MADE EASY

Mechanical Engineering

Toppers Handwritten Notes

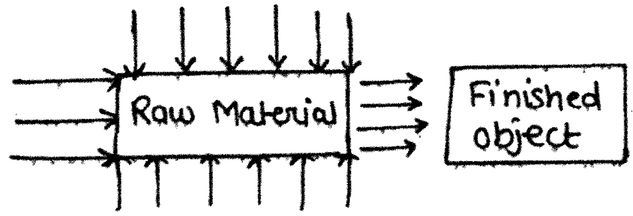
Production Engineering

• Manufacturing Process :→

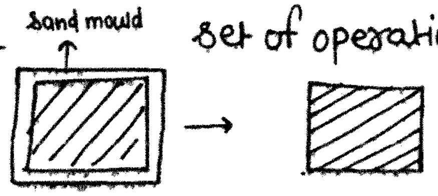
Manufacturing :→ It is a Process of converting raw Material into a finished Product.

It is a Process of value addition to raw material Such that final object is having more value in market when compare to raw Material.

ORE
↓
Furnace
↓
Liquid Metal
↓
Casting



Set of operations



• Classification of Manufacturing Process :→

1. Casting
2. Forming
3. Fabrication Process
4. Material removal Process

A. Zero Process

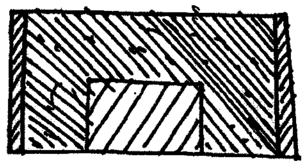
B. Additive Process

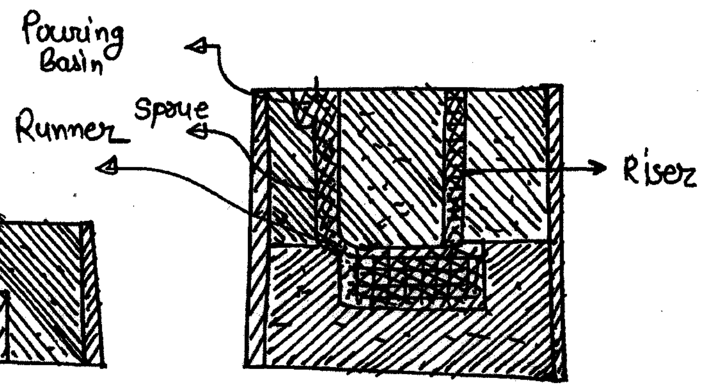
C. Subtractive Process

Casting:→ It is a Process in which molten Liquid metal is allow to Solidify in a Predefined mould cavity.

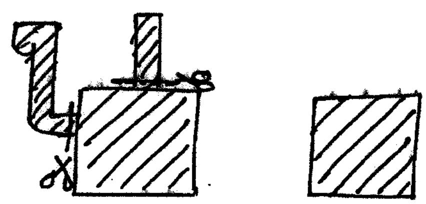
After Solidification by breaking the mould required shape of the object is Produced

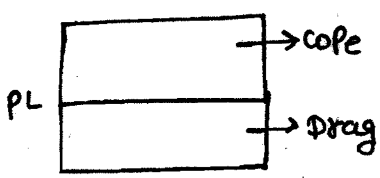
1. Pattern
2. Moulding Sand
3. Tools



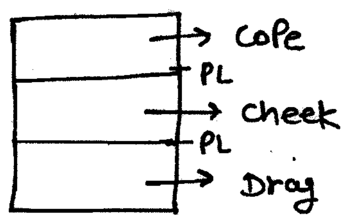


draw spike

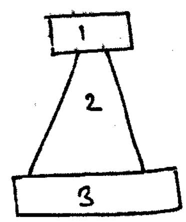




Two Box



Three Box



Advantanges:→

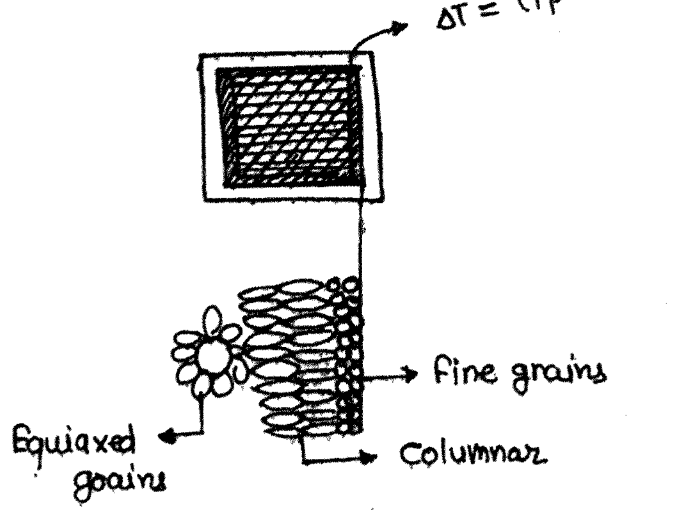
1. Complex shapes of the object can be easily Produced
2. Less expensive Process
3. Ductile and Brittle materials can be easily Produced.
4. Large Size objects Can be Produced by casting only. (100-150 Ton)

   eg. Machine tools Bed (lathe Bed), Road Roller, Turbine Housing etc

$T_p = T_m + \Delta t$ → degree of superheat (150°c - 200°c)

T_m → Melting temp.

T_p → Pouring temp.



