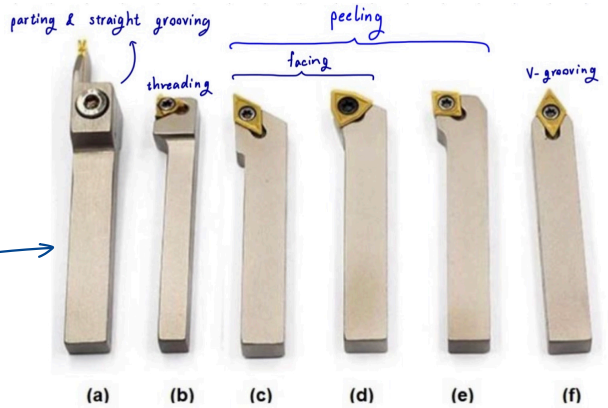
MANU CHEAT SHEET! (according to old exams.)

To find the cutting condition (f: Machine feed rate, V: cutting velocity, d: depth of cut) (and machining time)

Step 0) Define cutting procedures (common + logical sense using these tools)
(define cutting type, d: depth of cut)



Step 1) Calculate spindle speed, MRR.

1. given V from the table. 50 m/min

Material	High-Speed Steel Cutter ft/min	High-Speed Steel Cutter m/min	Carbide Cutter ft/min	Carbide Cutter m/min
Alloy steel	40–70	12–20	150–250	45–75
Aluminum	500–1000	150–300	1000–2000	300–600
Bronze	65–120	20–35	200–400	60–120
Cast iron	50–80	15–25	125–200	40–60
Free machining steel	100–150	30–45	400–600	120–180
Machine steel	70–100	21–30	150–250	45–75
Stainless steel	30–80	10–25	100–300	30–90
Tool steel	60–70	18–20	125–200	40–60

2. Calculate N

3. given SE from the table

APPROXIMATE ENERGY REQUIREMENTS IN CUTTING OPERATIONS (at drive motor, corrected for 80% efficiency; multiply by 1.25 for dull tools).

Material	Specific Energy W · s/mm³	Specific Energy hp · min/in.³
Aluminum alloys	0.4–1.1	0.15–0.4
Cast irons	1.6–5.5	0.6–2.0
Copper alloys	1.4–3.3	0.5–1.2
High-temperature alloys	3.3–8.5	1.2–3.1
Magnesium alloys	0.4–0.6	0.15–0.2
Nickel alloys	4.9–6.8	1.8–2.5
Refractory alloys	3.8–9.6	1.1–3.5
Stainless steels	3.0–5.2	1.1–1.9
Steels	2.7–9.3	1.0–3.4
Titanium alloys	3.0–4.1	1.1–1.5

4. calculate $MRR = \frac{60P}{SE}$ (mm^3/min)

Step 2) Calculate f of the steps of the defined process.

1. Define d and number of steps.
2. From MRR formula of the selected process, calculate f.
3. Repeat step 2. for each cutting steps.
4. Repeat steps 1., 2. and 3. for the remaining steps.

Step 3) Calculate machining time.

1. Calcuate t for each step
2. Sum the results from all steps.

To find minimum power to cut

Step 1) Find MRR

Step 2) find power

To reduce/increase power

P is directly proportional to f (P increases → f increases)

To find cutting power

Step 1) Find shear force

Step 2) Find missing angles

Step 3) Find R

Step 4) Find cutting force

Step 5) Find cutting power

FORMULAS

Spindle speed

$$N = \frac{1000V}{D_o}$$ [D_o: Outside diameter]

Power

$$P = \frac{SE \times MRR}{60}$$ [SE: Specific Energy]

Mill cutting angle

$$\theta = \arccos\left(1 - \frac{2d}{D_o}\right)$$ [D_o: mill outside diameter]

MRR

- turning: $MRR = \frac{\pi}{4}(D_o^2 - D_f^2) \cdot f$ [D_o: outside diameter, D_f: final diameter]
- facing: $MRR = \frac{\pi}{2} D_o d f$
- drilling: $MRR = A_s \cdot f$ [A_s: hole surface area] (general)
  $MRR = \frac{\pi D_o^2}{4} \cdot f$ [D_o: drill diameter] (common drill)
- sawing: $MRR = k \cdot h \cdot f$ [k: kerf, h: sawed depth]
- milling: $MRR = w \cdot h \cdot f$ [w: width, h: height] (simple)
  $MRR = \frac{1}{2} \times \frac{f}{T} \times \frac{D_o}{2} \times \theta \times w$ [D_o: mill outside diameter, T: # of teeth, θ: mill cutting angle, w: width] (general)

(unit is mm/rev. If we want mm/min, multiply f with N)

Machining time

$$t = \frac{L}{f}$$ [L: length that the tool travels across a workpiece.]

Shear Force

$$F_s = U_{ss} \times A_s$$ (general)

$$F_s = \frac{U_{ss} \times w \times d}{\sin\theta}$$ (milling blade)

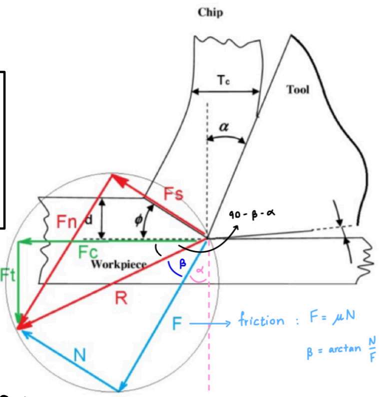
[U_{ss}: ultimate shear stress, w: tool width]

Milling blade angles

$$\alpha = \arccos\left(\frac{1-2d}{D_o}\right)$$

$$\beta = \arctan\left(\frac{1}{\mu}\right)$$ [μ: friction coeff.]

$$\phi = \arctan\left(\frac{d}{T_c}\right)$$ [T_c: chip thickness]



friction: $F = \mu N$, $\beta = \arctan \frac{N}{F}$ } $\beta = \arctan \frac{1}{\mu}$

Radius (R-value)

$$R = \frac{F_s}{\cos(\phi + 90 - \beta - \alpha)}$$

Cutting force

$$F_c = R\cos(90 - \beta - \alpha)$$

Cutting power

$$P = F_c \cdot V_c$$ [V_c: cutting speed]

Name____ Student ID____________________

School of Engineering

King Mongkut's Institute of Technology Ladkrabang

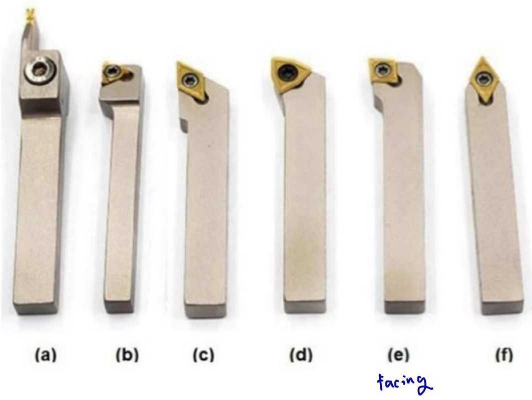
Midterm Examination 1st Semester Academic Year 2022

