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MTM → finishing → surface finish
→ specified shape/size

→ material removal

Machining process → to achieve desired dimensional / shape takes tolerance and surface finish.

→ Material Removal

→ cutting tool → mechanical force
– shear deformation
– chip formation

MTM ✓

→ EDM → C/T → No forces

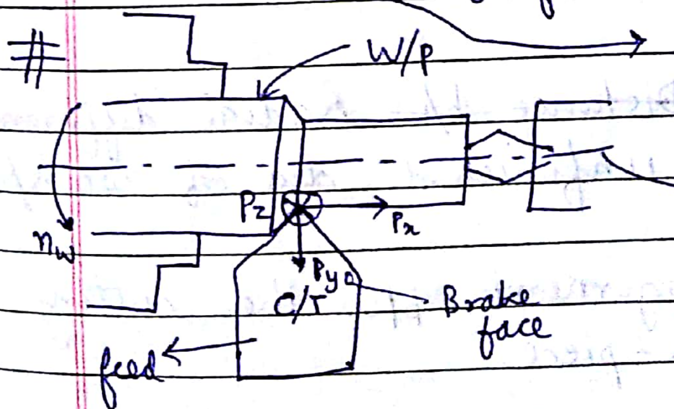
Taper Turning → cylindrical surface with changing dia.

Boring → ~~Reduce~~ Increase the dia of bore

Machine Tools and machining
→ forces ↓ and energy ↓
→ temperature ↓
→ surface finish ↓
→ dimensional tolerance - improved

↑ tool life

#



This is imp. (Central line necessary to show cylinder)

→ Pz would bend / defect the tool. If it deflects

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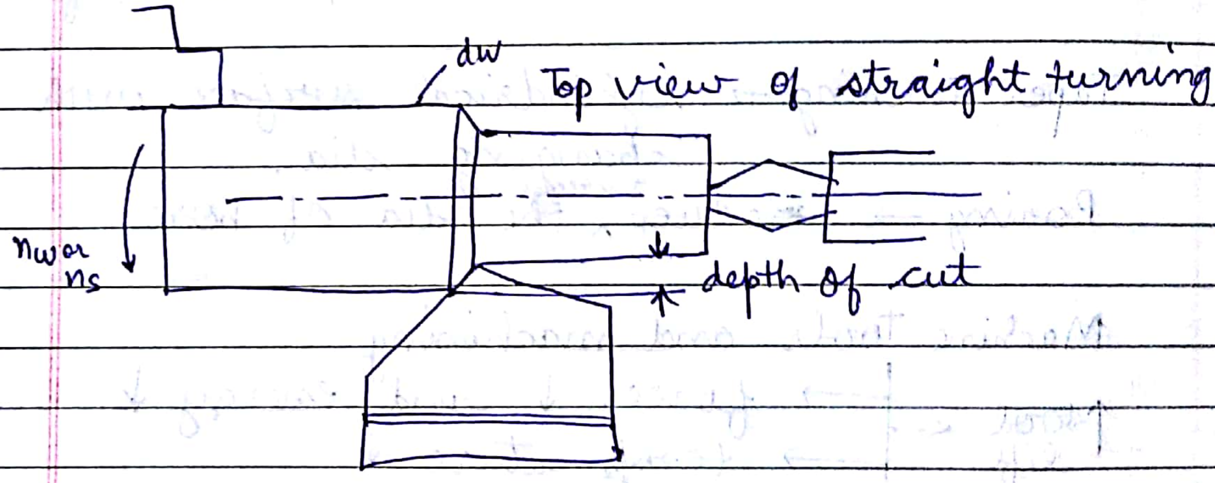
surface finish would reduce.
→ P_z would cause torsion on work-piece.

issues in machining:-
→ chip formation ↑. (force/energy)

tool life
↳ tool wear mechanism

Process Parameters
Some of typical machining Operations
↳ estimation of MRR
↳ Kinematic motions required in machine tool.



→ Depth of cut → ~~Distance b/w~~ Radial difference b/w finished & unfinished dia of workpiece.

→ measure of engagement b/w the cutting tool and work-piece.

→ Feed — Distance covered by cutting tool in a single revolution of job. (mm/rev)

→ n_s/n_w → Rotational speed of work-piece/spindle (rpm)

→ feed rate → mm/min

→ Cutting speed/vel → peripheral speed of the work-piece at the machining zone in turning.

v_c → m/min

$$\boxed{V_c = \frac{\pi d n_w}{1000}}$$

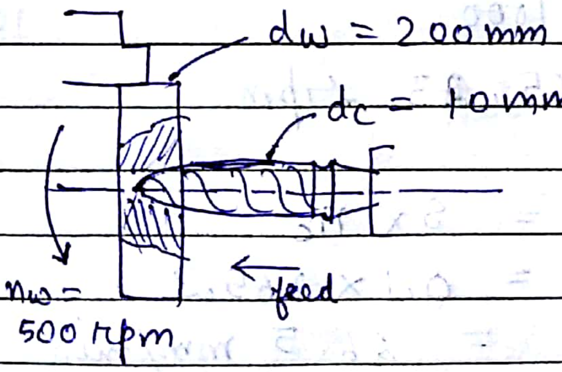
d → mm n_w → rpm

→ d_w → dia of work piece

→ Due to friction b/w generated chip and the tool, heat will be generated which is determined by feed, depth of cut, cutting speed (which are the process parameters).

$d_w = 100$ mm $n_w = 200$ rpm

$$V_w = \frac{\pi \times 100 \times 200}{1000} = 62.8 \text{ m/min}$$



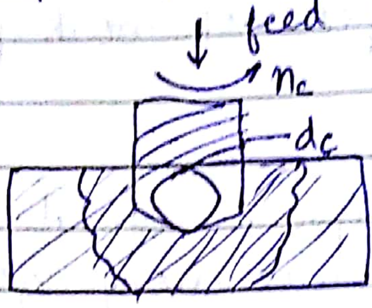
$$V_c = \frac{\pi d n}{1000}$$

$$= \frac{\pi \times 10 \times 500}{1000} = 5\pi$$

15.7 m/min

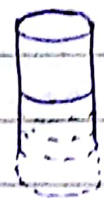
Here the cutter dia. is important as we have to bother for machining zone.

→ Depth of cut



To find MRR
→ Rate at which material is being removed
(mm^3/s or mm^3/min)

Geometrical similarity →
Toothpaste coming out of circular tube.



We will know feed; feed rate is to be found (It won't be given as it is not process parameter)

Given :- $v_c = 10\ m/min$
$d_c = 12\ mm$
$\text{feed} = s = 0.1\ mm/rev$

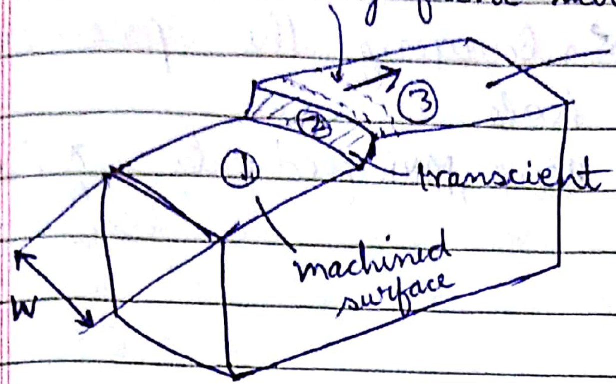
$$MRR = \frac{\pi}{4} \times d_c^2 \times (\text{feed rate})$$

$$\cancel{10 =}\ V_c = \frac{\pi d n_w}{1000} \qquad 10 = \frac{\pi \times 12 \times n_w}{1000}$$

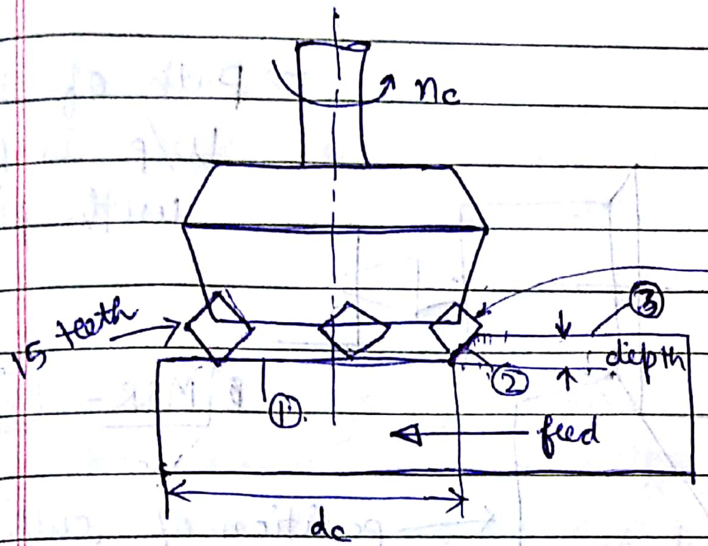
$$n_w = 265.3\ rpm$$

$$\text{feed rate} = S_m = S \times n_c$$
$$= 0.1 \times 265.3$$
$$= 26.5\ mm/min$$

$$MRR = \frac{\pi}{4} \times 12^2 \times 26.5$$
$$= \underline{2997.1}\ mm^3/min.$$



This can be achieved by face milling operation.



