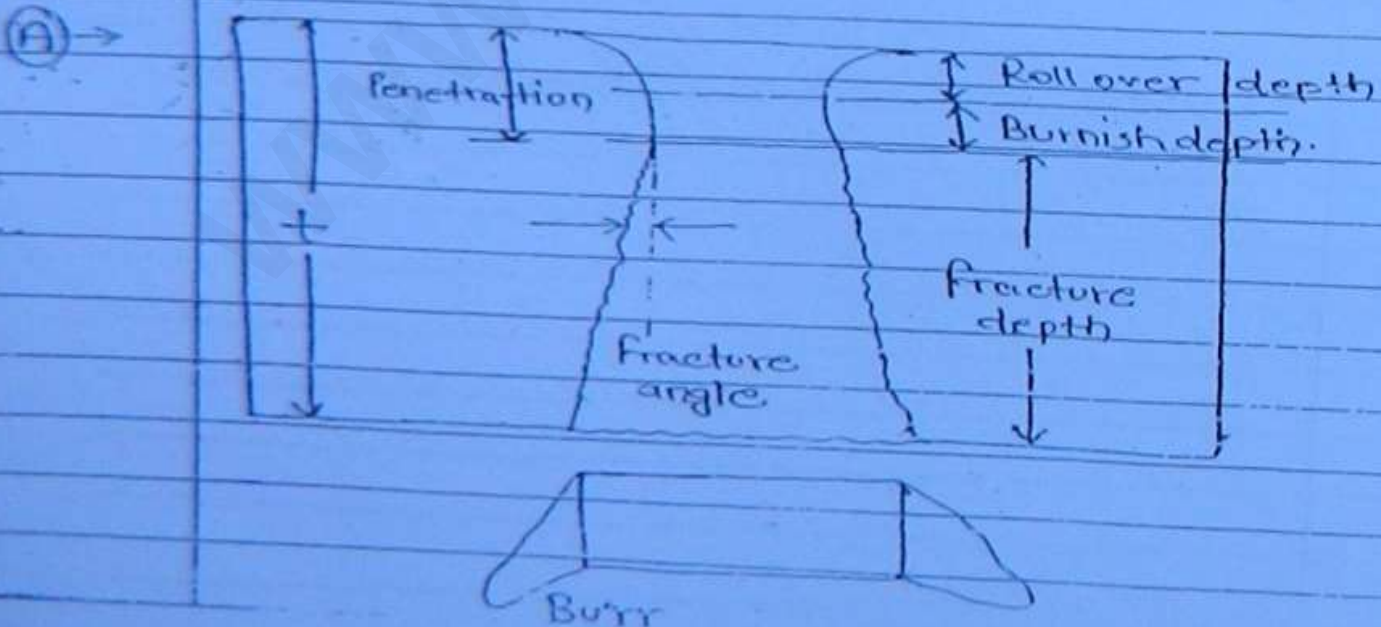
Shear

186

Punching

Where shear is provided over the punch or over the die and when β Blank holding pressure is high, shearing of sheet material is takes place.

When removed material is useful the process is called blanking. and when removed material is a waste the process is called punching.



Buyer

$$\text{Force} = K'(\pi D t)$$

Penetration

Shear over punch

1% of thickness

More ductile the material is larger will be the fracture angle and hence larger will be the size of burr produce. To accommodate large size burr, clearance b/w the punch and die should be more.

→ Punching Punch's exact clearance is provided over the die and shear is provided over the punch.

→ Blanking die's exact clearance is provided over the punch and shear is provided over the die.

187

Q: Determine the size of punch and die when 30mm dia blank has to be cut from a 2mm thick sheet take the clearance to be 3%. (1% of sheet thickness)

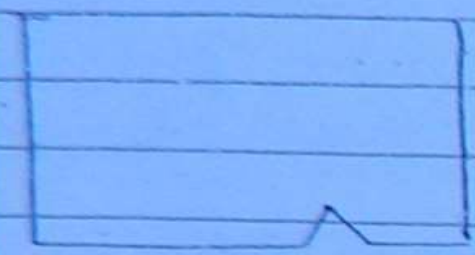
Sol: Die's exact = 30mm.

$$\text{Punch} = 30 - 2 \left(\frac{3}{100} \times 2 \right) \text{ Thickness of sheet.}$$

$$= 29.88 \text{ mm}$$

Q: Determine the size of punch and die when 25mm hole has to be created in a sheet of 2mm. Take clearance to be 2%.

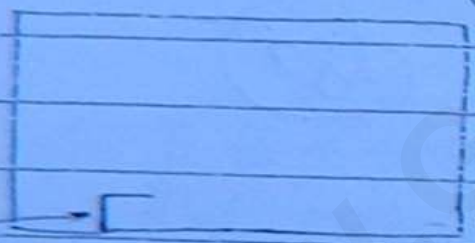
Sol. Punch = 25 mm
Die = 25.08 mm



Notching

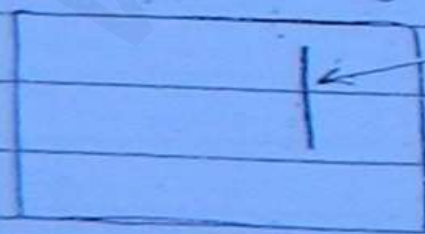
188

When a small amount of material is removed along the edges process is called Notching.



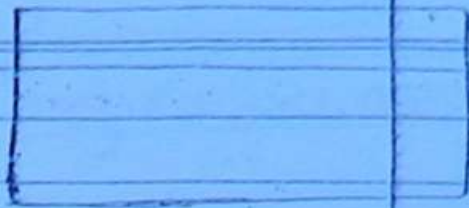
Lancing

When a tab is created without removing the material on the edge process is called Lancing.

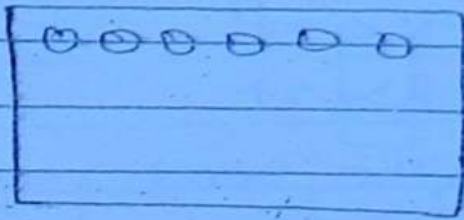


Slitting

When the tab is created in the middle of the sheet called Slitting.



When the material is removed completely either along the width or along the length direction it is called parting



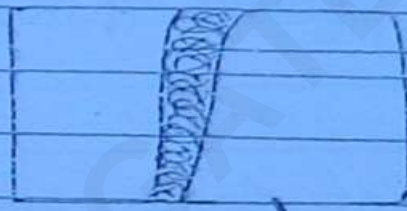
Perforating

189

It is a process of creating large no. of holes in the sheet metal

Nibbing:

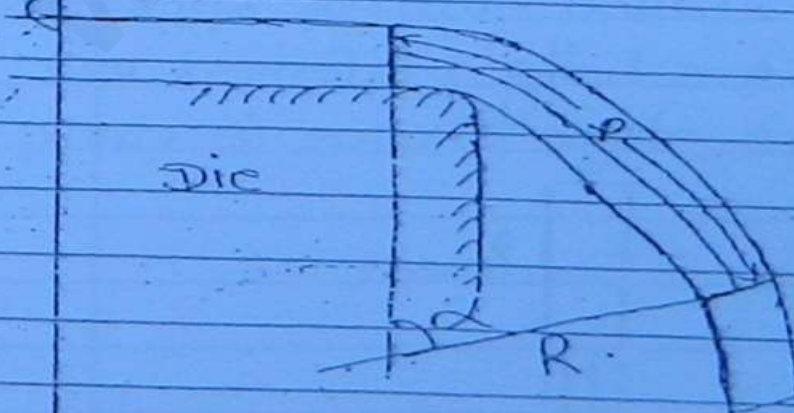
(चूरे का कुतरना)



etc. creating a path.

By using a small punch and die assembly it is a process of cutting the sheet along any profile.

Bending:



Spring Back

L - Bend allowance

$$\text{Bend allowance} = \alpha (R + K_1 t)$$



Bend angle in rad

R - Bend Radius

t - thickness

K₁ - stretch factor

$$= 0.33 \quad R < 2t$$

$$= 0.5 \quad R \geq 2t$$

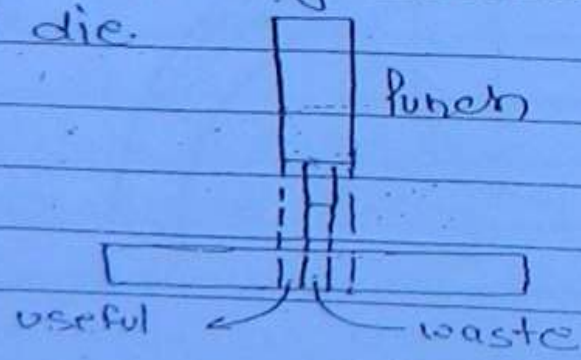
190

length of neutral plane in the bend region is called bend allowance. When the load is removed from the sheets elastic strains will recover and a portion of material is on hand called spring back.

Types of dies:

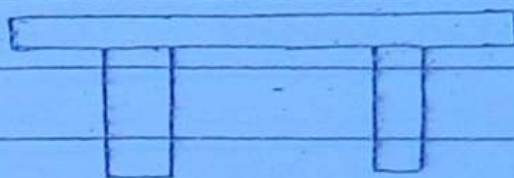
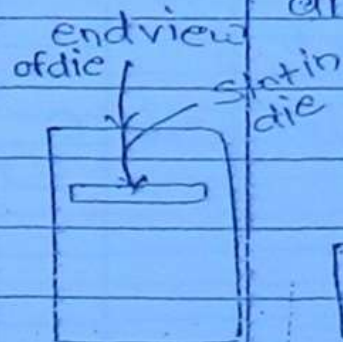
(1) Simple die: When single operation is being performed on a single station and in one stroke it is called simple die.

(2) Compound die: When multiple operations are being performed on a single die in a single stroke is called compound die.

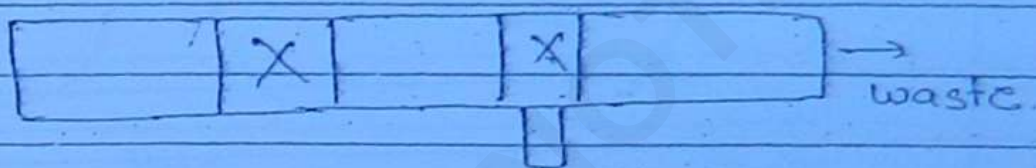


In making washer.

- 3) Progressive die: When multiple operations are being performed on multiple station in a single stroke it is called progressive die.
cycle lock casing is produce by progressive die



19/1

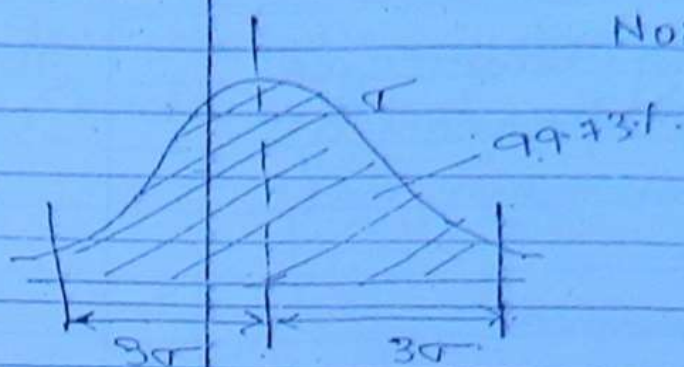


1. Final product

192

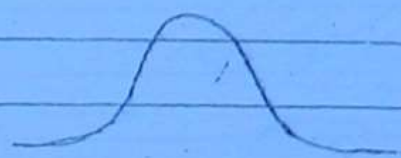
METROLOGY

Normal distribution



$\pm 3\sigma \rightarrow 6\sigma$ - Process capability

Desired tolerance



Hole

193



Shaft

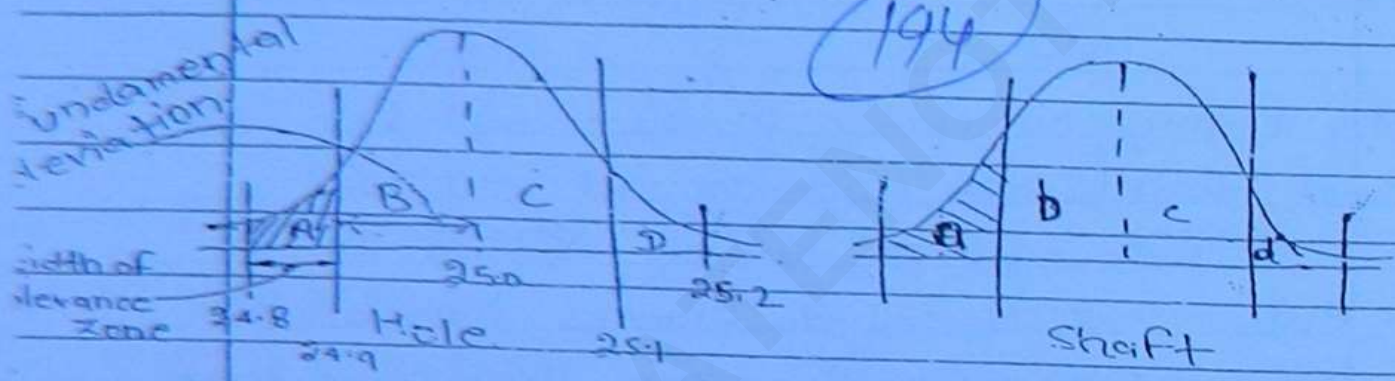
Products coming out of the machine, will follow a normal distribution and around 99.73% component will appear within ~~the~~ $\pm 3\sigma$ limit this 6σ is called process capability of machine. Whatever dimension that have been produce cannot be duplicated because of the same reason. Desired tolerance is a acceptable variation in the size specified by the consumer. In 99% cases it is the hole which is made first because standard size of drills and reamers are available. Suppose there is a m/c producing hole & shaft having the process capability = desired tolerance, when a shaft is selected randomly from the shaft lot and a hole is selected randomly from the hole lot, assembly can be made. This call is called full-interchangeability.

It is having following advantages:

- (1) Hole and shaft can be produced at different places where man and materials are cheap.
- (2) Standardisation is possible.
- (3) Maintenance becomes cheap and easy.

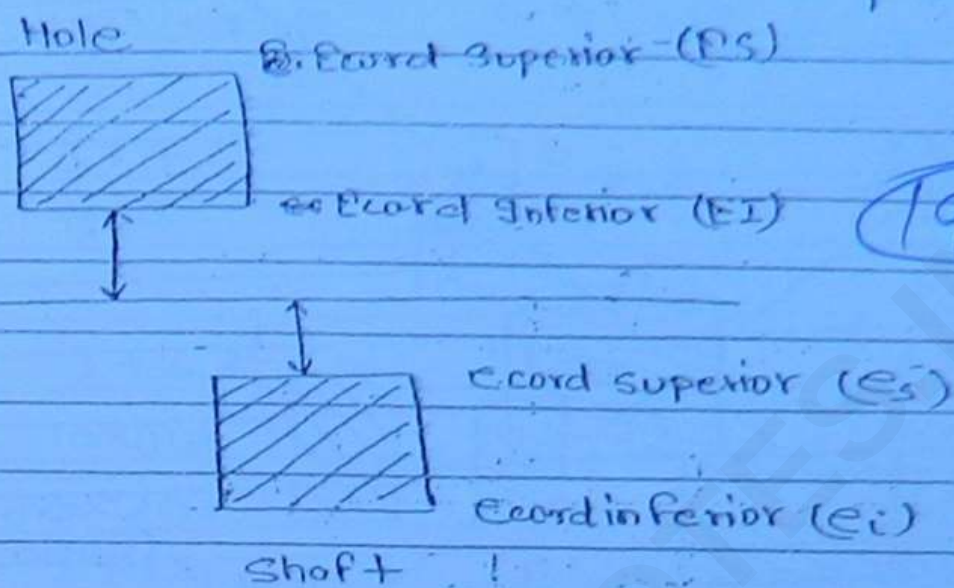
Let Process capability = 4 (D.T.)

