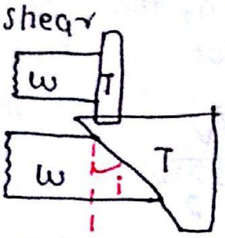
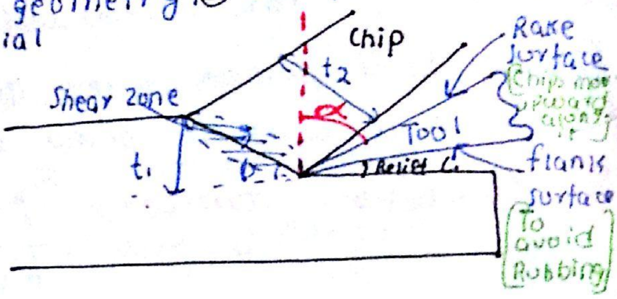
Metal cutting :- ① m/c used, ② cutting tool material and geometry, ③ work piece ④ cutting parameters, ⑤ work holders ## Process: Removing material as chips

Mechanics of m/c :- Deformation by shear

Classification of m/c :- orthogonal / oblique





Orthogonal - ① cutting edge of tool at 90° to tool feed ② chip flow ⊥r to cutting edge ③ i = 0 ④ chips get coiled (∴ heat & pr. concn) ⑤ ↑ Tool life ⑥ 2 force component ⑦ sloting, parting

Oblique - ① at an acute ∠. ② at an ∠. ③ i ≠ 0 ④ chip flow side way (↓ heat → pr. concn) ⑤ ↓ ⑥ 3 ⑦ milling drilling

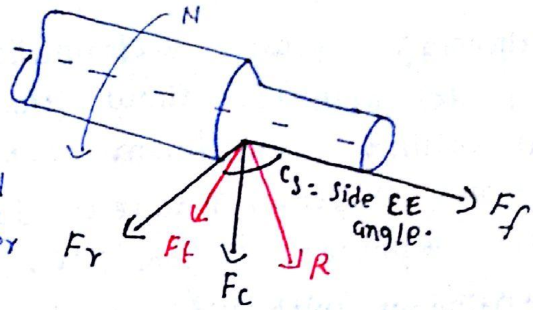
Forces in single pt. Tool : F_r = Radial force (Along axis of tool)

F_f = feed force

F_c = In direcn of depth

F_t = Res. of F_r, F_f

R = " " F_t, F_c



Orthogonal ~~$F_t = 0$~~ $F_r = 0$ $F_t = F_f$ $R = \sqrt{F_f^2 + F_c^2}$

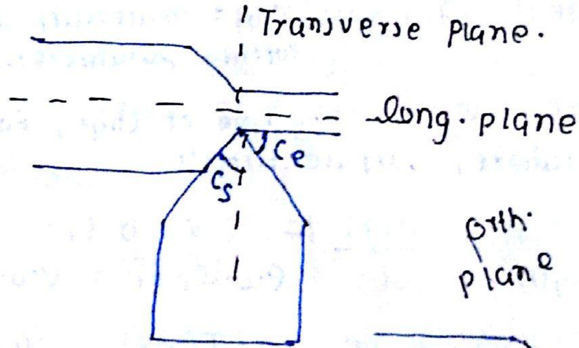
cutting force F_c = in direcn of cutting velocity, largest, ver. plane, tangential to work surface, Tangential force, 99% of power

Feed force F_f = Hori. plane, ∥ to axis of work, direcn of tool feed, 30-60% of F_c

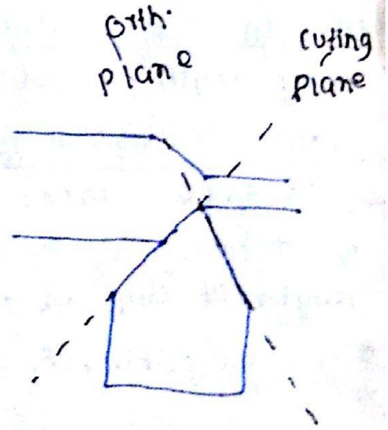
F_R = ⊥r to m/c surface in hori. plane along Tool axis, 20-40% F_c. $F_r = 0$ for orthogonal

Tool signature : ASA - American standard asso. system ① Tool in hand : Tool is considered idle against w.p. ② based on m/c Ref. plane

ORS - orthogonal Rake system ① Tool is active and works against w.p. ② based on Tool R.P.



ASA	ORS
3 Ref. planes	3 Ref. planes
1- Hori. base plane	1- hori base plane
2- Long. plane (i) ⊥r to B.P. (ii) ∥ to feed direcn	2- cutting plane (i) ⊥r to B.P. (ii) passes thru side cutting edge
3- Transverse plane (i) ⊥r to both planes (ii) ∥ to Transverse motion of tool	3- orthogonal plane ⊥r to both planes



ASA - α_b, α_s, θ_e, θ_s, C_e, C_s, R

ORS - I, α_n, θ_e, θ_s, C_e, λ, R

I = Inclination ∠.

α_n = normal rake

λ = approach ∠ = 90 - C_s

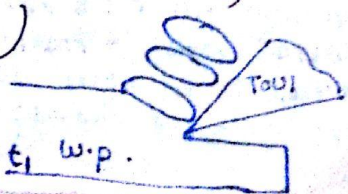
CTST(-) $\tan I = \cos C_s \tan\alpha_b - \sin C_s \tan\alpha_s$ CAB (C_s, α_b) CAS (C_s, α_s)

CTST(+) $\tan\alpha_n = \cos C_s \tan\alpha_s + \sin C_s \tan\alpha_b$ (CAS - CAB)

Types of Chips : 1- Discontinuous - Brittle fracture, small segments of chips, Easy to handle

condn - ↓ cutting speed, ↓ Rake ∠, ↓ feed, Brittle work material, ↑ t_1 w.p.

effects - Tool life ↓, Power ↑, sur. finish ↑

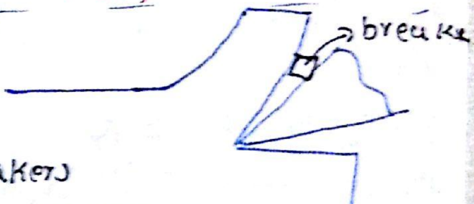


(1) Turbine for underwater power stations → (i) Tubular Turbine.
(ii) Bulb Turbine.

(2) → η of pump is less than that of Turbine generally.
→ More losses in pump due to eddies and Turbulence.

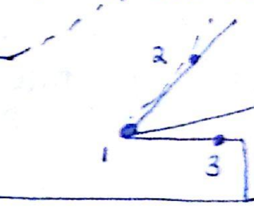
(3) Cavitation Number = $\frac{P - P_v}{\rho v^2/2}$ P = Abs pressure ρ = Density
P_v = vap. " of fluid V = free stream velocity

(4) When a moving Automobile experience wind resistance →
Then use $\frac{F}{\rho v^2 d^2}$ = const. Thus $\frac{F_2}{F_1} = \left(\frac{V_2}{V_1}\right)^2$.



2-Continuous: ↑ plastic deformation, longer continuous chips, desirable b/c show stable cutting.
Spiral Coiling can harm operator or finish ∴ chip breakers
Condition - ↑ speed, ↑ Rake ∠, ductile, suitable cutting fluid, ↓ t_1
Effects - ↓ power, ↑ Tool life, steady and stable forces, ↓ μ b/w chip and tool.

3- Continuous with BUE: Ductile material, ↓ speed, weld spots at tip of tool-(1) which later breaks into 1,2,3.
Condition - ↓ speed, ↓ Rake ∠, material with ↑ adhesion
Effects - ↓ flank wear, ↑ Tool life, ↓ sur. finish, ↑ power ↔ ↑
* disappears with ↑ in speed, rak ∠, suitable cutting fluied.



