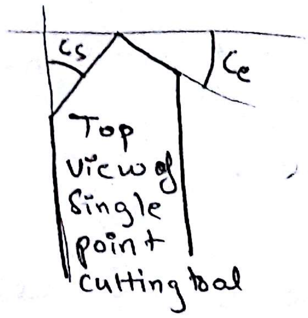
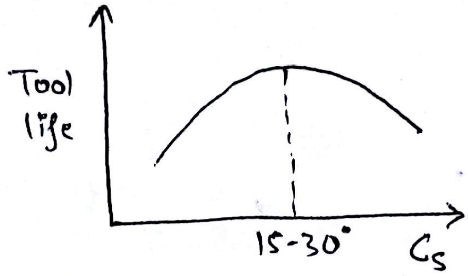
MACHINE TOOL

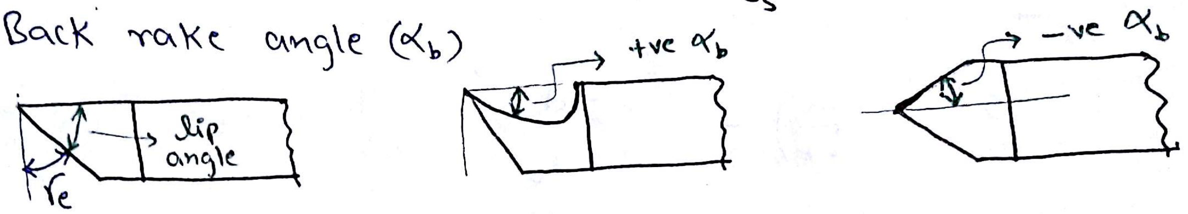
Tool Geometry

- 

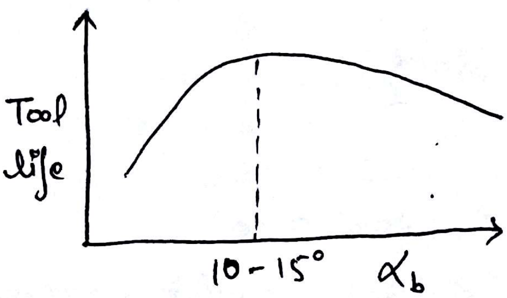
C_s = Side cutting edge
C_e = end cutting edge



- Back rake angle (α_b)



$\alpha_b = 0$	$\alpha_b = +ve$	$\alpha_b = -ve$
- used for medium Strength w/p	- used for Soft & Ductile w/p	- Used for hard & Brittle w/p
- C.I, Brass	- M.S.	- Carbide



LATHE

- Cutting velocity = $V = \frac{\pi D N}{1000}$ here, V = m/min, D = mm, N = rpm
- machining time = $t_m = \frac{l_e}{f N}$ here l_e = mm, f = mm/rev, N = rpm, t_m = min
- MRR = $f d V \times 1000 = \frac{mm^3}{min}$

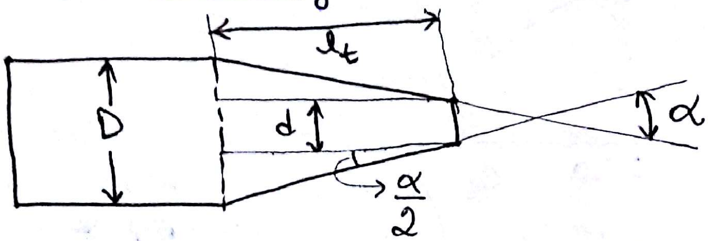
  f → $\frac{mm}{rev}$, d → mm, V → m/min

- Speed ratio in automobile & m/c tools generally follows geometric progression

$$N_{max} = N_{min} \, r^{n-1}$$

$$\frac{N_{max}}{N_{min}} = r^{n-1} = \text{Speed range ratio} = \frac{V_{max} \cdot D_{max}}{V_{min} \cdot D_{min}}$$