· Limitations of casting :→

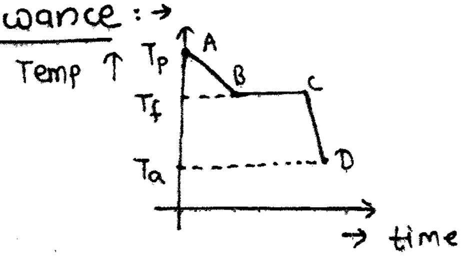
1. Casting objects are not having smooth surface finish.
2. It is Laborious and time consuming Process.
3. There is a Possibility of gas defects can be formed in the casting.
4. Due to Non-uniform cooling, non-uniform Grain-structure is Produced in the casting because of this Non-uniform Mechanical Properties will be Produced in the casting.

Pattern :→ It is replica of final casting to Produced with some allowances.

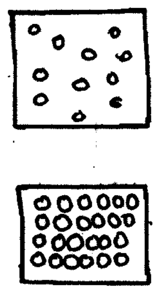
Allowances :→

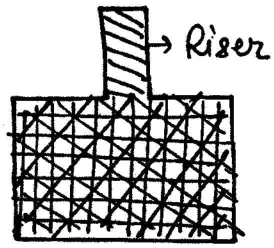
1. Shrinkage or contraction
2. Draft or Taper
3. Machining or finish
4. Shake or Rapping
5. Distortion or camber

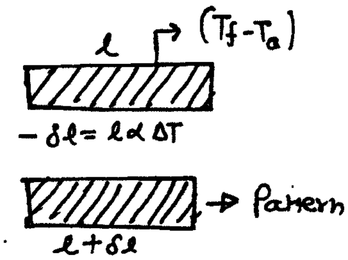
1. Shrinkage Allowance :→



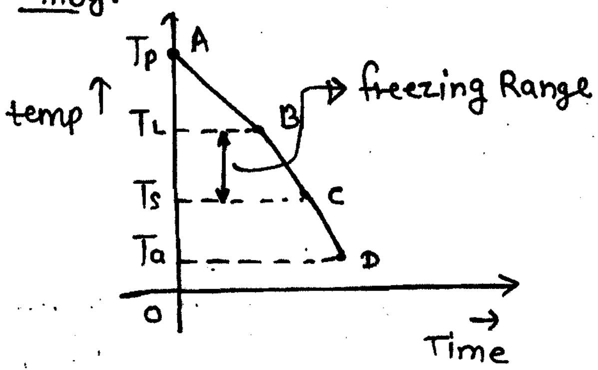
$(t_s)_r > (t_s)_c$ $t_s \rightarrow$ Solidification time







Alloy:



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

When the Liquid Metal is cooled from Pouring to freezing temp. Shrinkage is Liquid Shrinkage.

During Phase transformation shrinkage is Solidification Shrinkage.

With the solid casting is cooled from freezing to ambient temp. the shrinkage is solid shrinkage.

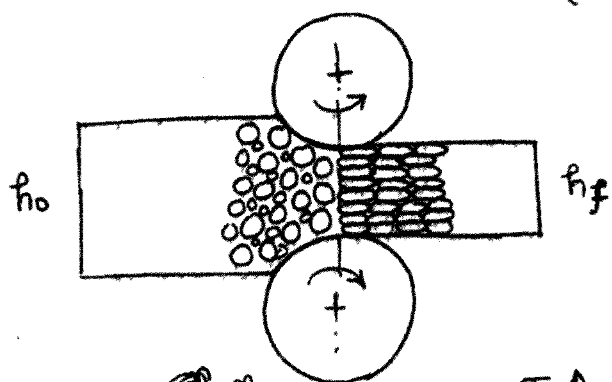
Liquid and Solidification shrinkage can be compensated by providing riser. Solid shrinkage can be compensated by providing shrinkage allowance in the Pattern.

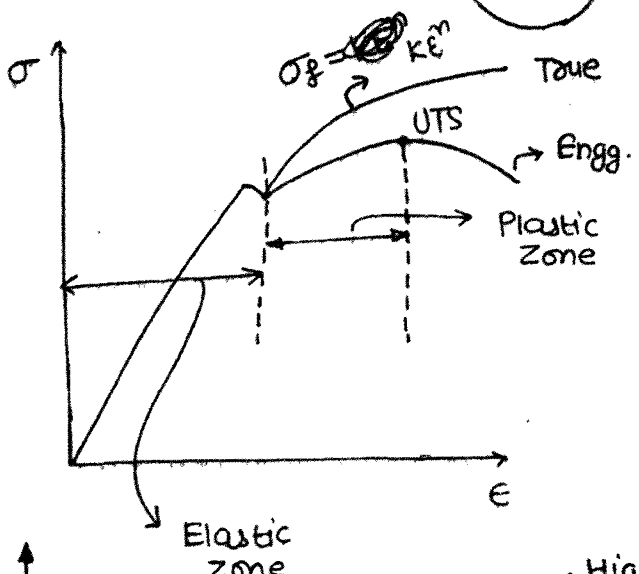
- Shrinkage Value : →

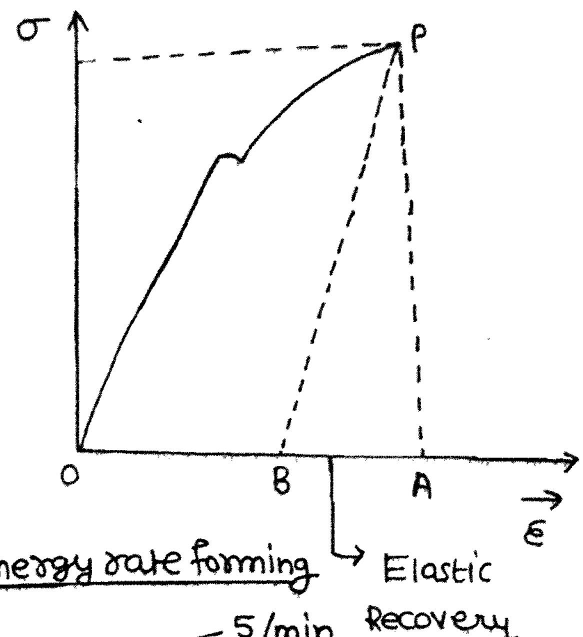
(i) Bismuth → Negligible
(ii) Whitemetal → 5mm/m
(iii) Cast Iron → 10mm/m
(iv) Aluminium → 13 mm/m
(v) Brass → 15 mm/m
(vi) Copper → 17mm/m
(vii) Steels → 20mm/m
(viii) Lead & Zinc → 23 mm/m

