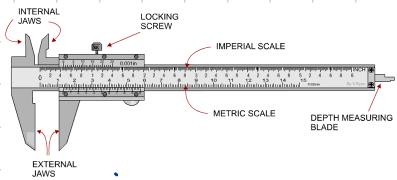
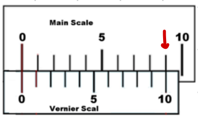
Basic Metrology & Inspection

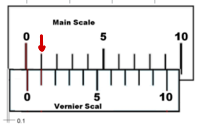
1. Vernir Caliper

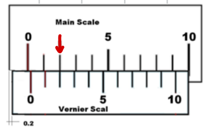
↳ Parts' name:

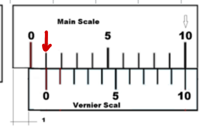


↳ Vernir Scale Length : $\frac{\text{main scale}}{\text{vernier scale}} = \frac{9}{10} = 0.9$ mm/slot

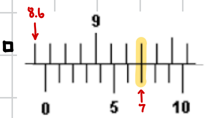




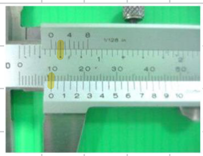




↳ How to Read : main scale + $\frac{\text{resolution}}{\text{num of vernir scale}}$ × aligned vernir num



- res = 0.1 mm
- reading value = $8.6 + \frac{0.1}{10} \times 7 = 8.67$



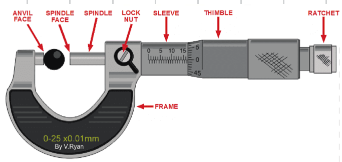
- inch : res = $1 \div 16 \div 8 = \frac{1}{128}$ in

  measurement = $\frac{6}{16} + \frac{1}{128} \times 2 = \frac{50}{128}$ in
- mm res = $10 \div 10 \div 20 = \frac{1}{20}$ mm.

  measurement = $10 + \frac{1}{20} \times 0 = 10$ mm

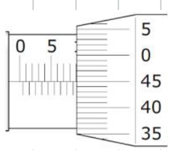
2. Micrometer

↳ Part's name



↳ How to Read : main scale + $\frac{\text{resolution}}{\text{num of micro scale}}$ × aligned micro num

[outer]

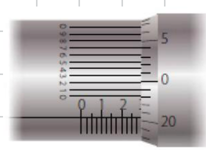


- res = $\frac{0.5}{50} = 0.01$ mm
- measurement = 8.5 + 0.01 (45) = 8.95 mm.

[inner]

- res : $\frac{0.5}{50} = 0.01$ mm
- measurement : 19.00 − (0.01)(49) = 18.51

[with reference line]



- res : $\frac{0.25}{25} = 0.01$ mm
- measurement : main + lower micro num × res + ref num × $\frac{\text{res}}{\text{num of ref lines}}$

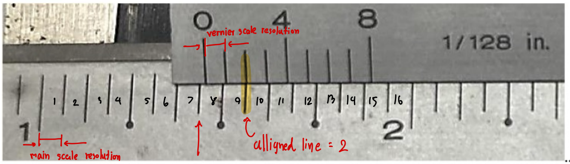
  $= 2.75 + 20(0.01) + \frac{1(0.01)}{10}$

  $= 2.951$ mm

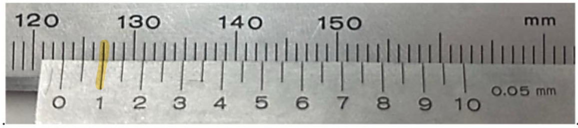
4. Measurement

a. Read this vernier scale (5 Points)

1



$1\frac{58}{128}$ inch



123.1 mm.