Known :- d_c, n_c, t, W

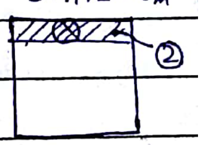
inserts or cutting edges or tooth

feed = 1.5 mm/rev

feed = 0.1 mm/tooth

feed (in milling) = S . Z ← no. of teeth

S.n.z = S_m



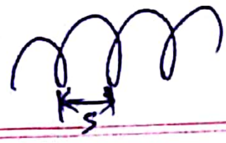
$$\therefore \text{feed rate} = \underbrace{(S.Z)}_{\text{feed}} . n_c$$

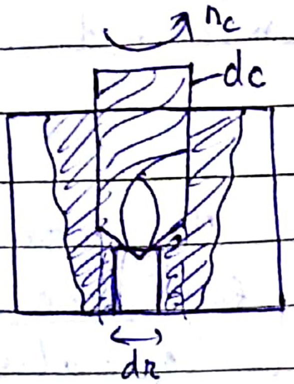
$$\therefore MRR = \underbrace{(S.Z.n_c)}_{\text{feed rate}} . \underbrace{W}_{\text{width}} . \underbrace{doc}_{\text{depth of cut}}$$

feed rate x width x depth of cut

$$\left[MRR = \text{Area of} \boxtimes \times \underbrace{S.n.Z}_{\text{feed rate}} \right]$$

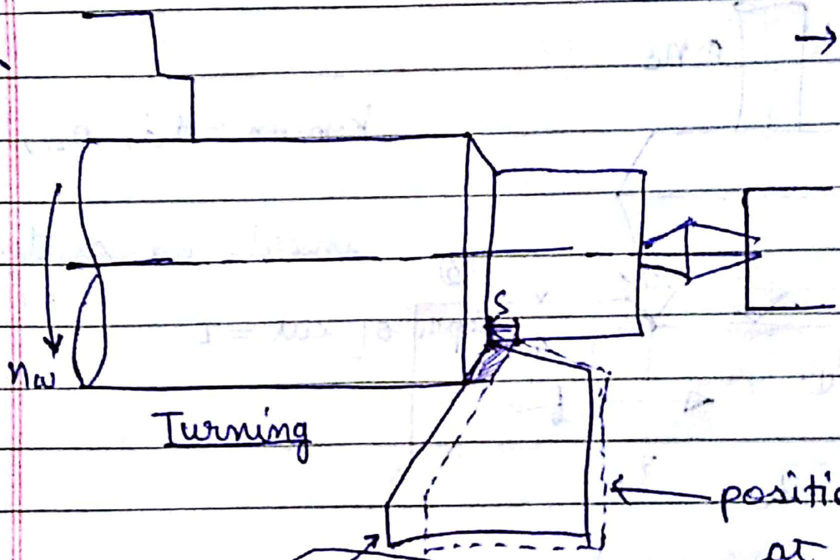
★ Find the cross sectional area where machining is taking place & how fast that area is being extruded.
↳ for calculation of MRR.



★ 

→ Enlarging the pre-existing hole

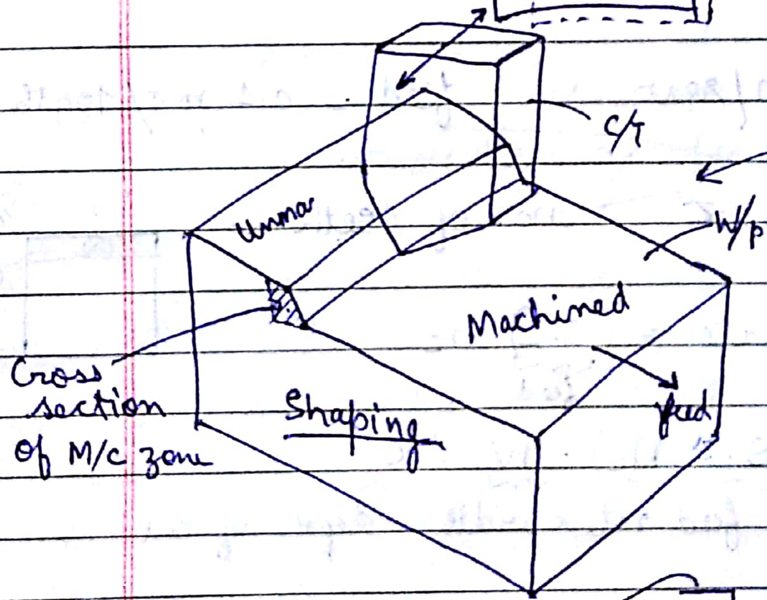
Here, $MRR = \text{feed rate} \times \frac{\pi}{4}(d_c^2 - d_r^2)$

★ 

→ Path of tip w.r.t W/p is helical with pitch = s

$\boxed{MRR = t \times S \times V_c}$

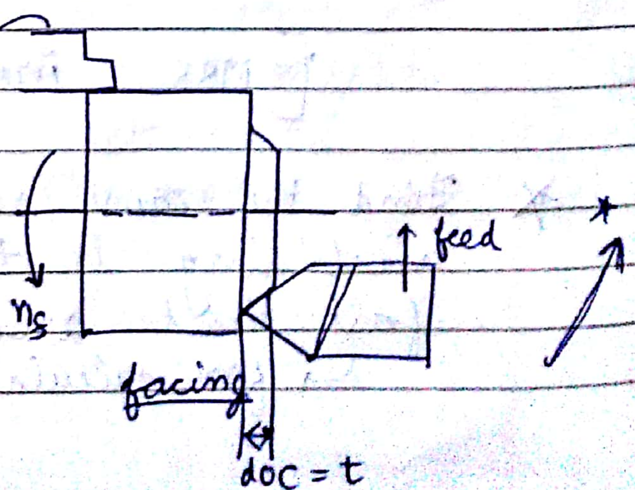
← position of cutting tool at earlier position (earlier revolution)



$\boxed{MRR = t \times S \times V_c}$

Here v_c is the to and fro cutting velocity of tool (stroke).

→ some typical operations in a lathe



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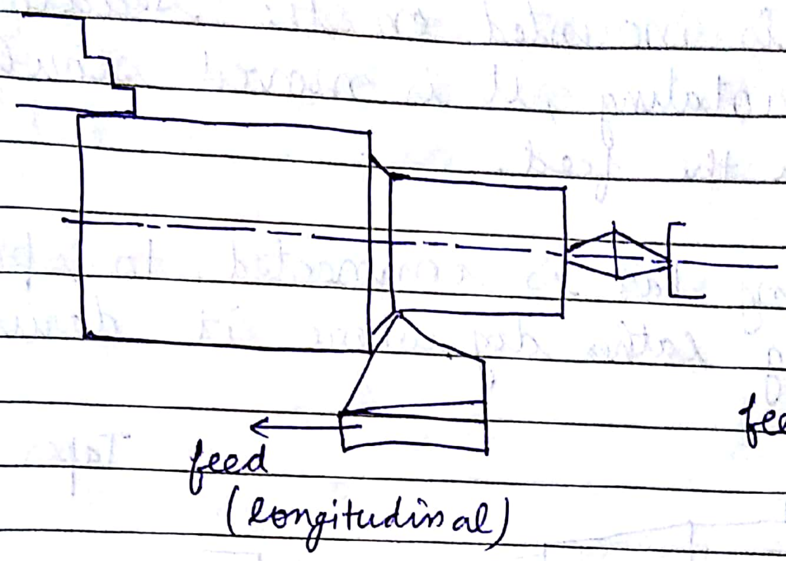
* motions : circular motion of the work-piece + transverse cross feed.



Straight turning

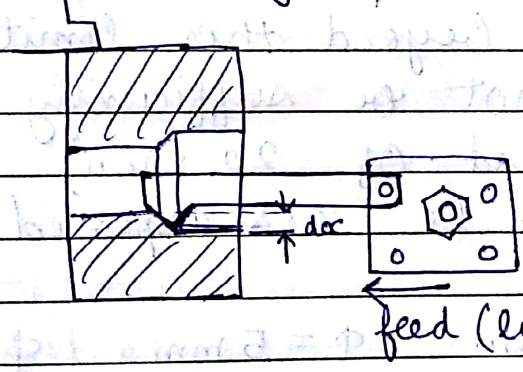
rotation of W/P + longitudinal feed motion of C/T.

→ Engagement of cutting tool & W/P is different.