- Taper turning

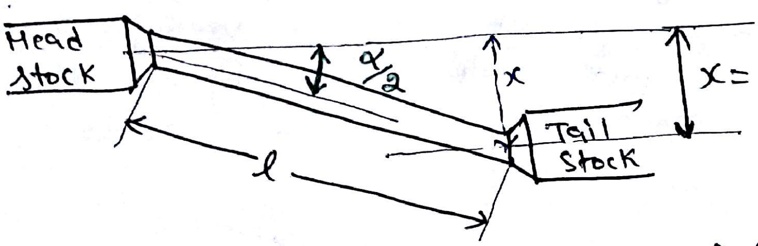


α = taper angle or included angle

$$\Rightarrow \tan\left(\frac{\alpha}{2}\right) = \frac{D-d}{2 \times l_t}$$

here, l_t = taper length

⇒ In tail stock offset method



x = offset

$$\sin\left(\frac{\alpha}{2}\right) = \frac{x}{l} \Rightarrow x = l \sin\left(\frac{\alpha}{2}\right)$$

-

Turret lathe	Capstan lathe
- Rigid m/c, hold workpiece upto 200 mm (Turret mounted on saddle.	- less rigidity (turret is mounted on auxilary slides), small jobs upto 60 mm
- no restriction on turret travel	- Auxillary slides limit the travel distenie
- feed is slow	- feed is fast
- No tail stock,	- No tail stock
2 tool post ⇒ 4 turning tool	2 tool post ⇒ 4 turning tool
1 turret ⇒ only grinding tool	1 turret ⇒ only grinding tool

- when doing milling on lathe m/c, milling cutter is fixed in chuck.

- For metric threads, thread angle = 60°
- most used threads

ACME
- Bear load in both dirn
- lead screw

Buttress
- Bear load in 1 dirn
- Bench vice

- Thread cutting on lathe [thread chasing] [High Quality threads] (Swiss automat)

⇒ RHT ⇒ move R → L [odd no. of idlers used]

⇒ LHT ⇒ move L → R [even no. of idlers used]

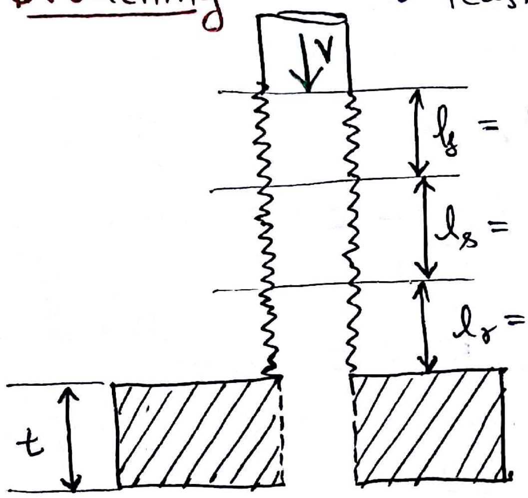
- Gear ratio = train value = Transformation ratio

$$= \frac{\text{lead of workpiece}}{\text{lead of leadscrew}}$$ [∴ for thread cutting]

⇒ 127 teeth gear is called translating gear and is used to convert pitch from inches to mm from lead screw to w/p.

Broaching

- least cutting speed



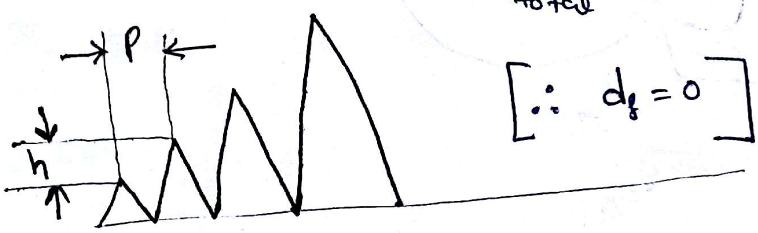
l_f = length of finishing teeth $= n_f \cdot P_f \Rightarrow n_f \cdot P_f$

l_s = length of Semifinishing teeth $= n_s P_s = \frac{d_s}{h_s} \cdot P_s$

l_r = length of roughing teeth $= n_r \cdot P_r = \frac{d_r}{h_r} \cdot P_r$

$d_{total} = d_r + d_s$

[∴ $d_f = 0$]