Inch

Step 1 : find resolution of main scale

- main res $= \dfrac{\text{increment}}{\text{num of lines}} = \dfrac{2-1}{16} = \dfrac{1}{16}$ inches

Step 2 : find resolution of vernier scale

- vernier res $= \dfrac{\text{main res}}{\text{num of vernier lines}} = \dfrac{\frac{1}{16}}{8} = \dfrac{1}{128}$ inches

Step 3 : Read the measurement

- measurement = main scale + (vernier res × alligned line num)

$= (1 + \frac{7}{16}) + (\frac{1}{128} \times 2)$

$= 1\frac{58}{128}$ inches

Millimeter

- main res $= \dfrac{\text{increment}}{\text{num of lines}} = \dfrac{130-120}{10} = 1$ mm

- Vernier res $= \dfrac{\text{main res}}{\text{num of vernier lines}} = \dfrac{1}{20}$ mm.

- measurement = main scale + (vernier res × alligned line num)

$= (123) + (\frac{1}{20} \times 2)$

$= 123.1$ mm.

2

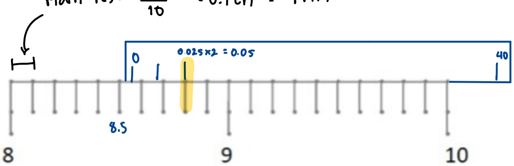
b. Please draw a vernier scale from provided main scale to meet 0.025 mm. resolution. (5 Points)

- vernier scale resolution = vernier res $= \dfrac{\text{main res}}{\text{num of vernier lines}} \longrightarrow 0.025 \text{ mm} = \dfrac{1\text{ mm}}{n}$

$\longrightarrow n = 40$

main res $= \dfrac{9-8\text{ cm}}{10} = 0.1$ cm $= 1$ mm

∴ draw vernier scale which has 40 slots

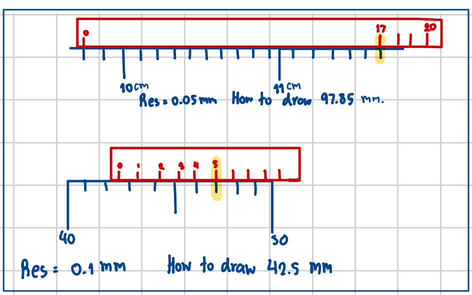


if instruction tells you to draw 8.55 cm

alligned vernier line $= \dfrac{8.55 - 8.5}{0.025} = 2$

want, main scale, vernier resolution

Another Example

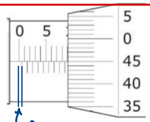


3

c. Micrometer scale has resolution of 0.005 mm. What are its screw thread pitch and micro scale division (5 Points)

↳ $\frac{\text{Pitch}}{\text{Division}} = \frac{5}{1000} = \frac{1}{200} = \frac{2}{400} = \dots$ any value which match 0.005 mm resolution

$\text{Res} = \frac{\text{Pitch}}{\text{Division}} = \frac{0.5}{50} = 0.01$



← Division = 50

Pitch = 0.5mm (Main Scale Resolution)

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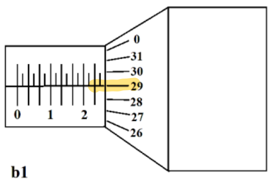
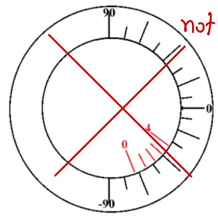
4

b. What are the resolution of these scale and read its value



b1



b2

not in the exam

Step1 : Define Pitch & Division & Vernier Scale res

- Division = 32
- Pitch (main res) $= \frac{\text{increment}}{\text{num of lines}} = \frac{1}{6}$ mm.
- Vernier res $= \frac{\text{main res}}{\text{Division}} = \frac{\frac{1}{6}}{32} = \frac{1}{192}$ mm

Step2 : Read Measurement

- measurement = (main scale) + (vernier res × allinged line)

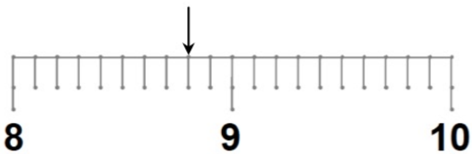
$= (2 + \frac{1}{6} \times 3) + (\frac{1}{192} \times 29)$

$= 2\frac{125}{192}$ mm.