Selective Assembly



If the process capability of both hole and shaft is ^{worse} than the desired tolerance then the process capability range is divided into subgroups. As the machine is producing part each and every part is inspected and placed in different subgroups. Variation in dimensions within the subgroup are now equal to desired tolerance. So when a hole is selected randomly from subgroup A and a shaft selected randomly from subgroup a assembly can be made. This process of achieving fully

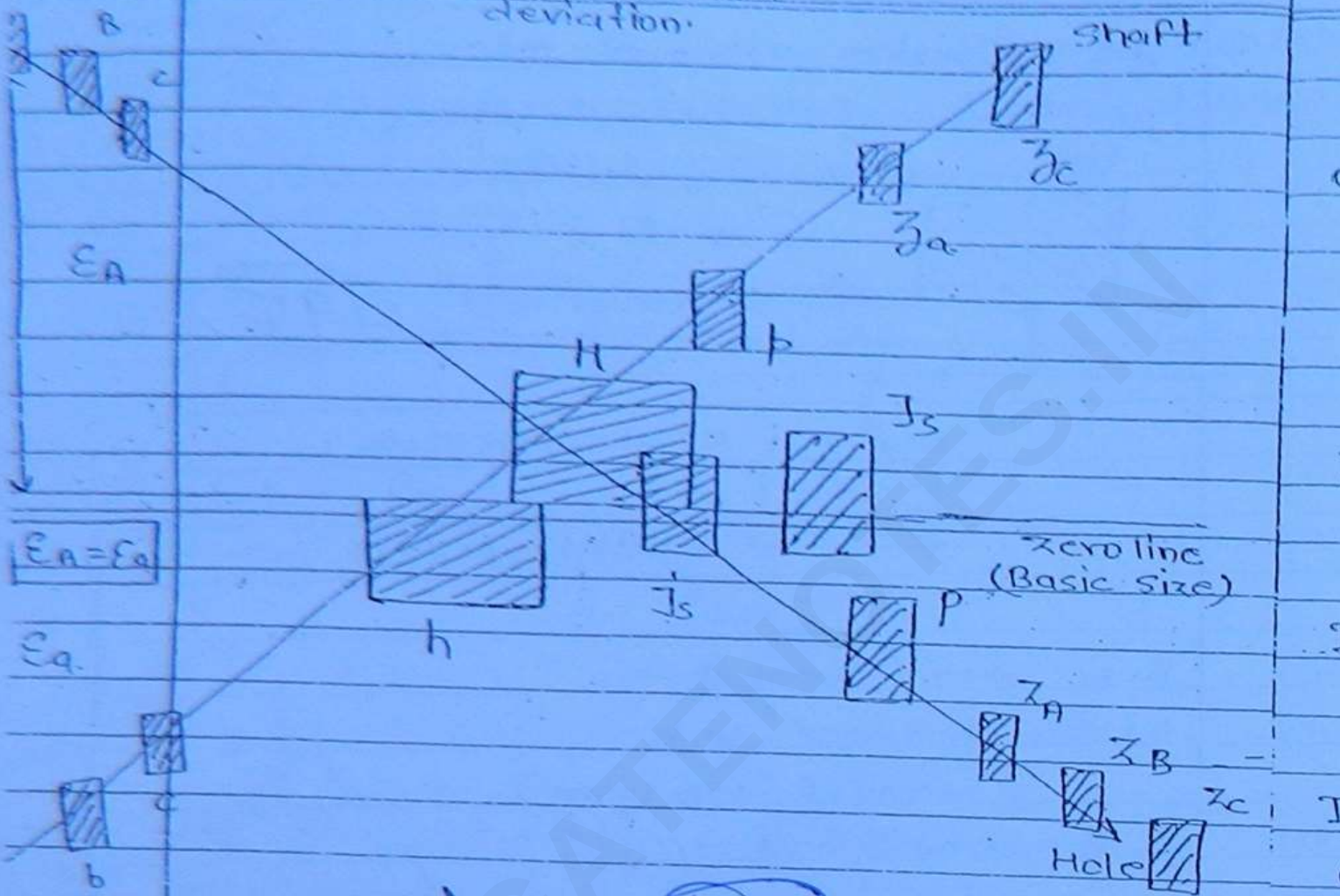
Interchangeable system although m/c are not capable is called selective assembly.



- (i) Basic Size / Nominal Size
- (ii) Width of tolerance zone
(Grade of tolerance)
- (iii) Fundamental deviation.

Basic size is the size for which you have designed the system and Nominal size is the nearest round No as per the standard. Fundamental deviation is the distance b/w the basic size and the width of tolerance zone in other word distance b/w the zero line & the limit closure to it either record superior or record inferior.

25 types of fundamental deviation.



196

unilateral

Bilateral

fund
hole
i

① Initially 16 grades
 ② Initially IT was 1

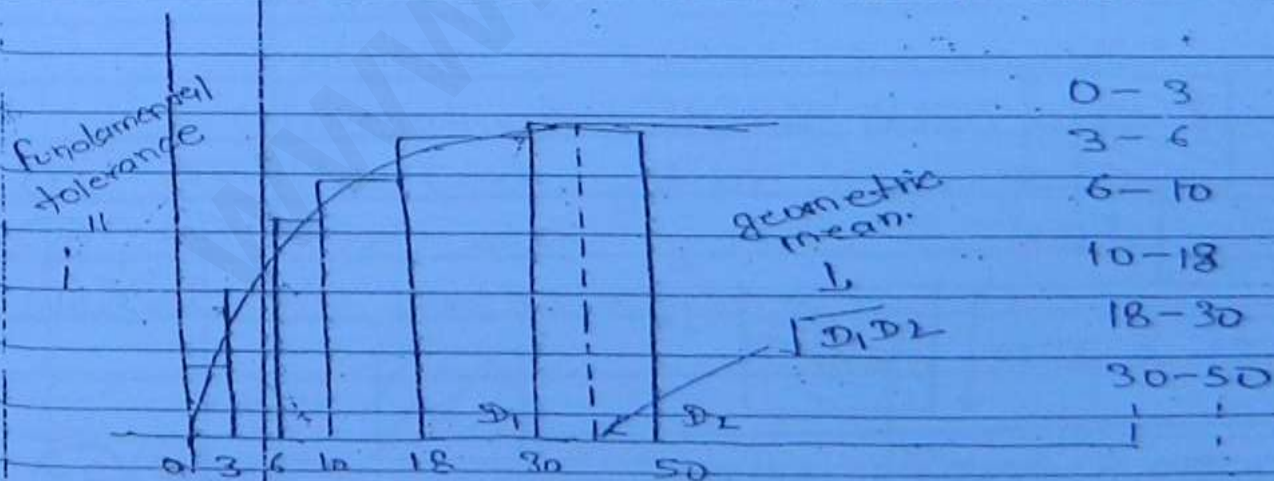
18 grade of tolerances.

IT → International tolerance

IT01	IT0	IT1	IT2
$0.3 + 0.008 D$	$0.5 + 0.012 D$	$0.8 + 0.02 D$	
		a	ay
IT3	IT4	IT5	IT6
ay^2	ay^3	$(10)^{1/5} i$	$10i$
		$ay^4 = 7i = 7i$	$10i$
IT7	IT8	IT9	IT10
$10 \times (10)^{3/5} i$	$10 \times (10)^{2/5} i$	$10 \times (10)^{3/5} i$	$10 \times (10)^{4/5} i$
$16i$	$25i$	$40i$	$64i$
IT11	IT12	IT13	IT14
$100i$	$160i$	$250i$	$400i$
IT15	IT16	197	
$640i$	$1000i$		

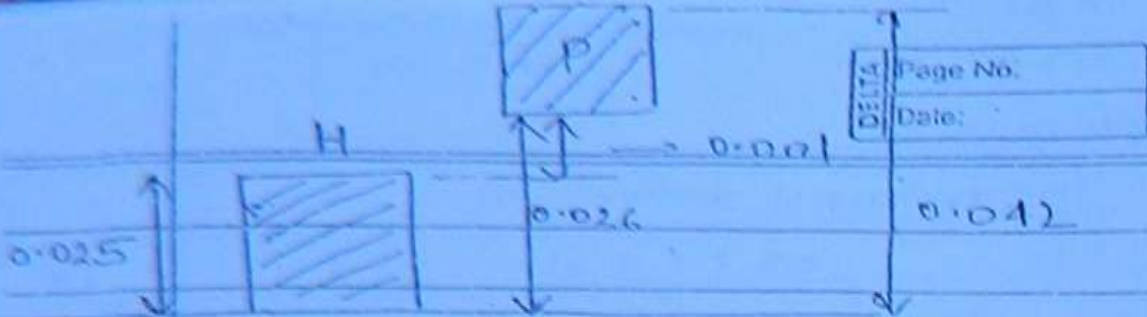
3-Step preferred series

IT01 - IT4 → empirical formula,
 IT5 - IT10 → Geometric mean
 IT12 - IT18 → Preferred series



$D \rightarrow 38$

$$i = 0.45 D^{1/3} + 0.001 D \quad D = \sqrt{D_1 D_2}$$



min interference = 0.001

max " = 0.042

max = 50.025

Hole

min = 50.0

max = 50.042

Shaft

min = 50.026

IS-2006

69)

2.

100 $F_8 h_{10}$

80-120

$E_f = 5.5 D^{0.41}$

IT8 = 25 μ

IT10 = 64 μ

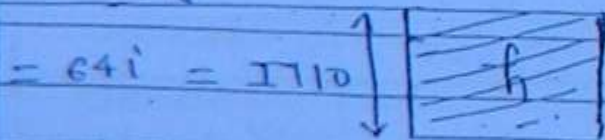
F

i.



IT8 = 25 μ

$E_f =$



IT10 = 64 μ

$i = 0.45 D^{1/3} + 0.001 D$

$E_f = 5.5 D^{0.41}$

$D = \sqrt[3]{80 \times 120} = 97.9795 \text{ mm}$

198

IAS

80

2

$$E_f = 5.5 \times D^{0.41}$$

$$E_f = 36.035 \mu = 0.036 \text{ mm}$$

$$i = 0.45 \times (97.9795)^{1/3} + 0.001 \times 97.9795$$

$$= 2.1725 \mu$$

$$25i = 0.054 \text{ mm}$$

$$64i = 0.139 \text{ mm}$$

$$\text{allowance} = 0.036 \text{ mm}$$

Hole $\left\{ \begin{array}{l} \text{max} = 100.09 \\ \text{min} = 100.036 \end{array} \right.$

Shaft $\left\{ \begin{array}{l} \text{max} = 100 \\ \text{min} = 99.261 \end{array} \right.$

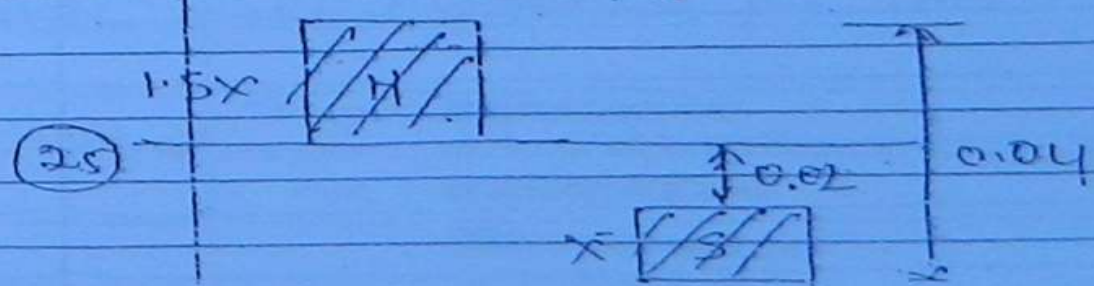
199

IAS-2002

- Q. If the targeted value is 25 mm and it is a clearance fit with min clearance 0.02 mm & max clearance = 0.04 mm if the tolerance of hole = 1.5 times tolerance of shaft determine the limit of hole & shaft. For

- (i) Hole Basis system
- (ii) Shaft Basis system

Sol: (i) Hole Basis system.



$$1.5x + x + 0.02 = 0.04$$

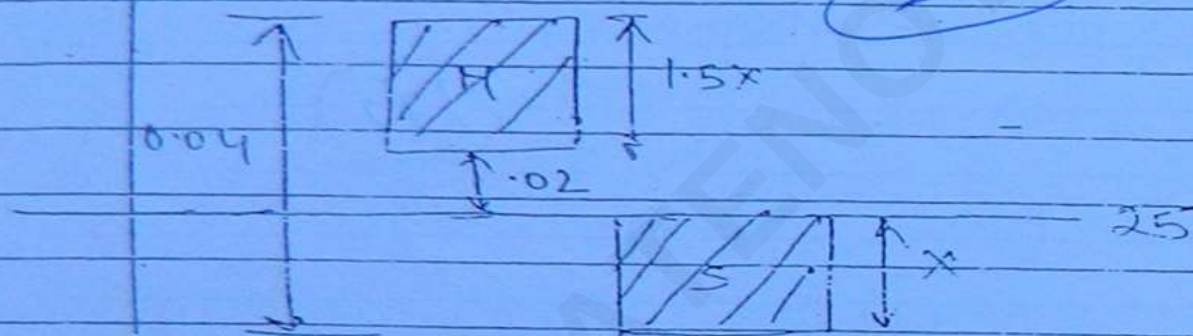
$$x = 0.008$$

Hole $\begin{cases} \text{max} = 25.012 \\ \text{min} = 25.00 \end{cases}$

Shaft $\begin{cases} \text{max} = 24.98 \\ \text{min} = 24.972 \end{cases}$

② Shaft basis.