Turning → ~~axial~~ ~~Radial~~ Axial

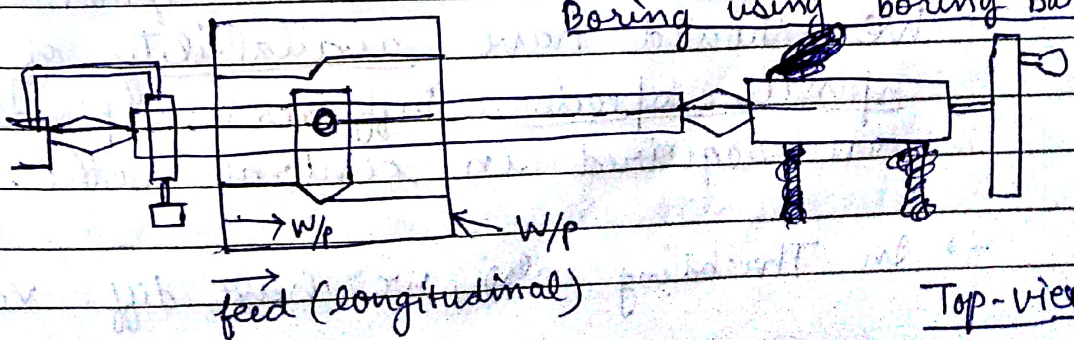
Facing → ~~Radial~~ ~~Axial~~ Radial

Boring w/p using a boring tool



Boring - enlarging a pre-existing hole

Boring using boring bar

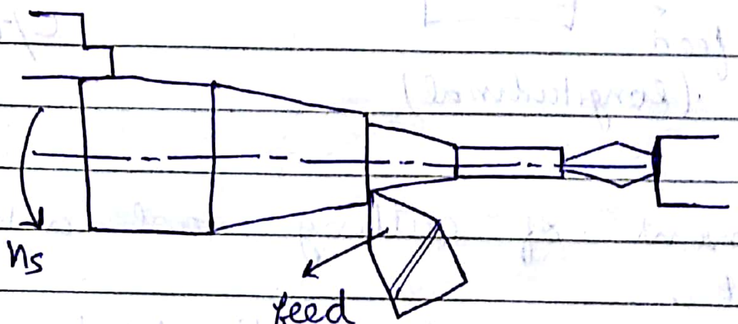


Here Boring bar is rotated ; W/p is stationary.
→ Lathe dog / Job catcher

→ Boring bar is ~~mouded~~ mounted b/w the centres.
→ W/p is mounted on the saddle ; it is not rotating, it is moved slowly (linearly) to give the feed.

→ Boring bar is connected to spindle using lathe dog where it derives power.

Taper turning



→ When machining low carbon steel like HSS, V_c should be ≤ 20 m/min.
This is critical speed & $V_c \leq 20$ m/min.
If V_c is ↑↑ beyond this limit, tool life would not be sufficiently large. (2 min instead of 20 min)
Tool need to be resharpened.

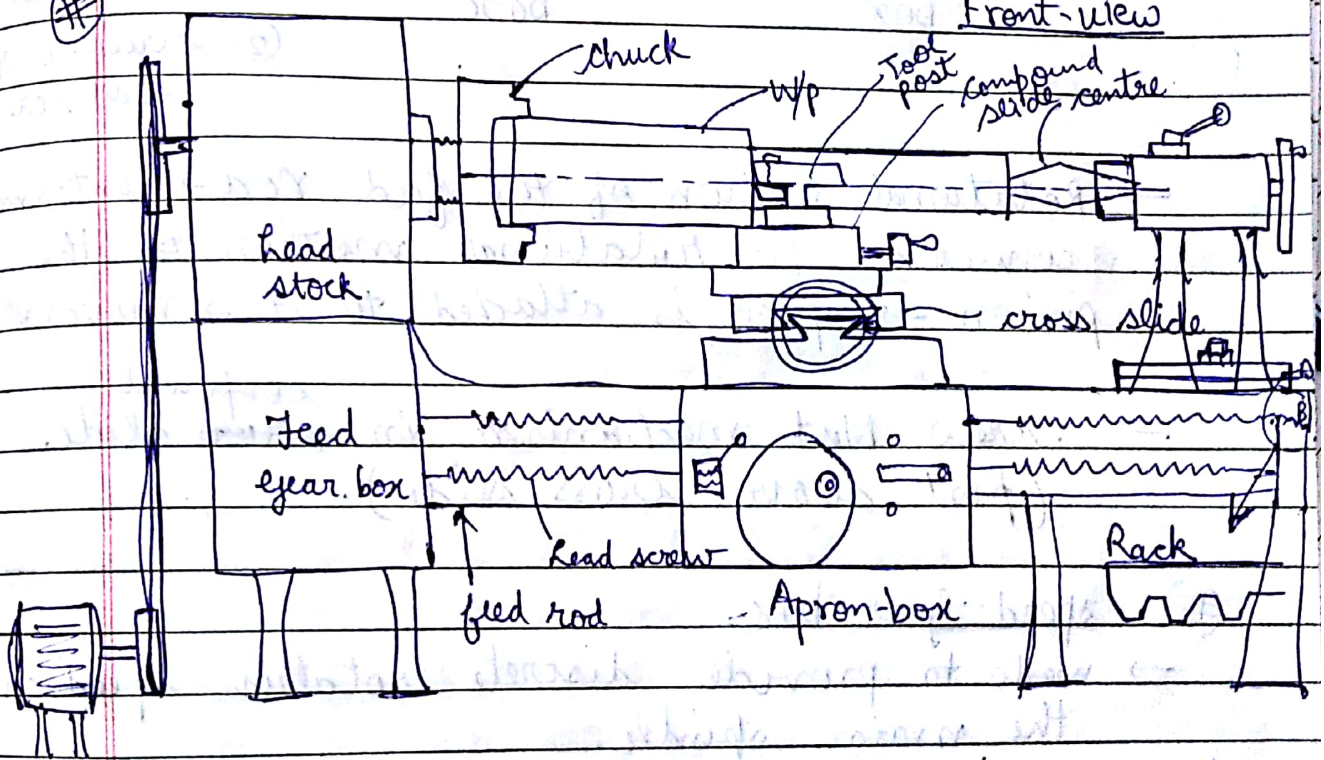
$\phi = 20$ mm $\phi = 5$ mm $\phi = 150$ mm
All need to maintain 20 m/min.
We should have availability of different spindle speeds. Different spindle speeds are required in central Lathe.

→ In Threading also, we have diff. V_c.

1. Requirement of diff V_c comes with difference in operation (turning v/s thread cutting)
2. Also it depends on what material you are machining (Low carbon steel v/s High carbon steel)
3. Longitudinal feed
4. cross feed
5. Motion in inclined plane of my choice

#

Front-view



→ A can be moved w.r.t. B (Upper part of tailstock can be moved). Axis of spindle will be different from central axis.

→ head stock has speed gear box

→ Rack on the underside of a lathe bed.

→ Apron-box hangs in front of lathe bed.

→ Apron-box has 2 motions — automated & manual.

→ Manual motion is done with help of the wheel.

→ When apron box moves, everything on top of it moves along with it.

→ Belt-pulley mechanism is friction drive while the gear is mechanical drive, no friction will be there → teeth interlocking

→ Motion & power comes from

speed gear box → feed gear box — ① circular due to feed rod
② circular of lead screw

→ Rotational motion of the feed rod → internally converted to rotational motion of the pinion → apron is attached to it → moves ✓.

→ Screw-Nut mechanism in ~~cross~~ compound slide. (part above cross slide).

speed gear box

→ needs to provide discrete rotation speed on the main spindle.

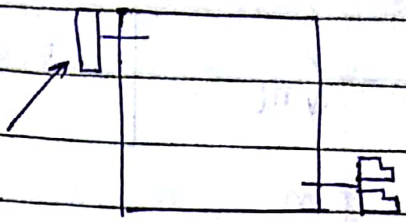
Feed gear box

→ need to provide automatic discrete feeds in longitudinal & cross direction

It should enable machining of standard threads (metric thread, module thread, british threads)

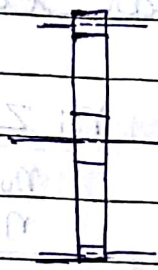
Kinematic diagram of speed gear box

power & motion
from an electric
motor,

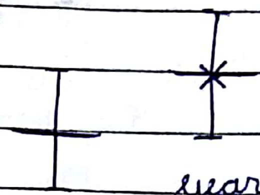


power & motion
(rotational)
– discrete speeds

P.T.O.



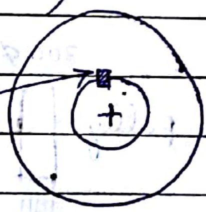
Gear
(actual)
(ED representa^n)

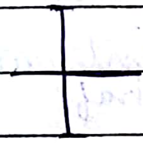


gear
is
"keyed in"
on the shaft

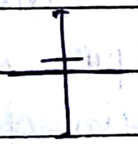
"keyed in"

→ This prevents rotation and translation of gear

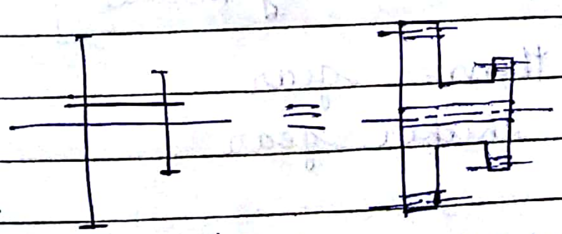




← Gear can freely Rotate
Freely mounted gear.

→ 

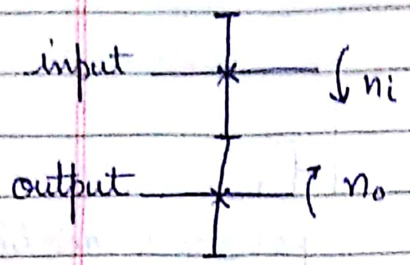
← This cannot be rotated but can be slided (sliding gear). Gear rotates along with the shaft, and can be slided along the shaft.

→ 

(Schematic) ≡ ED

2 gear are manufactured together (not welded) and can slide on shaft.