- **Metal Forming :→**

Bulk forming	Sheet Metal forming [t < 5mm]
1. Rolling	1. Punching / Blanking
2. Forging	2. Deep drawing
3. Drawing	3. Strech forming
4. Extrusion	4. Bending
$\left(\frac{A}{V}\right)\downarrow$	$\left(\frac{A}{V}\right)\uparrow$







$$\boxed{\sigma_f = K\epsilon^n}\ *$$

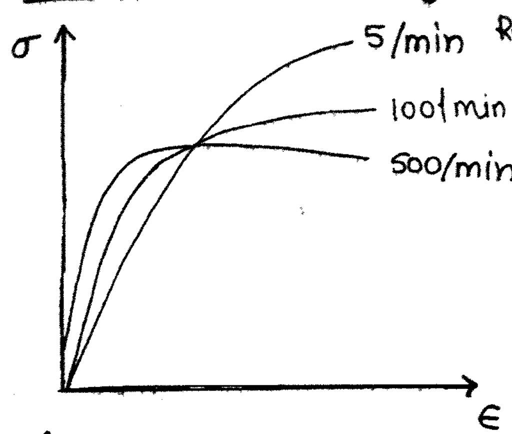
↳ flow Stress

Hollomon Equation

$0 < n < 1$

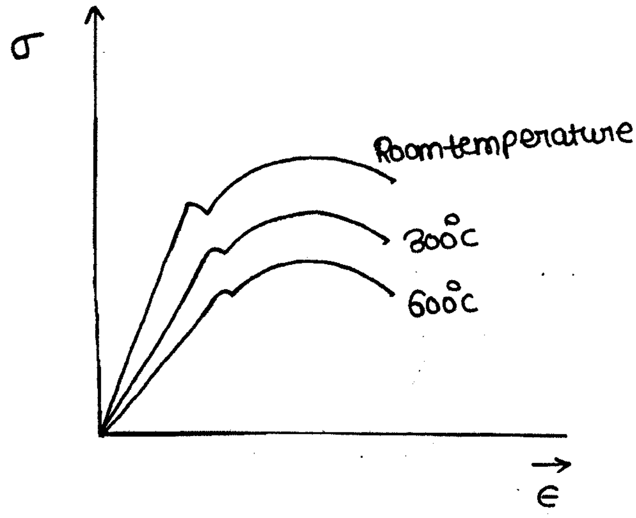
n: Strain Hardening Exponent

- High Energy rate forming



$\frac{d\epsilon}{dt}$

fig: At Room temperature



Elastic Recovery $\propto \frac{1}{E} \propto$ yield Stress

$\propto \frac{1}{(B/t)}$

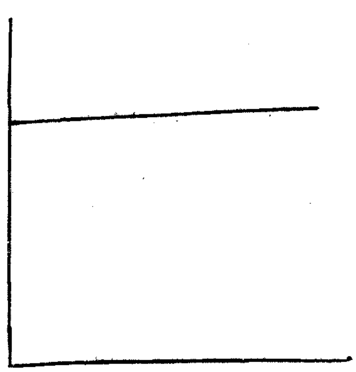
K = Strength coefficient

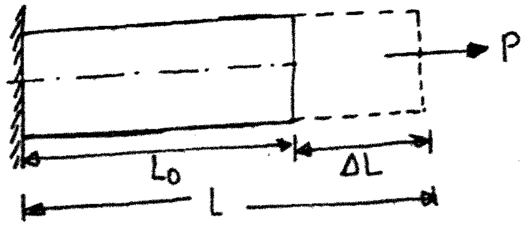
ϵ = true strain

Mechanical Properties appearing in stress-strain diagram like yield strength, ultimate tensile strength and % of elongation depends upon rate of deformation. (Strain rate)

As the rate of deformation increases stress-strain diagram shift towards left and there is an increase in yield strength of the material and elastic Recovery is Reduced. In case of High Energy rate forming techniques due to high strain rates Elastic Recovery is Negligible and the accuracy of the Component is High.

If the temperature is increasing stress-strain diagram shift towards right and yield strength of this material is decrease.





$A_o \rightarrow$ Initial Area

$L_o \rightarrow$ Initial ~~Area~~ Length

$A \rightarrow$ Instantaneous Area

$L \rightarrow$ Instantaneous Length

$e \rightarrow$ Engg. Strain $= \frac{\Delta L}{L_o}$

$\epsilon \rightarrow$ True Strain

$\sigma \rightarrow$ Engg. Stress

$\sigma_t =$ True Stress

$$L = L_o + \Delta L$$

$$\frac{L}{L_o} = 1 + \frac{\Delta L}{L_o} \Rightarrow \boxed{\frac{L}{L_o} = 1+e}$$

$$A_o L_o = A L$$

$$\frac{A_o}{A} = \frac{L}{L_o}$$

$$\sigma_t = P/A$$

$$= \frac{P}{A} \times \frac{A_o}{A_o}$$

$$\sigma_t = \frac{P}{A_o} \times \frac{A_o}{A}$$

$$\boxed{\sigma_t = \sigma(1+e)} \star$$

$$d\epsilon = \frac{dL}{L}$$

$$\epsilon = \int_{L_o}^{L} \frac{dL}{L} = \ln\left(\frac{L}{L_o}\right)$$

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

$$\boxed{\epsilon = \ln\left(\frac{l_f}{l_o}\right) = \ln\left(\frac{A_o}{A_f}\right) = \ln\left(\frac{d_o}{d_f}\right)^2} \star$$

Q Determine engineering strain, true strain, % elongation, % Reduction in Area.