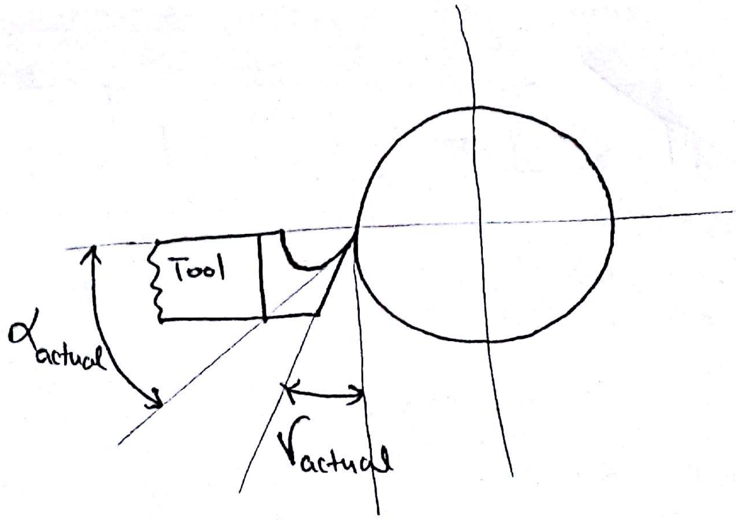
machining time

$$= \frac{l_c}{V} = \frac{t + l_f + l_s + l_r}{V}$$

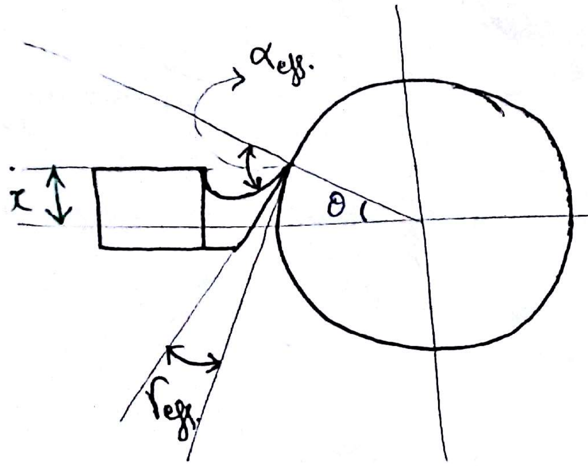
- multipoint cutting tool
- Cut slots, grooves, gears, can m/c circular & non circular holes
- $n_r > n_s > n_f$

- <u>Tool offset errors</u>

ideal condition



1) Tool offset above

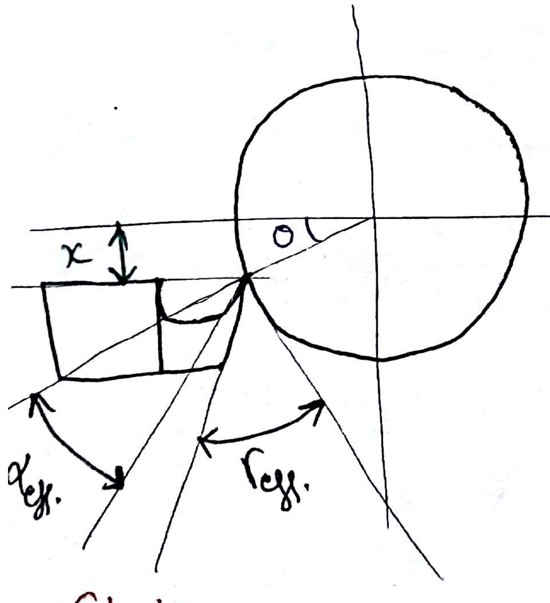


$$\alpha_{eff} = \alpha_{actual} + \theta$$

$$\gamma_{eff.} = \gamma_{actual} - \theta$$

$$\theta = \sin^{-1}\left(\frac{x}{R}\right)$$

2) Tool offset below



$$\alpha_{eff} = \alpha_{actual} - \theta$$

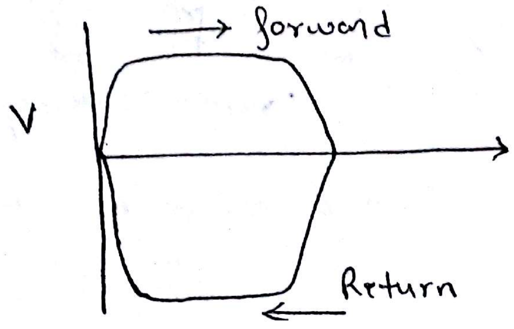
$$\gamma_{eff.} = \gamma_{actual} + \theta .$$