⊛ Transmission Ratio = u



$$\boxed{u = \frac{n_o}{n_i}}$$

$n_i d_i = n_o d_o$
↓
P.C.D. of gear

when $d_p = m \cdot z$

m = module

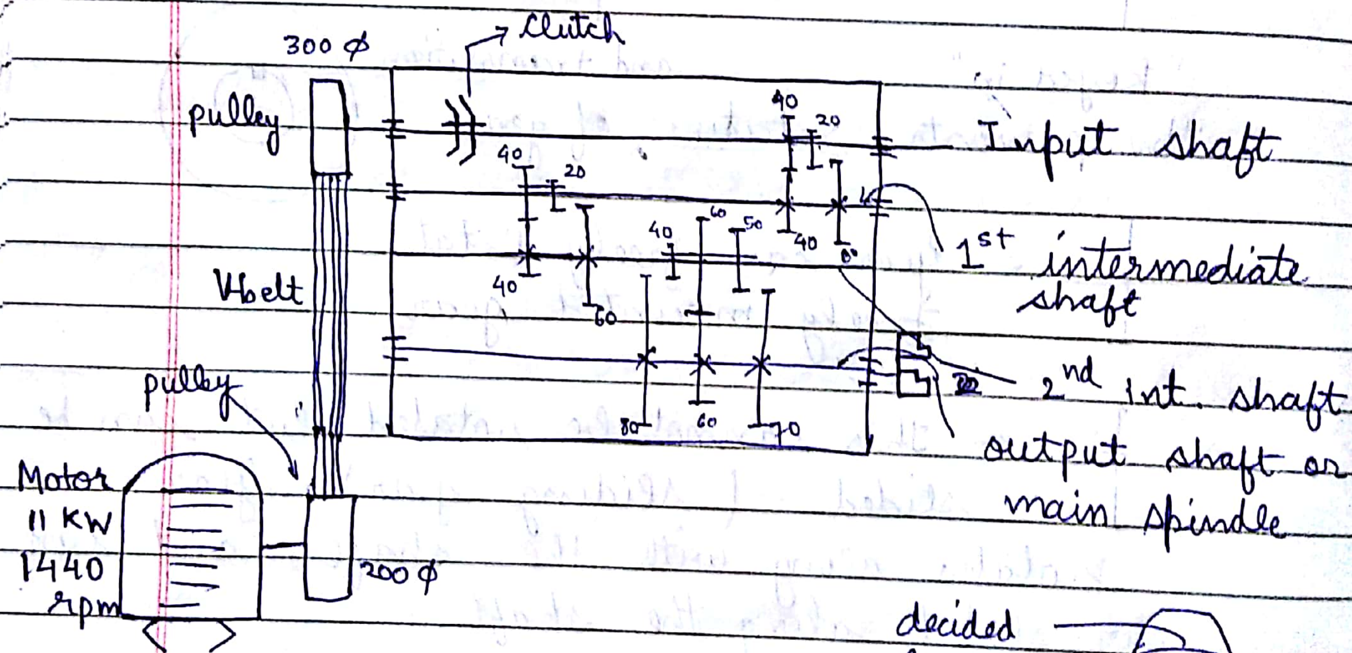
z = no. of teeth

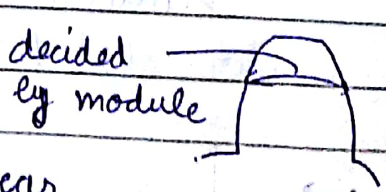
2 gear can only mesh ~~the~~ if $m_1 = m_2$

$$n_i z_1 = n_o z_2$$

$$\boxed{\frac{n_o}{n_i} = \frac{z_1}{z_2} = u}$$

Speed Gear Box :





→ Low module :- thinner gear
High module :- thicker gear

→ module ∝ Torque required to transfer
↳ affects strength of tooth.

→ Clutch is used to stop the spindle by disengage the clutch. It is a friction device so mech. & elec. components won't fail easily.

→ Cluster can slide as a single piece. It will always rotate with spindle. Depending on which gear of cluster is engaged, speed and transmission ratio changes accordingly. Both gears in cluster

→ Total 12 possible output, To make it 24 we should have dual speed motor.

→ Module is kept same & is not changed generally.

$$d_1 = m z_1 \qquad d_2 = m z_2$$

$$m(z_3 + z_4) = m(z_1 + z_2)$$

→ Find max. & min. speed at output.

→ speed at pulley $= \frac{2}{3} \times \cancel{1440}^{480} = 960$ rpm

Max:

$$\frac{40}{40} \times \frac{40}{40} \times \frac{60}{60} \times 960 = \underline{960 \text{ rpm}}$$

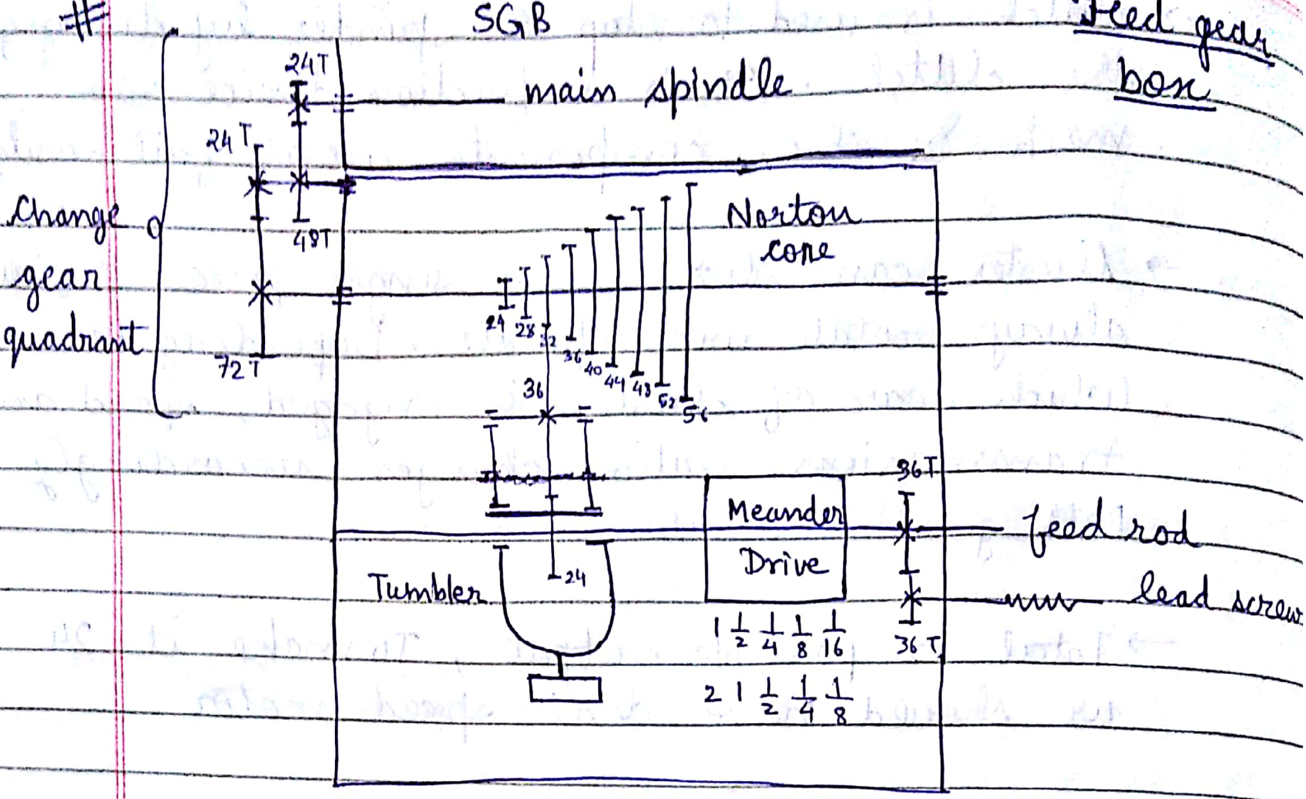
$$\text{Min} = \frac{20}{60} \times \frac{20}{60} \times \frac{40}{80} \times 960 = \frac{1}{3} \times \frac{1}{3} \times \frac{1}{2} \times 960 = \frac{160}{3}$$

$$= \underline{53.33 \text{ rpm}}$$

$$\approx 53 \text{ rpm}$$

$$[\, n_m \times U_{pulley} \times U_{1/2} \times U_{2/3} \times U_{3/4} \,]$$

Feed gear box



→ Idlers are used to change the direction & to compensate the distance between the shafts.

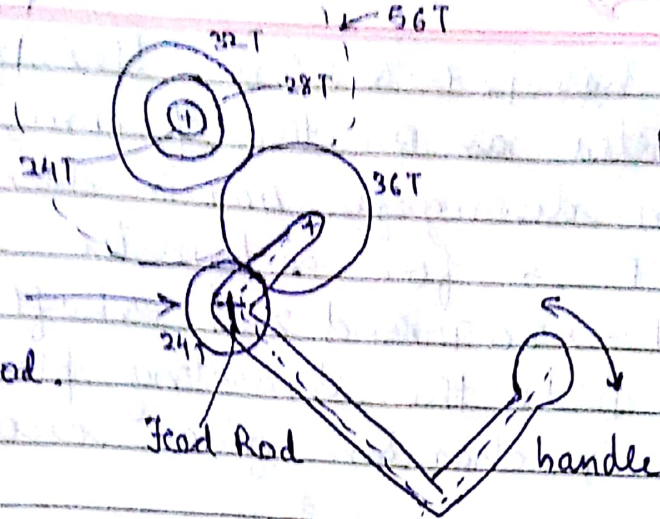
→ 9 speed Norton cone

→ Meander Drive has selectable transmission ratios; at a time only 1 of the 2 series (either $1, \frac{1}{2}, \frac{1}{4} \cdots$ or $2, 1, \frac{1}{2} \ldots$). Total of 5 selectable Transmission Ratios.