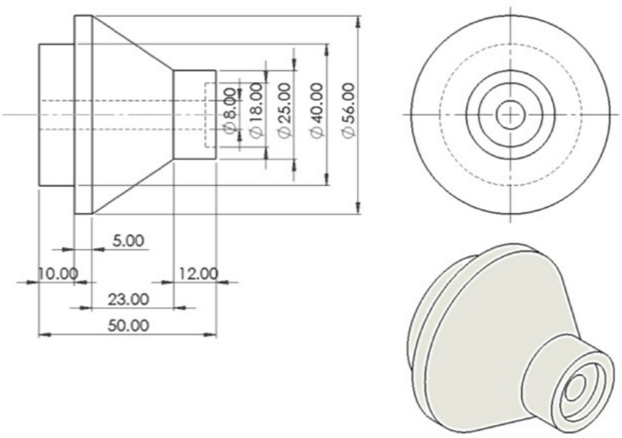
Subject 01416319 Manufacturing Process Class RAI

Friday 1st September 2023 Time 13.30pm to 16.30 pm.

Rules and Explanation.
1. Calculator and Text Books are allowed
2. Exam manuscript contains 4 Questions
3. For all questions, write answer in this manuscript.
4. You can use both side of papers.

1. The giving part as drawing is made from a Ø60 mm steel shaft with 200 mm. length. Cutting tool is a carbide cutter. Turning machine has spindle power is 3kW. (30 Points)





a. Explain the cutting procedures (steps) and define each step which a tool a to f from picture.

1) use (e) to do facing

2) use (c) to peel of (straight turning) the shaft with depth of 4 mm for 50 mm

3) use (d) to peel of (straight turning) with depth of 31 mm for 12 mm

4) use (f) to create a taper (taper turning) at 12mm from the edge to 34 mm

5) use (a) to create a groove (turning & external grooving) for 10 mm starting at 40 mm from the edge

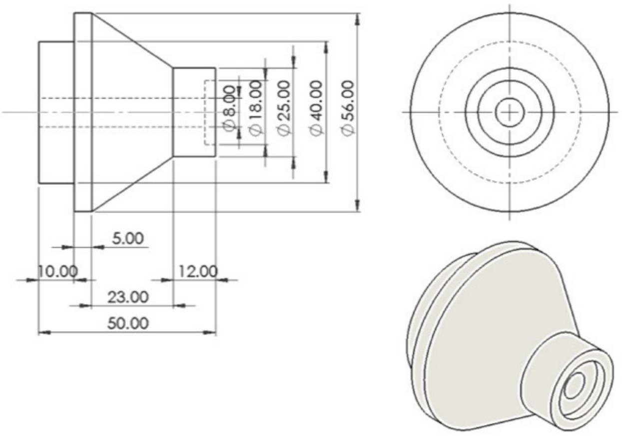
6) use a 8 mm to drill the hole across the workpiece

7) use (e) to expand the hole (boring) from 8 mm to 18 mm

8) use (a) to cut the workpiece out of the main shaft (cutting off / parting)

1. The giving part as drawing is made from a Ø60 mm steel shaft with 200 mm. length. Cutting tool is a carbide cutter. Turning machine has spindle power is 3kW. (30 Points)

(a) (b) (c) (d) (e) (f)



b. In every step, define the cutting condition that associate to machine's power.

As material is steel, cutting speed is 50 m/min and SE = 9.3 /mm^3

- $N = \dfrac{1000V}{D_o}$

$= \dfrac{1000 \times 50}{60}$

$= 833.33$

- $P = \dfrac{SE \times MRR}{60}$

$MRR = \dfrac{3000 \times 60}{9.3}$

$= 1.94 \times 10^4$

step 1 : $MRR = \frac{\pi}{2} \cdot D_o d f$

*assume that depth of cut is 1 mm

$f = \dfrac{1.94 \times 10^4 \times 2}{\pi (60)(1)}$

$f = 205.4$ mm/min

step 2 : $MRR = \frac{\pi}{4}(D_o^2 - D_f^2) \cdot f N$

$f = \dfrac{4 \cdot MRR}{\pi \cdot (D_o^2 - D_f^2)}$

$= \dfrac{4 \cdot 1.94 \times 10^4}{\pi} \times \dfrac{1}{D_f^2 - D_o^2}$

$= \dfrac{24643.3}{(D_o^2 - D_f^2)}$

$= 2.5 \times 10^4 \times (60^2 - 56^2)^{-1}$

$= 53.11$ mm/min

step 3 : $f = 2.5 \times 10^4 \times (D_o^2 - D_f^2)^{-1}$

$= 2.5 \times 10^4 \times (56^2 - 25^2)$

$= 9.81$ mm/min

step 4 : $f_{max} = 2.5 \times 10^4 \times (56^2 - 25^2)$

$= 9.81$ mm/min

step 5 : $f = 2.5 \times 10^4 \times (56^2 - 40^2)^{-1}$

$= 16.04$ mm/min

step 6 : $MRR = A_s \cdot f$

$f = \dfrac{1.94 \times 10^4}{\pi \cdot (\frac{8}{2})^2}$

$= 385$ mm/min

step 7 : $f = 2.5 \times 10^4 \times (18^2 - 8^2)^{-1}$

$= 94.78$ mm/min

step 8 : $f = \dfrac{1.94 \times 10^4 \times 2}{\pi (40)(1)}$

$= 308.04$ mm/min

c. Estimate total processing time from your plan for producing one workpiece.