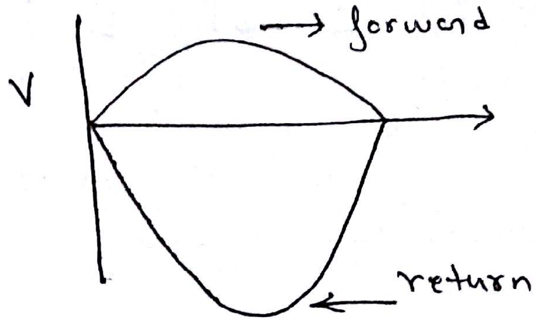
$$\theta = \sin^{-1}\left(\frac{x}{R}\right)$$

<u>Shaping</u>

- feed is given to table by "Ratchet & Pawl" mechanism
- Reciprocation to tool is given by "whitworth QRMM"
- Clapper box is used to lift tool during return stroke
- used to m/c small flat w/p.

Hydraulic shaper	mechanical shaper





Hydraulic shaper

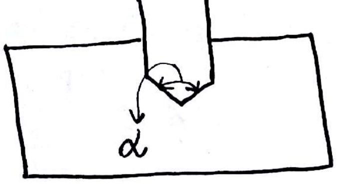
- withstand heavy loads
- involves constant speed throughout
- more no. of strokes can be obtained at given speed of cutting
- can withstand the vibrations induced due to intermittent motion

Mechanical shaper

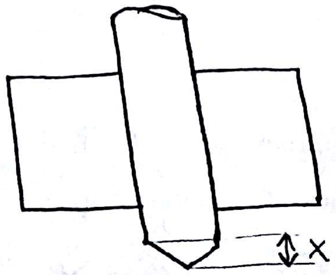
- Speed is max. at midstage of stroke
- simple in construction

- **Planner** :→ w/p reciprocates
  - → tool is given feed motion
  - → heavier and more rigid than shaper
  - → Very large compared to shaper
- **Slotter** :→ invented before shaper
  - → Ram reciprocates vertically
  - → NO QRMM used

Drilling



blind hole



Through hole

machining time = t_m

$$t_m = \frac{l_c}{f N}$$

f → mm/rev, N → rpm

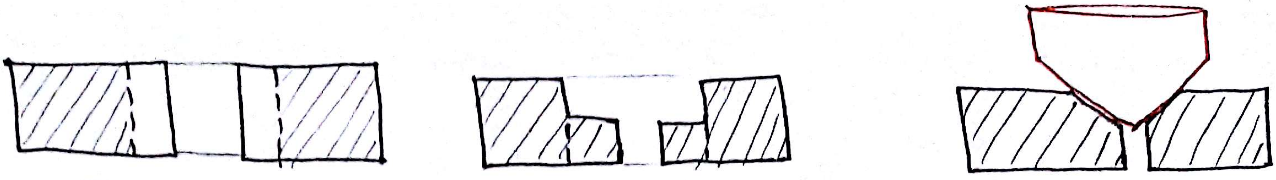
$$l_c = l_a + l_o + X + t$$

l_a → approach, l_o → overtravel, X → compulsory approach $= \dfrac{0.5D}{\tan\frac{\alpha}{2}}$