→ There are some common total transmission ratios like $\frac{24}{24} \times 1 = 1$ & $\frac{48}{24} \times \frac{1}{2} = 1$

So in total $9 \times 5 = 45$ available transmission ratios, these are repeated.

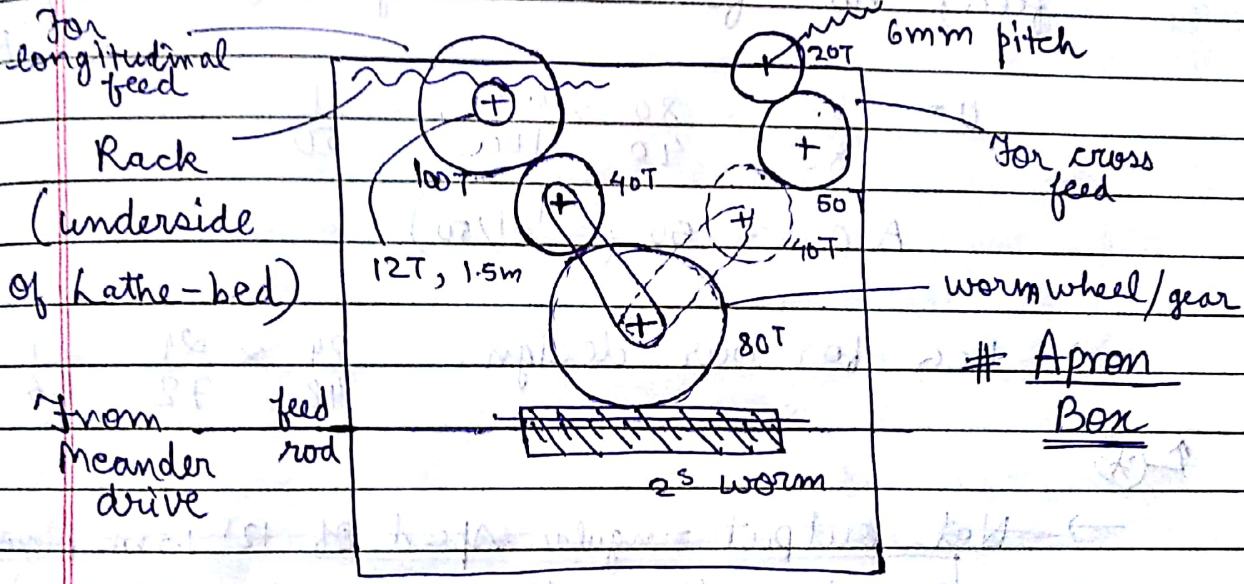
→ Tumbler



24T is ⊥ to feed rod.

Rotate the handle so that 36T gear can be engaged to different gears of Norton cone. The whole handle thing could be slided on the feed rod so that 36T could be engaged with different gears. 24T gear is fixed.

Apron Box



→ Apron receives from either feed rod or lead screw depending on user. Lead screw generally used for threading.

→ On feed rod, a worm is mounted having 2 start thread (to increase the pitch). Worm wheel has 80T

→ On the same ~~rod~~ shaft where 100T is mounted, pinion gear is also mounted

(*) → Angular speed of 12T 1.5m pinion

$= n_s \times U_{CG} \times U_N \times U_M \times \frac{1}{A.C.}$

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which has 12T & 1.5m. The pinion is mounted ~~as~~ on the frame of the box.

→ Arm disengages 40T & connects another 40T → for automatic cross feed

50T → 20T and 20T shaft has a screw nut ⊥ to the drawing plane → screw nut

This mechanism gives cross slide.

→ Apron constant = $\frac{1}{\text{(Transmission ratio b/w feed-rod \& longitudinal-feed pinion)}}$

It is only there for longitudinal feed; not for cross feed (no concept of A.C.)

$U = \frac{2}{80} \times \frac{80}{40} \times \frac{40}{100} = \frac{1}{50}$

$A.C. = 50 \ (= 1/(1/50))$

→ U_{CG} for our design :- $\frac{24}{48} \times \frac{24}{72} = \frac{1}{6}$

(*)

→ ~~Net output angular speed of 12T 1.5m pinion =~~

$$\boxed{S_m = n_s \times U_{CG} \times \underset{\text{Norton cone}}{U_N} \times U_M \times \frac{1}{AC} \times (\pi \underbrace{m z}_{d_p})}$$

Feed Rate

from SGB (in rpm)

$U_M = (2, 1, \frac{1}{2}, \frac{1}{4}, \frac{1}{8})$ (Assume)

$\therefore S_m = 120 \text{ rpm} \times \frac{1}{6} \times 1 \times 2 \times \frac{1}{50} \times (\pi \times 1.5 \times 12)$ mm

$= 45.2$ mm/min

Assuming that it is engaged with the start most gear

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$$\text{feed} = \frac{S_m}{n} = S = U_{CG} \times U_N \times U_m \times \frac{1}{AC} \times (\pi m z)$$

$$= 0.452 \text{ mm/rev}$$

Min. feed $= \frac{1}{16} \times$ ~~feed~~ 0.452 $\left(\text{min } U_m = \frac{1}{8}\right)$

Max. feed =

Max. cross feed $= n_s \times \frac{1}{6} \times \frac{56}{24} \times 2 \times \left(\frac{2}{80} \times \frac{80}{40} \times \frac{40}{50} \times \frac{50}{20}\right) \times 6$

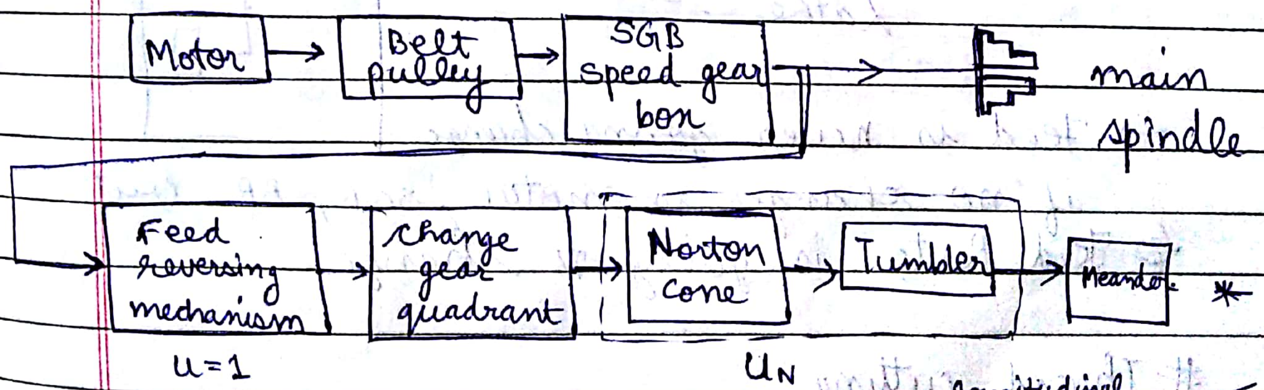
pitch of cross-feed lead-screw

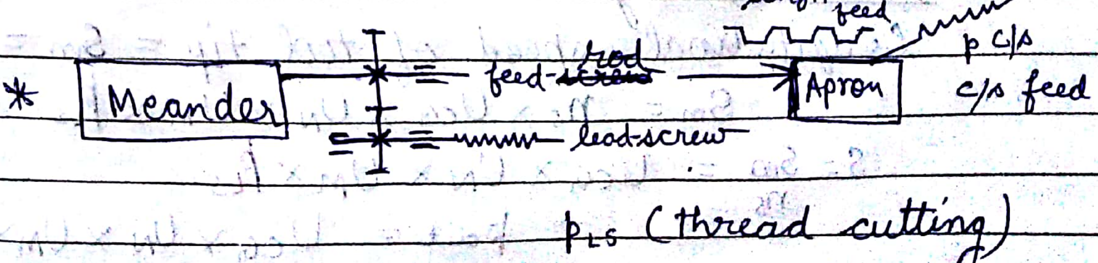
$= S_m \text{(cross-feed)} = 56$

$S\text{(cross-feed)} = \frac{S_m (c_f)}{n_s} = 0.47$

→ Apron attached to saddle (together called carriage). Saddle hangs on lathe bed and slides. Glides & slides provide support to saddle.

Kinematic Block Diagram of Centre-Lathe:





Metric Lathe?

→ If the lead screw has a standard pitch in mm → then it is a metric.

How power goes directly to tumbler?

→ In case of british, power does not come to Norton cone, it comes directly to tumbler.

→ $n_{spindle} = n_M \times U_{BP} \times U_{SGB}$ (Main spindle speed)

→ $n_{feed\ rod} = n_S \times U_{GG} \times U_N \times U_M$

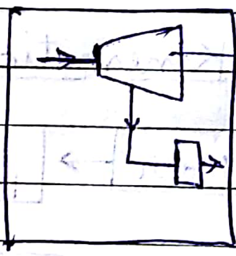
→ $S_m\ (mm/min) = n_S \times U_{CG} \times U_N \times U_M \times \frac{1}{A.C.} \times (\pi m z)$

(m → module
z → no. of tooth of pinion)

→ $S_m = n_S \times U_{CG} \times U_N \times U_M \times \circledast \times P_{c/s}$

where $\circledast$ → Transmission ratio b/w feed rod & c/s feed ~~to~~ Lead Screw.