step 1 : $t = \frac{56}{2} / 205.4$

step 2 : $t = 50 / 53\ 11$

step 3 : $t = 12 / 9.81$

step 4 : $t = 34 / 9.81$

step 5 : $t = 10 / 16.04$

step 6 : $t = 50 / 385$

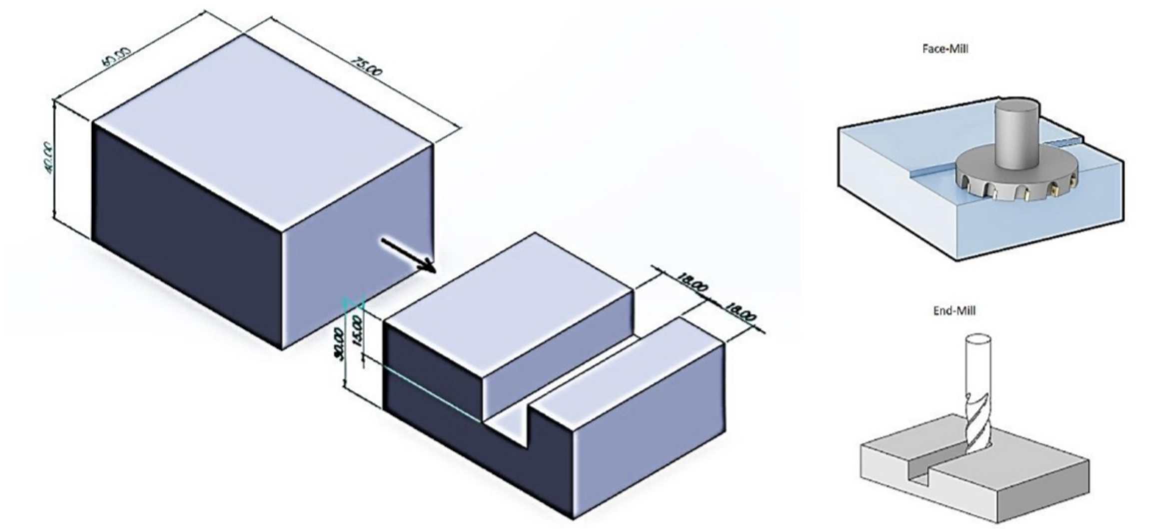
step 7 : $t = \frac{18-8}{2} / 94.78$

step 8 : $t = \frac{40}{2} / 308.04$

$t_{total} = 6.64$ min

$f = 20$ mm/min

2. Want to cut an aluminium block as picture and define cutting feed at 20 mm. per minute. Cut with a face-mill diameter 80 mm. 6 teeth and end-mill diameter 12 mm. 4 teeth. (20 Points)



face - mill

- $MRR = W \cdot h \cdot f$
  $= 75 \times 10 \times 20$
  $= 15000$

- $P = \frac{SE \times MRR}{60}$
  $= \frac{1.1 \times 15000}{60}$
  $P = 275$ W

End - mill

- $MRR = 18 \times 15 \times 20$
  $= 5400$

- $P = \frac{1.1 \times 5400}{60}$
  $= 99$ W

Therefore, with the cutting feed of 20 mm/min the machine is required to have a power at least 275 W

3. Calculate cutting power for Face-Mill Ø 80 mm. ~~12 Teeth~~ cutting on a Steel Block 80 mm. Width ($W = 80$) with depth of cut 0.6 mm ($d = 0.6$). Using cutting tool diagram below for cutting force calculation.

Shear Strength of Steel = 300 N/mm^2

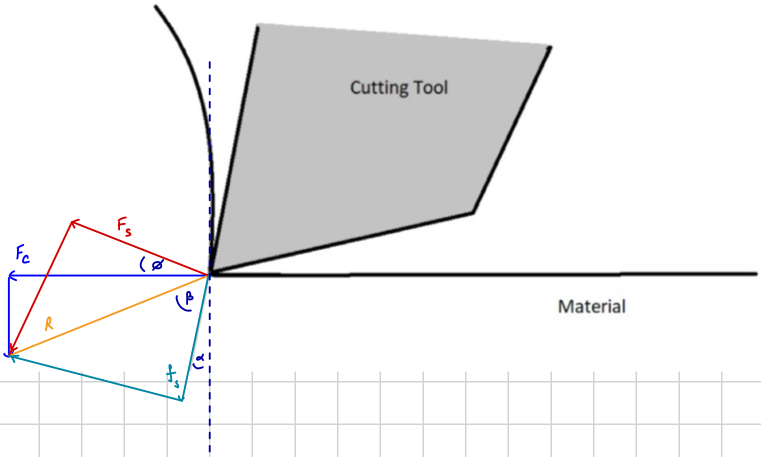
Friction Coefficient Carbide – Steel = 0.4

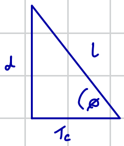
Chip Thickness = 0.2 mm.

Feed use 200 mm/min

Cutting Speed =120 m/min

Find the power of the milling machine that suits to this cutting condition





$\longrightarrow \tan\phi = \frac{d}{T_c}$

$\phi = \arctan\left(\frac{0.6}{0.2}\right)$

$= 71.56$

find F_s . $F_s = \frac{U_{ss} \times wd}{\sin\phi}$

$= \frac{300 \times 80 \times 0.6}{\sin(71.56)}$

$F_s = 15179$ N

find missing angles

▸ $\alpha = \cos^{-1}\left(1 - \frac{2d}{D_0}\right)$

$= \cos^{-1}\left(1 - \frac{2 \times 0.6}{80}\right)$

$\alpha = 9.936$

▸ $\beta = \arctan 1/\mu$

$= \arctan \frac{1}{0.4}$

$= 68.199$

find R

▸ $F_s = R\cos(\phi + 90 - \beta - \alpha)$

$R = \frac{15179}{\cos(71.56 + 90 - 9.936 - 68.199)}$

$= 132665$ N

find F_c

▸ $F_c = R\cos(90 - \alpha - \beta)$

$= 132665 \cos(90 - 9.936 - 68.199)$

$= 129830$ N

find Power

▸ $P = F_c \cdot V_c$

$= 129830 \times \frac{120}{60}$

$= 259661$ W

So, the required cutting power is 260 kW

- spindle speed (RPM) : $N = \frac{1000V}{D_o}$
  - D_o : outside diameter (mm)
  - V : rotation speed / cutting speed (m/min)

Material	High-Speed Steel Cutter ft/min	High-Speed Steel Cutter m/min	Carbide Cutter ft/min	Carbide Cutter m/min
Alloy steel	40–70	12–20	150–250	45–75
Aluminum	500–1000	150–300	1000–2000	300–600
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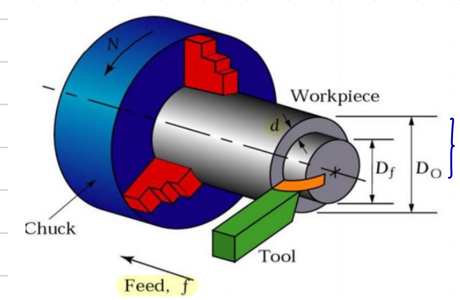
Tool steel	60–70	18–20	125–200	40–60

- Material removal rate (mm^3/min)

  straight tuning
  - $MRR = A \cdot f = MRR = \frac{\pi}{4}(D_o^2 - D_f^2)\ f$
  - 

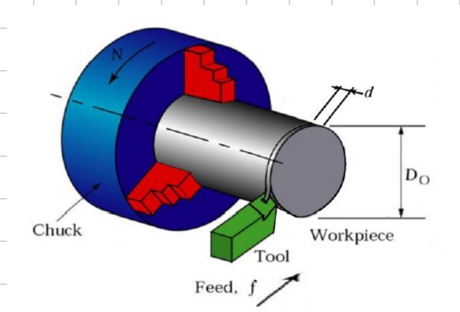
$D_{avg} = \frac{D_o + D_f}{2}$

- f : feed rate (mm/min)

Material	Roughing Cut (IPR)	Finishing Cut (IPR)
Mild steel	.005 - .020	.002 - .004
Tool steel	.005 - .020	.002 - .004
Cast Iron	.005 - .020	.002 - .004
Brass	.005 - .020	.002 - .004
Aluminum	.005 - .020	.002 - .004