For Rod which is double in Length

Sol^n.

$$L_f = 2L_o \Rightarrow \boxed{\frac{L_f}{L_o} = 2}$$

$$A_o l_o = A_f l_f$$

$$\frac{l_f}{l_o} = \frac{A_o}{A_f} = 2$$

$$e = \frac{2L_o - L_o}{L_o} = 1$$

$$\boxed{e = 1}$$

$$\epsilon = \ln(1+e)$$

$$\boxed{\epsilon = \ln 2 = 0.693}$$

% Reduction in Area =

$$\frac{A_o - A_f}{A_o} = \left(1 - \frac{1}{2}\right) \times 100$$

$$= 50\%$$

% elongation = 100%

MANUS + FACTUS

To make by Hand

New grains are forming

Material Removal Process: → "MACHINING"

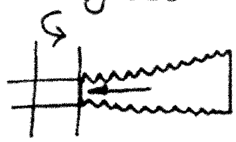
→ Geometry, Application

Single Point Cutting tool

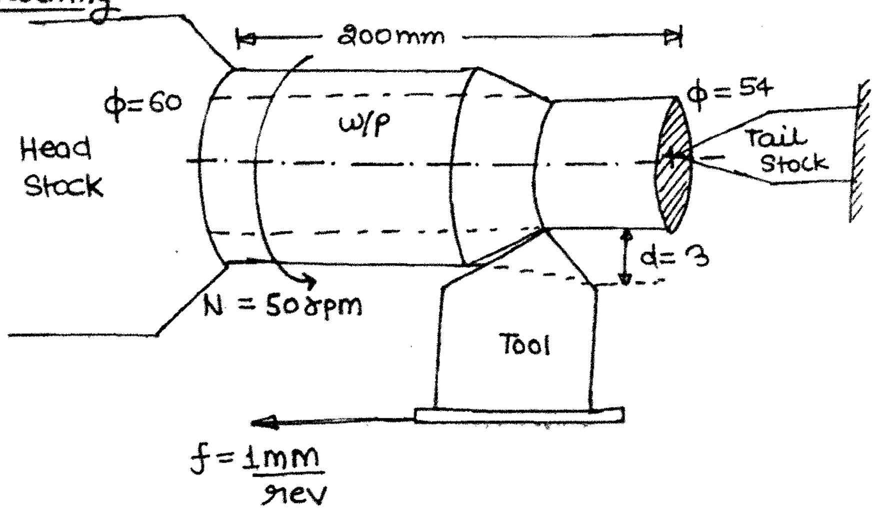
Multi Point Cutting tool

Traditional	Non-Traditional
• Turning	• ECM
• Grinding	• EBM
• Milling	• LBM
• Broaching etc.	• USM
	• WJM etc

Multi Point Cutting tool ↓ $n \times$ (Single Point Cutting tool)



• Turning: →

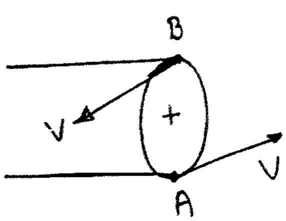


$$t_m = \frac{L}{V}$$ L → W/P, V → (D,N) ↳ W/P

$$t_m = \frac{L_e}{fN} = \frac{200}{1 \times 50} = 4\,min$$

fN → Axial Speed

where $L_e = L_{w/p} + \text{Allowance}$



→ tangential velocity

$V = \phi(D, N)$

$$V = \frac{\pi D N}{1000} \frac{m}{min}$$

Q→ Evalulate the time of machining a Brass bar of dia 50mm and Length 50mm, final dia is 42 mm. Spindle speed is 450rpm feed 0.2mm/rev., depth of cut 3mm and Length of approach is 3mm.

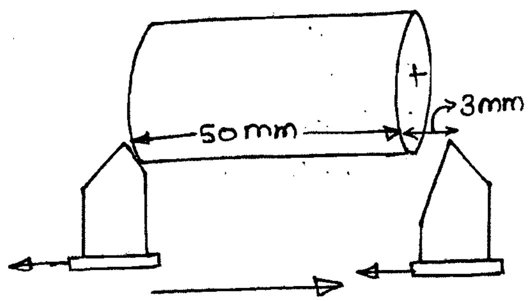
Solⁿ→

$D = 50mm$
$\updownarrow d = 3mm$ } Roughing
$D = 44\ mm$
$\updownarrow d = 1mm$ } Finishing
$D = 42mm$

$$t_m = \frac{L_e}{fN} \times n$$

$$t_m = \frac{53}{0.2 \times 450} \times 2$$

$$t_m = 1.177\ min$$



Rapid tool transverse = G00 (CNC code)

→

Que→ Find the machining time for a mild Steel Bar of diameter 52mm which is to be reduced to 44mm dia along the Length of 200mm with an approach allowance of 5mm. Cutting Parameter are as follows