→ Arrangement in Metric Lathe :-



→ Feed is never gonna change if no changes in motor, SGB, BP but → Feed Rate is going to change.

Thread cutting

Longitudinal speed of tool tip = S_m =

$$S_m = n_S \times U_{CG} \times U_N \times U_M \times P_{LS}$$

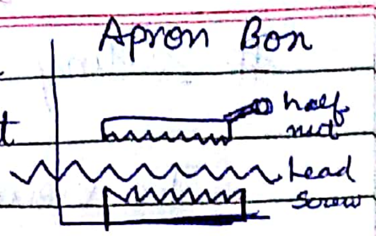
$$S = \frac{S_m}{n_S} = U_{CG} \times U_N \times U_M \times P_{LS}$$

$$p_{cut} = U_{CG} \times U_N \times U_M \times P_{LS}$$

P_{LS} → Lead screw pitch

p_{cut} = pitch of thread cutting

→ Feed ~~Reversing~~ Reversing mech → To change the ~~gear~~ direcⁿ of feed according to our requirement. eg. to make left hand thread cutting etc.



* Half nut & feed mech. cannot be engaged simultaneously. Half nut is mounted TO apron & can be used to connect apron box to lead screw. It automatically disengages feed rod. Rotation of ½ nut is not obtained; so as the lead screw rotates, the apron moves → used for thread cutting.

→ Apron drive – there is friction clutch, if there is any damage in the cutting tool → clutch will save and prevents overload. In thread cutting mech, there is no friction drive → thus can't prevent overload.

Norton cone = 32, 36, 40, 44, 48, 52, 56

Tumbler = 32 ; Idler = 36 ; P_{LS} = 16 mm

Meander = $\{1, \frac{1}{2}, \frac{1}{4}, \frac{1}{8}, \frac{1}{16}\}$

Change gear = $\{\frac{24}{32} \times \frac{32}{54}\}$ $U_M = 1$

Calculation???

Pitch of Thread?

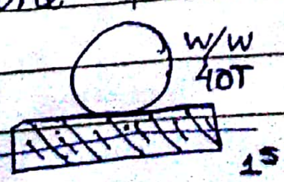
	UN	32	36	40	44	48	52	56	60
$U_M = 1$	Pait	8	9	10	11	12	13	14	15
$\frac{1}{2}$		4	4.5	5	5.5	6	6.5	7	7.5
$\frac{1}{4}$									
⋮									

Pitches of standard threads that can be machined.

What about the 9th gear of Norton cone?

⇒ Total = 8 × 5 = 40 pitches (threads

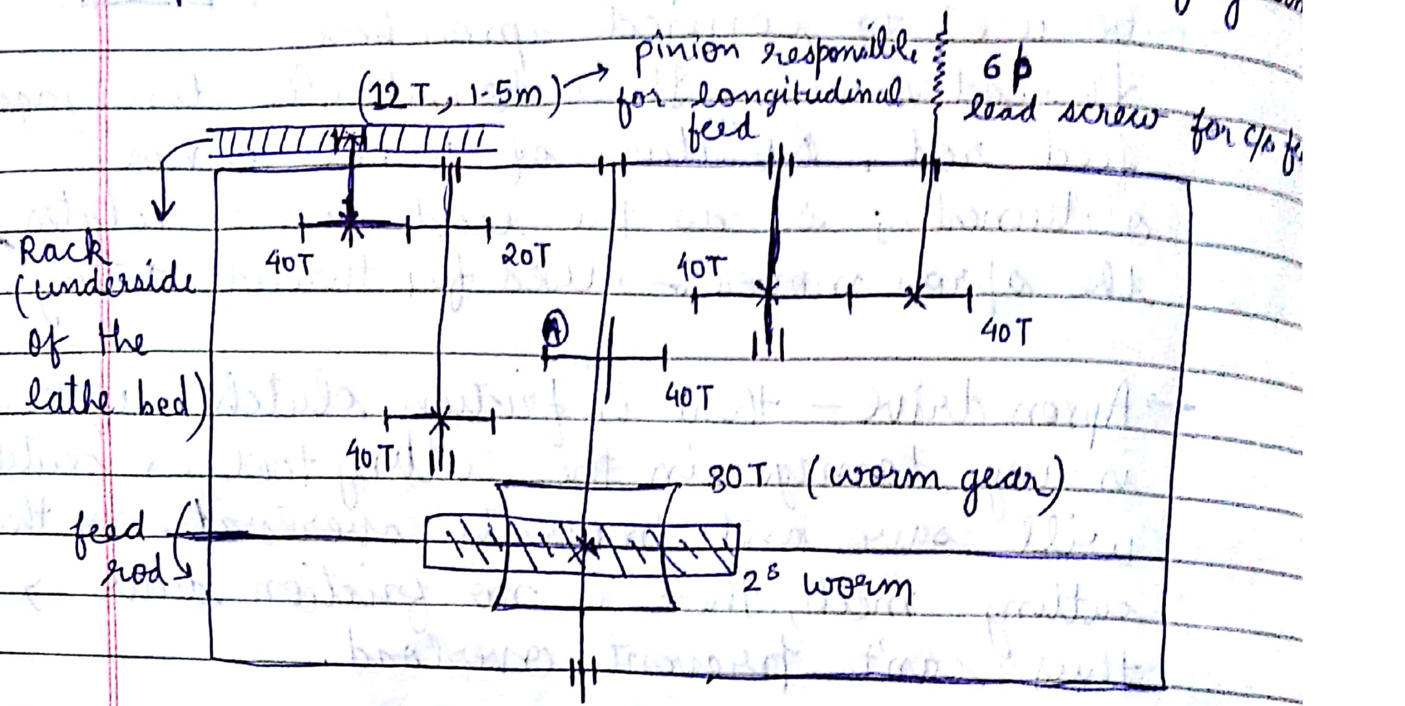
→ U_{CG} can be changed to machine threads of larger pitch.



Date 18/1/18

Sliding Apron :

Top view :- Earlier Apron shown is "swinging arm

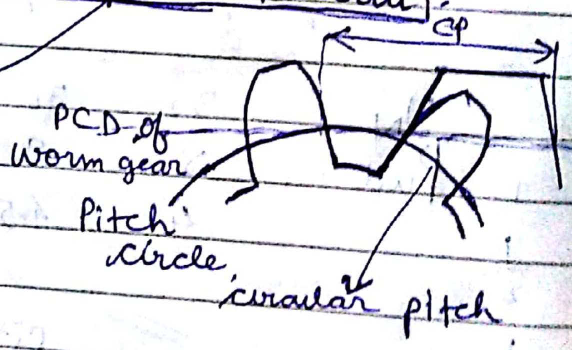


At this moment, sliding gear Ⓐ is in neutral position. Auto-longitudinal or auto-c/s feed → not engaged.

Kinematic diagram of module thread :

$Z \times CP = \pi m Z$ Defn

$\Rightarrow \boxed{CP = \pi m}$



$U_{CG} = 1/2$

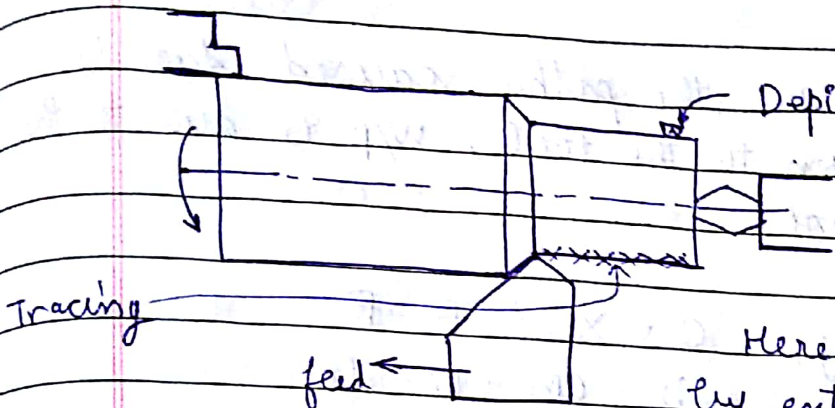
$\frac{1}{2} \times \frac{48}{32} \times 1 \times 16 = 12$

$U_{CG} \times U_N \times U_M \times P_{LS} = P_{cut}$

Module 2

Generatrix and Directrix } to identify different motions required in m/c tools to generate surfaces

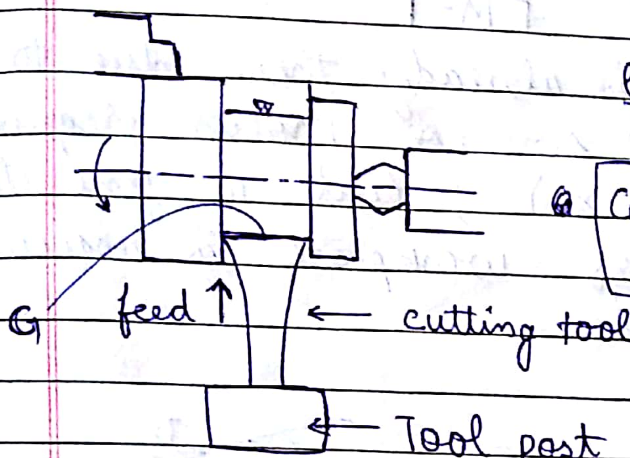
Depicts good surface finish



Straight Turning

Here cylinder is generated by extrusion of a circle.