Roughing: 0.127 - 0.508; Finishing: 0.051 - 0.102

$\hookrightarrow$ IPR = 25.4 × MPR

facing cut
- cutting time : $t = \frac{D_o/2}{fN}$
- 

- volume $= \frac{\pi D_o^2}{4} \cdot d$

  $\hookrightarrow MRR = \frac{\pi D_o^2 d}{4t}$

  $= \frac{\pi D_o^2 d}{4} \cdot \frac{2fN}{D_o}$

  $MRR = \frac{\pi}{2} D_o d f N$

- MRR can reflect energy in cutting ⟶ approximate required power of cutting
  - $P = \frac{SE \times MRR}{60}$

    unit conversion

  - SE : Specific energy ⟶ (J/mm^3 or $W \cdot s/mm^3$)
  - P must be less than the motor's P / S.F. to ensure safety & quality

    $\hookrightarrow$ S.F. = $\frac{max}{design}$

APPROXIMATE ENERGY REQUIREMENTS IN CUTTING OPERATIONS (at drive motor, corrected for 80% efficiency; multiply by 1.25 for dull tools).

Material	Specific Energy W · s/mm³	Specific Energy hp · min/in.³
Aluminum alloys	0.4–1.1	0.15–0.4
Cast irons	1.6–5.5	0.6–2.0
Copper alloys	1.4–3.3	0.5–1.2
High-temperature alloys	3.3–8.5	1.2–3.1
Magnesium alloys	0.4–0.6	0.15–0.2
Nickel alloys	4.9–6.8	1.8–2.5
Refractory alloys	3.8–9.6	1.1–3.5
Stainless steels	3.0–5.2	1.1–1.9
Steels	2.7–9.3	1.0–3.4
Titanium alloys	3.0–4.1	1.1–1.5

- Material removal rate (mm^3/min)

planning & shaping

- planing : workpiece move

  shaping : cutting tool move

- $MRR_{fw} = V \times d \times f$

  $MRR_{fw} = 2 \times V d f$

  $\Big\}\ MRR_{all} = 1.5 \times V \times d \times f$

  ↳ $P = \frac{SE \times MRR_{fw}}{60}$ — only forward cut the workpiece

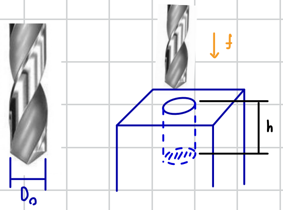
drilling

- turning speed . $N = \frac{1000V}{\pi D_o}$
  - D_o : drill diameter

    V : cutting speed

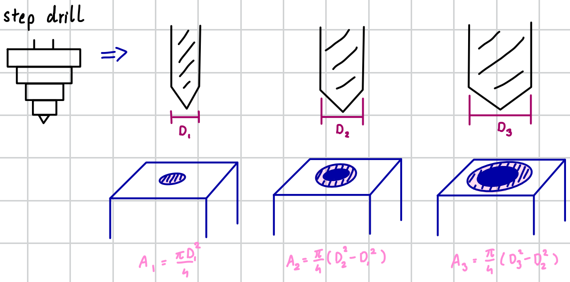
- $MRR = A_s \cdot f$

  common drill



$$MRR = \frac{\pi D_o^2}{4} \cdot f = \frac{\pi D_o^2 H}{4} \times \frac{1}{t}$$

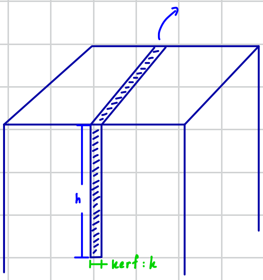
step drill

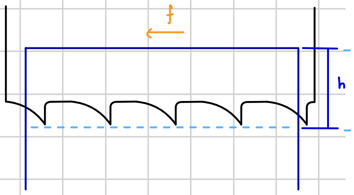


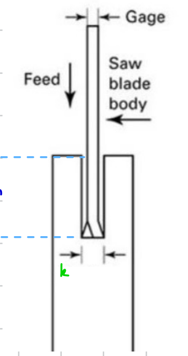
$$MRR = \frac{\pi}{4}(D_2^2 - D_1^2) \times f$$

sawing

$$MRR = \frac{A \times k}{t} = k \cdot h \cdot f$$

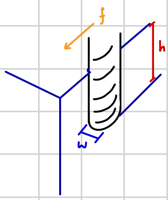




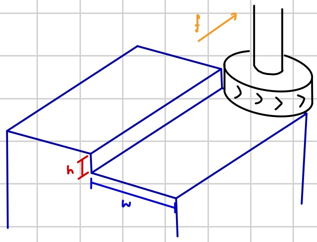


milling

- cutting tools = multi-tooth cutter spinning & feeding → depth & feeding
-



end milling

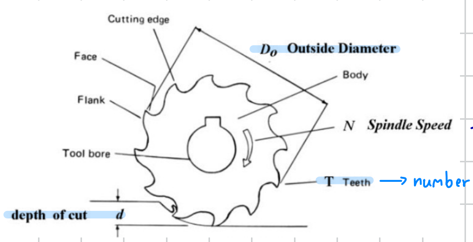


face milling

$MRR = w \cdot h \cdot f$
(simple formula)

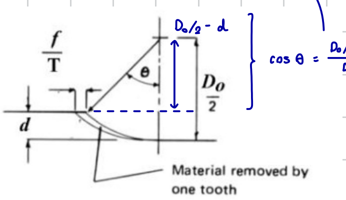
- chip from milling is in a bend triangular shape
  - this is used to cal $MMR = \frac{1}{2} \times \frac{f}{T} \times \frac{D_o}{2}\, \theta \times w$

    (general formula)



T Teeth → number of teeth

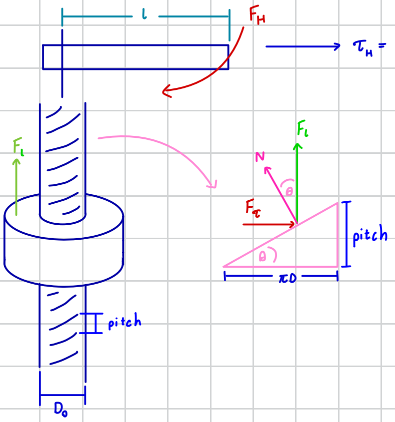
cutting angle : $\theta = \cos^{-1}\left(1 - \frac{2d}{D_o}\right)$



$$\cos\theta = \frac{D_o/2 - d}{D_o/2}$$

- both horizon & vertical use the same calculation

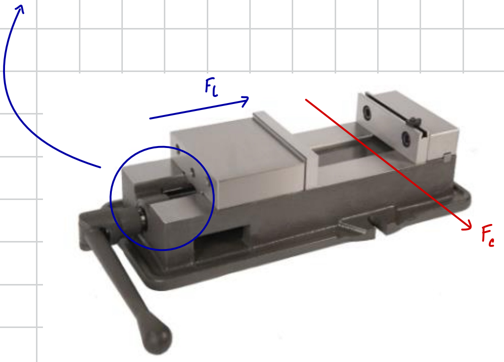
- Vise



$\tau_H = F_H \cdot l = F_\tau \cdot \frac{D}{2}$

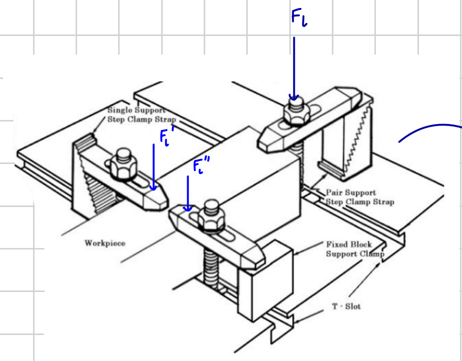
$\frac{\pi D}{pitch} = \frac{F_L}{F_\tau}$