- if point angle/lip angle not given

$X = 0.3D$ for blind hole
$X = 0.5D$ for through hole

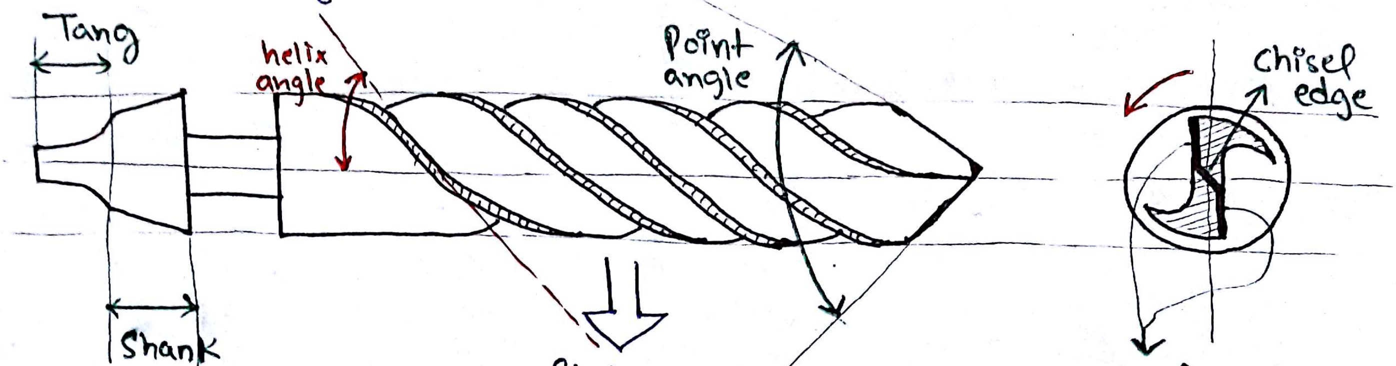
} → Steels



Boring   Counter Boring   Counter Sinking

- Spot facing is used to remove burs from counter boring holes so that nuts can fit easily.

- <u>Drill Geometry</u>



flute → easy chip flow
→ easy oil flow

⇒ Rake angle is minimum at dead center and it increases to maximum at periphery and becomes equal to helix angle

⇒ Soft & Ductile w/p ⇒ Point angle ↓
Rake angle ↑
helix angle ↑ (b/w 34 to 38°)
Known as fast helix drill [high twist low strength]
high lifting of chips

⇒ Hard & strong w/p
⇒ Point angle ↑
Rake angle ↓
helix angle ↓ (b/w 12–22°)
Known as slow helix drill
[low twist strong]
low lifting of chips

- Deep hole drilling
1) Gun drilling → 3mm ≤ Drill ≤ 50 mm
2) BTA → 15mm ≤ Drill ≤ 600 mm

- Trepanning : large diameter holes are produced without drilling, only periphery material is removed.
- Tapping : used for making internal threads
- Lapping : Sizing & finishing a hole already hardened

Reaming

→ it is an operation performed for sizing & finishing the hole, improves dimensional tolerance and accuracy.

Reamers

Right Hand
- blind holes
- pull chips toward shank

Left hand
- m/cing through holes
- push chips out of hole at other end

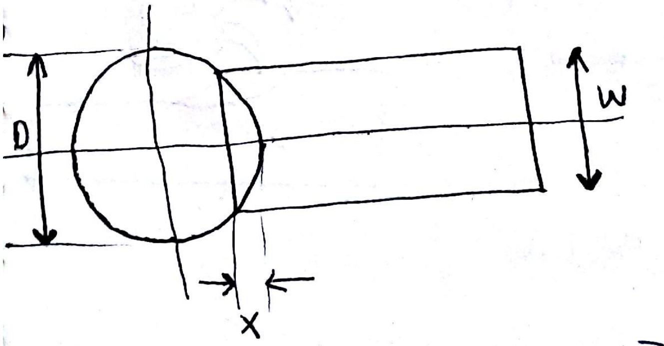
Straight
- rake angle is zero
- flutes are parallel to axis

- Reamers are having even number of flutes to reduce the cutting forces.

Milling

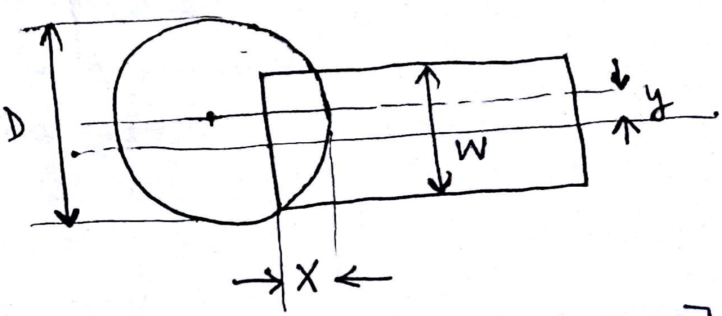
1. Face milling [verticle milling]