Independent variables: Tool: material, shape, condn   work: material, condn, Temp.
Cutting parameters: f, N, C. fluid work holding & fixturing

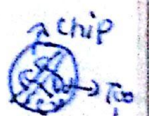
Dependent variables: Type of chip, Force & Energy dissipated, Temp. Rise, wear & failure, surface finish

MRR in Tool cutting: # $\rho \cdot v_c \cdot b \cdot t_1 = \rho \cdot v_f \cdot b \cdot t_2$ ⇒ $v_f = v_c \cdot r$
By length of cut: $\rho \cdot b \cdot l_1 \cdot t_1 = \rho \cdot b \cdot l_2 \cdot t_2$ $r = \frac{t_1}{t_2} = \frac{l_2}{l_1}$

Specific cutting Energy: U_c (J/m3): $U_c = \frac{F_c}{b \cdot t} = \frac{N}{m^2} = \frac{N \cdot m}{m^3} = \frac{J}{m^3}$
$W = F_c \cdot U$ mrr: $U \cdot b \cdot t$ (m3/s)

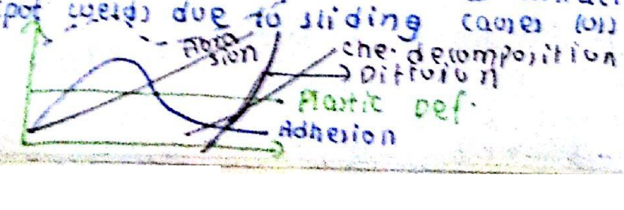
Q- Turning: F_c, F_T given - outer dia D velocity V Rake ∠ α depth of cut d length of chip l_2. Ans: $F = F_c \sin\alpha + F_T \cos\alpha$ $\lambda = \tan^{-1}\frac{F}{N}$ * $t_1 \cdot b \cdot \pi D = t_2 \cdot b \cdot l_2$
$N = F_c \cos\alpha - F_T \sin\alpha$ $r = \frac{t_1}{t_2} = \frac{l_2}{\pi D}$ find φ
Q- Normally: Find F_s using τ_s, b, t_1, ϕ. Find F_c by $\frac{F_s}{\cos(\phi+\lambda-\alpha)} = \frac{F_c}{\cos(\lambda-\alpha)}$

Mechanism of Tool wear: 1- Diffusion: - At ↑ T diffusion of Alloying elements (from ↑ concn to ↓ concn) towards chip.
- depends on concn gradient & Temp.



2- Abrasion: If material has very hard particle due to Rubbing it dislodges from other
3- Adhesion: - At ↑ T & Pr. metallic bond b/w chip & tool at contact pt).
as weld spots - Fracture of spot welds due to sliding causes loss of material from both surfaces

Wear Rate vs speed:



① (i) ~~(i)~~ single pt. Tools : Turning, Boring, Shaping, planing.

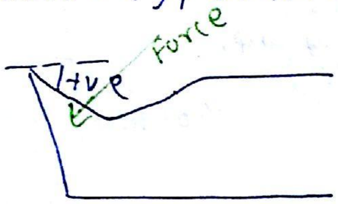
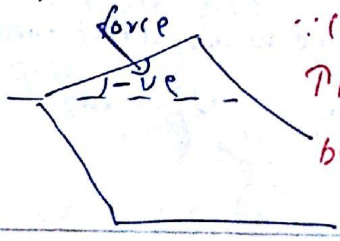
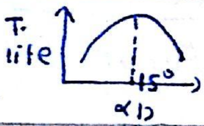
(ii) multiple pt. " : Drilling, Reaming, Tapping, milling, Broaching, Sawing.

② **RAKE ∠.** Guide the chip away from the cutting edge

Thus ↓ chip pressure on face ⇒ ↓ force, ↓ power

Large α : Soft and ductile material, ↓ power, Easy cutting

Small α : To cut hard material, ↑ Tool strength, ↑ Tool life.

-promotes chip formation -Reduces Force, power consumption +ve Rake		-ve Rake
(i) work material	Soft and ductile	↑ strength alloys, hard, brittle
(ii) Type of cutting	continuous	Interrupted
(iii) Forces	Shearing, Bending 	compressive (∵ For carbide Tools)  ∵ carbide ↑ compressive σ but ↓ Tensile
(iv) Heat dissipation and Tool life	Poor	Good
# For ↓ speeds # ↓ F_c, Power needed.		* For less Tensile strength tools * Best α_b = 22°

Note 0° back Rake ∠ → Brass, Thread cutting.

③ (i) End clearance (θ_e) : Allows End of cutting Tool to Enter work

(ii) side " (θ_s) : " side of Tool to advance into "

④ (i) Side cutting edge ∠ (C_s) (15°-30°) : -It determines chip flow direcⁿ.
-prevents Interference as tool enters w.p.

→ Large C_s : ↑ Tool life, ↑ chatter, vibration.

→ How life ↑ : By this wider chips produced → Heat over large Area

→ Imp : Thus no effect on force, power. * $T_{max} \propto \sqrt{f \cdot \cos C_s}$

Too small affects surface finish.

(ii) ECEA (8°-15°) :

⑤ NOSE RADIUS : ↑ finish, Tool life, F_c, power, vibration, chattering

Too large → chatter

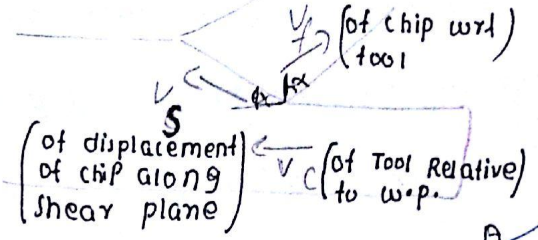
Too small → weakens pt.

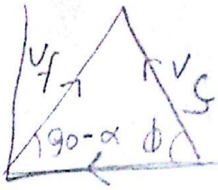
(6) (i) Chip thickness Ratio: $r = \frac{t_1}{t_2} = \frac{\sin\phi}{\cos(\phi-\alpha)}$ $\tan\phi = \frac{r\cdot\cos\alpha}{1 - r\sin\alpha}$

$t_1/t_2 = l_2/l_1$.

(ii) Shear Strain: $\gamma = \tan(\phi-\alpha) + \cot\phi$

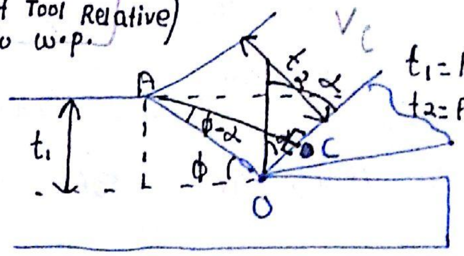
(iii) Velocity Relation:





2-D orthogonal cutting:
↳ completely defined by α and θ
- Assume:
1- perfectly sharp tool
2- shear zone
3- No chip side flow

$V_f = V_c \cdot r$



$t_1 = AO \sin\phi$
$t_2 = AO \cos(\phi-\alpha)$

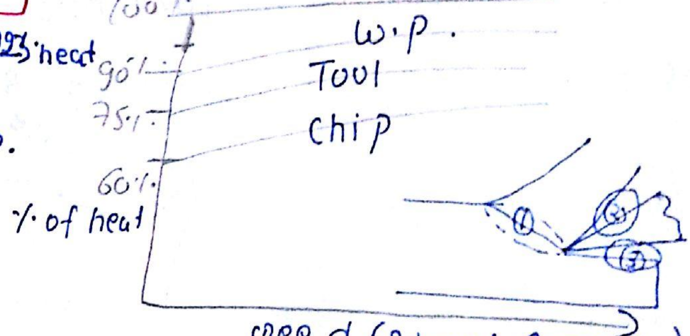
(iv) $t_1 = f\cdot\cos C_s$ $b = \frac{d}{\cos C_s}$

max. temp. $\propto \sqrt{t_1} \propto \sqrt{f\cdot\cos C_s}$

(7) Heat generated in m/c ing Power 99% heat

(i) primary zone (Around shear plane)
-Partly carried by chip, (T ↑es) - Rest Retained by w.p.
(ii) secondary " (Tool chip Interface)
(↑es with cutting speed)
(iii) Tertiary " (Tool work)

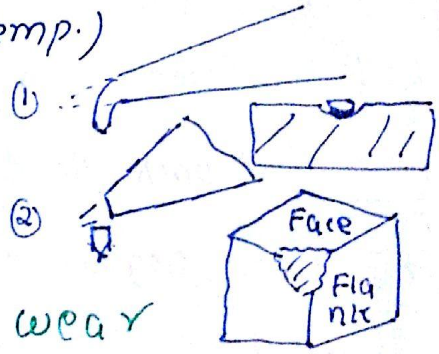
Heat in (ii) > (i) >>>> (iii)
↳ ↓ Tool life, ↓ Tool hardness