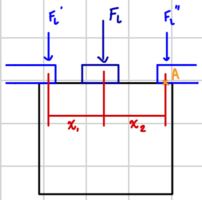
$F_L = \frac{\pi}{pitch} \cdot F_H \cdot 2l$



F_c : cutting force

$\mu \times F_L > F_c$





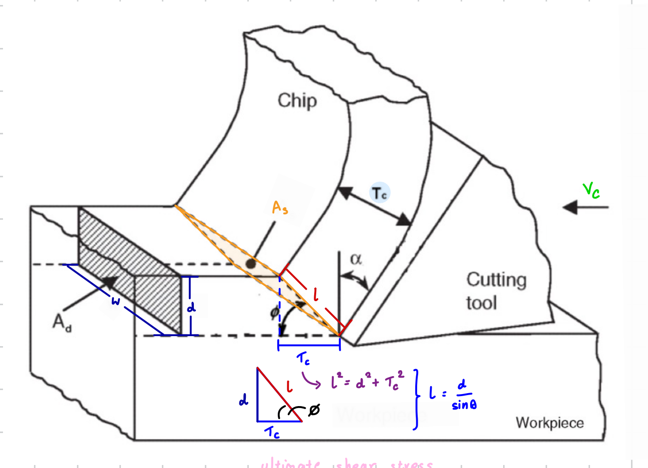
set A as pivot

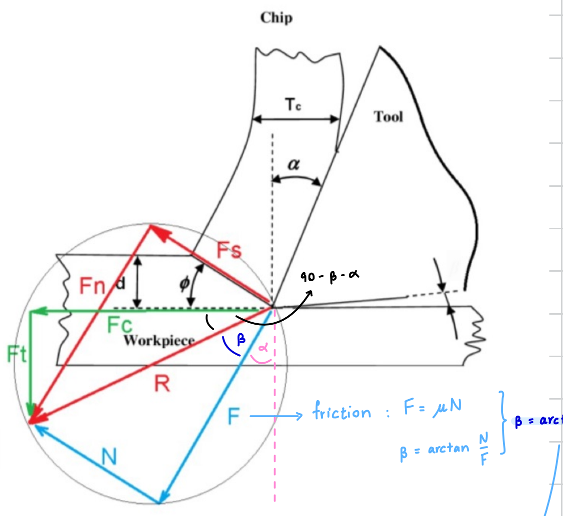
$\Sigma \tau = 0$

$F_L \cdot x_2 = F_L' \cdot (x_1 + x_2)$

$F_L' = \frac{F_L x_2}{x_1 + x_2}$

▸ Cutting Force





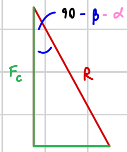
F → friction : $F = \mu N$

$\beta = \arctan \frac{N}{F}$ } $\beta = \arctan \frac{1}{\mu}$

▸ shear force : $F_s = U_{ss} \times A_s$ (ultimate shear stress)

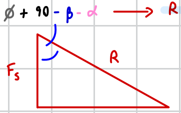
$= U_{ss} \times wl$

$$F_s = \frac{U_{ss} \times w \times d}{\sin\theta}$$



$F_c = R\cos(90 - \beta - \alpha)$

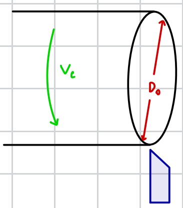
$\phi + 90 - \beta - \alpha \longrightarrow R = \frac{F_s}{\cos(\phi + 90 - \beta - \alpha)}$



$$\boxed{P = F_c \cdot V_c}$$

calculate power from physical shear strength

▸ effect of f (feeding rate)



from $N = \frac{1000V}{D_o}$

$\downarrow$

$V_c = \frac{1000N}{D_o}$

← feed : mm/revolution

↳ affect w

($w \propto f$)

• Thermal Condition

- All cutting power turns to heat ($\Sigma E_1 = \Sigma E_2$)
- All parts (workpiece, tool, chip) share heat equally

from $Q = mc\Delta T$

$\downarrow$

$$\boxed{\frac{P_c}{3} = \frac{mc\Delta T}{\Delta t}} \longrightarrow \rho C \cdot MRR \cdot \Delta T$$

$\frac{M}{\Delta t} = \frac{\rho V}{\Delta t} = \rho\ MRR \longrightarrow MRR = A \cdot f$

dissipate 3 parts

$Q = \frac{P_c}{3} \longrightarrow P_c = \frac{MRR\ \ SE}{60}$

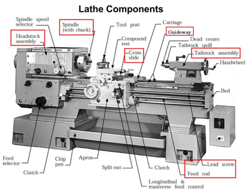
processing time : $\Delta t = \frac{h}{f} \longrightarrow \frac{P_c}{3} = mc\Delta T\ \frac{f}{h}$

↳ h: cutting distance along direction of f

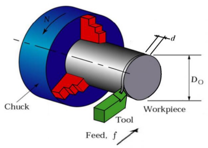
▸ room temp : 25°C

↳ work piece temp = $25 + \Delta T$

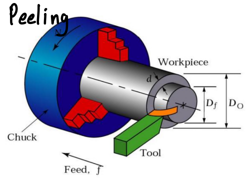
Machining Process



Facing



Peeling



สูตร

- Turning (การกลึง)

หลักๆ
- Facing
- peeling
- Drilling

$N = \frac{1000V}{\pi D_o}$ (Spindle speed : RPM)

V = cutting speed (เขาให้มา, ดูตาราง)

D_o = Original Diameter

$Power = \frac{SE \times MRR}{60}$ (Power : watts)

SE = Specific energy (ดูตาราง)

Facing (ลดความยาวชิ้นงาน)

(material removal rate : mm^3/min)

$$MRR = \frac{\pi D_o . d . f . N}{2}$$

d : depth of cut

f : feed rate (ดูในตาราง)