3. Measurement

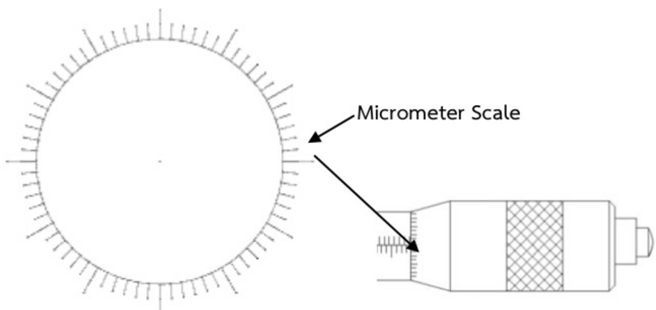
a. Please draw a vernier scale at marking point on provided main scale to meet given resolution. (10 Points)

Resolution 0.1 Unit



Resolution 0.25 Unit

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



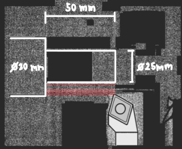
If micro meter has screw pitch at 16 threads per inch (or 1/16 inch), the resolution is ....inch.

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

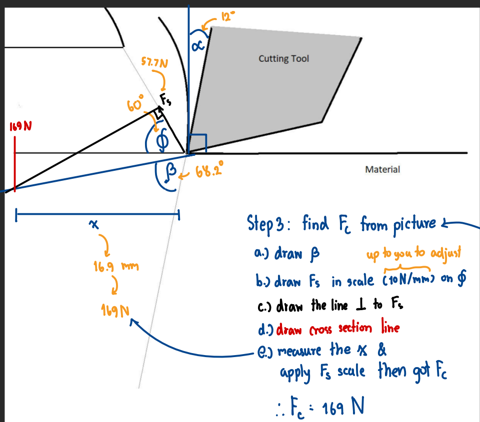
Cutting

Planning the Cutting Process

- Machine Power is 1000 W
- Turning Process that we want to cut a cylinder workpiece from diameter of 30 to 25 mm. with 50 mm. long.
- Cutting tool is carbide and material is low carbon steel. Low carbon steel has Shear Strength of 300 N/sq.mm



- Shear Angle and Shear Plane as Picture (copy and drew within this picture)



- Initial cutting conditions are depth of cut 1 and f 200 mm/minute
- Turn on the spindle speed at 1200 RPM
- Friction Coefficient between carbide and steel = 0.4
- if there are missing parameters, let define yourself and write down "this self-define parameter".

Step 1 : List the Parameters

- $D = 30$ mm
- $d = 25$ mm
- $L = 50$ mm
- $\sigma = 300\ N/mm^2$
- $\alpha = 12°$ } measure from picture
- $\phi = 60°$
- $N = 1200$ RPM
- cutting condition: DOC = 1 mm
  $f = 200$ mm/minutes
- $\mu = 0.4$
- $\beta = \tan^{-1}\left(\frac{1}{0.4}\right) = 68.2°$

Step 2 : Calculate for F_s & V_c

- $F_s = \dfrac{\sigma \cdot DOC \cdot f}{\sin\phi \cdot \text{teeth } N} = \dfrac{300 \cdot 1 \cdot 200}{\sin 60° \cdot 1 \cdot 1200} = 57.7\ N$

  1 tooth from picture

- $V_c = \dfrac{\pi D N}{1000} = \dfrac{\pi \cdot 30 \cdot 1200}{1000} = 113.1\ m/min = \dfrac{113.1}{60}\ m/sec$

Step 4 : Calculate Cutting Power

$P_c = F_c \times V_c = 169 \times \dfrac{113.1}{60} = 318.56$ Watt

Step 5 : Check Cutting condition

Machine Power = 1000W > 318.56 = P_c

∴ cutting condition : DOC = 1 mm & f = 200 mm/min is OK.