Grooving



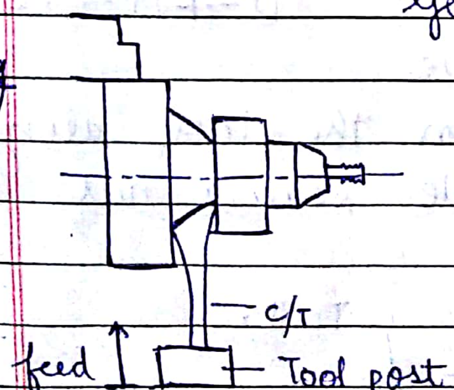
Cutting motion – work peice
Feed motion – Tool

G – CM – W – Tr
D – FM – T – Tr

→ Here cylinder is generated by rotating a line about some axis

→ Generatrix is the line, directrix is axis. Generatrix is moved over directrix to get a surface.

Parting

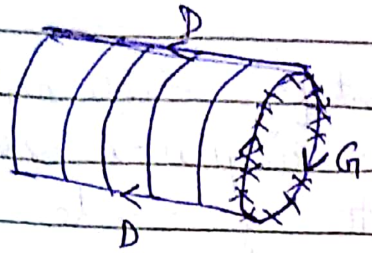


G – X – T – F
due to Form of tool

D – CM – W – Tr

Here we are getting the Generatrix due to feed of tool

A line is there due to form of tool; the line rotates → Directrix ← due to CM

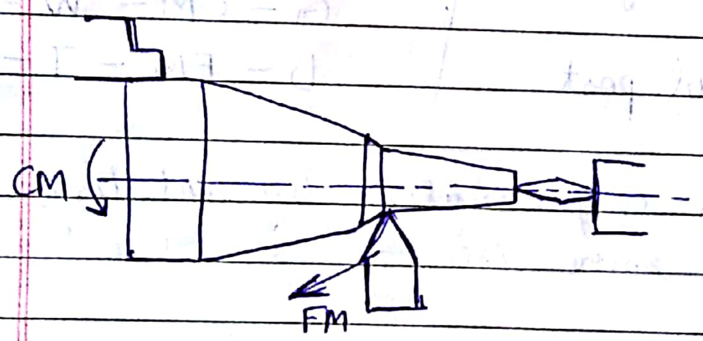


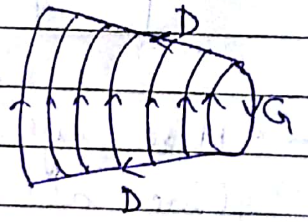
Tracing In straight turning the line of the directrix is being traced.

Gen. & Dir. are the paths caused due to motion given to the tool, W/P & due to the form of tool.

For grooving, G – X – T – F
D – CM – W – Tr
FM – T

The generatrix is already there due to form of tool; so no motion required to generate (∴ X); but to generate directrix, CM of workpiece is required → directrix in motion.





G – CM – W – Tr
D – FM – T – Tr

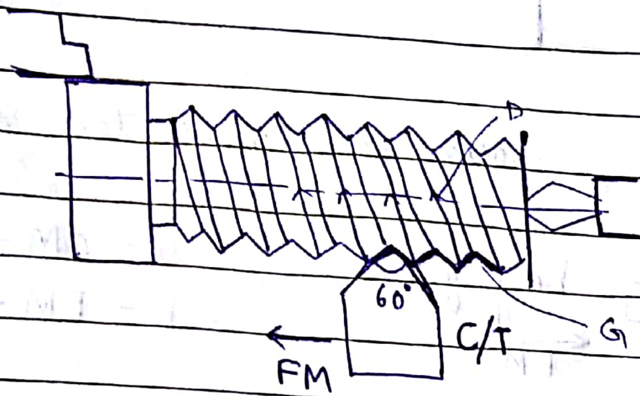
For central lathe, for taper turning swivel motion helps to turn the tool along the inclined line → simple screw nut mechanism

For CNC : $D - \begin{Bmatrix} FM_L - \\ FM_{cys} - \end{Bmatrix} T - Tr$

In CNC, taper turning is done by 2-axis

motion ; The two motions are coupled (FM_{L} & $FM_{c/s}$) ; Their coupling law decides the shape and depends on open ay.

Threading



The shape of the tool decides the generatrix. Here the contact region is the groove, so it is the generatrix.

$$\left.\begin{array}{l} D - CM - W - \\ \quad \underbrace{FM}_{} - T - \end{array}\right\} Tr \qquad G - X - T - F$$

Coupled Motion → Achieved due to lead screw

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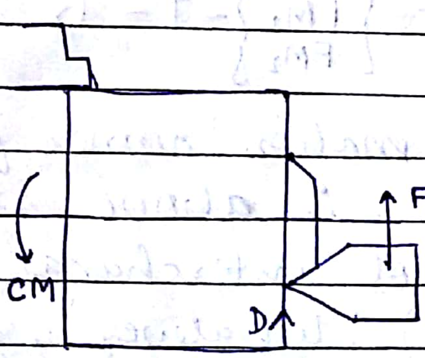
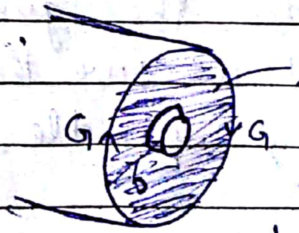


Facing
G - CM - W - Tr
D - FM - T - Tr



Date 19/1/18
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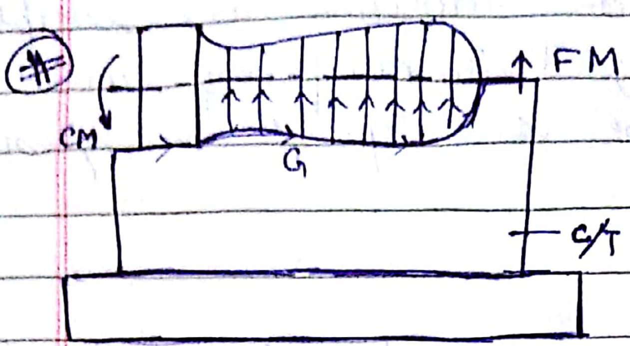
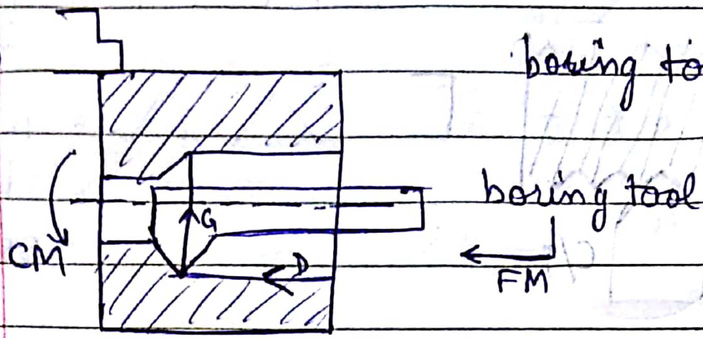


Form Turning

G - X - T - F

D - CM - W - Tr

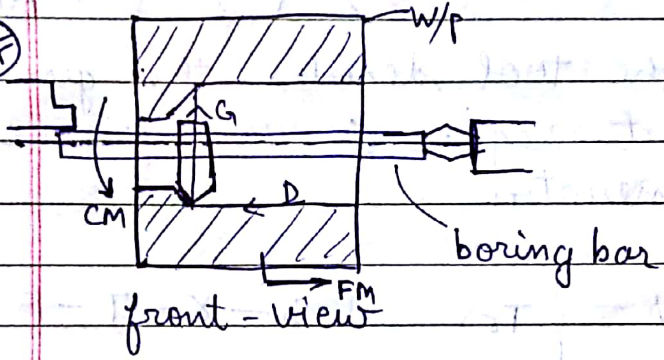
FM - T



boring tool mounted on tool post

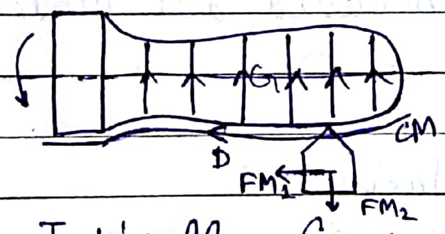
G - CM - W - Tr

D - FM - T - Tr



G - CM - T - Tr

D - FM - W - Tr



CNC form turning

G - CM - W - Tr

$D - \left\{ \begin{matrix} FM_1 \\ FM_2 \end{matrix} \right\} - T - Tr$

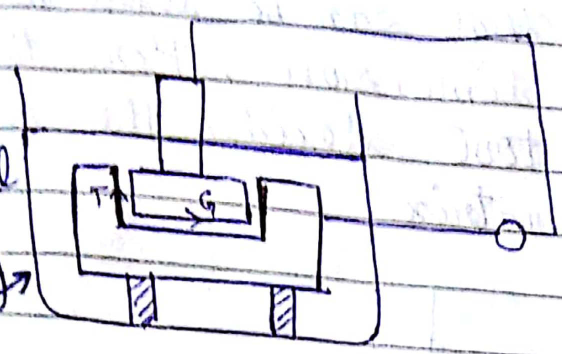
→ Typically Generatrix motion comes first, then you give feed, ∴ above statement is true & we cannot interchange G & D there (by convention). Whatever we are doing first which decides the generating path → generatrix (first we give the CM)

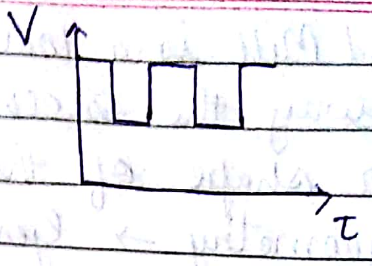
→ For a straight turning, spindle is switched on first.