Peeling (ลด Diameter ชิ้นงาน)

$$MRR = d \times f \times N \times \pi D_{avg}$$

$$d = \frac{D_o - D_f}{2}$$

$$D_{avg} = \frac{D_o + D_f}{2}$$

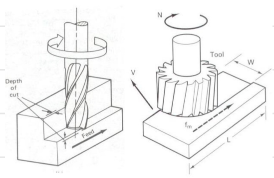
Drilling (เจาะรู)

$$MRR = \frac{\pi D_o^2 . f}{4}$$

* ถ้า f (feed) มีหน่วย mm/rev ต้องคูณ N
  ,, mm/min ไม่ต้อง

* depth of cut drilling คือ Diameter รู

- milling (การกัด)



End Milling   Face Milling

สูตร

2 สูตรนี้ เหมือนกัน ใช้อันไหนก็ได้

$$MRR \cong \frac{1}{2} \times \frac{f}{T} \times \frac{D_o}{2} \underset{\text{radian}}{\theta} \times w \quad , \quad MRR = \underset{mm.}{d} \cdot \underset{mm.}{w} \cdot \underset{mm/min}{f}$$

$$\theta = cos^{-1}\left(1 - \frac{2d}{D_o}\right)$$

w = face width

× 25.4 inch/rev → mm/rev

Material	Roughing Cut (IPR)	Finishing Cut (IPR)
Mild steel	.005 - .020	.002 - .004
Tool steel	.005 - .020	.002 - .004
Cast Iron	.005 - .020	.002 - .004
Brass	.005 - .020	.002 - .004
Aluminum	.005 - .020	.002 - .004

การตัดปกติ ต้องมี 2 แบบ

- Rough cut (ตัดหยาบๆ)
- Fine cut (เกลางาน) (usually 2 step)

ต้องคำนึงถึง Machine power ด้วย (M/C)

ถ้า Power > M/c power

ต้องแบ่งการตัดเป็น step ย่อยๆ

ex. Power = 35000 watts (เกิน)

M/c power = 1000 watts

$\therefore \frac{35000}{1000} = 35$ step

เพิ่มเอาเอง ตามความเหมาะสม (แล้วแต่เรา) ~ 15, 20

35+15 = 50 step ก็ได้

* (Recommended)

depth of cut (d) $0.1 < d < 1$

Fine   Rough

เลือก ค่าใน interval เองได้

ex: Fine cut 0.1 mm

แบ่ง step เป็น 2 Fine ที่เหลือ Rough

*สมมุติ Depth of cut 10 mm

∴ 50 step
- 2 Fine ⟶ (10 mm) − 2(0.1) = 9.8 mm
- 48 rough ⟶ $\frac{9.8}{48}$ → 1 step d = 0.204 mm

* วิธีเช็คว่า ตัดชิ้นงานได้ไหม

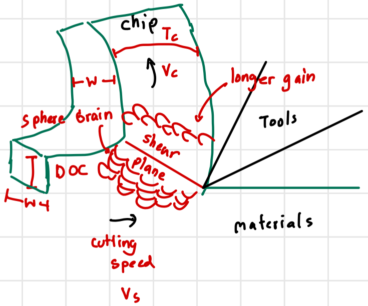
จาก M/c power

→ 1 → maximum rough cut

เข้าสูตร MRR → หา Power.

การหา Cutting Power แบบ วาดเทียบ สัดส่วน

• Turning



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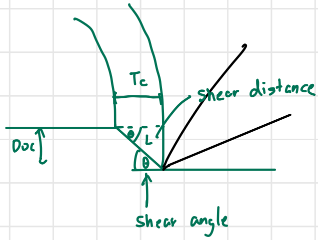


สูตร

$$\theta = \tan^{-1}\left(\frac{DoC}{T_c}\right)$$

$$L = \frac{DoC}{\sin\theta} \quad (mm)$$

$$A_T = L \cdot W \quad (mm^2)$$

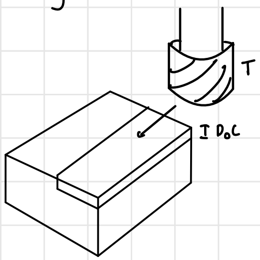
σ_s = shear strength

$$F_s = \sigma A_T \quad (N)$$

$$F_s = \mu N$$

$$\beta = \tan^{-1}\left(\frac{N}{F_s}\right)$$

• Milling



• ต้องหาค่า W ก่อน ทำวิธีแบบ Turning

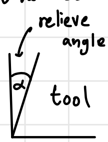
$V_s \rightarrow$ หา N

ใส่สูตร $W = \frac{f_{mm/min}}{N_{rev/min}\, T}$

ได้ W → หา เหมือน Turning

How-to (ใช้ Protractor, ไม้บรรทัด วัดตามจริง)

① โจทย์ให้ schematic การตัดมา



② หาค่า Variable ตามสูตร

ex. W = 1 mm.
DOC = 1 mm
T_c = 0.8 mm
σ_s = 300 N/mm^2
μ = 0.9
V_s = 30 m/min

$$\theta = \tan^{-1}\left(\frac{DOC}{T_c}\right)$$

$$\theta = 51^\circ$$

$$L = \frac{DOC}{\sin(51^\circ)}$$

$$L = 1.25 \text{ mm}$$

$$A_T = \underset{L}{1.25} \times \underset{W}{1}$$

$$= 1.25 \text{ mm}^2$$

$$F_s = \sigma \cdot A_T$$

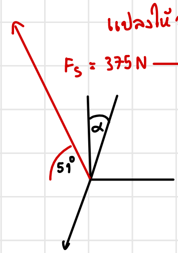
$$F_s = 300 \times 1.25 = 375 N$$

$$\beta = \tan^{-1}\left(\frac{1}{0.9}\right) = 48^\circ$$

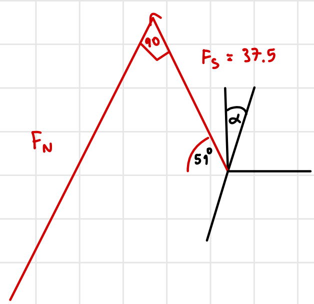
③ วาด F_s ตามองศา θ (51°) ระนาบ แกน X

แปลงให้วาดรูปพอ ÷10

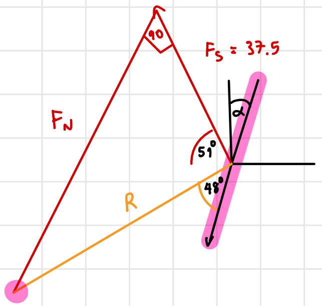
F_s = 375 N ⟶ 37.5 mm



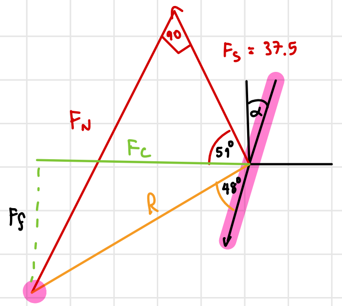
④ วาด F_N ตั้งฉากกับ F_s ยาวลงมา



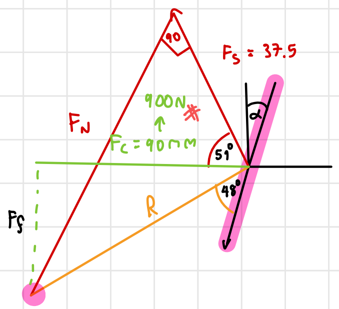
⑤ วาด เส้น R จาก β (48°) ตามระนาบใบมีด จนไปตัด F_N



⑥ ลาก F_c มา ขนาน กับจุดตัด R , F_N



⑦ วัดความยาว F_c จากจุดขนานจุดตัด ถึงจุดเริ่มต้น X 10 ปรับขนาด สเกล (ใช้ไม้บรรทัด)



แล้วเอาเข้าสูตร Cutting power

$$\text{Cutting power} = F_c \cdot V_s$$

$$= \frac{900\,N \times 30}{60}$$

$$= 450\ N\cdot m/s = J/s = W$$

Name____ Student ID______________________

School of Engineering

King Mongkut's Institute of Technology Ladkrabang

Midterm Examination 1st Semester Academic Year 2022

Subject 01416319 Manufacturing Process Class RAI

Friday 30th September 2021 Time 13.30pm to 16.30 pm.