200



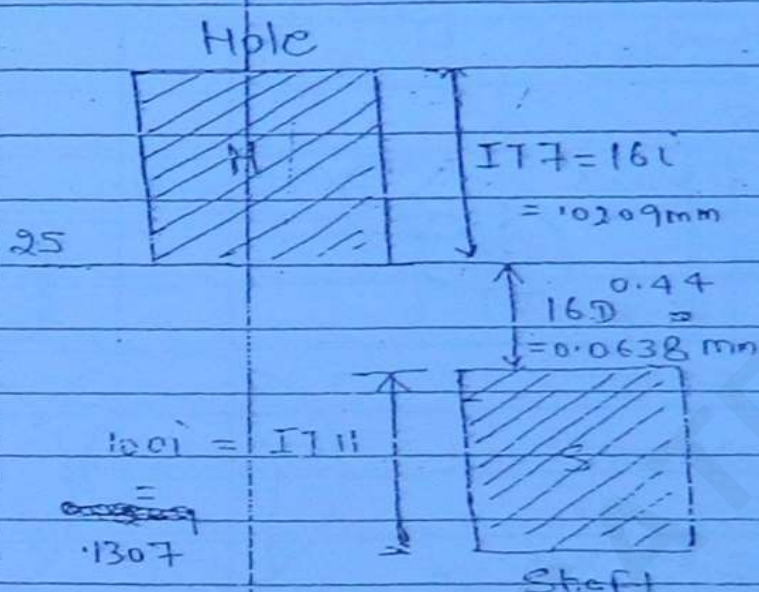
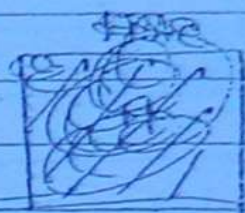
$$x = 0.008$$

Hole $\begin{cases} \text{max} = 25.032 \\ \text{min} = 25.02 \end{cases}$

Shaft $\begin{cases} \text{max} \rightarrow 25.00 \\ \text{min} \rightarrow 24.992 \end{cases}$

Q: Calculate the limit and sizes for fit 25 H7/d₁₁ if the fundamental deviation of d type of shaft is $E_d = -16 D^{0.44}$.

Sol



201

$$i = 0.45 D^{1/3} = 0.001 D$$

$$D = \sqrt[3]{18 \times 30} = 23.237 \text{ mm}$$

$$i = 1.307 \mu$$

$$IT_{11} = 100 \times i = 130.7 \mu = 0.1307 \text{ mm}$$

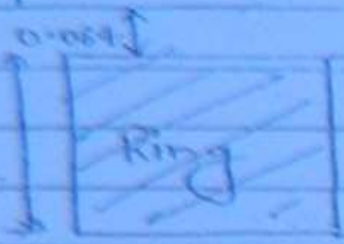
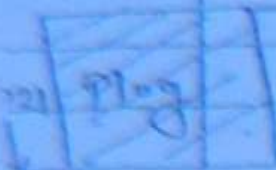
$$IT_7 = 20.912 \mu = 0.0209 \text{ mm}$$

Hole $\left\{ \begin{array}{l} \text{max} = 25.0209 \text{ mm} \\ \text{min} = 25 \text{ mm} \end{array} \right.$

Shaft $\left\{ \begin{array}{l} \text{max} = 24.9362 \text{ mm} \\ \text{min} = 24.8055 \text{ mm} \end{array} \right.$

No wear, because work tolerance is less than

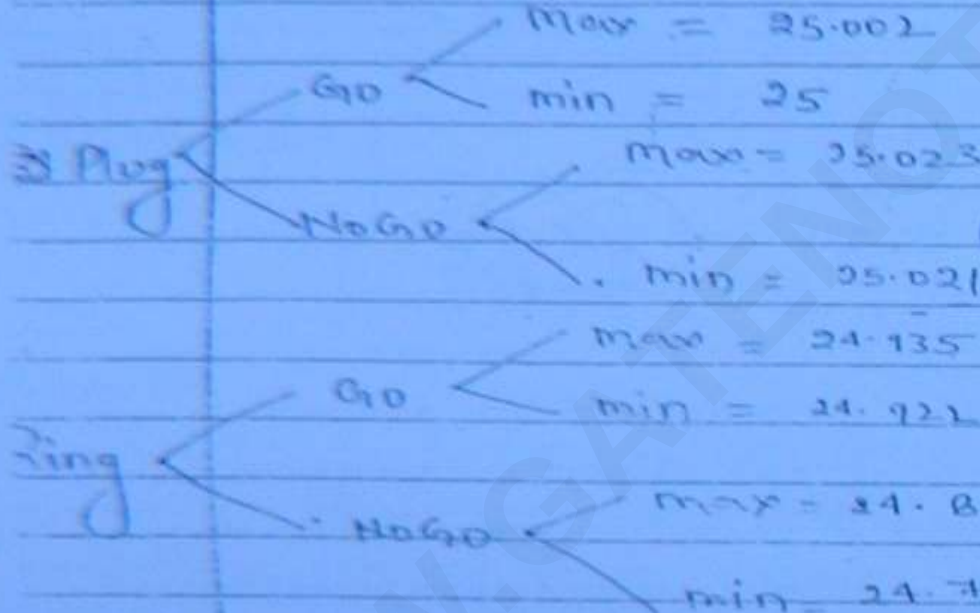
Page No.	109
Date	



0.0013

0.0013

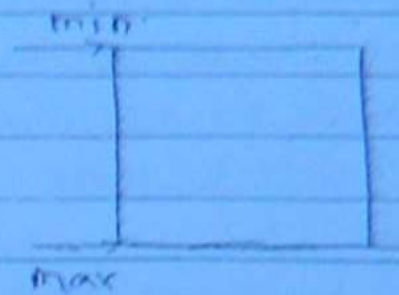
0.0013



202

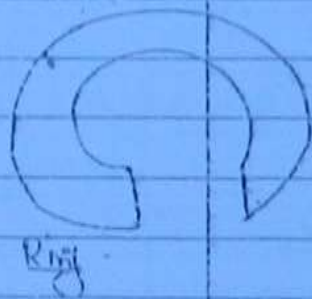
LIMIT GAUGING:

Holes $\rightarrow$ Plug $\begin{cases} \text{Go} \\ \text{NoGo} \end{cases}$



Shafts $\rightarrow$ Ring $\begin{cases} \text{Go} \\ \text{NoGo} \end{cases}$

(203)



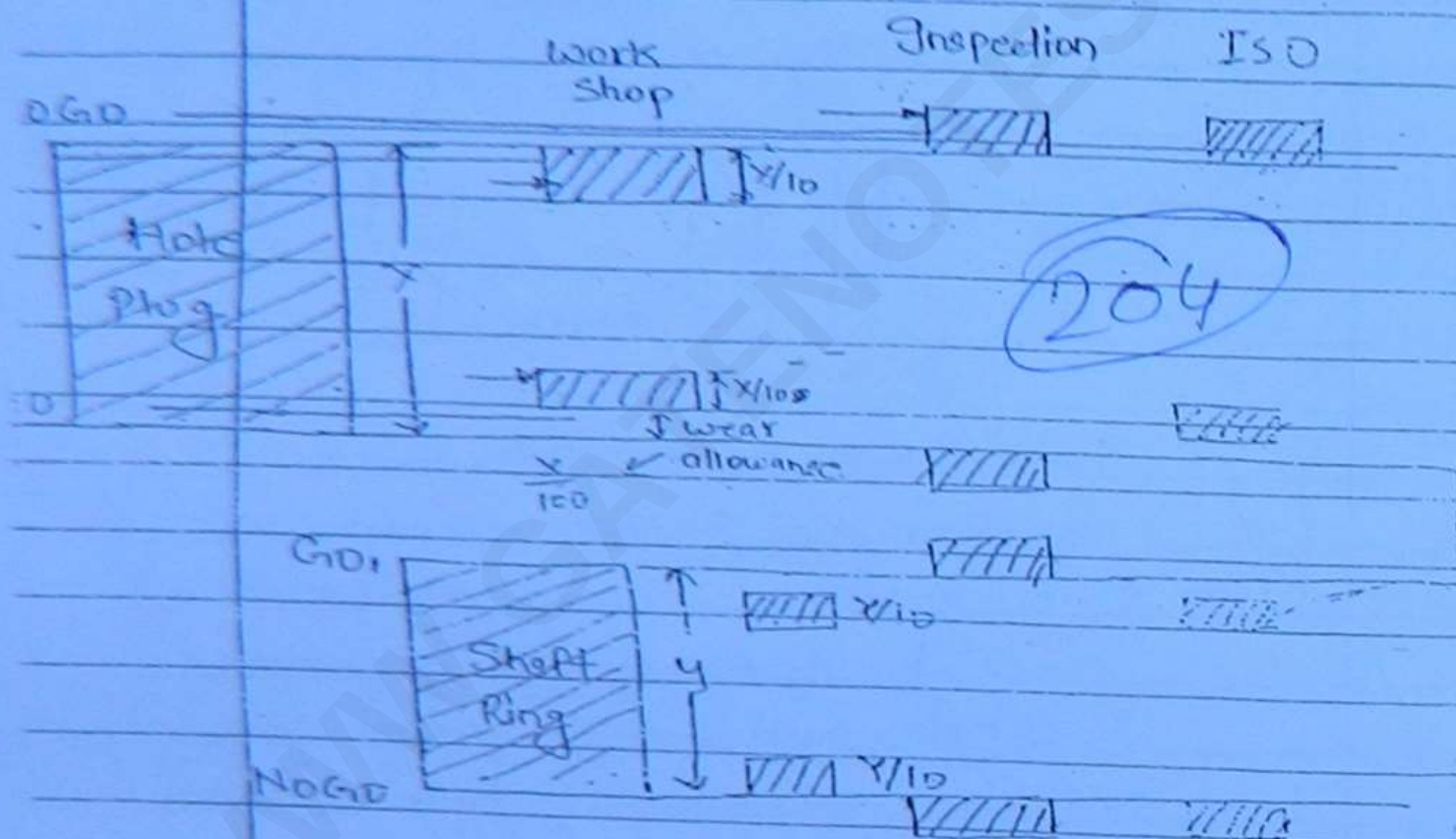
Limit Gauges are used to check whether the hole & shafts are coming within specified tolerance or not. If Go gauge go inside the hole and NoGo gauge does not go it means the hole is within

acceptable limit. If Go gauge does not go it means hole is undersized and when NoGo gauge goes inside the hole it means the hole is oversized. These gauges are designed according to Taylor principle which has two statements

- ① Go gauges are designed at max material limit condition & NoGo gauges are designed at min material limit condition.

2) Go gauges are designed to check shape as well as size and has to be in the full form. Since the go gauge has to cover the entire working length of hole so there will be wear over the go gauge so wear allowance has to be given.

No go gauges are used to check one element at a time or practically it should be a thin sheet.



$$\text{Gauge tolerance} = \frac{1}{10} (\text{work tolerance})$$

$$\text{Wear allowance} = \frac{1}{10} (G.T.)$$

if work tolerance < 0.09
No wear allowance

Philosophy of work shop gauge is that we will not produce anything defective so tolerances will be -towards the work tolerance. It can be observed in this case that some of the good part will be treated as bad part.

Philosophy of inspection department is that already lot of effort has been taken to produce the component so no good part should be rejected so the tolerances will be away from the work tolerance. In this case we can observe that some of the bad part will be treated as good part.

Since inspection gauges are already in service so no wear allowances are given over the go gauge. In I.S.O. gauges go gauge is taken from the workshop & no go gauge is taken from the inspection.

205

Q: Design Go & No-go plug and Ring gauges for 25H7/d11 fit.

Sol: Previous page:

Material for Gauges:

Property:

- ① Hardness.
- ② low coefficient of thermal expansion.
- ③ Corrosion Resistance.
- ④ gauges should be light i.e. low density.
- ⑤ material should be able to machine to a great degree of accuracy.

1: En-24 High Carbon Steel.

↓
European North series

for dimensional stability.

2: Inver → (36% Ni, Rest iron)

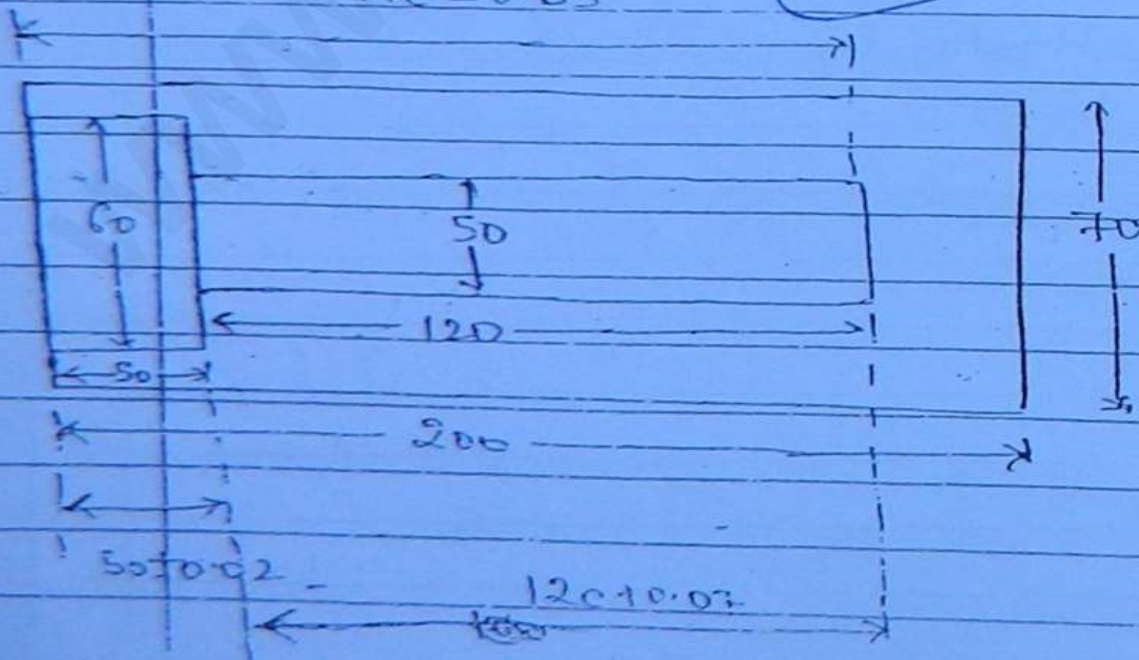
3: El Inver → (42% Ni, Rest iron)

4: Glass → checking Rifle Barrels & Guns.

Tolerance Sink:

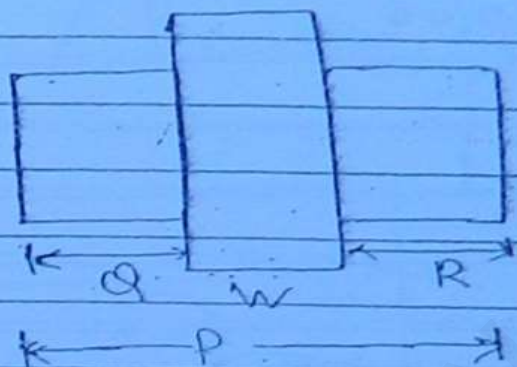
170 ± 0.05

206



A design engineer can not provide tolerances on each and every section - one section must be left blank as sink. Tolerance of Sink is Algebraic Summation of all the tolerances and only like minded tolerances can be added (i.e. either unilateral or bilateral tolerances can be added)

Gate 2003.