Symmetric



$$X = \frac{1}{2}\left[D - \sqrt{D^2 - W^2}\right]$$

Asymetric



$$X = \frac{1}{2}\left[D - \sqrt{D^2 - (W+2y)^2}\right]$$

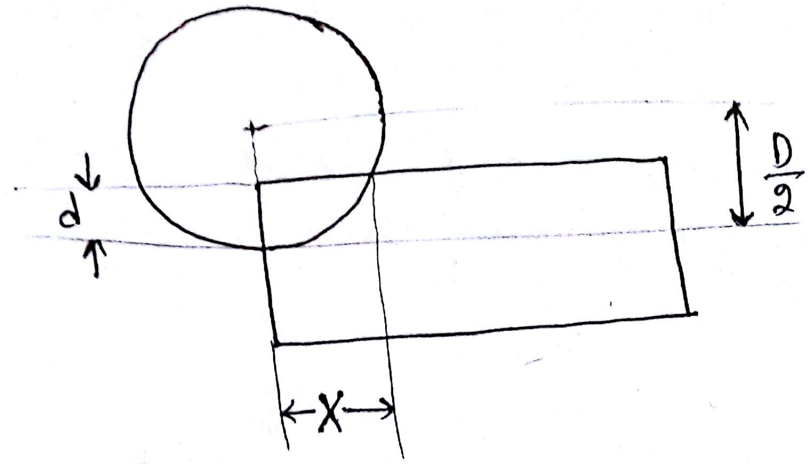
$$t_m = \frac{l_c}{f_m} = \frac{l_c}{f_t \cdot Z \cdot N} = \frac{l + l_o + l_a + X}{f_m}$$

$[\because f_m = f_t \cdot Z \cdot N]$

- f_m → mm/min
- f_t → mm/tooth
- Z → no. of tooth
- N → rpm

• when D < w then $X = \frac{D}{2}$

2. Peripheral milling [Horizontal milling]



$X = \sqrt{Dd - d^2}$

$t_m = \frac{l + l_a + l_o + X}{f_m}$

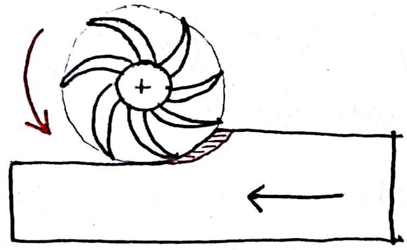
$f_m = f_t \cdot z \cdot N$

here, maximum chip thickness $= \frac{2 f_m}{N z} \sqrt{\frac{d}{D}}$

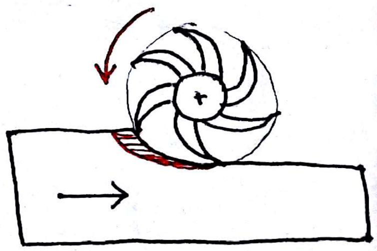
minimum chip thickness = 0

avg chip thickness = $\frac{max + min}{2} = \frac{f_m}{N z} \sqrt{\frac{d}{D}}$

⇒ Upmilling - Chip thickness varries from minimum to maximum
- Tool life is less
- surface finish is poor
- Cutter tends to lift w/p



⇒ Downmilling - Dirⁿ of cutter & w/p are same
- Chip thickness is max at start & mini at end
- higher tool life
- better surface finish
- cutter tends to push w/p towards table



Indexing

1. Direct indexing : Bevel gears are used
Speed ratio ⇒ 24 : 1

2. Simple / plain indexing: worm & worm wheel are used
Speed ratio ⇒ 40 : 1

Grinding

- Highest cutting speed
- highest specific cutting energy ($\frac{J}{mm^3}$)
- Grinding ratio = $\frac{\text{Vol. of material removed from w/p}}{\text{Vol. of grinding wheel wear}}$

- Reason for low MRR
  - Size effect
  - welding effect
  - Negative rake angle

Grinding wheel specification

Attack Gate to Get a Seat in BARC

- Attack → Abrasive
- Gate → Grain Size no.
- Get → Grade
- Seat → Structure no.
- BARC → Bond

1. Abrasive

- CBN → Very hard w/p
- Carbide: SiC → Hard w/p
- Carbide: B_4C
- Al_2O_3 → Soft & medium w/p ⇓ HSS, Bronze, Brass, MS, CI
- Dimond

2. Grain Size

Grain Size = $\frac{1}{GSN}$ inches   1 inch = 25.4 mm

3. Grade / Hardness

- A to H → Soft wheel [for hard w/p]
- I to P → medium wheel
- Q to Z → Hard wheel [for soft w/p]

- Rubbing, glazing, blunting ⇒ when H-H combination used

Dressing → removing of worn out abrasive from wheel by single point cutting tool

4. Structure number

- 0 – 7 ⇒ Dense structure
- 8 – 16 ⇒ Open structure

- Dense structure ⇒ for finish grinding & Hand w/p
- Open Structure ⇒ for rough grinding & soft w/p
- Avg gap b/w abrasive = $\frac{\text{Structure no.}}{1000}$ inches
- Reason for loading
  - ↳ mismatch of structure
  - ↳ slow rpm of wheel
  - ↳ improper cutting fluid supply.