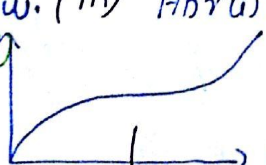
speed (Adv. of ↑speed: 80% heat carried by chip)

(8) Type of Tool failure (~~Power ↑, unable to~~ cut, ↓ sur fin.)
(i) plastic deformation (Due to ↑T)
(ii) mechanical breakage (Due to ↑ Forces)
(iii) Gradual wear < C.W. / F.W.
* (i)(ii) can be eliminated but not (iii)

(9) Reason for Tool wear
(i) Diffusion (at ↑ Temp.)
(ii) Adhesion
(iii) Abrasion

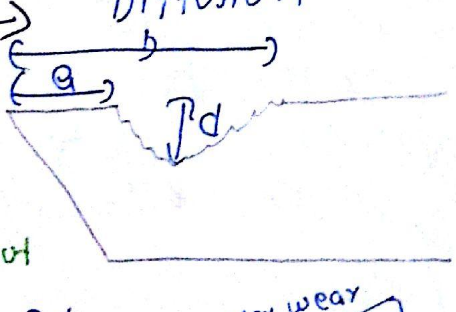


(10) TYPE OF WEAR



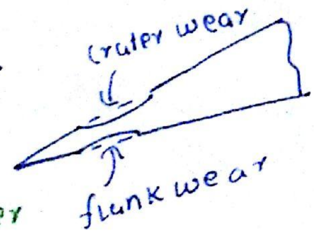
(i) CRATER WEAR → (ii) Flank wear

mainly by → Diffusion



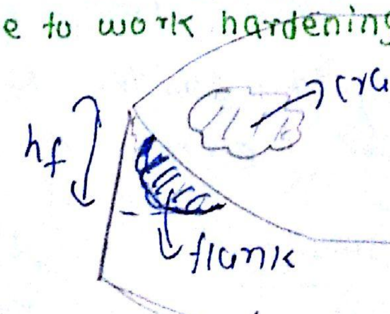
- Tool worn out if $X > .4 - .6$

$X = \frac{2d}{a+b}$

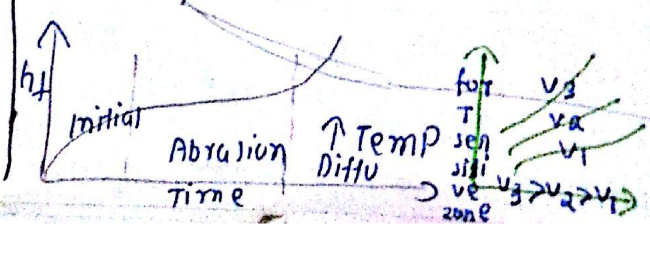


- At tool face at a short distance by chips flowing over face due to ↑T.

- Abrasion, Adhesion, at ↑T diffusion
- At corner and notch of tool
- Due to work hardening & sudden engagement.



- hf limit .5 - .8 mm



① **Cutting Tool material** PROPERTIES: HOT or RED HARDNESS, WEAR RESISTANCE, Toughness, ↑K, ↑Cp, ↓μ, Thermal stability & ↓α, $1.35 < \frac{H_T}{H_{wp}} < 1.5$

→ CS, HSS (Mo series, W series), Cast alloys (Stellite) (Non Fe alloys made by casting), Cemented carbide (P, M, K) (By Powder metallurgy) (WC, TiC, TaC), Coated carbide (TiC, TiN, TiCN), Ceramics (Cemented oxide) (By P-metallurgy, sintering), Diamond (for carbides), CBN, UCON. (made by Rolling)

→ $1.35 < \frac{\text{Hardness Tool}}{H\ w.p} < 1.5$

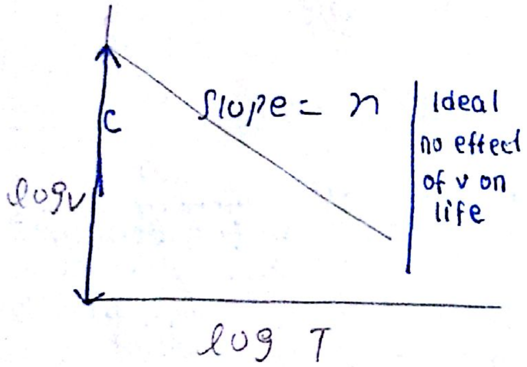
(i) CS, HSS → Forging
(ii) Stellite → Casting
(iii) ceramic, carbide → powder
(iv) UCON → Rolling

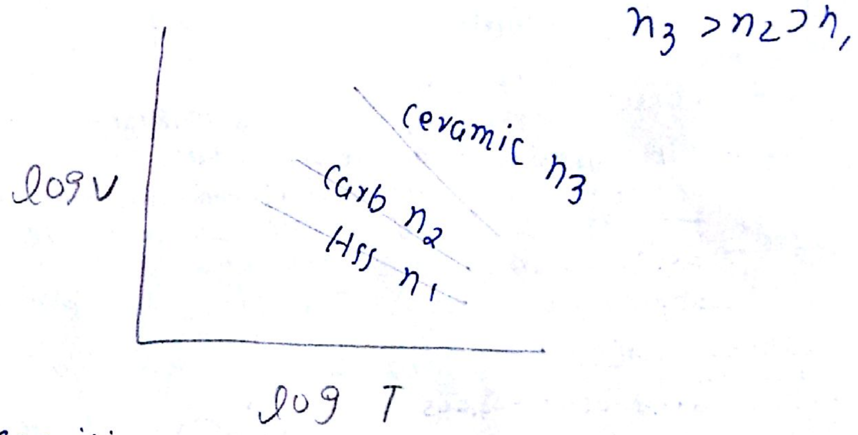
② **Tool life** $V \cdot T^n \cdot f^p \cdot d^q = C$.

→ Effect on Tool life: $V > f > d$

→ n: HSS [.08 – .2], Carbide [.2 – .5], Ceramic [.5 – .8]

→ superior: ceramic > carbide > HSS





→ ↓n ⇒ Tool life sensitive to cutting speed

→ ↑C ⇒ ↑ Tool life.

③ **Machinability** Factors affecting it: (Ease of m/cing a given material)

(i) Tool life
(ii) surface finish
(iii) cutting force
(iv) power needed
(v) MRR

C_m = m/cing cost per unit time
C_e = Regrinding cost per grinding

T_m = M/cing time in mins/unit
T_i = Idle time in mins/unit [loading + unloading]
T_c = Tool changing Time in mins/failure

→ $T_m = \frac{L}{fN} = \frac{L\pi D}{fV}$

→ No. of Tool failures per work piece $= \frac{T_m}{T} = \frac{T_m \cdot V^{1/n}}{C^{1/n}}$

→ Total cost per unit $= C_m \cdot T_m + C_m \cdot T_i + C_m \cdot \frac{T_m}{T} \cdot T_c + \frac{T_m}{T} \cdot C_e$

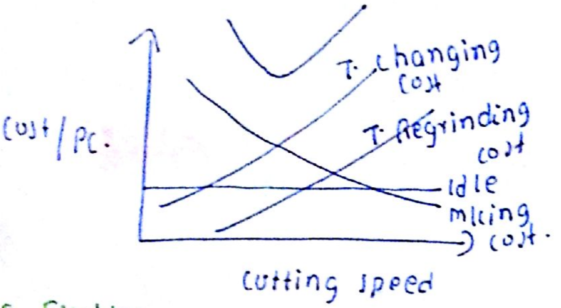
→ " Time per unit $= T_m + T_i + \frac{T_m}{T} \cdot T_c$.

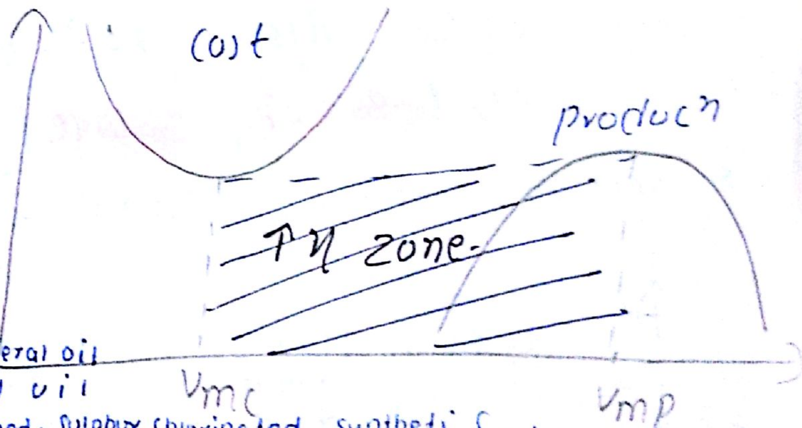
→ Rate of production $R_p = \frac{1}{T}$.