267

$$P = 35 \pm 0.08$$

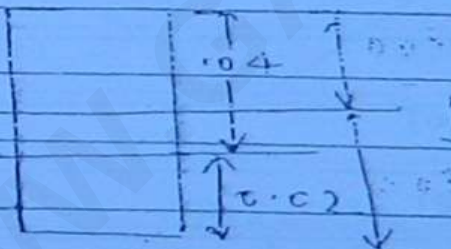
$$Q = 12 \pm 0.02$$

$$W = ?$$

$$R = 13 \begin{matrix} +0.04 \\ -0.02 \end{matrix}$$

Sol:

$$\begin{matrix} 13.01 \\ 0.02 \end{matrix}$$



For 13.01 ± 0.03 making unilateral

for R

$$W = P - (Q + R)$$

$$= 35 - (12 + 13.1)$$

$$W = 9.99$$

$$\text{Tolerance} = 0.08 + 0.02 + 0.03$$

$$= 0.13$$

$$\therefore W = 9.99 \pm 0.13$$

$$\left. \begin{matrix} \text{or} \\ W = 10 \begin{matrix} +0.12 \\ -0.14 \end{matrix} \end{matrix} \right\} = \text{equal}$$

Shortcut:

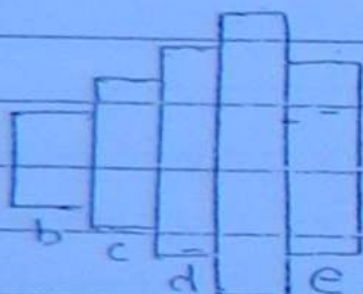
$$W = P - (Q + R)$$

$$= 35 \begin{matrix} +0.08 \\ -0.08 \end{matrix} \Rightarrow \begin{matrix} +0.06 \\ -0.04 \end{matrix} \begin{matrix} 72.5 \end{matrix}$$

Cross addition of tolerances

$$= 10 \begin{matrix} +0.08 + 0.04 \\ -0.08 - 0.06 \end{matrix}$$

$$W = 10 \begin{matrix} +0.12 \\ -0.14 \end{matrix}$$



208

$$k \xrightarrow{a} x \xrightarrow{e}$$

$$a \begin{matrix} +0.005 \\ -0.001 \end{matrix}, b \begin{matrix} +0.01 \\ -0.01 \end{matrix}$$

$$e \begin{matrix} -0.002 \\ -0.003 \end{matrix}, x = ?, d \begin{matrix} 0 \\ -0.001 \end{matrix}, e \begin{matrix} +0.005 \\ 0 \end{matrix}$$

~~208~~

$$X = a - (b + c + d + e)$$

$$= \begin{matrix} +0.005 \\ -0.001 \end{matrix} - \left[\begin{matrix} +0.01 - 0.002 + 0 + 0.005 \\ -0.01 - 0.003 - 0.001 + 0 \end{matrix} \right]$$

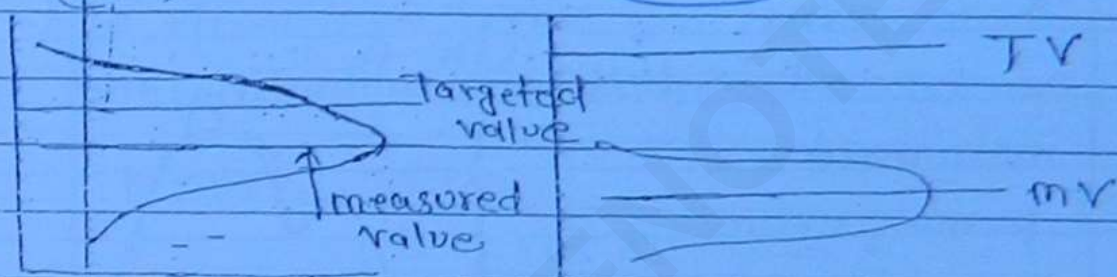
$$= \begin{matrix} +0.019 \\ -0.014 \end{matrix}$$

Active / Passive Inspection:

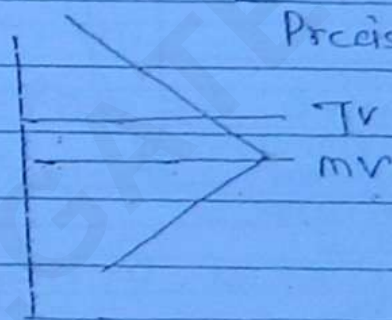
Active Inspection is online inspection and if something goes wrong corrective action can be taken. Passive inspection is of line inspection i.e. when the part has already being produced checking it a good or bad.

Accuracy / Precision: $\leftarrow$ (group) (standard deviation)
(single value) (mode)

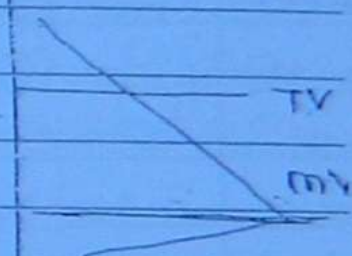
209



Accurate & Precise



Precise but Not Accurate



Accurate, Not Precise

Neither Precise nor accurate

Accuracy refers to the closeness to the exact value and precision refers to repeatability. Accuracy refers to the mode or the individual value and precision refers to the standard deviation or group.

Types of errors:

- ① Error of instrument
- ② Error of measurement

210

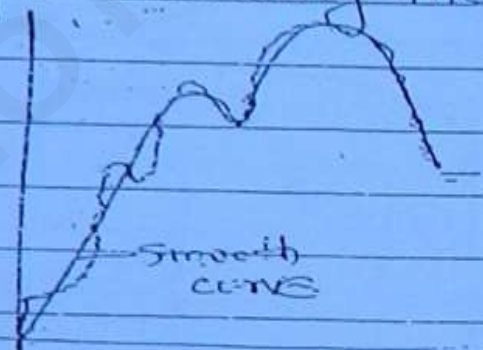
Instrument errors: → ① System error

↓ (Systematic error)

→ System errors appears due to variation in the relationship b/w different links.

These errors are very systematic and can be eliminated by calibrating the instrument.

② Short period error

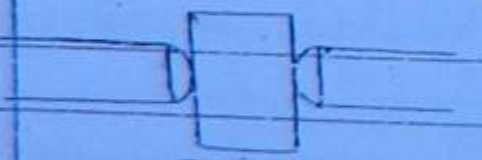


These error appear due to change in the environmental condition of m/c. & such error

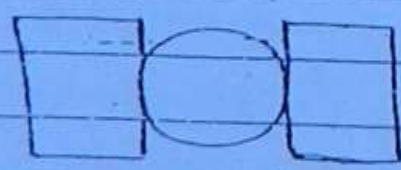
errors can be taken care of by neglecting such data.

③ Erratic error: These errors appear when either some link is missing or there is improper relationship b/w the two links.

Error of measurement:



Square Plate / Square ended gauge

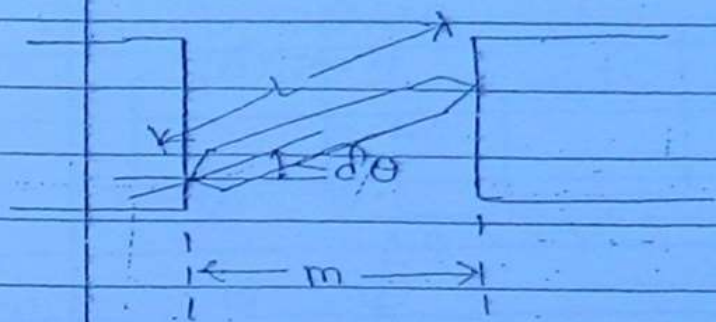


Spherical / cylindrical section / Flat ended gauge

Vernier calliper is not a good metrological instrument because a reference plane is not defined. This plane is well defined in micrometer/screw gauge.

① Cosine error:

(211)



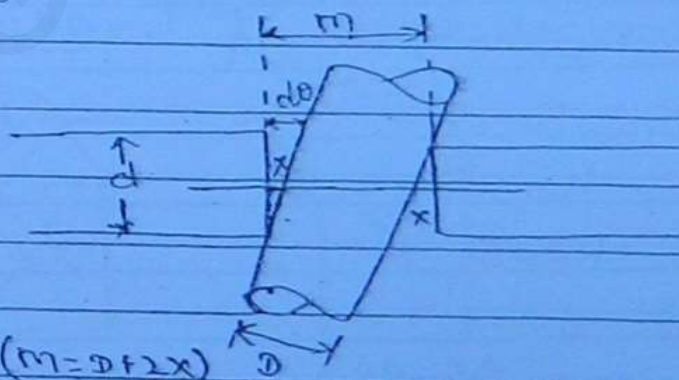
$$\text{Error} = L - m$$

$$= L - L \cos \delta\theta \rightarrow 0$$

$$\because \delta\theta \rightarrow 0$$

As it can be seen from the analysis that cosine errors can be neglected from the measurement.

② Sine error:



$$\text{error} = m - D \because (m = D + 2x)$$

$$\text{error} = 2x = d \times \delta\theta = d \cdot \delta\theta$$

$$\because \frac{x}{d/2} = \tan \delta\theta$$

$$x = \frac{d}{2} \tan \delta\theta$$

Can not be neglected.

build up of linear / Base dimensions.

Slip Gauges:

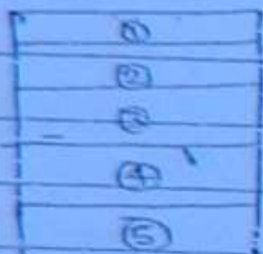
material
(high Ni / high cr steel)

Normal Set

Special Set

1.001 - 1.009	- 9 Set.
1.01 - 1.09	- 9
1.1 - 1.9	- 9
1 - 9	- 9
10 - 90	- 9
	<u>45</u>

26.852 mm	
1.002	①
25.85	
1.05	②
24.8	
1.8	③
23	
③	④
20	
②	⑤



5 set

212

Special Set:

1.001 - 1.009	- 9 set.
1.01 - 1.49	- 49 Set.
0.5 - 9.5	- 19
10 - 90	- 9
1.005	- 1
	<u>87</u>

26.852	
1.002	①
25.85	
1.35	②
24.5	
4.5	③
20	
20	④

4 set.

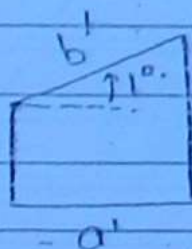
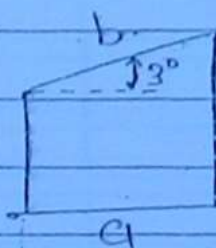
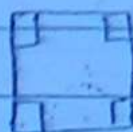
build up of Angular dimension

Date: 10/1
Page: 1

deg :	1	3	9	22	41
minuts	1	3	9	27	47
Fraction:	0.05	0.1	0.2	0.5	

(13)

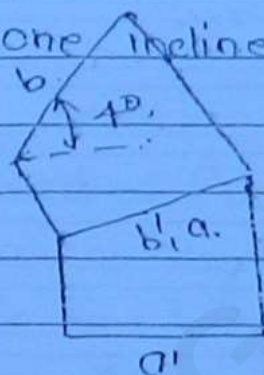
for 90° square is used



(213)

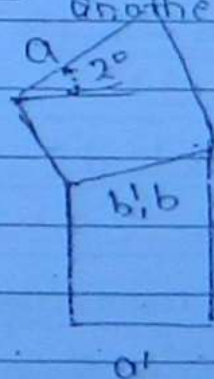
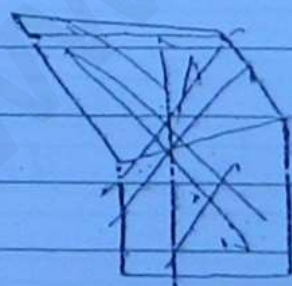
Addition:

one inclined & one flat

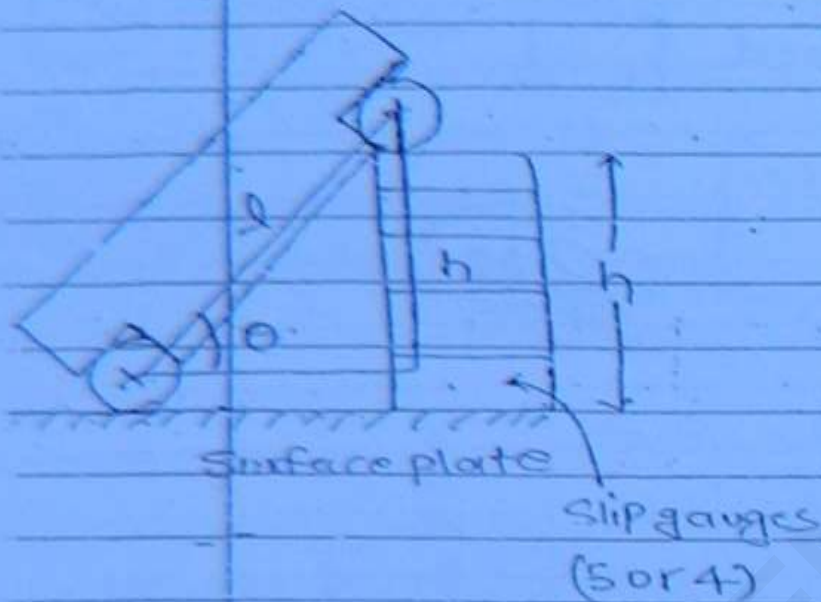
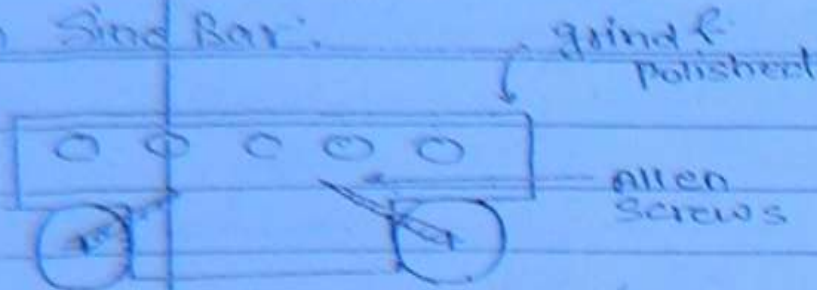


Subtraction:

one inclined & another inclined also



② Sine Bar:



$$\sin \theta = \frac{h}{l}$$

(214)

$$\begin{aligned} \text{Case } d\theta &= \frac{l dh - h dl}{l^2} \\ &= \frac{dh}{l} - \frac{h}{l} \frac{dl}{l} \end{aligned}$$

$d\theta$ = error in angle measurement

dl = error in center line distance b/w rollers

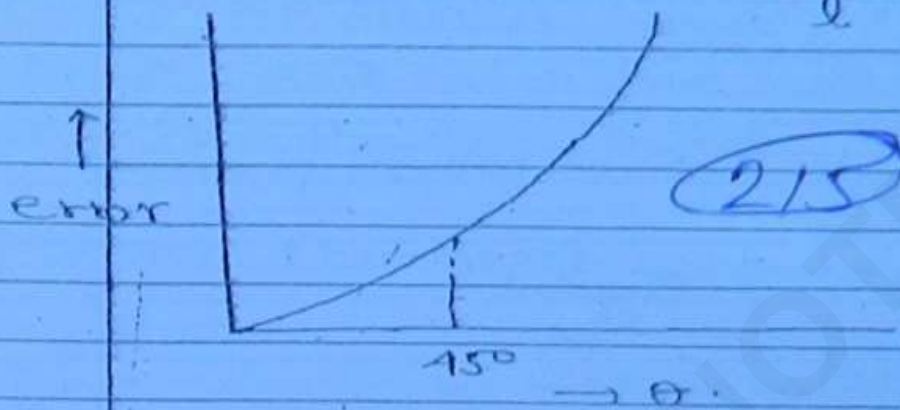
dh = total tolerance of Slip gauges / tolerance sink.

because slip gauges are very accurate that is why dh can be neglected compared to dl

mechanical measurement is called metrology.

$$\cos \theta \cdot d\theta = - \frac{h}{l} \frac{dl}{l}$$
$$= - \sin \theta \cdot \frac{dl}{l}$$

$$d\theta = - \tan \theta \cdot \frac{dl}{l}$$

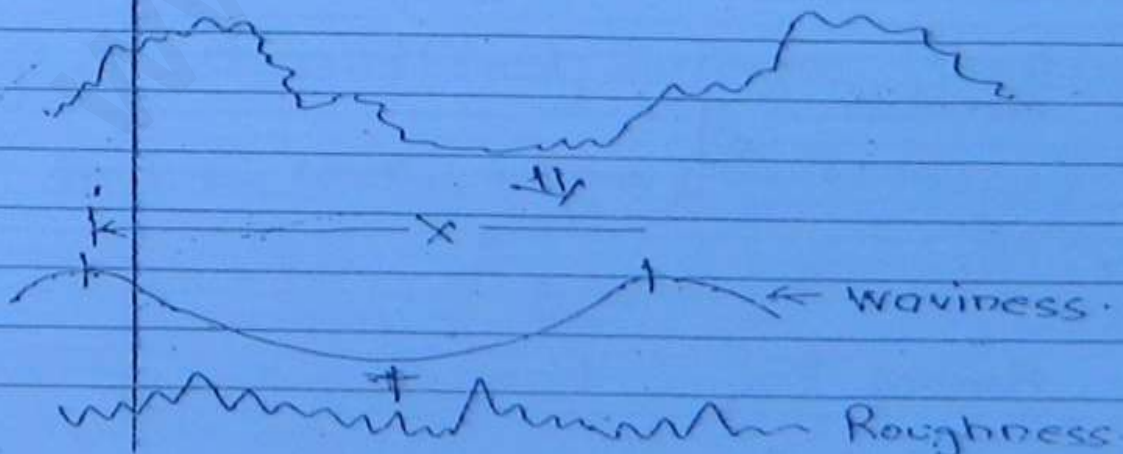


As the error is proportional

It can be observed from the graph that when the angle increases beyond 45° error shoots up to infinity. So sine bars are not used to measure angle beyond 45° .