Roughing Pass :- $V_{max} = 35 m/min$, $d = 3mm$, $f = 0.3\ mm/rev.$

Finishing Pass :- $V_{max} = 50 m/min$, $d = 1mm$, $f = 0.1\ mm/rev.$

$$N = \frac{V \times 1000}{\pi \times D_{max}}$$

$$V = \frac{\pi D N}{1000} \ \frac{m}{min}$$

Roughing

$$N = \frac{35 \times 1000}{\pi \times 52} = 214.24\,rpm$$

$$t_{m_1} = \frac{205}{0.3 \times 214.24} = 3.189\,min$$

Finishing

$$N = \frac{50 \times 1000}{\pi \times 46} = 345.9\,rpm$$

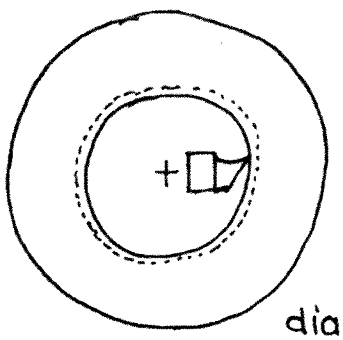
$$t_{m_2} = \frac{205}{0.1 \times 346} = 5.92\,min$$

$$t_m = t_{m_1} + t_{m_2}$$

Total time (t_m) = 9.11 min

If V_{max} is given $N = \frac{V \times 1000}{\pi \times D_{max}}$

is V_{avg} is given $N = \frac{V \times 1000}{\pi \times D_{avg}}$



dia enlargement

Hollow cylinder

Internal Turning ⇒ "Boring"

L = 100mm Hollow cylinder d = 2mm V = 30m/min

30mm ⟶ 40mm f = 0.1mm/rev.

time of machining

Sol^n →

30
↓ d = 2
34
↓ d = 2
38
↓ d = 1
40

1st Pass

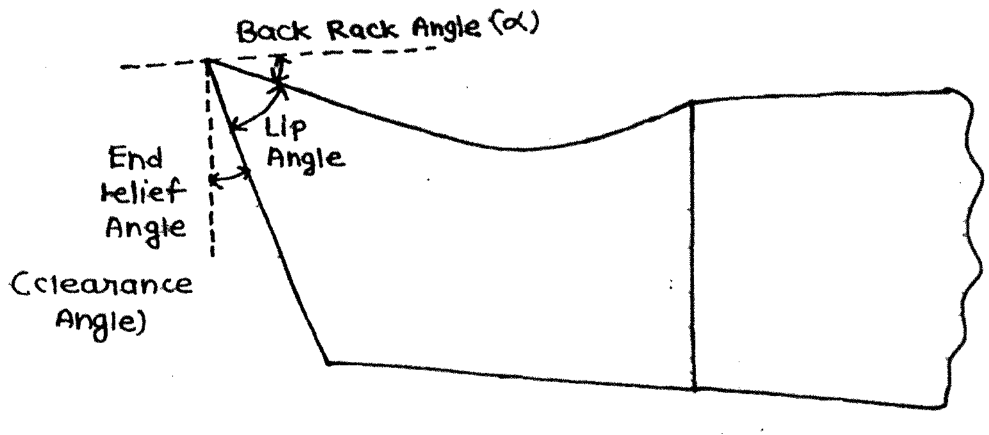
$$N = \frac{30 \times 1000}{\pi \times 32} = 298.41\,rpm$$

$$t_1 = \frac{100}{0.1 \times 298.41} = 3.35\,min.$$

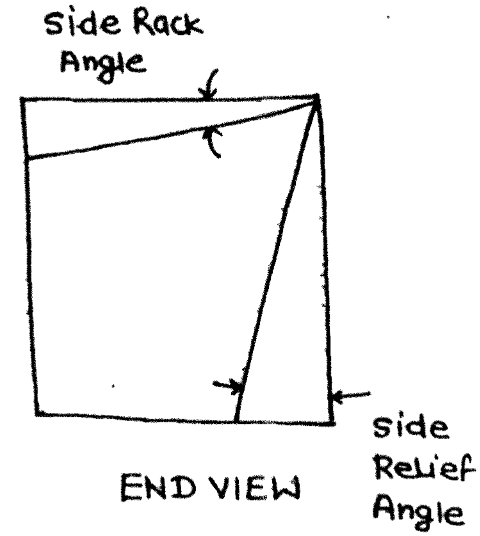
2nd Pass

$$N = \frac{30 \times 1000}{\pi \times 36} = 265.25\,rpm$$

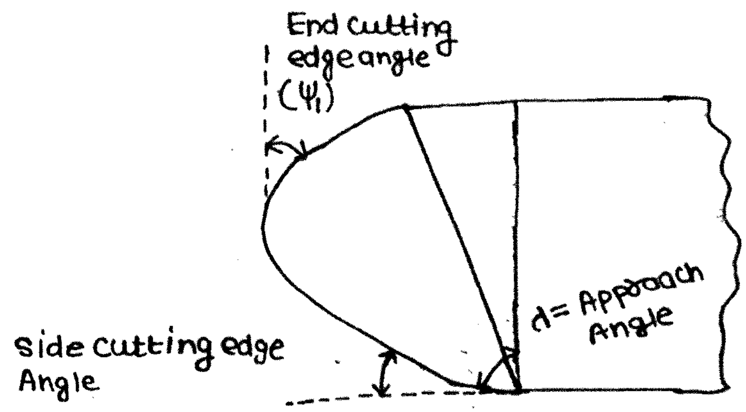
$$t_2 = \frac{100}{0.1 \times 265.25} = 3.77\,min$$



ELEVATION



END VIEW

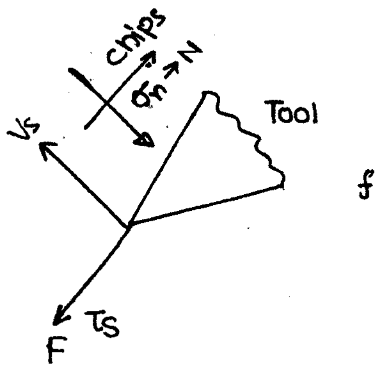


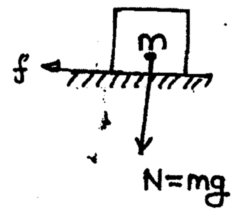
PLAN

- Back Rack Angle

A Line is drawn Parallel to the tool Axis passing through the tip of the tool, the angle this Line makes with the Rack Face is called Back Rack Angle.