(i) for min. cost $\left[\frac{dC_e}{dv} = 0\right]$ $\left[\frac{\partial R_p}{\partial v} = 0\right]$ (ii) for max. producn.

→ $V_{mc} = \dfrac{C}{\left[\left\{\frac{1}{n}-1\right\}\left\{T_c + \frac{C_e}{C_m}\right\}\right]^n}$ $V_{mp} = \dfrac{C}{\left[\left(\frac{1}{n}-1\right)\cdot T_c\right]^n}$

→ $T_{mc} = \left\{\frac{1}{n}-1\right\}\left\{T_c + \frac{C_e}{C_m}\right\}$ $T_{mp} = \left\{\frac{1}{n}-1\right\}\cdot T_c$.





Cutting Fluids:
1- water based → Solutions / Emulsions
2- mineral oil based → inactive oil → mineral oil / fatty oil; → Active oil: sulphirised, sulphur chlorinated, synthetic

④ USM → Frequency: 20-30 KHZ (Beyond hearing Range ∴ no noise) → Amplitude: 25-100 μm

mixed in these (water, Benzene, oil, glycerol) (B_4C, SiC, Diam, Al_2O_3, BSiC).

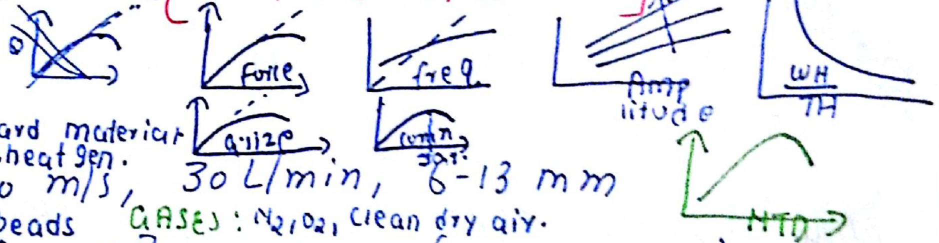
→ Apply: Dentistry, Jewellery, Stone cutting, Die making → For hard and brittle [Glass, Ceramic, Carbide]

Tool: should stand vib. & corrosion -coating to avoid wear - SS, LCS

→ Can't use for :- Ductile - low MRR

→ ↑ surface finish, easy for hard material

Adv: ↑ accuracy, safe & noiseless, ↓ heat gen.



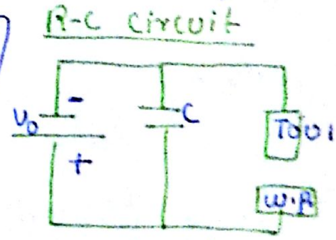
⑤ AJM 2-10 MPa, 150-300 m/s, 30 L/min, 6-13 mm

Abrasive: Al_2O_3, SiC, $NaHCO_3$, glass beads GASES: N_2, O_2, clean dry air.

⑥ EDM Temp. of spark [8000-1500°C], spark gap (.025 - .05 μm),

D.C. supply [30-240 V], MRR [300 mm³/min]

R-C circuit



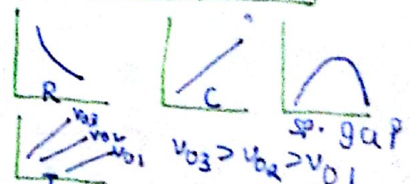
→ Imp. For max. power $V_d = .72\, V_0$.

→ Apply (i) only for electrical conductor

(ii) wire drawing, sinking, extrusion dies

(iii) micro holes for nozzles, narrow slots.

(iv) Hard carbides, Aero space industry



⑦ MRR PAM > ECM > EDM > AJM > USM > EBM > LBM (can interchange)

PEME LBM > EBM > USM > ECM > EDM > PAM > AJM

↳ (i) AJM goes to last (iii) Reverse MRR for PEME.

(ii) ECM > EDM in both

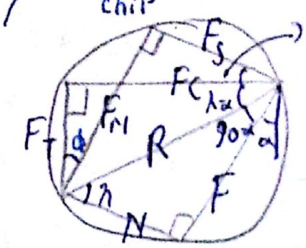
① FUN (i) F = ~~$F_T \cdot \sin\alpha + F_C \cos\alpha$~~ $F_C \cdot \sin\alpha + F_T \cdot \cos\alpha$

SUN (ii) N = ~~$F_T \cos\alpha - F_C \sin\alpha$~~ $F_C \cdot \cos\alpha - F_T \sin\alpha$

} $\mu = \tan\lambda = \frac{F}{N}$ b/w Tool & chip

(iii) F_S = $F_S = \frac{\tau_s \cdot t_1 \cdot b}{\sin\phi}$ $P = F_C \cdot v$; $F_C \cdot \cos\phi - F_T \sin\phi$

(iv) F_N = $F_C \sin\phi + F_T \cos\phi$



CT - F_C, F_T | SC, CS, CS, SC | (+, -, -, +) | AF: α α φ φ

② (i) Ernest and merchant : $2\phi + \lambda - \alpha = \pi/2$.

(ii) merchant's 2nd soln : $2\phi + \lambda - \alpha = C_m$ [69°-82° for steel]

(iii) Lee and shafeer : $\phi + \lambda - \alpha = \pi/4$. From circle:

(iv) Stablem : $\phi + \lambda - \frac{\alpha}{2} = \pi/4$.

$F_C = F_S \cdot \cos\phi + F_N \cdot \sin\phi$

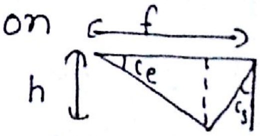
$F_T = F_N \cdot \cos\phi - F_S \cdot \sin\phi$

$R = \frac{F_S}{\cos(\phi+\lambda-\alpha)} = \frac{F_C}{\cos(\lambda-\alpha)}$.

③ h, C_e, C_s, f [CE, TCS] h = max. ht. of surface Roughness f = mm/Rev

(i) $$h_{max} = \frac{f}{\cot C_e + \tan C_s}$$

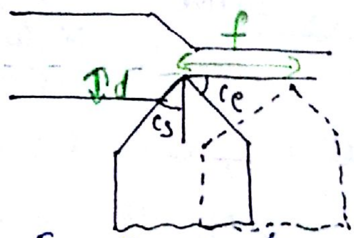
Surface finish puts limit on max. feed.



(ii) $$h_{max} = \frac{f^2}{8r}$$

(iii) $$R_A = \frac{h_{max}}{4}$$

R_A = Avg. line of Roughness.



if ↑r → vibration, chattering, Force↑, Power↑

For smooth surface → ↓feed, ↓C_e, ↑C_s.

Tool Radius Provided → Good surface finish, longer tool life

④ MERCHANT'S CIRCLE DIAGRAM

$$F_S = \frac{\tau_s \cdot t_1 \cdot b}{\sin\phi} \qquad F_C = F_S \cdot \frac{\cos(\lambda-\alpha)}{\cos(\phi+\lambda-\alpha)}$$

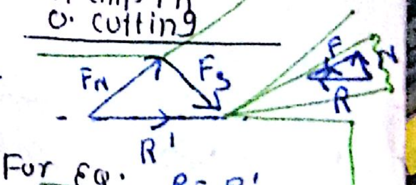
only depends on φ } $$\text{Power} = F_C \cdot V = F_S \cdot v \cdot \frac{\cos(\lambda-\alpha)}{\cos(\phi+\lambda-\alpha)} = \frac{\tau_s \cdot t_1 \cdot b \cdot v}{\sin\phi} \cdot \frac{\cos(\lambda-\alpha)}{\cos(\phi+\lambda-\alpha)}$$

Forces acting on chip in O. cutting

$$\text{Specific cutting Energy} = \frac{F_C}{bt} = \frac{N}{m^2} = \frac{J}{m^3}$$

F_C = Cutting force = along cutting velocity

F_T = Thrust force = Normal to " "



For Eq. $R = R'$

⑤ (i) Turning : For outer surface

(ii) Boring : Enlarging of existing hole made by drilling or casting

(iii) counter-" : To Enlarge only a limited portion of hole

(iv) "-sinking : To " end of hole to give it conical shape for short distance

(v) Tapping : To make internal threads using Tap.