Surface Finish:

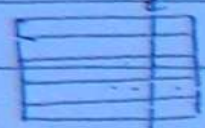
Characteristics of Surface:



large wave length deviation of the surface is called waviness and it is produced by m/c vibration, error in guide ways, chatter etc. small wave length disturbances produced by excessive increase in temp, improper application of cutting fluid etc. lead to roughness.

lay: It is the predominate surface pattern produced by feed marks.

operation
shaper, planer etc.

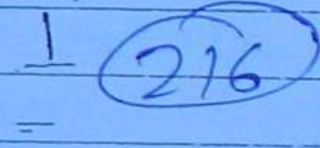


Parallel lay

Symbol



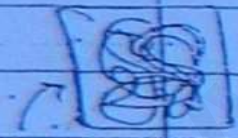
Perpendicular lay



Crossed



Knurling operation



Multidirectional



Grinding



circular lay



Facing operation



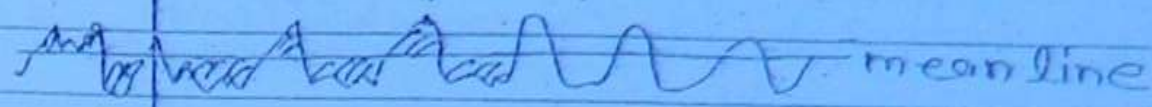
Radial Ray



Slitting operation

Methods of establishing datum.

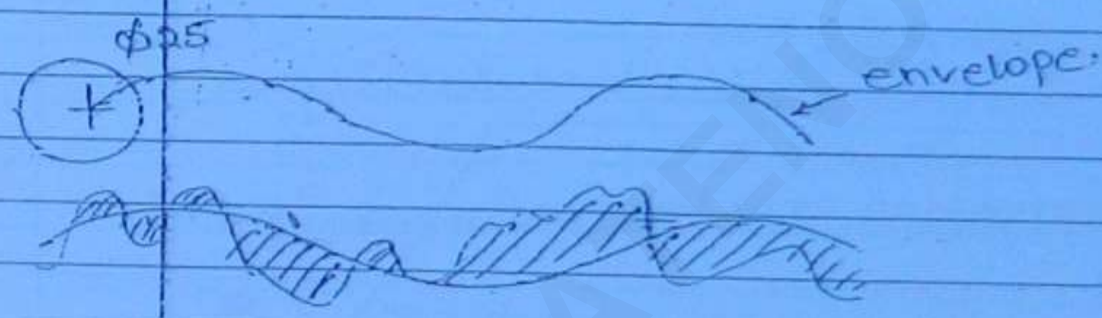
① M system (Mean line)



A horizontal line is drawn in such a way that the area above the line is equal to area below the line. This line is called mean line & all the measurement are taken from this line. In India we follow this.

② E-system (Envelope)

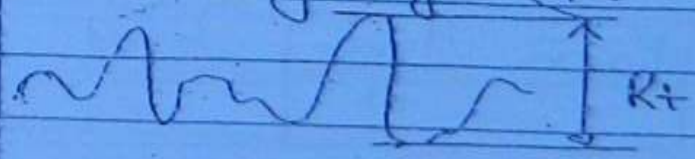
(217)



Sphere of 25mm diameter is rolled over the surface and the locus of its centre is being traced this envelope is shifted in the downward direction till the area above the envelope and below the envelope is same. In U.S.A. this system is followed.

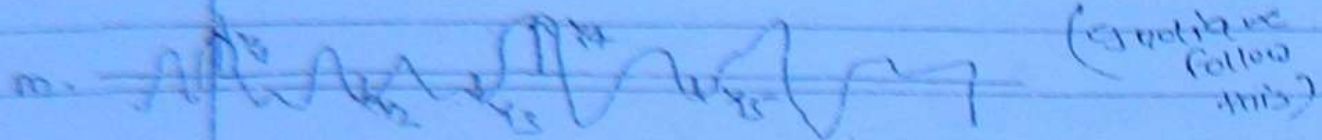
Ways of Quantified Surface Roughness.

① Peak to valley height (R_t or H_{max})



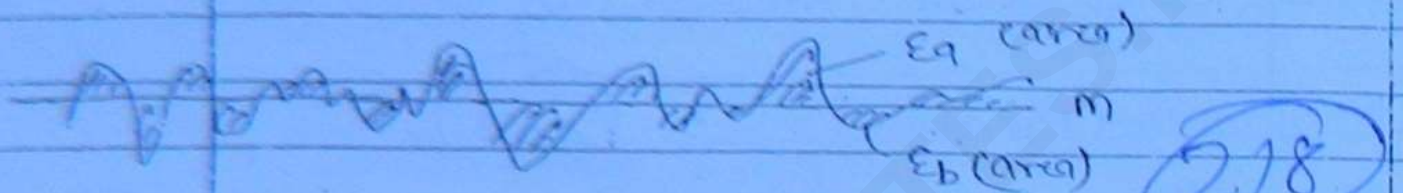
Not a very accurate method.

② Centre line average value (CLA) [R_a]



$$R_a = \frac{y_1 + y_2 + y_3 + \dots + y_n}{n}$$

(we will take mode, so all are +ve. values)

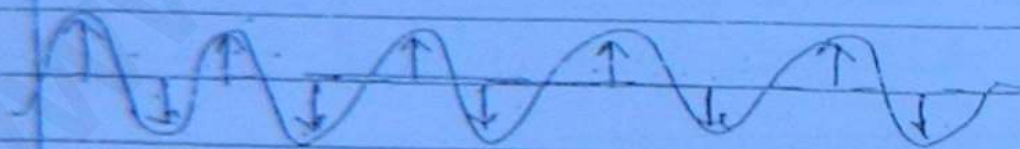


$$R_a = \frac{E_a + E_b}{L}, \quad L = \text{cutoff length.}$$

Length under observation over the surface is called cutoff length.

③ R-m.s. value. = $\sqrt{\frac{y_1^2 + y_2^2 + \dots + y_n^2}{n}}$

④ is point value



It is the average of 5 highest peaks and five deepest valleys

$$R_a \approx \frac{H_{max}}{4}$$

$$H_{max} = f^2 / 8R \quad \text{if feed \& Nose radius is given.}$$

GP complete tool signature is given

$$H_{max} = f$$

$\tan \psi + \cot \psi_1$
 Side cutting edge angle End cutting edge angle.

Symbol:

219

CLA Values

8-25 μs

1.6-2 μs

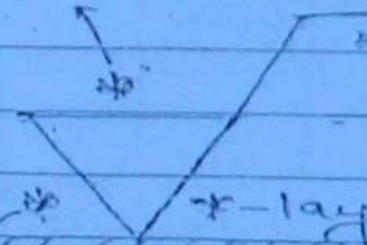
0.025-1.6 μs

< 0.025 μs

CLA value

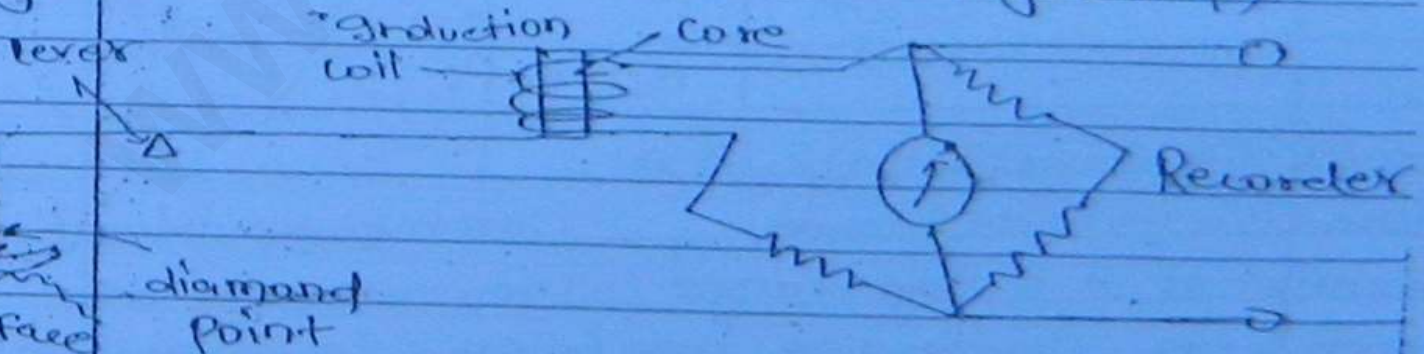
* Machining Method

* Cutoff length.



Machining allowance

Taly Surf! (used to record surface irregularity.)



flexible
material

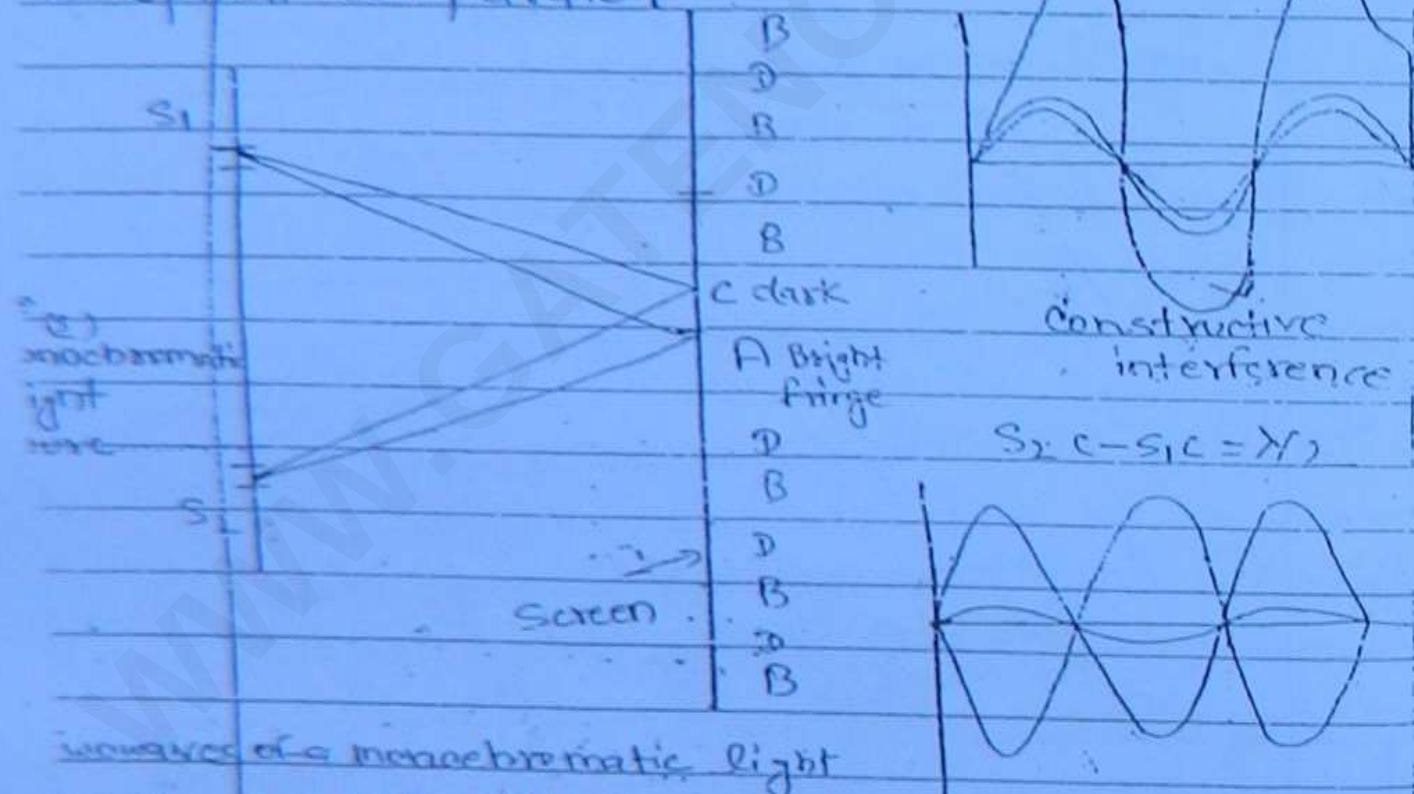
Tally surf is used to remove the surface irregularities on one side of the lever arm there is a diamond point which moves over the hill down the valleys and due to this that position of core on the other side of lever arm will change in the induction coil. This will change the effective resistance of the coil and change in resistance is recorded by wheat stone Bridge.