This Angle is measured in a Plane Parallel to the tool Axis Perpendicular to the base Plane.





$f = \mu N$

Temp. ↑ μ ↑ $\tau_s = \mu \sigma_n$

τ_s ↑ $\tau_s \not> k'$

↳ yield strength in shear

$\tau_s = k'$ sticking

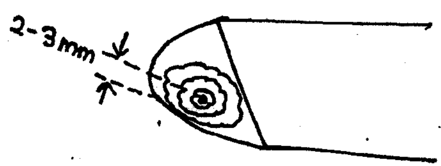
$\tau_s < k'$ → slipping

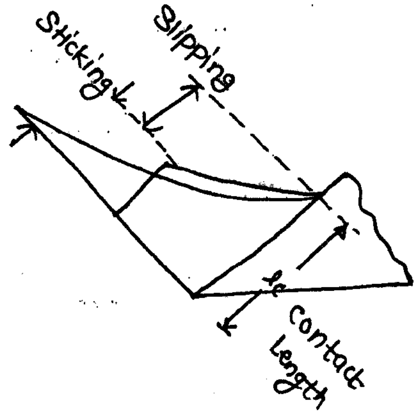
$F_c V = F_s V_s + F V_c$

↓ Cutting energy (Total)

↓ Shear Energy

↓ Friction Energy





α ↑, l_c ↓ A ↓

F ↓

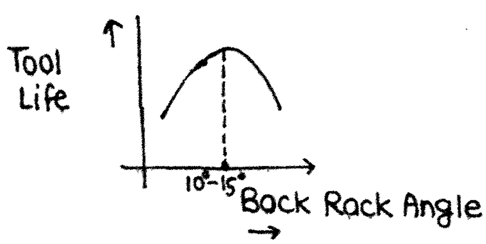
Amonton's Law

$F = \oint_A \tau_s$

$N = \oint_A \sigma_n$

Machining takes place by breaking the crystal structure of work material. The velocity with which crack is propogating inside the material is called shear velocity. As the crystals are breaking a portion of the energy comes out in the form of heat. Increase in temperature will increase the coefficient of friction and when the shear stress becomes equal to the yield strength in shear there will be sticking between the two materials.

> After machining as chips are flowing over the Rack Face there will be sticking between the chip and the Rack Face due to which chips continues to experience a heavy Drag. So max. temperature over the Rack Face appears 2-3mm away from the cutting edge. By increasing the back Rack Angle there will be decrease in the contact length between the chip and the Rack Face. Hence contact Area will decrease, so lesser energy will be required to overcome the friction between Rack face and the chip. This will decrease the overall power consumption.
>
> Secondary function of Back Rack Angle to Guide the chip Flow.



• Select

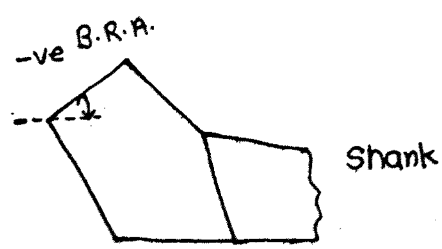
1> work-strong cu alloys (Brass & Bronze)

2> Threading or Plunge cut

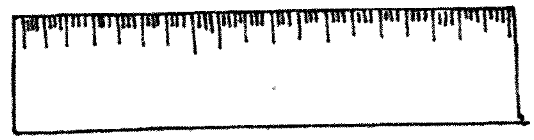
(i) $\alpha = 0$

(ii) Aluminium, Pb $\alpha = 5-10°$

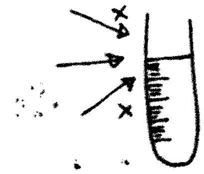
3> carbides or Ceramics $\alpha = -ve$



Metrology :→ [Science of Measurement]
↓
Standard is required



Parallax error



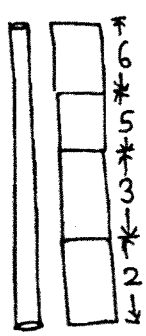
Line Standard

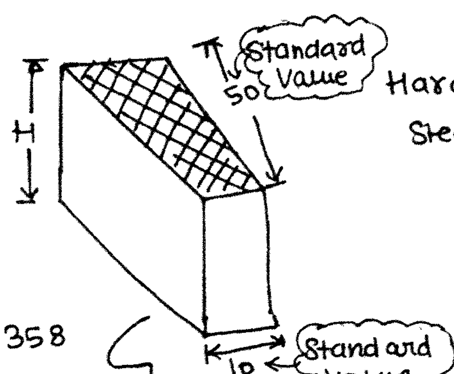
Standard ⇒ It is an authority which is set-up or established to measure Length, Weight, quantity, quality, angle etc.
eg: IOML → International organisation for measurement of Length.