(vi) Reaming : Required dimensional accuracy and surface finish is obtained by Multi-toothed Tool called Reamer.

⑥ Pt. L.

Pt. angle = 2β

↑β → For Hard and Brittle
↓β → For soft " Ductile

} opp. to Rake ∠.

① **GRINDING WHEEL SPECIFICATION** [Man. code, A, G, G, S, B, man code]

A Type of Abrasive [Al_2O_3, SiC, Diamond]

G Grain or Grit size [Size of Abrasive particle] [Fine, coarse]

G Strength of bond in wheel [Power of Abrasive particles to hold together] [Soft, medium, hard]

S Structure [Spacing b/w Abrasives] [Dense, open]

B Bond Type [V-vitrified, S-silicates, D-Diamond, B-Resinoid, E-Shellac]

② (i) St. wheel ⟶ only 1 grain size used.
(ii) Compound " ⟶ >1 " " ".

③ Coarse grain size : soft, ductile [open structure, hard wheel]
fine " " : hard, brittle [Dense ", soft wheel]

④ (i) off-hand grinding: work in hand pressed against rotating G.W.
(ii) surface " : To grind horizontal flat surface.

⑤ **GRINDING DEFECTS**
(i) GLAZING : If work material is hard, grains wear out quickly and sharpness of cutting edge lost.
(ii) LOADING : when chips occupy voids b/w Abrasive grains.

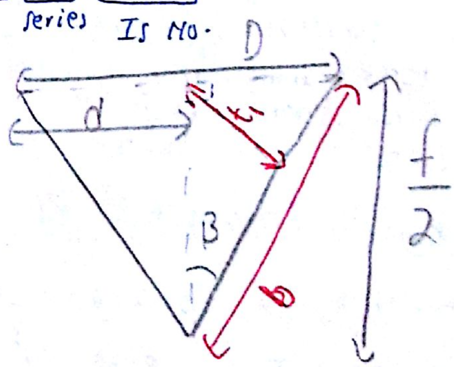
REMEDY : DRESSING ⟶ Reconditioning process to grind the grinding wheel itself.

---

① **Drill specification** Drill dia, series, material, I.S. No.

E.g. 10.5 H 1504 (Dia, series, IS No.)

series N → for Normal LCS
H → " Hard materials.
S → " soft and Tough.



② **m/c ing for Drill**

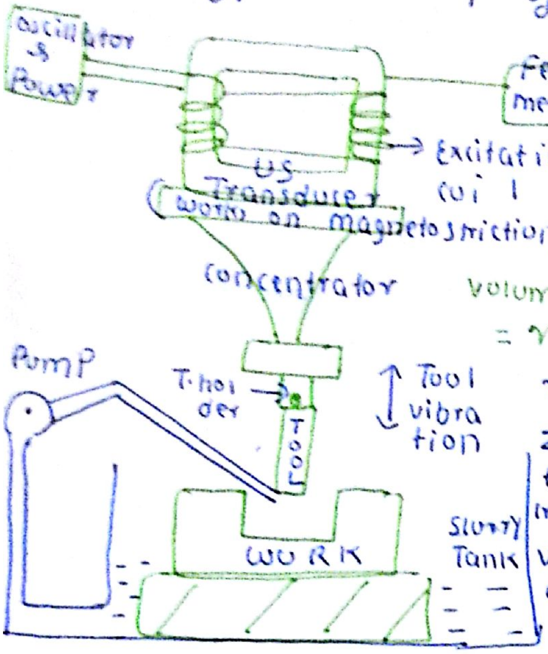
For 2 face $d = \frac{D}{2}$, $f = \frac{f}{2}$

For 3 face $d = \frac{D}{3}$, $f = \frac{f}{3}$

→ $b = \frac{d}{\sin\beta} = \frac{D}{2\sin\beta}$. → $t_1 = \frac{f}{2} \cdot \sin\beta$ → $V = \pi D N$

→ $\text{Time} = \frac{L + .3D}{fN}$ (.3D → Approach length)

USM: - Slurry of Abrasive grains hammered on w.p. by vibrating tool



volume of MRR $= rZV$

r = frequency

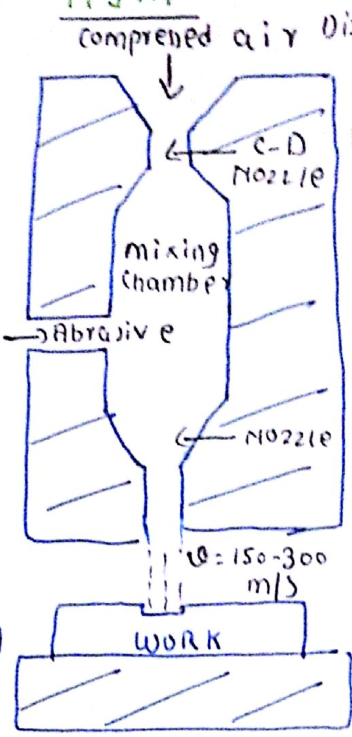
Z = no. of particles making impact/cycle

V = vol. of work dislodged/impact

AJM

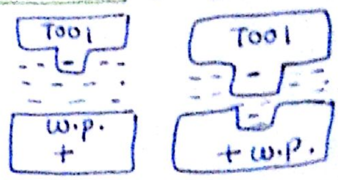
Adv: Cheap, ↓power, ↓heat

Disadv: ↓mrr, ↓sur. finish



Nozzles: subjected to wear

ECM: Reverse of electro plating



* Here no Tool wear
* use Tool, w.p. of same
* material from w.p. can add to Tool & change its shape → To prevent it electrolyte
* low voltage DC applied
* Anodic dissolution Removes material from w.p.
* constant feed motion to Tool & electrolyte pumped at ↑ pr.

mrr: 10-15 times of EDM

Power ↓, sur. fin. ↓

w.p. elec. conductor

Dielectric: salt soln

Electrolyte: 1- complete E. ckt
2- carry away heat & waste
3- Allow EC Reacn xly.

properties: ↑Elec., Thermal K, ↑Cp, ↓vis., non corrosive, toxic

* 20% NaCl in water, HCl in water, H_2SO_4 in water, HNO_3

$Q = \frac{ei}{\rho F}$ $\frac{cm^3}{sec}$ i = current (A) ρ = gm/cm3

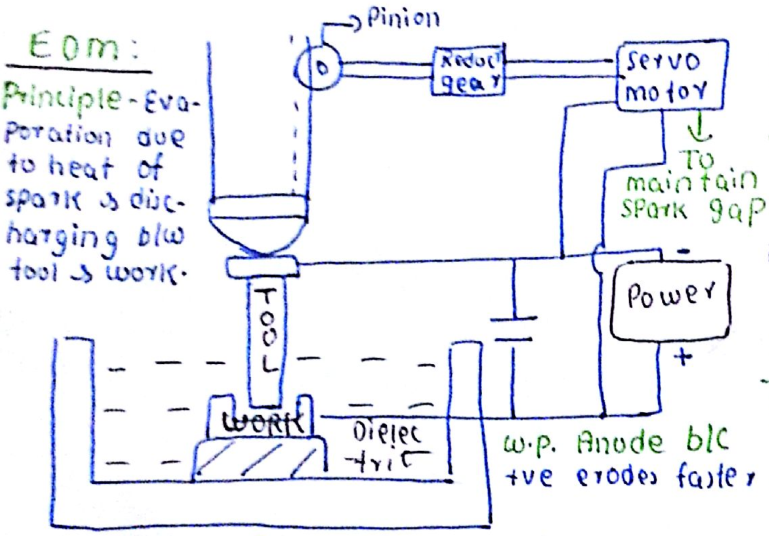
$e = \frac{A}{Z} = \frac{At.\ wt.\ (gm)}{valency}$ F = F. const = 96500

Alloy: % x_1, x_2, x_3 $\Sigma x = 100$

$\frac{100}{e} = \Sigma \frac{x_i}{e_i} = \Sigma$

EDM:

Principle - Evaporation due to heat of spark & discharging b/w tool & work.



w.p. Anode b/c +ve erodes faster

DIELECTRIC
1- Drive away chips
2- ↑es mrr
* ↓viscosity, inflammible, ↑cooling ability, chemically neutral

E.g. HC, some light oils, kerosene, paraffin oil

Tool wear ↑:

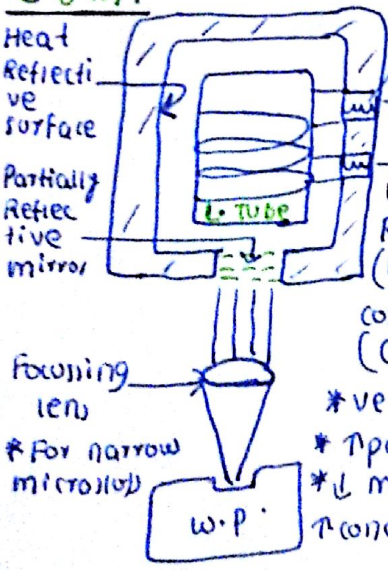
W. Ratio = $\frac{w.p.\ wear}{Tool\ \ ''}$

CI, brass, Cu W, Ag W

Adv: ↑mrr, ↑sur. fin., ↓power, can contour cavities.