Comparator:

220

$$S_1 A = S_2 A$$

① Optical Comparator

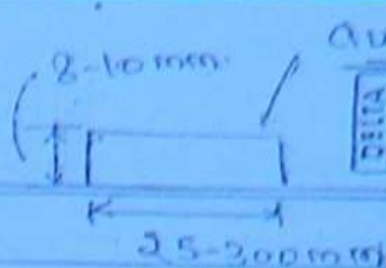
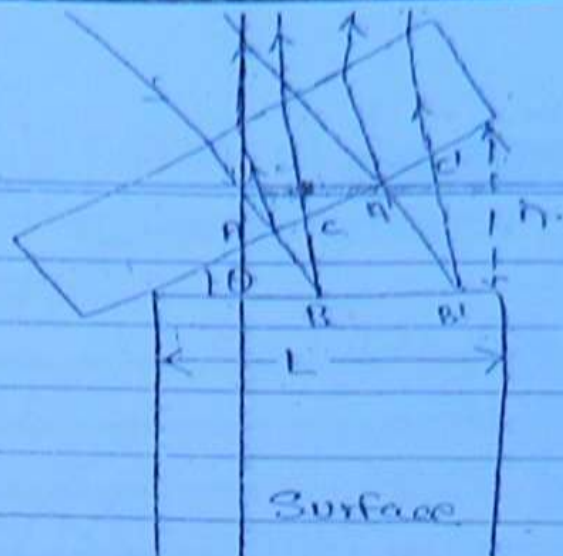


waves of a monochromatic light

if there is a path difference

Destructive interference

if multiple of λ a Bright fringe will appear over the screen due to Constructive interference. When there is a path difference of odd multiple of $\lambda/2$ there will be destructive interference and as a result of that a dark band will appear.



Quartz (Optical Flat)

Page No.

Date: 11/3

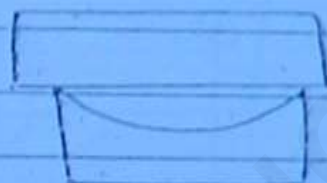
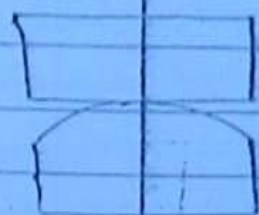
$$\frac{h}{L} = \tan \theta$$

AB + BC

$$= A'B' + B'C' = n\lambda$$

$$\Rightarrow 2A'B' = n\lambda$$

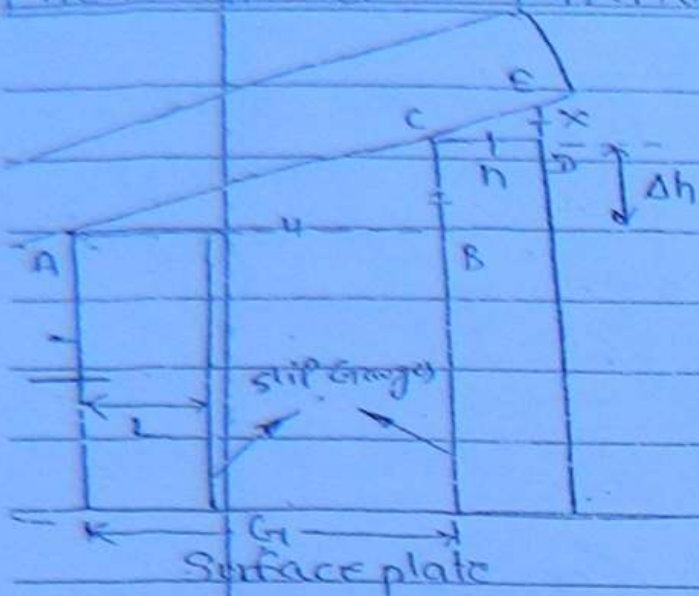
$$h = A'B' = n\lambda/2$$



(22)

As the angle b/w the optical flat & the surface increases path difference quickly multiplies by $\lambda/2$ so the fringes will become thinner & thinner & the no. of fringes in the surface will increase. Upon keeping an optical flat over convex surface, the angle b/w the optical flat & surface increases in the outward direction so the central fringes will be broad & in the outward direction fringe thickness will keep on decreasing. Opposite will be the case with concave surface. When incident ray is reflected from the surface a path difference of $\lambda/2$ will automatically be created so the central fringe will be dark & it is called Bull's eye.

Optical flat as comparator.



in ΔABC and ΔCDE

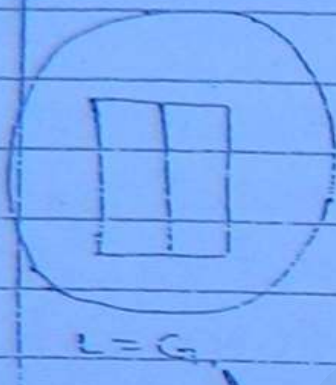
$$\lambda = \frac{h\lambda}{2}$$

$$\frac{ED}{BC} = \frac{CD}{AB}$$

$$\frac{\frac{h\lambda}{2}}{\Delta h} = \frac{L}{G_1}$$

$$\Delta h = \frac{h\lambda}{2} \left(\frac{G_1}{L} \right)$$

late 2008



$$L = G_1$$

$$h_1 = 1.00 \text{ mm}$$

$$h_2 = 1.002 \text{ mm}$$

$$\lambda = 0.00058928 \text{ mm}$$

$$\Delta h = \frac{h\lambda}{2} \left(\frac{G_1}{L} \right)$$

$$1.002 - 1.00 = \frac{h \times 0.00058928}{2} \left(\frac{1}{1} \right)$$

$$h = 6.787$$

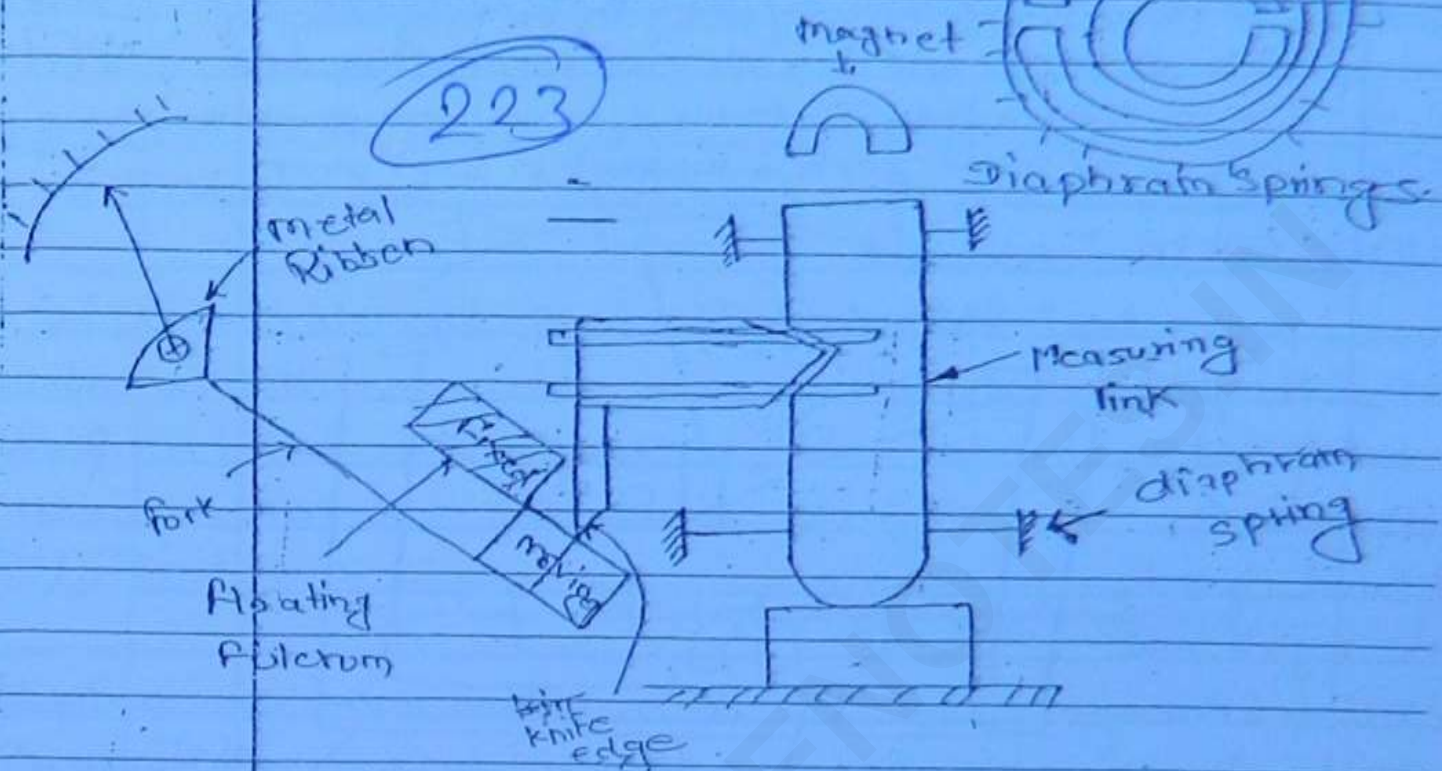
for both slip gauges No of fringes = $2h$.

$$2h = 13.57 \approx 13$$

fringe should be complete

Mechanical Comparators:

(A) Sigma Comparator



Characteristics of mechanical comparators are as follows

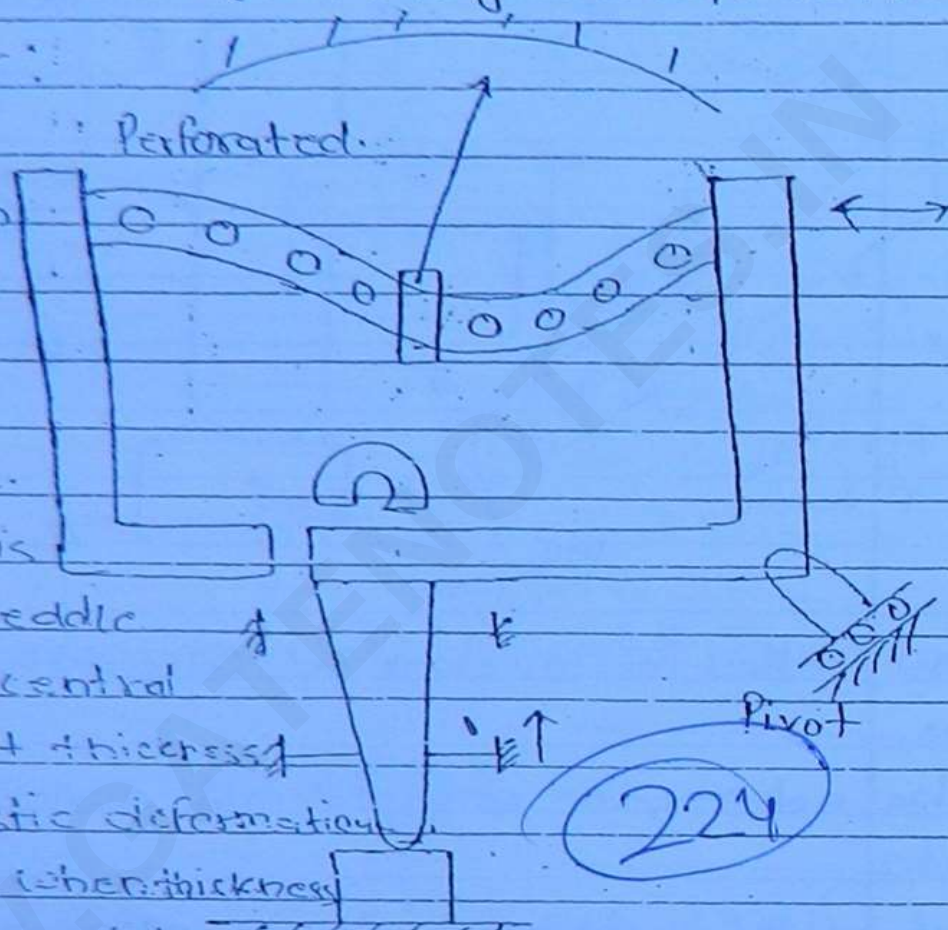
- (1) It does not require any external power supply to operate.
- (2) Accuracy of the instrument does not depend upon the accuracy of manufacturing of different links.
- (3) The magnification factor of these equipment is very low i.e. 1000:1.
- (4) Since there is inertia in the measuring link, this makes the equipment insensitive to measure small variation in dimension.

Sigma Comparator: Comparators always give the variation in dimension from a reference value. Different workpieces are kept under the measuring link for inspection. Helical springs are never used as restoring device in metrology because system takes time to come back to its original position.

Diaphragm springs with C slots is used as restoring device. C slots are being provided so that residual stresses are relieved. Measuring link is connected with a knife edge which rest over a floating fulcrum. This arrangement is done to always have a positive contact. By the movement of measuring link there will be deviation of fork and the value can be recorded. To ensure a uniform pressure over the link or to avoid jerk a magnet is kept over it.

Mikrokator:

1 Thin sheet is given left hand twist on the left side & Right hand twist on the right side. Central portion is Neutral and a needle is connected to central portion. If sheet thickness is too low plastic deformation will take place when thickness is very large there will be development of residual stresses. By the movement of measuring link the Right portion of the spring is either twisted more or twisted less. Due to imbalance in the twist causes the central portion to rotate. Helically twisted spring is perforated all along its length to relieve the residual stresses.



macroscopic level
Roughness
microscopic level

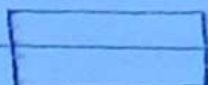
Page No.

115

Date:

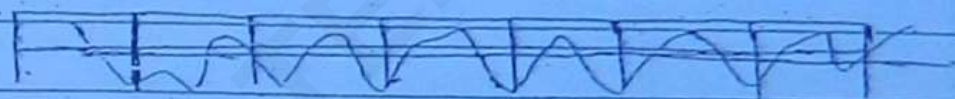
Straightness: Straightness is defined as the departure of surface from a reference straight line. This reference is being created by joining first & last point.