Rules and Explanation. 1. Calculator and Text Books are allowed
2. Exam manuscript contains 4 Questions
3. For all questions, write answer in this manuscript.
4. You can use both side of papers.

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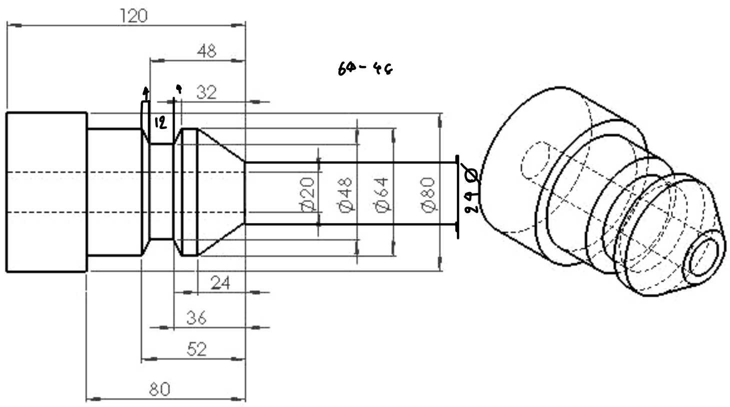
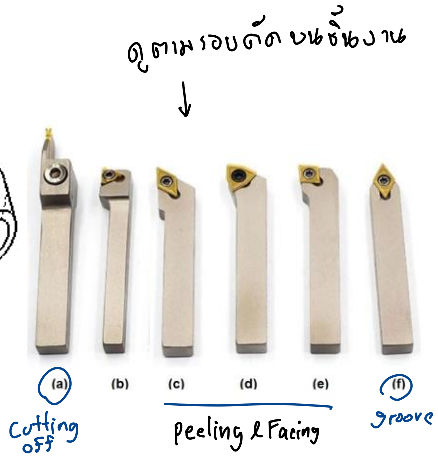
1. The giving part as drawing is made from a Ø80 mm steel shaft with 150 mm. length. Cutting tool is a carbide cutter. Turning machine has spindle power is 1kW. (30 Points)





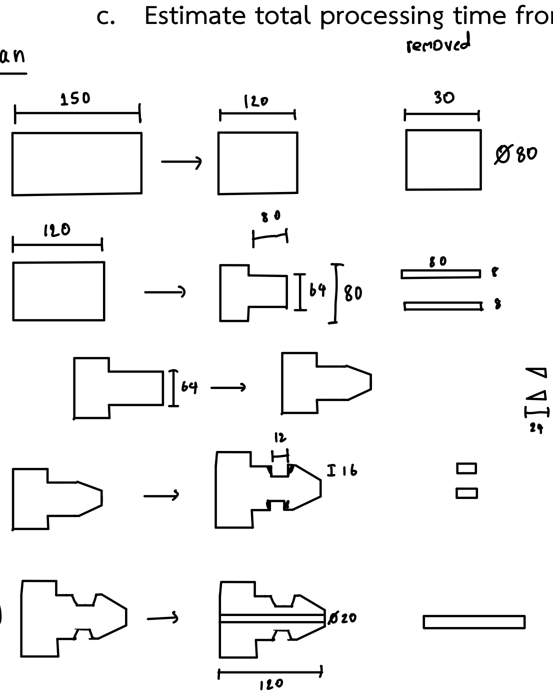
a. Plan cutting procedures (steps) and define which tool (define a to f from picture) is used in each step.

b. In each step please explain the cutting condition that associate to machine's power.

c. Estimate total processing time from your plan for producing a piece of this part.

$\frac{L}{f}$ = time

a) Plan



① Facing

② Peeling : use (c)

③ Taper turning : use (d)

④ Grooving : use (f)

⑤ Drilling : use screw

B) Name________________________________ Student ID____________________

Facing:

$T = \frac{D_o}{2fN}$, $MRR = \frac{\pi D_o^2 \cdot d}{4T}$, $MRR = \frac{\pi D_o \cdot d \cdot f \cdot N}{2}$, $Power \cong \frac{SE \times MRR}{60}$ $N = \frac{1000V}{\pi D_o}$

① calculate spindle speed (N)

$N = \frac{1000V}{\pi D_o}$ v = 180 m/min from table

$N = \frac{1000(180)}{\pi(80)}$

N = 716.197 RPM

calculate MRR

$MRR = \frac{\pi D_o \cdot d \cdot f \cdot N}{2}$ from table (mm/rev)

$MRR = \frac{\pi(80) \cdot (30) \cdot (0.020)(25.4)(716.197)}{2}$

MRR = 1371542 mm^3/min

calculate power

$Power = \frac{SE \times MRR}{60}$

$= \frac{9.3 \times 1371542}{60}$

= 212589 watt

$\boxed{M/C \text{ power} = 1KW}$

step = $\frac{212589}{1000}$

= 212.6 ≈ 213 steps

↓

250 steps

248 rough cut, 2 fine cut

total depth of cut 30 mm

2 fine cut 30 − 2(0.25) = 29.5 from table ; d = 0.25

28 rough cut $\frac{29.5}{248}$ = 0.1189 mm

Step) 1−28

Rough cut → f = (0.020)(25.4) = 0.508 mm/rev

d = 0.1189 mm

N = 716.197 RPM

step) 29−30

Fine cut

Fine cut → f = (0.004)(25.4) mm/rev

d = 0.25 mm

N = 716.197

② peeling

$MRR = d \times f \times N \times \pi D_{avg}$

$d = \frac{D_o - D_f}{2}$

$D_{avg} = \frac{D_o + D_f}{2}$

$d = \frac{80-64}{2} = 8$

$D_{avg} = \frac{80+64}{2} = 72$

MRR = (8)(0.020)(25.4)(716.19)(π)(72)