Lim: only for Elec. conductors

LBM:



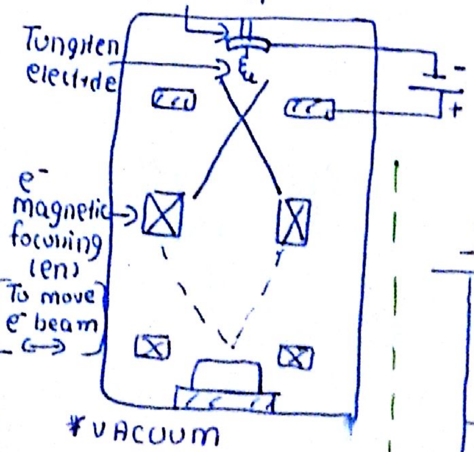
Laser source: Ruby laser (Al_2O_3 + .05% Cr)

continuous laser ($CO_2 - N_2$)

* For narrow microslots

* very costly
* ↑power consumpn
* ↓ mrr * not for ↑cond., ↑ Ref. material

EBM:

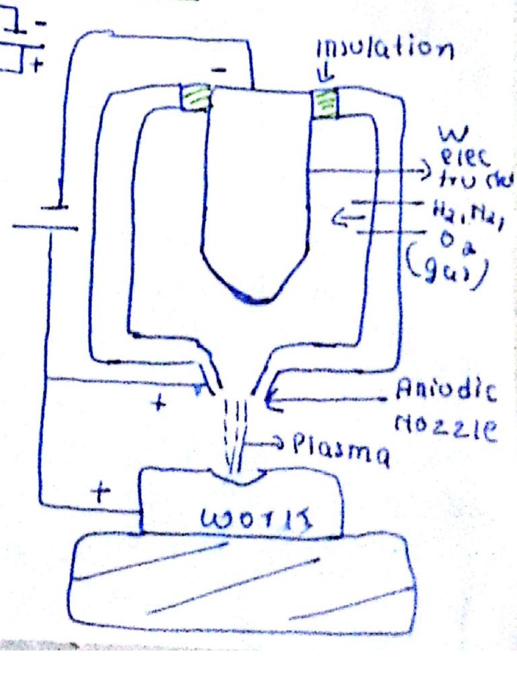


* vACCUM

Plasma: is a ↑T ionised gas

- For conductors

PAM:



① IN. Arc welding the arc length should be : times the

② Cutting Tool Material Required to sustain ↑ Temp: cermet

③ Centrifugal Casting : → Coarse grain size / → High ↑ density

④ To Melt Non-Fe Alloys : Induction furnace

⑤ Symbol to indicate Roughness : √

⑥ Follow board pattern : For castings having weak portions which may break due to Ramming.

⑦ In VT^n n for Ceramic Tools : ·6 - ·75.

⑧ " " " " Carbide " : ·2 - ·4

⑨ (i) Manual ⟶ Constant current I. (Droop char)
(ii) Automatic ⟶ " voltage V. (St. line ")

⑩ AHW : Arc b/w 2 W electrode Not b/w w.p. and e⁻trode.

⑪ GEAR GENERATING PROCESS : (i) Hobbing
(ii) Gear shaper
(iii) Rack planing

⑫ Surface finish by Honing : ·01 μm (CLA).

⑬ Railway Tyres fitted by ⟶ Interference fit

⑭ Laser Beam : No vacuum
e^- Beam : vacuum

⑮ Max. Reduction in tube drawing by : moving mandrel method.

⑯ To Extrude Brittle materials like CI : Hydrostatic Extrusion.

⑰ (i) Bolt heads : upsetting [localised forging of work piece]
(ii) Hexagonal " " : Closed die upsetting.
(iii) Railway wheels : → Roll forging (Earlier) / → Inv. casting (now)
(iv) a- Rifle barrel : Swagging.
b- gun : Gun drilling.

⑱ To manufacture Extrusion Nozzles : White Cast Iron.

⑲ GANG MILLING ⟶ 2 or more cutters mounted on common arbor, used simultaneously

① Dry and compressed air is used for milling → cast Iron.

② Ideally single pt. Thread cutting Tool should have → +ve Rake.

③ Crater wear is pre-dominant in → Tungsten Carbide (WC) Tools.

④ Internal gears can be made by → Gear shaping with pinion cutter.

⑤ N- Plane in Rolling:
(i) velocity of Roll ($\pi DN/60$) = velocity of material
(ii) Friction force = 0 (Shear = 0)
(iii) Normal force P = max.

⑥ For condition of self Entry: $\tan\theta \le \mu$ θ = Bite angle.

⑦ Nip angle = 2μ (Radian): it is the bite ∠ at Rolling limit.

⑧ In DEEP DRAWING
(i) curvature on die: (8-12)t   (iii) clearance on die: (1.2-1.4)t
(ii) Shear on punch: (4-6)t   (iv) pressure on Blank holder: 2% of Y.S.

⑨ Chip produced for brass = Discontinuous

⑩ 18-4-1 : W, Cr, V.

⑪ Slush casting → can be used for ornamental parts.

⑫

	Up or Conventional milling	Down or Climb milling
		
(i) cutter, work	opp. direcⁿ	same direcⁿ
(ii) Surface	poor	good
(iii) Tool life	low	High

⑬ Shrinkage values: mm/m

White metal (5) Cast Iron (10) Bronze (15) Copper (16)

Aluminium (17) Brass (18) Steels (20)

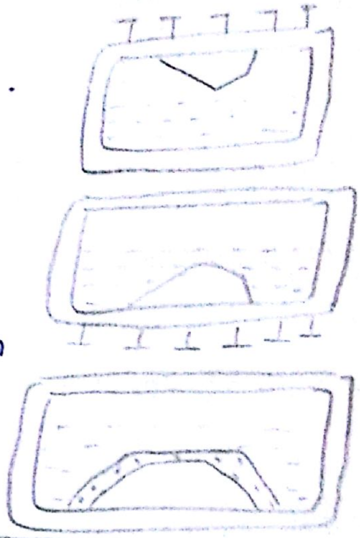
① Classification of Castings

(i) Expandable moulds
- A- SAND CASTING
- B- SHELL "
- C- INVESTMENT "
- D- CO_2 moulding
- E- Full moulding

(ii) permanent moulds
- A- CENTRIFUGAL C.
- B- DIE C. → Gravity / Pressure
- C- SLUSH C.

(iii) Continuous C.

① Shell moulding



→ Better surface finish and close dim^n Tolerance.
→ pattern: CI, Al, Brass Heated to 230-315°C
→ pattern clamped in box having: silica, Alchohol, Phenolic Resin
→ Invert the box: Thickness of sand stick to pattern
→ Dwell time: Time for forming
→ Heat pattern + shell → Then take out the shell
→ Join 2 shells →

Final

→ FOR NON-Fe METALS
→ Thin sec^n, sharp corner, small projec^n

② Investment Casting

→ WAX Pattern : LOST WAX PROCESS
→ Hg " : MERCAST PROCESS

→ CASTINGS OF : ↑ mt Pt. and ↑ strength Alloys

→ (A) wax pattern Rinsed in Alcohol (To Remove grease and dirt)
→ (B) After drying pattern dipped in slurry [si flour, water, ethyl silicate]
→ On slurry Add some fine grain ceramic : called PRE COAT (For Repitition of process)
→ Turbine, Jet blades.