LENGTH STANDARD
- Line Standard
  - eg: metre Scale
  - → Less time consuming
  - → Less Accuracy
- End Standard
  - eg: Slip Gauge
  - → Time consuming
  - → High Accuracy Skilled Labour
  - → required

IS- 919-1996

Range	Step Size	Number
1·001–1·009	0·001	9
1·01 – 1·49	0·01	49
0·5 – 9·5	0·5	19
10 – 100	10	10





Hardened Steel & Heat treated

Slip Gauge
↳ Ground to High Accuracy and Surface finish

eg:
96·999
1·009
1·49
4·5
90

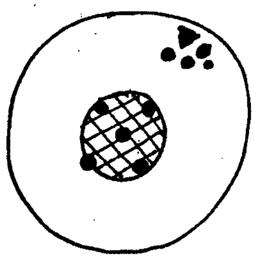
96·999

eg
72·358
1·008
1·35
6·5
50

58·975

eg: 58·975
1·005
1·47
6·5
50
58·975

- **Accuracy:** →
  It is the degree of closeness of a value with respect to true value.



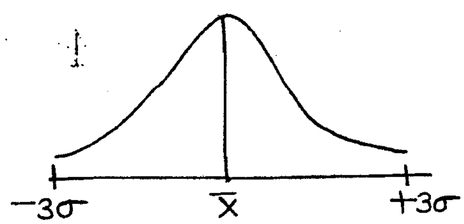
- **Precision:** → Degree of Repeatability
  It is the degree of closeness of a value w.r.t. other measured values

No Dimension is Exact ★
↳ Tolerance

- **Limits And Tolerance:** →

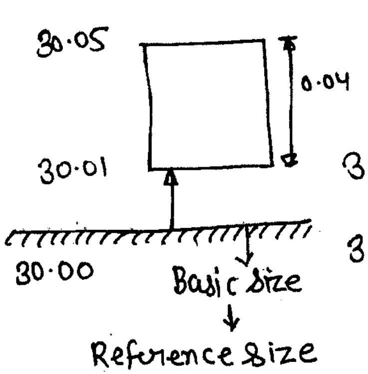
Limit → Permissible range within which value must lie

Limit ↙ Ecart Superieur ↘ Ecart Inferieur



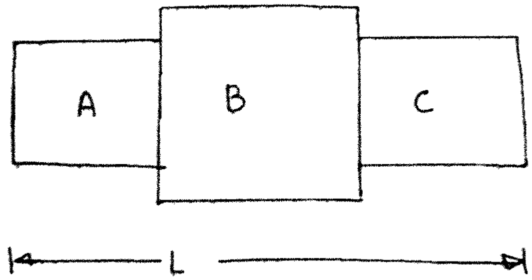
Value = $\bar{X} \pm 3\sigma$

Tolerance = ES − EI
↓
Difference b/w Upper Limit & Lower Limit



Tolerance

- Unilateral
  - $30^{+0.05}_{+0.01}$
  - $30^{-0.03}_{-0.06}$
- Bilateral
  - $30^{+0.03}_{-0.01}$ → Unequally Bilateral
  - 30.01 ± 0.02 → Equally bilateral



$B = L - (A + C)$

$= 30.01 \pm 0.06$

$A = 30^{+0.02}_{-0.04} = 29.99 \pm 0.03$

$B = ?$

$C = 40 \pm 0.02$

$L = 100 \pm 0.01$

$B = 30^{+0.07}_{-0.05}$

$B = 30.01 \pm 0.06$

$B_{max} = L_{max} - A_{min} - C_{min}$

$= 100.01 - 29.96 - 39.98$

$= 30.07$

$B_{min} = L_{min} - A_{max} - C_{max}$

$= 99.99 - 30.02 - 40.02$

$= 29.95$

Steps:

(I) convert all tolerance as equal bilateral.

(II) Use B.S. only in arithmatic operation.

(III) Add all tolerances.

Que → 17/WB/Ch-13

$R = 13.01 \pm 0.03$

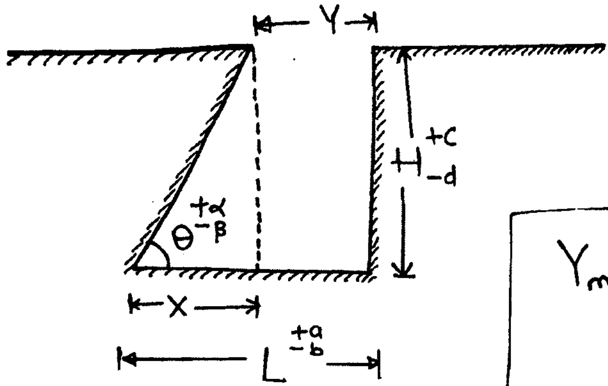
$W = 35 - 12 - 13.01 = 9.99$

$W = 9.99 \pm 0.13$

0.08
0.02
0.03
0.13

→

- **Compound Tolerance :→**



$$Y = L - X$$

$$Y_{max} = L_{max} - X_{min} = L^{+a} - \frac{H^{-d}}{\tan\theta^{+\alpha}}$$

$$Y_{min} = L_{min} - X_{max} = L^{-b} - \frac{H^{+c}}{\tan\theta^{-\beta}}$$

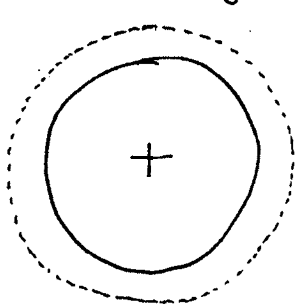
$$\tan\theta = \frac{H}{X}$$

$$X = \frac{H}{\tan\theta}$$

$$X_{max} = \frac{H_{max}}{(\tan\theta)_{min}} = \frac{H^{+c}}{\tan\theta^{-\beta}}$$

$$X_{min} = \frac{H_{min}}{(\tan\theta)_{max}} = \frac{H^{-d}}{\tan\theta^{+\alpha}}$$

- **Shaft Plating**



t = Plating thickness
D_i = diameter before Plating
D_f = diameter after Plating

$$D_f = D_i + 2t$$

$$t = 80 \pm 2\ \mu m$$

$$\text{dia after Plating} = 20^{+0.05}_{-0.03}\ mm$$

find the diameter of shaft before Plating.