Typically G & D are not mentioned for non-conventional processes.

#11

Non conventional Machining





G − X − T − F

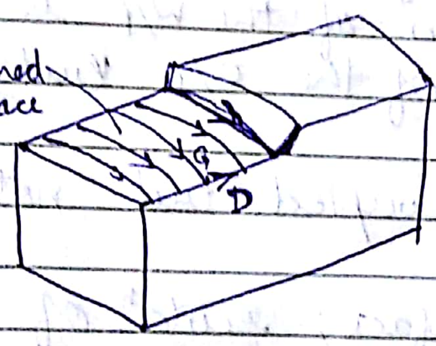
D − FM − T − Tr

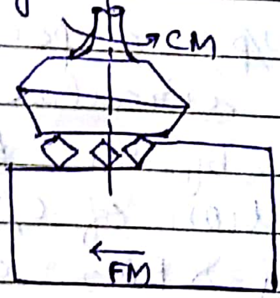
EDM
(Electron Discharge M/cing)

→ Tool was used to make square holes. cutting motion not required in EDM. For EDM to be applied, material should be ~~con~~ electrically conductive. Eg. Al cannot be m/c using EDM.

#11

Imp:





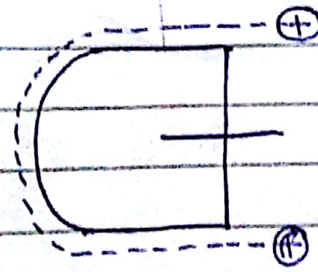
Face Milling

G − CM − T − Tr

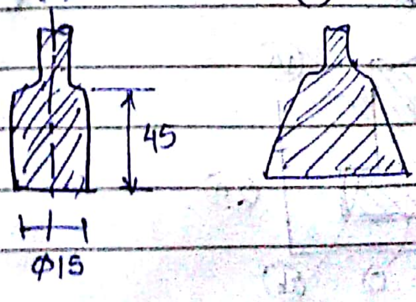
D − FM − W − Tr

→ In drilling both CM & Feed is provided to tool but in central lathe, CM is provided to w/p & feed to the tool using wheel

→ Shaping & Planing → YouTube ▶



(a) (b)



G − X − T − F

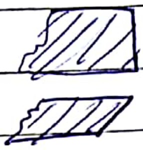
D − CM − T
FM$_1$ − T
FM$_2$ − T
T = Tr

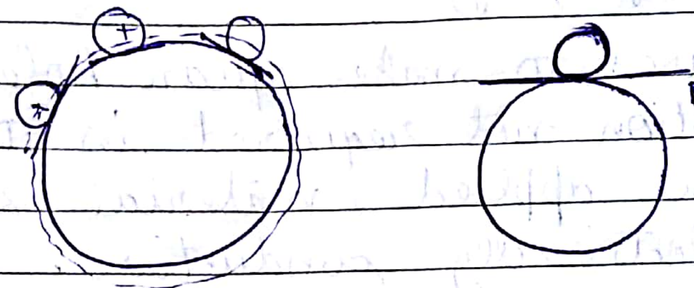
Tangent tracing


← several such cutting tools

End Mill is a tool that can be used to cut away the excess dimension. Here the form or shape of the tool decides the resulting geometry → Generatrix

End Mill (a)
End Mill (b)





common Tangent of 2 circles

→ Here the common tangent b/w cutting tool & W/p (a point in general)
→ The circular form of the W/p is generated not by the form of the C/T but by the rotation of C/T.
→ FM_1 & FM_2 are coupled but not CM; It is simultaneous.
→ To generate the surface; rotaⁿ of C/T is very much imp.

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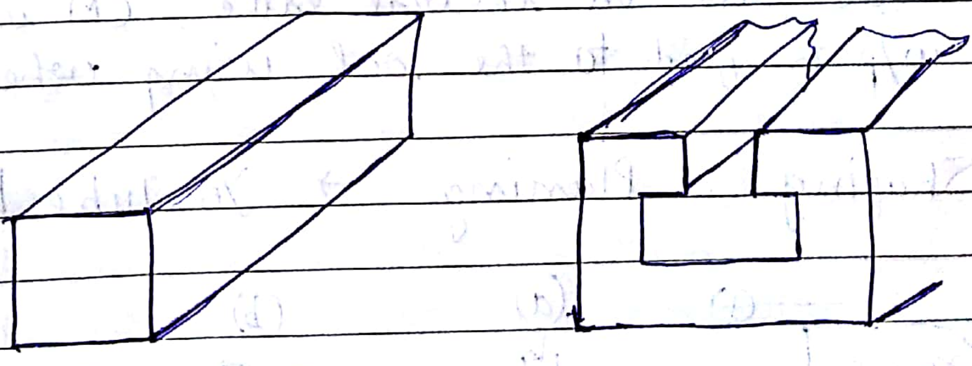
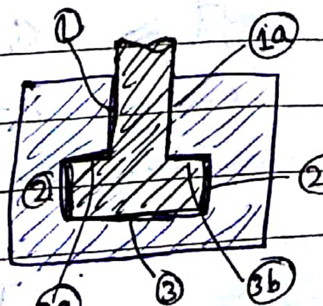
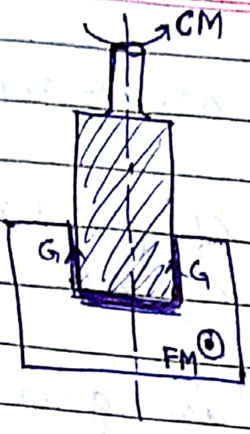


I-slot



why CM? → If we have a fixed no. of tools (say 1) ; this will dis-engage after some rotation; So CM is very important.

#



Face Surface

G — CM — T — Tr

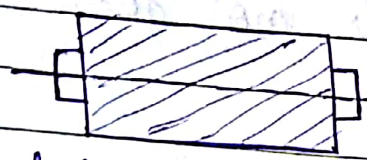
D — FM — T — Tr

Side Surface

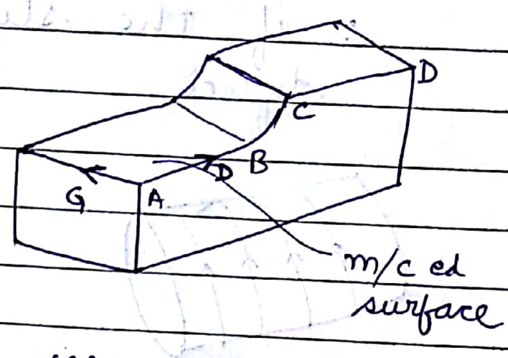
G — X — T — F

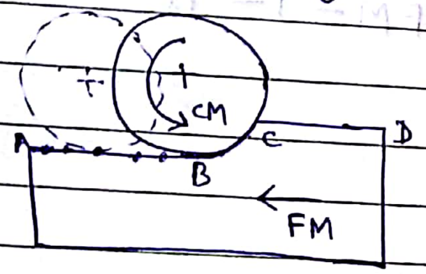
D — CM — T } T. Tr
FM — W

#



helical fluted
Slab milling cutter



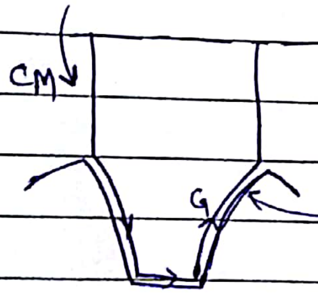


Up-milling operation

G — X — T — F

D — FM — W } T. Tr
CM — T

#



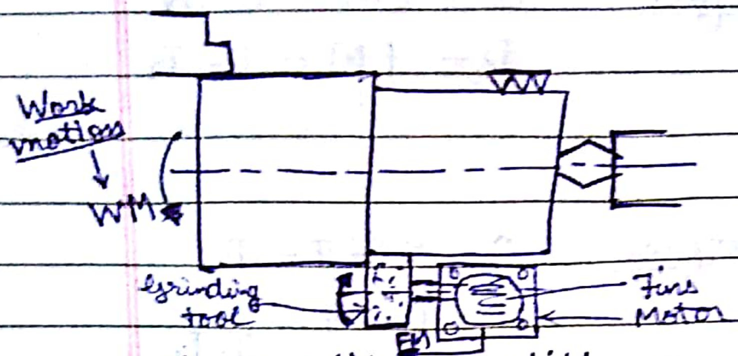
Helical Gear using form-milling cutter

Involute profile → dictated by no. of teeth
↳ provided by form of ~~too~~ cutter

G — X — T — F

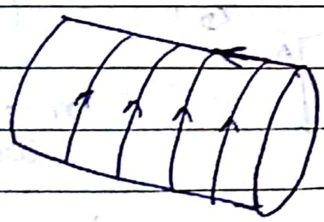
D — CM — T } T. Tr
FM — W

Rule of Thumb → If form of tool is defining either G or D, possibly by rotaⁿ of tool, then 1 of them is generated by Tangent Tracing.



There are 3 motions
1. FM
2. CM of grinding wheel
3. CM of W/P

→ Rigidity & stiffness is high in grinding because Material Removal is very less
∴ if the stiffness is not good, it will deflect.



G – { WM – W, CM – T } T. Tr

D – FM – T – Tr