Step 1 make wax pattern in die
Step 2 form a tree of these patterns using central sprue
Step 3 (A) Step 4 (B) Repeat it → layer of sand appear over it
Step 5 Heat it to Remove wax
Step 6 Fire shell in furnace to complete Remove wax.
Step 7 pour metal, solidify, break it, final Product.

③ SODIUM SILICATE OR CO_2 MOULDING: [For Hard Mould]

→ Hard mould: Better finish, dimn Tolerance

→ mix 3-4% Na_2SiO_3 with sand while preparing mould.

→ Pass CO_2 $Na_2SiO_3 + CO_2 \rightarrow Na_2CO_3 + SiO_2$ (colloidal)

→ Dis ad: ↓ Collapsibility

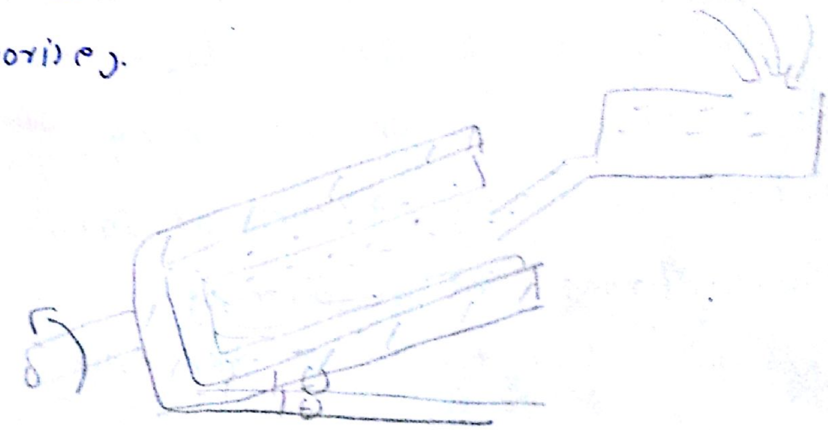
④ Full moulding or Lost Foam process:

Pattern: Plastic Polyesterene

moulding material: Gypsum or pop [∵ distortion while Raming ∴ sand ✗]

When hot metal poured: it vaporises.

⑤ CENTRIFUGAL CASTING



Rotated: 3000 rpm

Poured: At centre

C.Y = 95-98 %

outside grains → coarse

centre " → fine

Apply → large pipe, boiler, pressure vessels, flywheels, etc.

which have symmetry

Semi-centrifugal casting Placed on H.P., Rotated abt. vertical Axis

outer portions of Mould by → centrifugal

central " " " → gravity

Apply → wheel, pulley.

centrifuging No. of castings, Individual gates, central sprue

purpose: To force metal from a central Axis to individual mould cavities which are placed on circumference

Need Not be Axis-symmetric

Application: patterns for Investment casting.

⑥ Slush casting ↓ melting pt. material Brass Pb, Sn, Zn

Apply → Lamp shade, Toy, decorative item, Jewellery, Hollow castings with thin walls.

⑦ Continuous C Al, Cu ✓

Fe ✗

Numerical values for surface finish: 1- Peak to valley height:

- Distance b/w Test peak, Lest valley - R_t, R_{max}, H_{max} - Limitation (sudden Jerk)

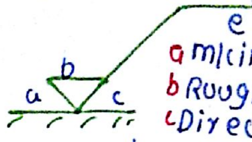
2- centre line avg. value: (i) Indi hts: $R_a = \frac{\Sigma y}{n}$ (ii) Area) $R_a = \frac{\Sigma a + \Sigma b}{L}$ L = cut off length

(iii) Ht. at funcn of x $R_a = \frac{1}{L}\int_0^L y \cdot dx$ * Approx $R_a = \frac{H_{max}}{4}$ $H_{max} = \frac{f^2}{8r}$ $H_{max} = \frac{f}{\cot \beta + \tan \alpha}$

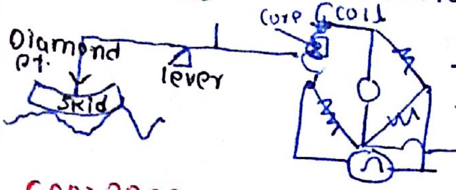
3- Rms: $R_g = \sqrt{\frac{\Sigma y^2}{n}}$ 4- 10 pt. value R_z = Avg. of 5 Test peaks & 5 Lest valleys.

Representation of surface finish:

1- ▽ (8.25 um) (1.6-8) (.025-1.6) (<.025) CLA

2-


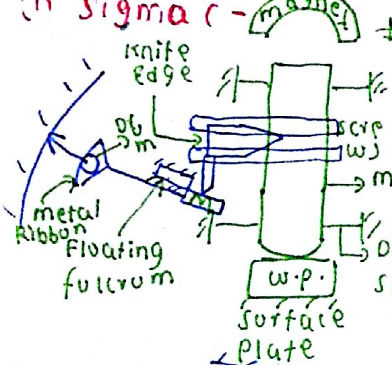
a machining allowance
b Roughness value
c Direcn of Lay
d Samping/cut off L
e Producn method

TALY SURF: - measures surface irregularities


- Diamond pt. at end of lever
- Skid to protect D. pt.
- As D. pt. moves in valley position of core in coil changes
- Resistance changes - use wheatstone bridge.

COMPARATORS: - Relative Inspection - measures dimn from a Reference value
- usually datum by slip gauges - dont move ↑ distances to maintain Precision.

1- Mechanical C: 1- cheap 2- No Ext. power supply 3- Accuracy Independent of A. in manufacturing diff. links 4- mag. factor limited to 1000 5- limited Range 6- insensitive to small changes in dimn due to inertia 7- usually it has linear scale.

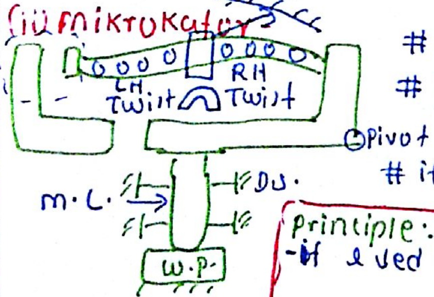
(i) Sigma C -


variation in size of w.p. → m.L. ↑or↓ → cylinder over Ribbon Rotates → deflection of pointer.

why D. spring & not helical: ∴ H.S. not used as Restoring device in measurement b/c it takes time to come back to Neu. position

C-slots in diaphgram spring: To Relieve any Residual stress in spring

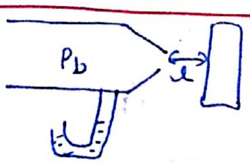
magnet - To avoid any Jerk & maintain uniform pressure.


(ii) Mikrokator


Due to pivot movt. of m.L. → movt. of Twisted spring

Thin metal strip: given LH Twist on L. side & RH Twist on R. side central portion neutral.

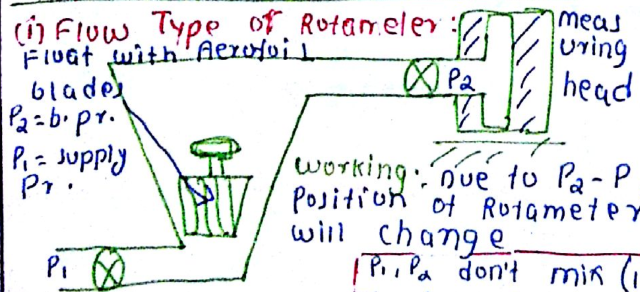
if w.p. size changes → imbalance in R.H. & L.H. Twist → central Portion rotates

Principle of AIR JET.
- if l ↓ed then P_b will ↑.


l = stand off distance

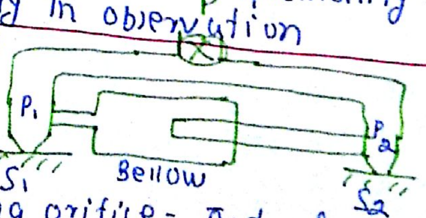
popular in Industry
- in process gauging
- M.F. ↑ 50000
- comp. air anyways used in industry

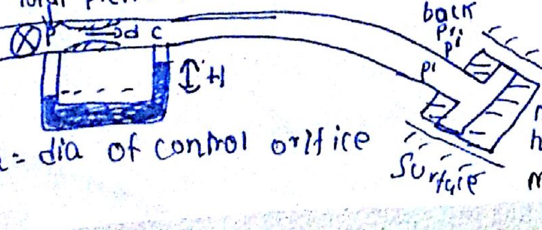
2- PNEUMATIC COMPRATORS:

(i) Flow Type or Rotameter:


M. head → Shape will be acc to geometry of w.p.
A. blades → so that float Rotates due flow of air otherwise it sticks & device becomes insensitive
Tapered Tube → To adjust air compressibility & hence maintain linearity in observation

working: Due to $P_2 - P_1$ Position of Rotameter will change

(ii) Differential type: - compares 2 surfaces
- 2 pressure streams
| P_1, P_2 don't mix (inside, outside bellow)
- based on bellow position from neutral can decide which one higher.