Soft Power

- Safty Factor = 0.6
- Efficient = 0.9

Should be told by problem (this is just example number)

- Motor Power = 1000 Watt

∴ Soft Power = 1000 × 0.6 × 0.9 = 540 Watt

Step 6 : Calculate Cutting Time

- Repeating Cutting = $\dfrac{(D-d)/2}{DOC} = \dfrac{5mm/2}{1mm} = 2.5 \approx 3$ rounds
- Cutting Time Per Round = $\dfrac{L}{f} \times 2 = \dfrac{50mm}{200mm/min} \times 2 = 0.5$ min = 30 sec/round

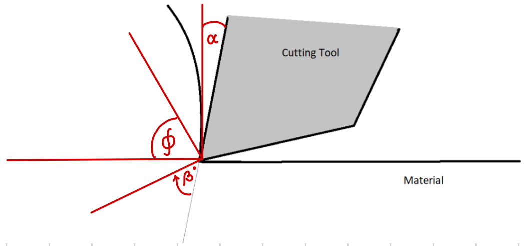
  go & back

Cutting Time = 3 × 30 = 90 sec

- Preparing & Grauging Time = 20 mins
- Total Cutting Time = Preparing & Grauging Time + Cutting Time = 21 mins 30 seconds

Cutting Condition & Power & Thermal

3. Calculate cutting power for Face-Mill ∅ 80 mm. 12 Teeth cutting on a Steel Block 80 mm. Width with depth of cut 0.6 mm. 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

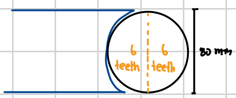


Step 1: List the Parameters.

- ∅ : D = 80 mm
- Teeth : T = 12 teeth
- Block Width : W = 80 mm
- Shear Strength : σ = 300 N/mm^2
- Friction Coef. : μ = 0.4
- $\boxed{\text{Chip Thickness} : t_c = 0.2 \text{ mm}}$ X for find α not in exam
- Cutting Speed : V_c = 120 m/min
- Depth of Cut : DOC = 0.6 mm
- Feed : f = 200 mm/min

Step 2: Calculate F_s

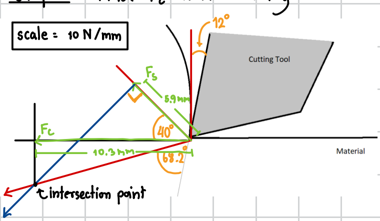
- $\beta = \arctan(\frac{1}{\mu}) = \arctan(\frac{1}{0.4}) = 68.2^\circ$
- α (measure from picture) = 12°
- $\phi = 45^\circ + \frac{\alpha}{2} + \frac{(90^\circ - \beta)}{2} \approx 40^\circ$
- $N = \frac{V_c(1000)}{\pi D} = \frac{120\ (1000)}{\pi\ (80)} \approx 477.5$ RPM
- $F_s = \frac{\sigma \cdot DOC \cdot f}{\sin\phi \cdot N \cdot T} = \frac{300 \times 0.6 \times 200}{\sin 40^\circ \times 477.5 \times 12} = 9.77$ N/tooth



- ΣF_s = contracted teeth $\times F_s = 6 \times 9.77 = 58.62$ N

Step 3: Find F_c from drawing

$\boxed{\text{scale} = 10 \text{ N/mm}}$



- $L_{F_s} = \frac{F_s}{\text{scale}} = \frac{58.62\text{ N}}{10 \text{ N/mm}} \approx 5.9$ mm
- $F_c = L_{F_c} \times \text{scale} = 10.3 \text{ mm} \times 10 \frac{N}{mm} = 103$ N