5. Bond

Vitrified bond → hard & Brittle [but cannot be used at high speed
Rubber bond → soft wheel [used for polishing]
Silicate bond → medium & high speed grinding wheel, it is known as water glass.

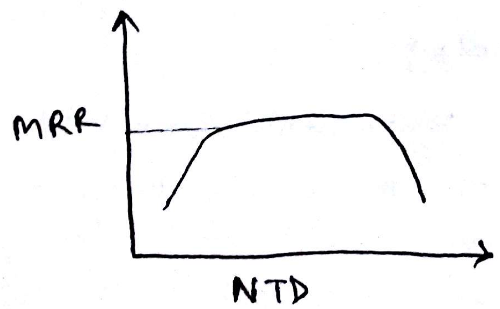
- Grinding wheel life is defined as time period b/w two successive dressing operations.

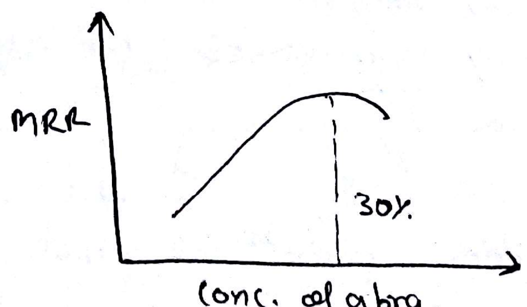
Centerless grinding

- Direction of w/p is opposite to all other wheels (guiding or regulating wheel & grinding wheel)
- Solid cylinder ⇒ External C.G. ⇒ RW < GW
- hollow cylinder ⇒ internal C.G. ⇒ RW > GW

Non- Traditional m/cing Process

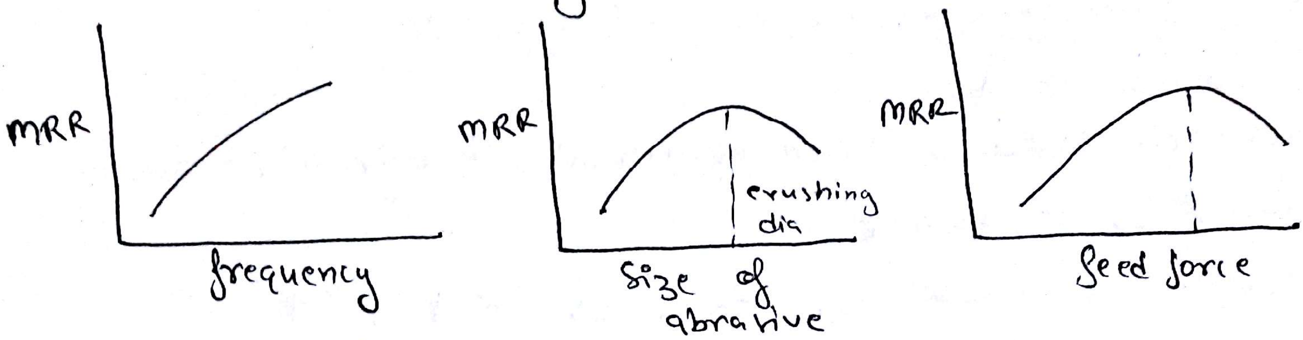
1. Abrasive jet machinig (AJM)





- abrasive speed = 100 to 300 m/s
  Pressure = 2 to 10 bar [Al_2O_3, SiC, glass powder]
- hard / Brittle material m/cing which are heat sensitive
  ex:- glass, quartz, cleaning & polishing plastics, deburring

2. Abrasive water JET m/cing
   - Cutting thick plate of steel, Al, metal matrix composites, fibre plastics.
3. water jet m/cing
   - Cutting thin plates, foils of soft material, paint removal, Cleaning, cutting frozen meet, leather.
4. Ultrasonic machining (USM)



- Vibratory frequency > 16 KHz
- tool vib. => 20-30 KHz
- tool amplitude => 0.01 to 0.06 mm
- tool is of low carbon or other ductile material
- m/cing of brittle material that has poor electric conductivity and cannot be machined by ECM/EDM.