(iii) Back pressure type:


dc = dia of control orifice

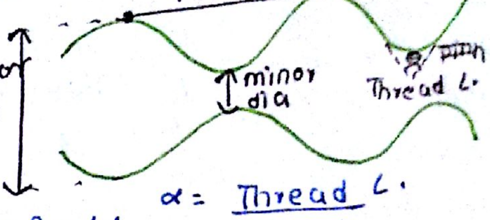
m → changes acc. to l
m = Area of measuring orifice = $\pi \cdot d_m \cdot l$
A (const.) " control " = $\pi/4 \cdot d_c^2$

$\frac{P'}{P} = A - b\left(\frac{m}{C}\right)$ (linear b/w $\frac{P'}{P}$ = .6 to .8)

Pneumatic sensitivity $\frac{dP'}{dm} = \frac{.4P}{m_{avg}}$ Indicators $= \frac{dR}{dP'}$

M.H. sen. = $\frac{dm}{dl} = \pi d m$

Screw Thread Metrology: Major dia – Ext. micrometer – Bench micrometer – optical projector – Tool maker's microscope



minor dia – optical projector – TMM – pointed anvil micrometer

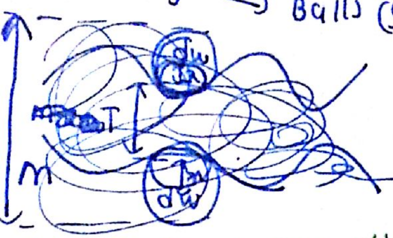
Angle – " " pitch – pitch gauges – optical projector

PCD – using wires < 2 wire for ↓ pitch, 3 " " ↑ " ; Balls (gears)

$PCD = M - 2 \cdot d_w + \frac{d_w}{2}(1 - \operatorname{cosec}\alpha) + \frac{P}{2}\cot\alpha$

$\alpha = \frac{\text{Thread } \angle}{2}$

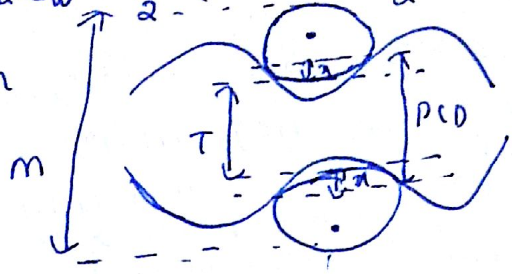
P = pitch



$T = M - 2d_w$

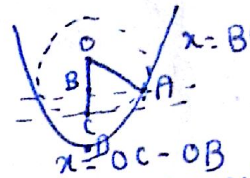
$PCD = M - 2d_w + 2x$

$x = \frac{d_w}{2} - (OD - BD)$



$PCD = T + 2x$

$= M - 2 \cdot d_w + 2x$



* For exact size dia i.e. Touch at pitch pt. $d_w = \frac{P}{2} \cdot \sec\theta$

Acceptance Test – on new m/cs before inducn for mass producn. – Check product – if error → reject

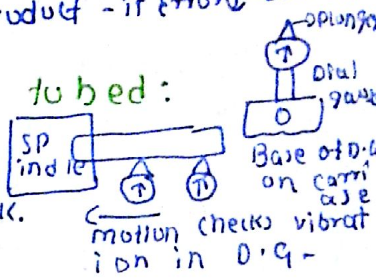
1- Dynamic: – on m/c in working condn – use std. condn

2- static: For 3 m/cs Lathe, milling, Drilling.

I For Lathe: (i) Is bed True (use spirit level) (ii) Is spindle axis ∥ to bed:

– use Reflector of Auto collimator

(iii) Is Axis of work ∥ to spindle axis: – 2 sets of Reading on w.p., on head stock.



TQM: - initiated in Japan - what it is: orgn wide quality focussed culture.
* A mgt. approach of orgn (centred on)→ quality (based on)→ participation of all members
(Aiming at)→ long term success (thru)→ < customer satisfaction / Benifit to (i) orgn members (ii) society. Empowering

Some guiding principles: 1- Objective (continuous quality ↑) 2- Approach: Team work, staff
3- Scale (Everyone: orgn, supplier, customers) 4- Std. (Do it Rt. the 1st time) 5- Measure (customer satisfaction)
6- philosophy: prevention. 7 Tools: commitment, participation, motivation, Edu, Training.

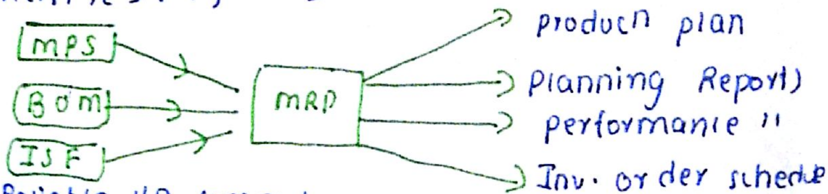
Implementation:

Plan	Do
1- Policy 2- methods	1- Edu & Trg. 2- imp. of change
Act 1- prevent 2- improve	**Check** 1- observe 2- Analyse

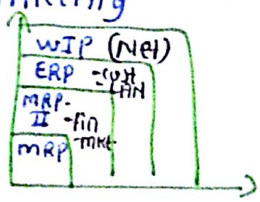
Elements: 1- customer orientation / satisfaction (dynamic - multi dimn) 2- Rt. 1st time
3- continuous improvement 4- Employee involvement 5- Empower staff
6- Benchmarking 7- Feedback
Benifits: To 1- customer 2- company 3- staff.
6 Phases of TQC: comprehension, commitment, competence, commn, correcn, continuance
Total Q. vs product Q.

TQ control: Q. maintenence + Q. improvement {(→) + ↑} (of)→ various grps. in orgn.

MRP: material Requirement planning
master producn sch., Bill of material,
Inv. status file *what it does *How it does
* Benifits * limitations Assembly oriented, Reliable i/p, computers.

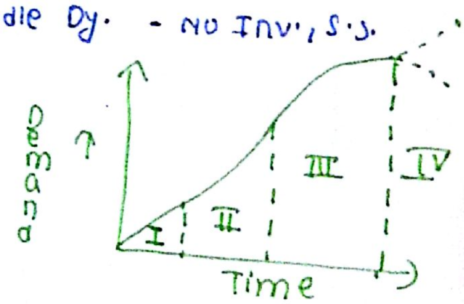


MRP-II: manufacturing Resource planning * MRP + financial + mkting
(i) strategic psc (ii) Tactical psc (iii) Executive psc
ERP- Enterprise Resource planning
WIP- web integrated planning (Buy + sell on net)



MRP - WA - ↑ Resource - Advance producn - push - can handle dynamic - Inv., S. stock
- Job or batch producn
JIT - JAP - ↓ Resource - on demand producn - pull - difficult to handle Dy. - No Inv., S.S.
- mass producn - ↑ n workers - good vendor Reln.

Product life cycle: Introducn - growth - maturity - < Rebirth / Decdn



Value: = Performance / funcn / Quality / cost
- cost value
- use "
- Esteem "
- Exchange "

V. Engg. → Before product in mkt.
V. Analysis → After " " "
BLAST → CREATE → REFINE.

PPC: PLANNING PHASE → Action phase → control phase

Planning phase:
- Prior p.: - Forecasting - order writing - Product design
- Active p.: - Tool control - material " - Routing - loading - scheduling

Action phase:
- Despatching

Control phase:
- Data collecn
- Interpretation
- Expiditing or Replan