Step 4: Calculate Power

- $P_c = V_c \cdot F_c$
  $= 120$ m/min $\cdot$ 103 N
  $= 2$ m/sec $\cdot$ 103 N
  $= 206$ Watt

Step 5: Check limited Machinery Power

- $P_c = 206 < 1000$ = Mach Pow

∴ accept cutting condition

$\boxed{DOC = 0.6 mm \ / \ f = 200 mm/min}$

Change These if P_c > Mach Pow

Step 5: Cutting Time

- L = 200 mm
- depth = 6 mm
- Cutting Round = $\frac{\text{depth}}{DOC} = \frac{6}{0.6} = 10$ rounds
- Cutting Time/Round = $\frac{L}{f} = \frac{200}{200} = 1$ min = 60 sec/round
- Total Cutting Time = Cutting Round × Cutting Time/Round
  = 10 × 60 = 600 sec
- Total Process Time = Total Cutting Time + Preparing Time + Gauging Time
  = 600 sec + 10 min — should explain why it is 10 min
  = 20 min

Step 6: Thermal

- $P_{tool} = P_{chip} = P_{workpiece} = \frac{P_c}{3} = \frac{206}{3} = 68.67$ Watt
- $\frac{P_c}{3} = \frac{mc\Delta T}{\Delta t}$; m = mass (g), ΔT = Temperature Diff (°C)
  ↳ $\Delta T = \frac{P_c}{3} \cdot \frac{\Delta t}{mc}$ c = Specific Energy Coefficient (J/g°C),
  Δt = Change of Time (s)

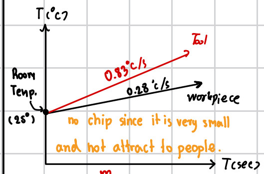
if weight of...

- tool = 0.2 kg
- workpiece = 0.5 kg
- chip = 0.001 kg

in 1 second

same material

- $\Delta T_t = 68.67 \times \frac{1}{200g \times 0.41} = 0.83^\circ C$ (c)
- $\Delta T_w = 68.67 \times \frac{1}{500g \times 0.49} = 0.28^\circ C$
- $\Delta T_c = 68.67 \times \frac{1}{1 \times 0.49} = 140.14^\circ C$



$\boxed{P \propto MRR}$

- $P = \frac{\rho V c \Delta T}{\Delta t}$ — ρV = m; $\frac{V}{\Delta t}$ → MRR (Material Removal Rate)
  How fast we get rid of material from workpiece

- Cutting Power; $P_c = F_c \times V_c$ — F_c: cutting force; V_c: cutting speed

Saft Power

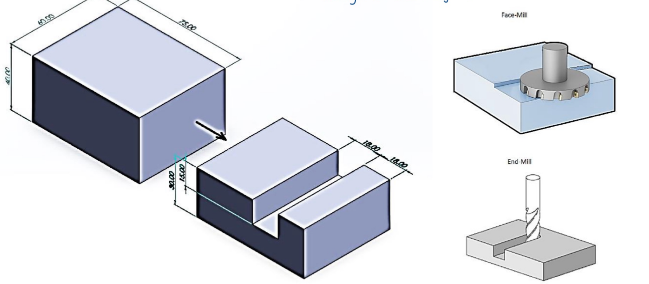
- Safty Factor = 0.6 — Should be told by problem (this is just example number)
- Efficient = 0.9
- Motor Power = 1000 Watt

∴ Saft Power = 1000 × 0.6 × 0.9 = 540 Watt

MRR & SE & Power

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)