5. Electro-chemical machining (ECM)
- High current, low voltage process
- MRR sequence => PAM > ECM > EDM > USM > EBM > LBM
- meterial removal by dissolution anode (w/p) in electrolyte
- MRR is independent of w/p physical properties
- Practicall no tool wear [Cu, brass, steel]
- $MRR = \rho Q = \frac{AI}{FZ}$; $\rho = gm/cm^3$, $Q = cm^3/s$, A = Atomic wt. | I = current, $F = 96500$, Z = valancy
- $I = J \times A$
- $J = \frac{K(V \pm \Delta V)}{y}$ here, $\frac{1}{K}$ = Specific resistance of electrolyte (Ω-cm)
  y = inter electrode gap (cm)
  ΔV = over voltage ($-\Delta V$)
  ⇒ under voltage ($+\Delta V$)
- $\left(\frac{Z}{A}\right)_{alloy} = x\% \left(\frac{Z}{A}\right)_p + (100-x)\% \left(\frac{Z}{A}\right)_q$

- Application – m/cing conducting material
  - complex profile like, turbine blade, nozzle, complex cavities, high strength material
  - drilling holes
  - die sinking

6. Electric Dischange machining (EDM)
- high voltage, low current process
- w/p ⇒ anode
- dielectric used ⇒ Transformer oil, Parafin oil, Kerosine
- tempr ⇒ 10,000°c
- for High MRR ⇒ tool ⇒ K ↑, C ↑

  w/p ⇒ K ↓, C ↓
- Application → Stamping tools,
  - forging dies
  - mould cavities
  - Slots of every type

→ $MRR = \frac{40 I}{T_m^{1.23}}$ cm³/min here T_m = melting point of w/p in °c

→ total time = idle time + dischange time

→ idle time or cycle time = $RC \ln\left(\frac{V_s}{V_s - V_c}\right)$ sec.

R = Changing resistance
C = changing capacitence
V_s = Supply voltage / open circuit voltage
V_c = changing voltage

→ Avg Power input = $\frac{\text{Total energy consumed per cycle}}{\text{Cycle time}}$

→ total energy consumed = $\frac{1}{2} C V_c^2$ (J/cycle)

→ on time or dischange time = $R_m C \ln\left(\frac{V_c}{V_d}\right)$

R_m = m/c Resistance
V_d = dischange voltage

→ to get maximum Power ⇒ $V_c = 0.716 V_s$

- for wire EDM ⇒ MRR = (X-S/c of cut) × (wire feed)

  X-S/c of cut = width of cut × w/p thickness

  width of cut = wire dia + 2(spark gap)

7. Electron Beam machining (EBM)
   - Electron gun (tungsten or tantalum filament)
   - 2°-4° taper for sheet thickness > 0.1 mm
   - fine gas orifice < 0.002 mm in space nuclear reactor
   - holes in injector nozzle in diesel engines
   - turbine blades
   - narrow slots

8. Laser Beam machining (LBM)
   - focus ⇒ $\frac{1}{100}$ mm² size
   - Taper ⇒ 1°-2° when thickness exceeds 0.25 mm
   - Extremely small holes in hard materials
   - fuel filters
   - Carburetors
   - jet engine blade cooling holes

9. Plasma Arc welding (PAM)
   - tempr ⇒ 11000°c to 30000°c
   - Practically used upto 16000°c
   - Profile cutting of stainless steel, Al Alloy, tantalum etc.

<u>Screw thread manufacturing</u>

- External thread cutting Process
  1) Thread Chasing [High Quality]
  2) Thread rolling
  3) Thread grinding
  4) open die threading
- Internal thread cutting Process
  1) Tapping
- Both internal & External
  1) Thread milling

<u>Gear manufacturing Process</u>

- External Gear Processes
  1) Gear Planning
  2) Gear hobbing [highly accurate due to indexing mechanism]
  3) Gear milling
  4) Gear broaching
- Both internal & External
  1) Gear shaping