Method to measure the Straightness:

i) Straight edge -  : It is a piece of block for which one surface

is exactly straight. By keeping the straight edge over the surface under examination, intensity of light from the interface is observed. Less intensity of light indicates that the surface is straight.

ii) Spirit level:



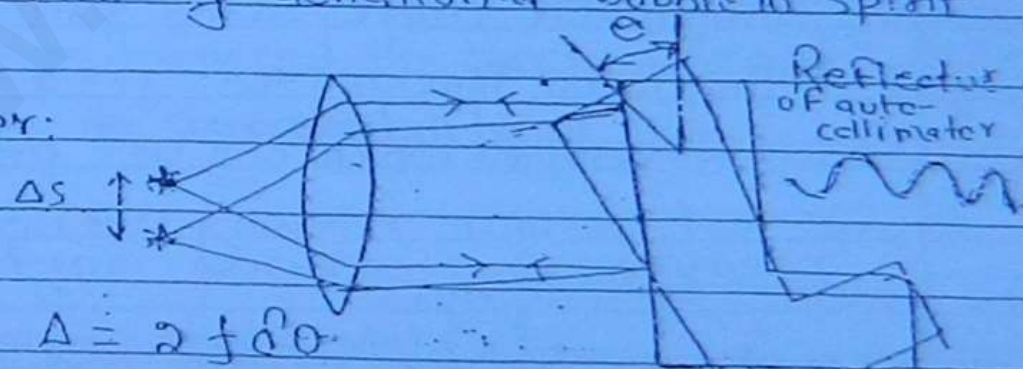
Surface under examination is divided into segments and the spirit level is kept from segment to segment - deviation of surface is recorded by deviation of bubble in spirit level.

iii) Autocollimator:

225

Δs

$$\Delta = 2 \pm 0.0$$

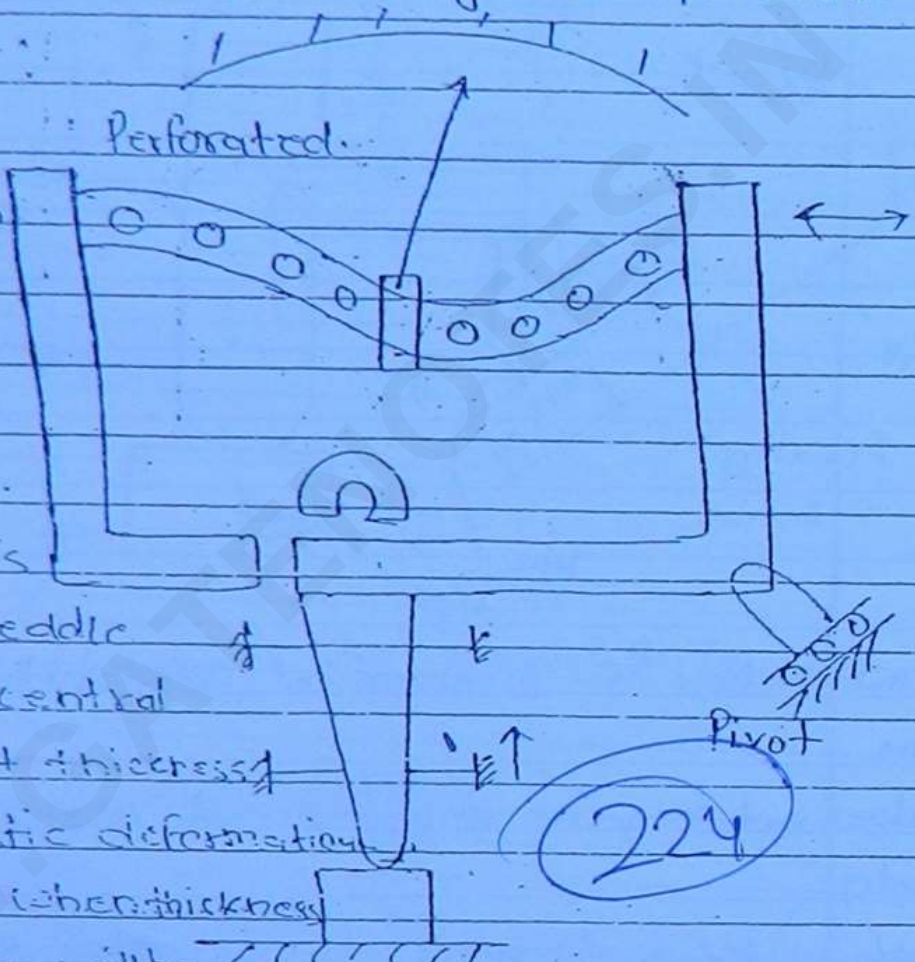


Reflector of autocollimator is moved along the surface under examination & deviation of surface is recorded in autocollimator.

Diaphragm springs with slots is used as restoring device. Slots are being provided so that residual stresses are relieved. Measuring link is connected with a knife edge which rest over a floating fulcrum. This arrangement is done to always have a positive contact. By the movement of measuring link there will be deviation of fork and the value can be recorded. To ensure a uniform pressure over the link or to avoid jerk a magnet is kept over it.

Mikrokator:

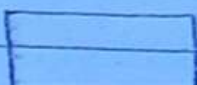
A thin sheet is given left hand twist on the left side & Right hand twist on the right side. Central portion is Neutral and a needle is connected to central portion. If sheet thickness is too low plastic deformation will take place when thickness is very large there will be



development of residual stresses. By the movement of measuring link the Right portion of the spring is either twisted more or twisted less. Due to imbalance in the twist, Causes the central portion to rotate. Helically twisted spring is perforated all along its length to relieve the residual stresses.

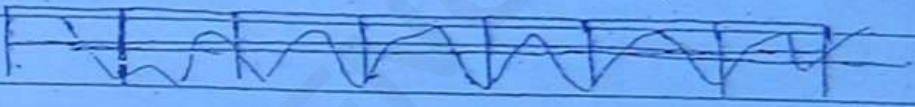
Straightness: Straightness is defined as the departure of surface from a reference straight line. This reference is being created by joining first & last point.

Method to measure the straightness:

i) Straight edge -  : It is a piece of block for which one surface

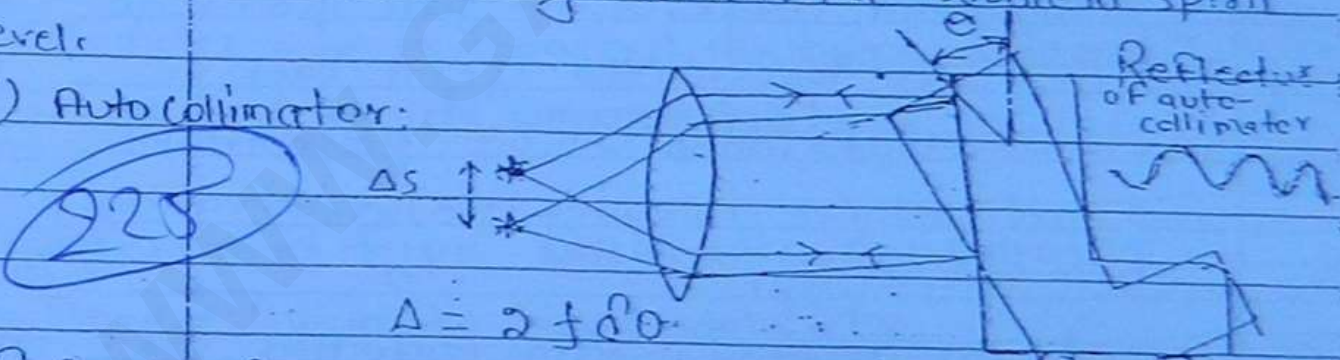
is exactly straight. By keeping the straight edge over the surface under examination, intensity of light from the interface is observed. Less intensity of light indicates that the surface is straight.

ii) Spirit level:



Surface under examination is divided into segments and the spirit level is kept from segment to segment - deviation of surface is recorded by deviation of bubble in spirit level.

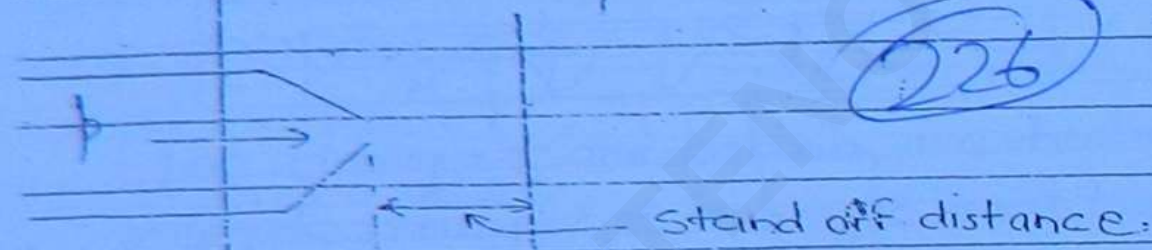
iii) Autocollimator:



Reflector of autocollimator is moved along the surface under examination & deviation of surface is recorded in autocollimator.

Page No. _____
Date: _____
Flatness: Flatness is the departure of Surface from a reference plane. A reference plane is created by moving ~~and~~ either autocollimator or spirit level in 3-direction. After defining the plane autocollimator is moved practically in all the direction and the departure of surface from this reference plane is noted ~~for~~ down. Max deviation of the surface is Quantitative representation of Flatness.

Pneumatic Comparator:



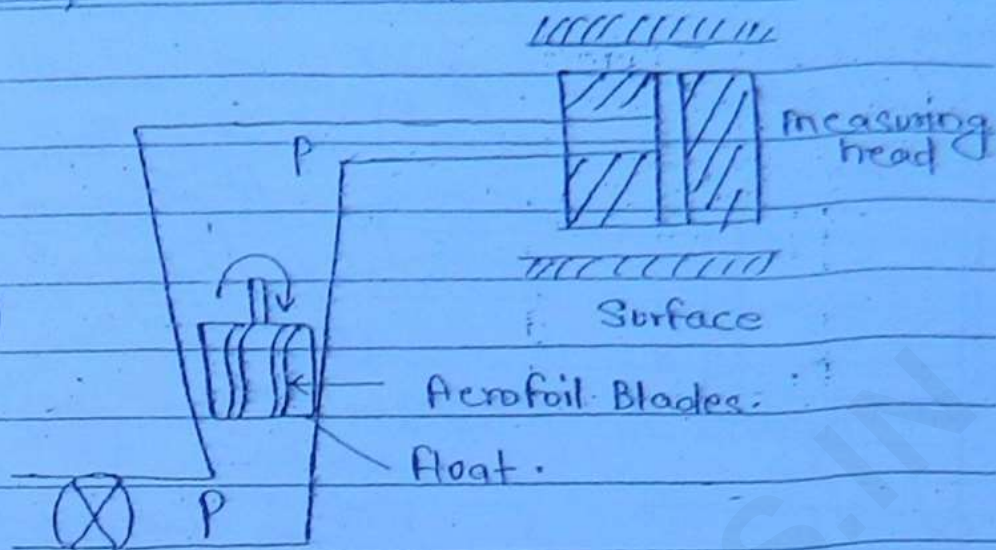
Pneumatic comparator works on the principle of an air jet i.e. upon blocking the jet a back pressure will develop which will be proportional to stand off distance. Following are the advantages of Pneumatic comparator.

- 1) Compressed air anyway used in industries for tightening of bolt, rivets, etc. Same compressed air is used in the measurement.
- 2) online inspection is possible.
- 3) Magnification factor is very high i.e. 50000:1.
- 4) It is a non contact type.

Type of Pneumatic Comparator:

① Flow type / Rotameter

227



Depending upon the stand off distance b/w the measuring head & surface there will be a back pressure & pressure difference decides the position of float. In the float there are aerodynamic blades so that float rotates in the rotameter tubes. if float comes in contact with the tube it will make the equipment insensitive to smaller change in pressure.

Rotameter tube is tapered to have linearity in the measurement due to compressibility of air.

② Differential type pneumatic comparator:

This type of pneumatic comparator

is used to see the variation

in the level of two

surfaces. Back pressure

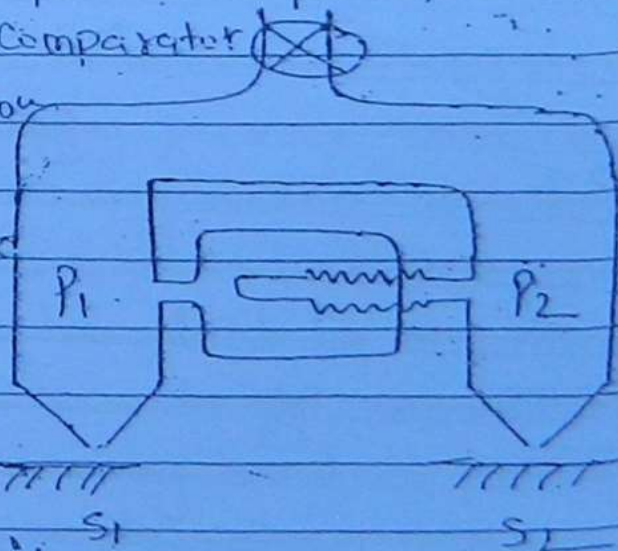
stream does not

mix inside the

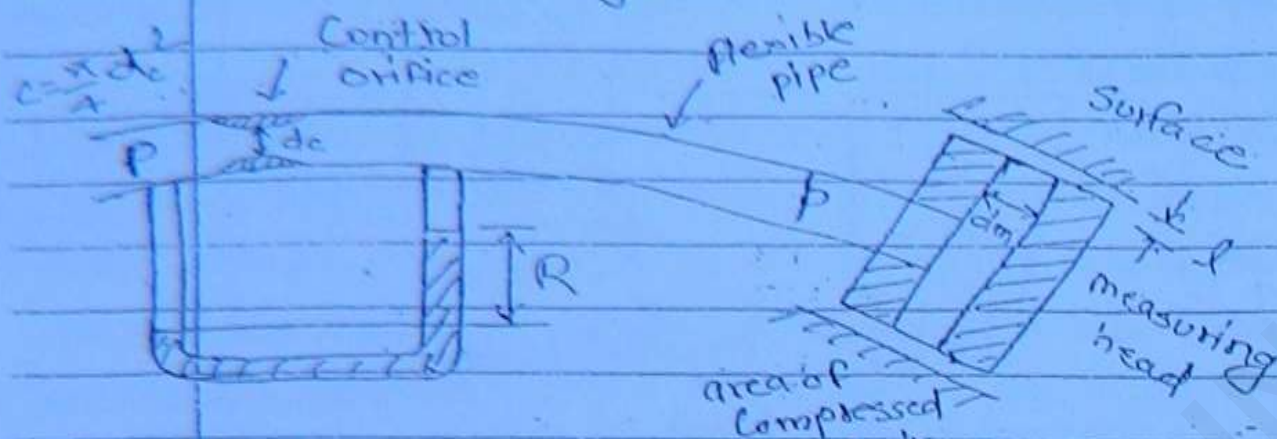
Bellow & by looking

at the position of

bellow from the centre it can be known that which surface is higher & which surface is lower

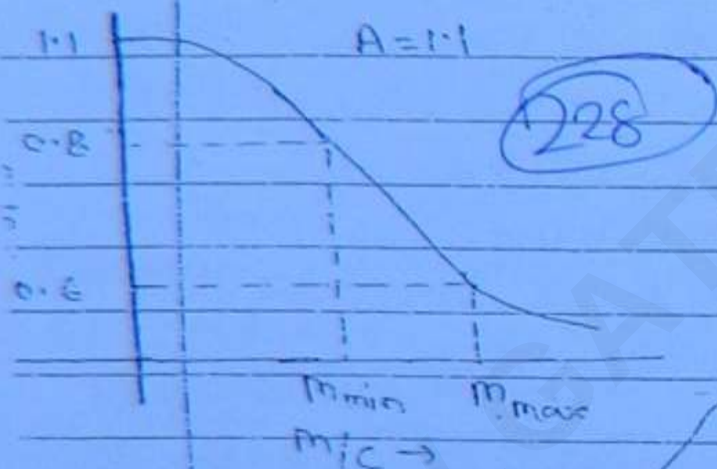


2 Back Pressure type:



$$p \propto M$$

$$P = A - b \left(\frac{M}{c} \right)$$



measuring head
area $m = \pi d_m l$

$$0.6 = 1.1 - \frac{b}{c} m_{\max} \quad \text{--- (1)}$$

$$0.8 = 1.1 - \frac{b}{c} m_{\min} \quad \text{--- (2)}$$

average

$$0.7 = 1.1 - \frac{b}{c} m_{\text{avg}}$$

$$\frac{b}{c} m_{\max} = 0.4 \quad \text{--- (3)}$$

$$\frac{b}{c} m_{\min} = 0.5$$

$$\frac{b}{c} m_{\min} = 0.3$$

$$\frac{m_{\max}}{m_{\min}} = \frac{5}{3}$$

$$\frac{m_{\max}}{m_{\min}} + 1 = \frac{5}{3} + 1 \Rightarrow \text{Range} = m_{\max} - m_{\min}$$

$$\frac{m_{\max}}{m_{\min}} - 1 = \frac{5}{3} - 1$$

$$\text{Range} = m_{\max} - m_{\min} = \frac{2}{3} m_{\min}$$

$$\frac{m_{\max} + m_{\min}}{2} = \frac{2}{3} \cdot \frac{m_{\min}}{2}$$

$$M_{\text{avg}} = \frac{4}{3} m_{\min} = 2 \text{ Range}$$

$$M_{\text{avg}} = 2 \text{ Range}$$

$$\frac{P}{P} = A - \frac{b}{C} m$$

$$\frac{dP}{dm} = -\frac{b}{C} P$$

229

$$\frac{b}{C} = \frac{0.4}{m_{\max}}$$

$$\frac{dP}{dm} = -\frac{0.4 P}{m_{\max}}$$

Pneumatic Sensitivity

As it can be seen from the Pneumatic Sensitivity that the system will be better when total pressure (P) is high, but the higher pressure require large size manometers, which may not be suitable for a Automatic point of view. When pressure is lower the signal may be lost by the time it reaches the manometer. So the manometer are placed as close to measuring head as possible. Response time of Pneumatic Comparator is poor because it takes time for the signal to reach manometer.