Material Science

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• Crystal Structures

(Glass → Supercooled Liquid)

1. Material science is basically study of relationship between structure and Properties of Engineering materials.

2. Based on the structure all engineering materials are classified into two basic types: They are Crystalline materials and Amorphous material.

3. Amorphous material Which do not exhibits regular, repeated & orderly arrangement of atoms / Ions / molecules
   eg: waxes, Polymers, Glass, charcoal etc.

4. Crystalline materials are those materials which exibit 3-D, Long range, Periodicity of arrangement of atom, Ions or molecule in the Internal structure.

Crystalline Materials

↳ Atomic Solids → Metals

↳ Ionic Solids → Ceramics

↳ molecular Solids → Crystalline Polymers

Amorphous materials

Can exist any state

Can be converted into crystalline materials

Crystalline $\xrightarrow[\text{Cooling}]{\text{fast}}$ Amorphous

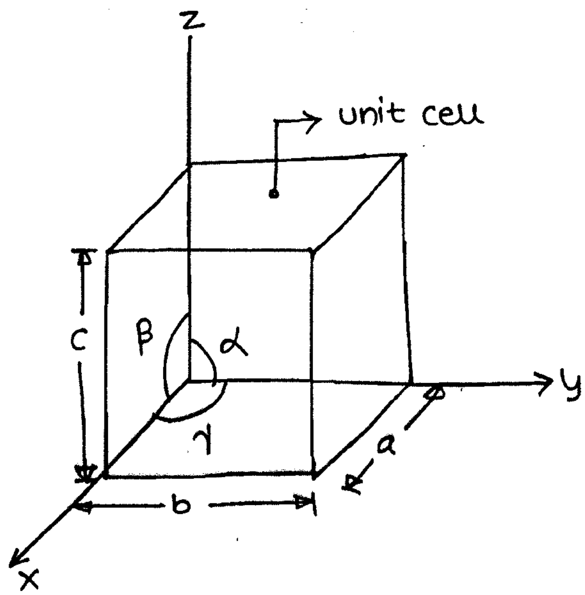
Material type
└ (We cannot Judge by Naked eye)

5. Crystal structure of unknown material are determine by X-Ray diffraction technique. This is experimental technique.

6. Based on X-Ray diffraction technique all crystalline materials classified into seven crystal system and these are sub classified into 14 Bravais Lattices

7. The term crystal system refers to basic shape of unit cell whereas bravais Lattices refers to Atomic Arrangements within a unit cell

8. A unit cell is defined as the smallest representative group of atoms, which when repeated in all the crystallographic direction for Infinite number of times results in the development of crystal lattice.



x, y, z = crystallographic axes

a, b, c = Lattice Parameter

α, β, γ = Interaxial angles

Stability → minimization of Potential energy

Crystal System	Geometry	Bravais Lattices
Cubic ↳ Metal	$a=b=c$ $\alpha=\beta=\gamma=90^\circ$	Simple (S), BCC, FCC
Tetragonal	$a=b\neq c$ $\alpha=\beta=\gamma=90^\circ$	ST, BCT
orthorhombic	$a\neq b\neq c$ $\alpha=\beta=\gamma=90^\circ$	SO, BCO, FCO ECO
Rhombohedral	$a=b=c$; $\alpha=\beta=\gamma\neq 90^\circ$	SR
Hexagonal For metal	$a=b=c$ $\alpha=\beta=90^\circ, \gamma=120^\circ$	SH
Monoclinic	$a\neq b\neq c$ $\alpha=\gamma=90^\circ\neq\beta$	SM, ECM
Triclinic	$a\neq b\neq c$ $\alpha\neq\beta\neq\gamma\neq 90^\circ$	STr

Simple (S)
Body centred (BC)
Face centered (FC)
End centered (EC)
→ Generally

• Some Important defination

1. crystal lattice is defined as a 3-D dimensional Network of Lines in Space, It is also known as Line Lattice.

2. Space Lattice is defined as 3-D dimensional Network of Points in Space, It is also known as Point Lattice.

3. Primitive cell is defined as a simple cubic unit cell having atoms only at the corners.

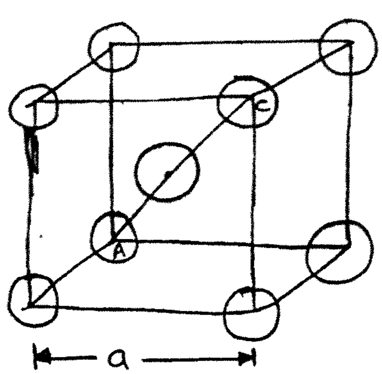
4. Lattice Parameter is defined as the distance b/w centres of neighbouring corner atoms

5. crystal structures characteristics

Characteristic	BCC	FCC	HCP
a to r relation	$a = \frac{4r}{\sqrt{3}}$	$a = \frac{4r}{\sqrt{2}}$	$a = 2r$
Average no. of atoms (Nav)	2	4	6
coordination number	8	12	12
Atomic Packing Factor (APF)	0.68	0.74	0.74

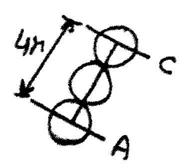
Let 'a' = Lattice Parameter
r = Atomic Radius

• BCC



AC = Body diagonals of unit cell
$= a\sqrt{3} = 4r$

$$a = \frac{4r}{\sqrt{3}}$$



example →

Fe [Except in 910 – 1400°C]
W, Cr, V, Mo, Ta etc.
Hard & Brittle