= 658361 mm^3/min

Calculate power

$Power = \frac{(9.3)(658361)}{60}$

= 102045.955 watt

step) $\frac{102046}{1000}$

102.046 ≈ 120 steps

118 rough cut, 2 fine cut

total depth of cut 8 mm

2 fine cut 8 − (0.25 ×2) = 7.5 mm

118 rough cut : $\frac{7.5}{118}$ = 0.0635 mm

Step) 1−118

Rough cut → f : 0.508 rev/mm

d = 0.0635 mm

N : 716.197 RPM

step) 119−120

Fine cut → f = 0.508 rev/mm

d = 0.25 mm

N = 716.197 RPM

③ Taper turning

$MRR = d \times f \times N \times \pi D_{avg}$

$d = \frac{D_o - D_f}{2}$

$D_{avg} = \frac{D_o + D_f}{2}$

$d = \frac{64-24}{2} = 20$

$D_{avg} = \frac{88}{2} = 44$

MRR = (20)(0.020)(25.4)(716.19)(π)(44)

= 1005830 mm^3/min

Calculate power

$Power = \frac{(9.3)(1005830)}{60}$

Power = 155903 watts

step) $\frac{155903}{1000}$ ≈ 155.9 → 156

↓

170 steps

168 Rough cut, 2 Fine cut 0.1 mm

total depth of cut 20 mm

2 fine cut 20 − (0.2) = 19.8

168 rough cut = $\frac{19.8}{168}$ = 0.117 mm

step 1−168)

Rough cut → f : 0.508 rev/mm

d = 0.117 mm

N : 716.197 RPM

Fine cut → f = 0.508 rev/mm

d = 0.01 mm

N = 716.197 RPM

Name________________________________ Student ID________________

④ Grooving

$d = \frac{D_0 - D_f}{2}$

$D_{avg} = \frac{D_0 + D_f}{2}$

$d = \frac{64-48}{2} = 8$

$D_{avg} = \frac{64+48}{2} = 56$

$MRR = (8)(0.020)(25.4)(716.19)(\pi)(56)$
$= 512058.82$

Calculate power

$Power = \frac{(9.3)(512058.82)}{60}$

$= 79369.11$ watt

$Step = \frac{79369.11}{100} = 79.3 = 80$ step

$\downarrow$

100 step

98 rough cut — 2 fine cut

total depth of cut 8 mm

2 fine cut $8 - (0.25 \times 2) = 7.5$ mm

98 rough cut : $\frac{7.5}{98} = 0.0635$ mm

Step 1-98

rough cut $\longrightarrow$ $f = (0.020)(25.4) = 0.508$ mm/rev
$d = 0.0635$ mm
$N = 716.197$ RPM

Step 99-100

Fine cut $\longrightarrow$ $f = 0.508$ mm/rev
$d = 0.25$ mm
$N = 716.197$ RPM

⑤ Drilling

$$MRR = \frac{\pi D_o^2 . f}{4}$$

mm/rev (x N) คูณ N

mm/min (No x) ไม่คูณ

$MRR = \frac{\pi(20)^2(0.020)(25.4)}{4}$

$= 114299.96\ mm^3/min$

$Power = \frac{(9.3)(114299.96)}{60}$

$Power = 17716.4938$ watt

Step drill

$\frac{17716.4938}{1000} = 17.716$ step

$= 25$ step

23 step R — 2 step F

$2(0.1) = 0.2$

$D.of = 20 - 02 = 19.8$

$\therefore$ Rough cut : $\frac{19.8}{23} = 0.86$ mm

Step 1-23 R.C

d.o.f : 0.86 mm
f : 0.508 mm/rev
N : 716.197 RPM

Step 24-25 F.C

d.o.f : 0.1 mm

c.) $T = \frac{L}{f}$

① $T = \frac{80\ mm}{(25.4)(0.20)(716.197)\ mm/min} = 0.021 = 1.26$ seconds

$\uparrow$ ข้1

$= 1.26 \times 30$

$= 37.8$ sec

② $T = \frac{80\ mm}{(25.4)(0.20)(716.197)\ mm/min} = 0.021 = 1.26$ seconds

$= 1.26 \times 30$

$= 37.8$ sec

③ $T = \frac{\quad}{\quad}$

⋮

จนครบทุกวิธี

Name____ Student ID____________________

2. If we do full face milling on an aluminium block with face width 65 mm. with depth of cut 0.5 mm. and cutting feed at 20 mm. per minute. Using cutting tool as carbide face mill cutter with diameter 80 mm. 6 teeth. (20 Points)

   a. Show how to find the minimum power of milling machine that can cut in given cutting condition and the value of that minimum power.

   b. If you want to reduce the cutting power for 50%, explain how.

a.) minimum power

$$MRR \cong \frac{1}{2} \times \frac{f}{T} \times \frac{D_o}{2} \theta \times w$$

k.f.d.w.

$$MRR = \frac{1}{2} \times \frac{20}{6} \times \frac{80}{2} \theta \times 65$$

$$\theta = \cos^{-1}\left(1 - \frac{2d}{D_o}\right)$$

$$= \cos^{-1}\left(1 - \frac{2(0.5)}{80}\right)$$

$$= 0.158279, \; 9.07^\circ$$

$$MRR = \frac{1}{2} \times \frac{20}{6} \times \frac{80}{2} (0.158) \times 65$$

$$MRR = 684.6$$

$$\text{Power} = \frac{SE \times MRR}{60}$$

$$= \frac{0.4 \times 684.6}{60}$$

$$= 4.56 \text{ watts}$$

b.) reduce cutting power 50%

$$2.28 \text{ watts} = \frac{0.4 \times MRR}{60}$$

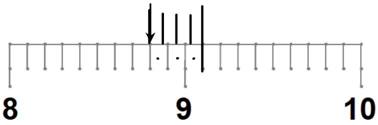
50% $\Rightarrow$ $MRR = 342 \text{ mm}^3/\text{min}$

$$342 = \frac{1}{2} \times \frac{f}{6} \times \frac{80}{2} (0.158) \times 65$$

$$f = 9.99 \text{ mm/min}$$

Change cutting feed to 9.99 mm/min #

Vernier (exercise)

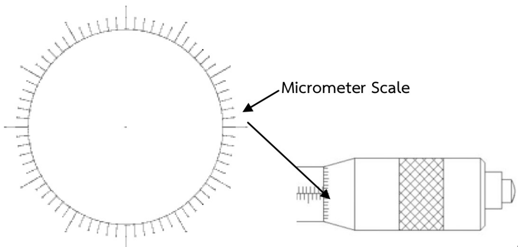


Resolution 0.25 Unit

$\frac{1}{0.25} = 4$ เส้น (ถอยมา 1 เส้น)

step → $1 - 0.25 = 0.75$

b. Micrometer scale as is the picture (72 divides), what is the resolution of this micrometer? (10 Points)



$\left(\frac{1}{16}\right) \div 72 = 8.680 \times 10^{-4}$

If micro meter has screw pitch at 16 threads per inch (or 1/16 inch), the resolution is ....inch.

$\frac{1.8}{72} = 0.025$

If micro meter has screw pitch at 1.8 mm, the resolution is ....mm.