Magnification factor = output / input

$$= \frac{dR}{dl}$$

$$= \frac{dR}{dp} \times \frac{dp}{dm} \times \frac{dm}{dl} \rightarrow \begin{array}{l} \text{measuring} \\ \text{head} \\ \text{sensitivity} \end{array}$$

Indicator sensitivity

$$m = \pi d m l$$

$$\frac{dm}{dl} = \pi d m$$

230

The characteristic eqn of a pneumatic Comparator is represented by $\frac{p}{P} = 1.1 - 0.5 \frac{m}{C}$

which is linear in the range of 0.6 to 0.8 = p/p .

if the control orifice is 0.5 mm dia measuring orifice is 1 mm dia, indicator sensitivity $\frac{dR}{dp} = 25 \text{ mm} / 1 \text{ kgf/cm}^2$ pressure difference

if the total pressure is 2 bar determine
for (i) linear range of instrument

$l_{\max} - l_{\min}$ &

(ii) overall magnification

Sol: (i)

$$0.6 \geq 1.1 - 0.5 \frac{\pi d m l_{\max}}{\frac{\pi d^2}{4}}$$

$$0.6 = 1.1 - \frac{0.5}{4 \times 1 \times l_{\max}} (0.5)^2$$

$$l_{\max} = 0.0625 \text{ mm}$$

$$0.2 = 1.1 - 0.5 \times \frac{\pi d_m \cdot l_{\min}}{4}$$

$$8 = \frac{0.5 \times 1 \times l_{\min} \times 4}{(0.5)^2} = 3$$

(231)

$$l_{\min} = 0.0375 \text{ mm}$$

linear range $l_{\max} - l_{\min} = 0.025 \text{ mm}$

$$\begin{aligned} \textcircled{2} \quad \frac{dP}{dL} &= \frac{0.4 \times 2 \times 10^5}{\pi \times d_m \times \left[\frac{l_{\max} + l_{\min}}{2} \right]} \\ &= \frac{0.4 \times 2 \times 10^5}{\pi \times 1 \times \left(\frac{0.0625 + 0.0375}{2} \right)} \end{aligned}$$

$$= 509295.8179$$

$$\frac{dP}{dL} = \pi \times d_m = \pi \times 1 = \pi$$

$$dR = 25 \text{ mm}$$

$$dP = 1 \text{ kN/m}^2$$

$$\begin{aligned} \text{Magnification} &= \frac{(509295.8179 \times \pi \times 25)}{1000} \\ &= \frac{40000000}{1000} \end{aligned}$$

$$= 40000 \text{ } \underline{\underline{A_2}}$$

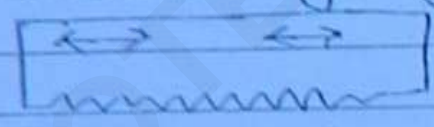
Screw thread Metrology:

- i) Major dia.
- ii) minor dia.
- iii) Pitch Pitch
- iv) Angle
- v) Pitch circle dia. (effective dia)

Major dia measurement $\begin{cases} \text{Flat ended micrometer} \\ \text{Tool makers microscope} \\ \text{Pointed anvil micrometer} \end{cases}$

Minor " " $\begin{cases} \text{Tool maker's microscope} \end{cases}$

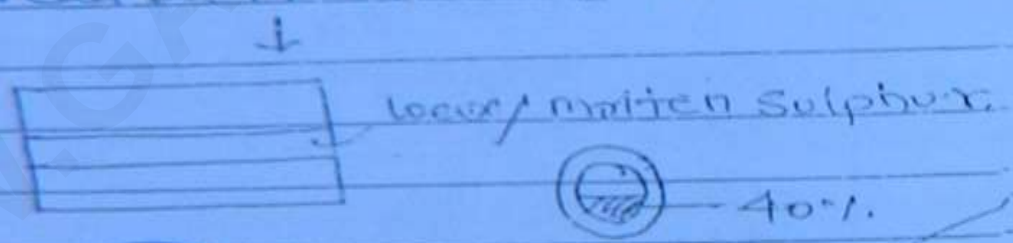
Pitch measurement — Thread Pitch gauges.



Angle measurement $\rightarrow$ Projector.

Pitch circle dia. measurement $\rightarrow$ 2 or 3 wire Method.

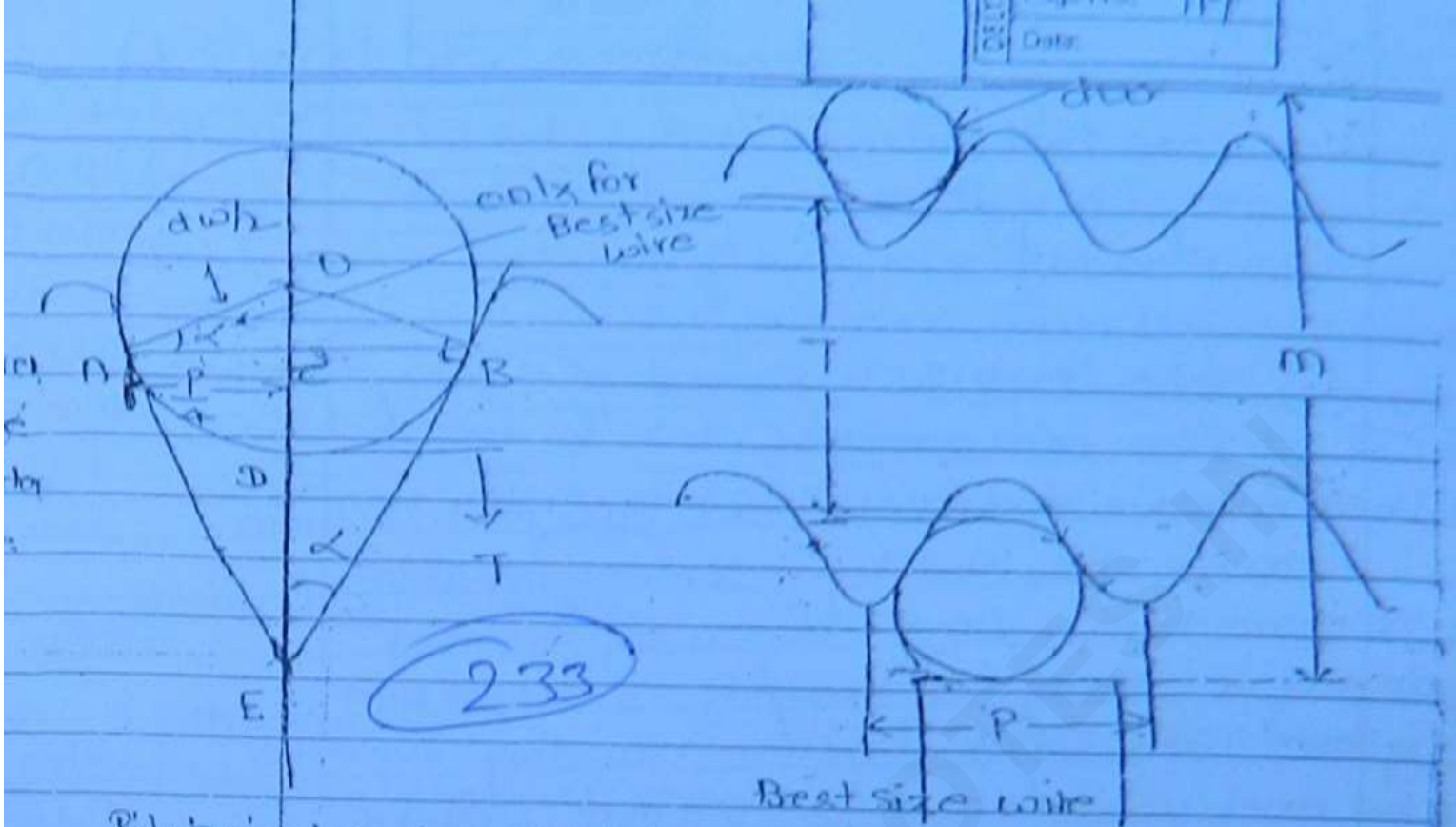
Internal thread measurement



For Best size wire

$$\frac{P/4}{dw/2} = \cos \alpha$$

$$dw_{best} = \frac{P}{2} \sec \alpha$$



Pitch circle dia. = $T + 2CD$
(P.C.D.)

$$T = m - 2dw$$

$$CD = OD - OC =$$

$$OC = OE - CE$$

in ΔORE

$$\frac{OE}{OB} = \sin \alpha$$

$$OE = \frac{dw \csc \alpha}{2}$$

in ΔBCS

$$OC = \frac{dw \csc \alpha}{2} - \frac{P \cot \alpha}{4}$$

$$\frac{BC}{CE} = \tan \alpha$$

$$CE = \frac{P \cot \alpha}{4}$$

$$CD = \frac{dw}{2} (1 - \csc \alpha) + \frac{P \cot \alpha}{4}$$

$$\therefore P.C.D. = T + dw(1 - \csc \alpha) + \frac{P \cot \alpha}{2}$$

Rolls are used for years
Rolls are used for threads

DELTA

Page No.

Date:

Grade 03:

Q:

$$\alpha = 30^\circ$$

$$p = 2 \text{ mm}$$

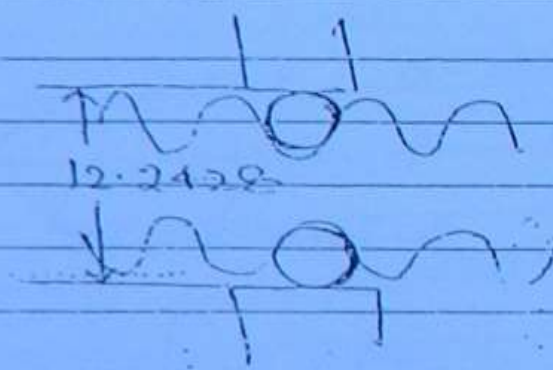
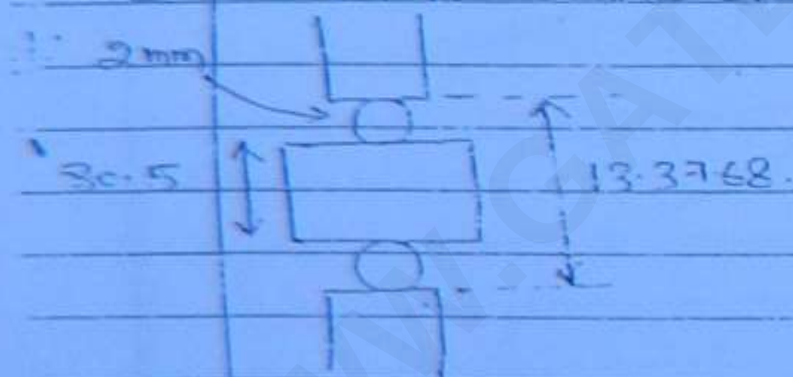
$$dw = \frac{p}{2} \sec \alpha = \frac{2}{2} \sec 30$$

$$= 1.155 \text{ Rollers}$$

234

Grade: 03

Q: A metric screw thread of pitch 3.5 mm is to be checked by 2 mm dia wire. The micrometer reading over a cylindrical standard of size 30.5 mm is 13.3768 mm along the wire, similar reading over the thread end wire is 12.2428 mm. Determine the effective diameter.



$$\text{Correction Factor} = 30.5 - 13.3768$$

$$= 21.1232 \text{ mm}$$

$$M = 12.2428 + 21.1232$$

$$M = 33.366 \text{ mm}$$

$$T = M - 2dw$$

$$= 33.366 - 2 \times 2$$

$$= 29.366$$

$$PCD = 29.366 + 2 (1 - \cos 30) + \frac{3.5}{2} \cot 30$$

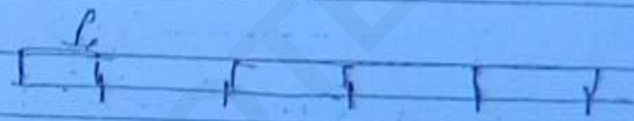
$$= 30.39 \text{ mm}$$

Acceptance test:

Dynamic test: Acceptance test are conducted on a new machine before including it in mass production. Dynamic test are those which are performed when the m/c are working. Standard materials are machined at a particular speed, feed & depth of cut combination and its accuracy and surface finish is observed.

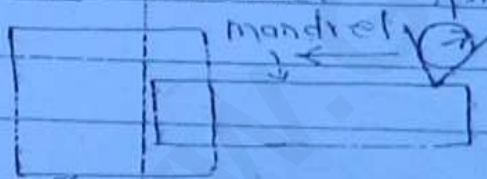
Static test: (235) Spirit level.

1st test: whether the bed is flat?



Machine bed is divided into segments and by keeping the spirit level from segment to segment position of its bubble is noted down.

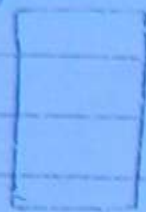
2nd test: whether spindle axis is parallel to bed?



A Mandrel is fitted in the spindle & is properly centered.

Base of the dial gauge is fixed over the carriage with plunger touching one side of mandrel. Carriage is then moved towards the spindle and if the spindle axis is parallel there will be no variation in dial gauge. But it is not possible to have these errors zero so these errors are permissible in the upward direction and towards the tool.

Grinding wheel



Conceal

single point with / Negative
Rack.
angle.

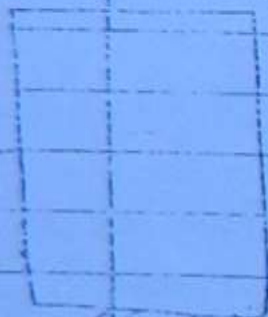
Two type of Feed:

① In feed: — depth of w/p $\downarrow$ [w/p]

② Through: $\rightarrow$ Parallel to w/p. [w/p]

if In feed $>$ through feed.
grinding is called material removal
creep feed grinding $\downarrow$

In feed $<$ through feed.
high speed grinding (finishing operation)



236

structure

if space is more open structure
less closed "

for ductile — open.

Brittle — closed.

Continuous chip (to support open)
Purified form chip

WWW.GATENOTES.IN