Cutting Plan & Power using MRR



Step 1: Calculate MRR

- $MRR = A \times f = \frac{\text{Volume}}{\text{Time}}$

  - Face Mill : $MRR = (75 \times 10) \times (20) = 15000 \ \frac{mm^3}{min}$

    width depth feed

  - End Mill : $MRR = (12 \times 15) \times (20) = 3600 \ \frac{mm^3}{min}$

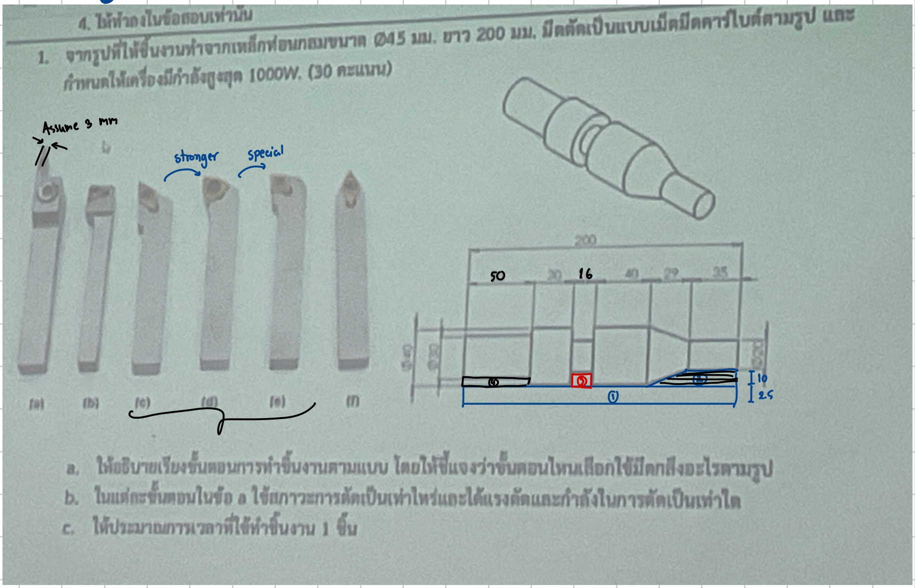
Step 2: Calculate Specific Energe using P_c from previous problem

- $P_c = \frac{MRR \times SE}{60} \longrightarrow SE = \frac{60 P_c}{MRR}$

  - Face Mill : $SE = \frac{60 \times 206}{15000} = 0.824 \ W \cdot sec/mm^3$

  - End Mill : $SE = \frac{60 \times 206}{3600} = 3.43 \ W \cdot sec/mm^3$

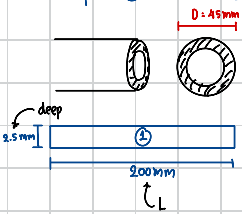
Cutting Plan



Procedure

Default Setting

1.) Cut part ① with tool ⓓ with cutting condition $\underbrace{DOC = 1\,mm \ \& \ f = 200\,mm/min \text{ or } W = 1\,mm}$



- $MRR = \frac{Volume}{Time} = A \cdot f = \left[\frac{\pi D^2}{4} - \frac{\pi (D - 2DOC)^2}{4}\right] \cdot f = 27{,}650\ mm^3/min$
- Assume $SE = 3$ (default)

$P_c = \frac{MRR \cdot SE}{60} = 1382.5\ W$ > 1000 W ∴ not satisfy

Reduce DOC from 1 mm to 0.5 mm

$P_c = 691.25\ W$ < 1000 W ∴ satisfy

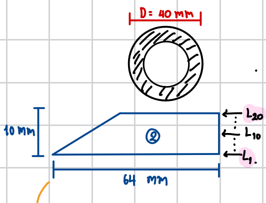
- Cutting Time: → Round $= \frac{deep}{DOC} = \frac{2.5}{0.5} = 5$ rounds (ถ้าไม่ลงตัวให้ปัดขึ้น ex. 5.5 rounds → 6 rounds)

new DOC which fit P_c

→ Cutting Time per Round $= \frac{L}{f} = \frac{200}{200} = 1\,min$

Total Cutting Time (T_1)
= Round × Cutting Time per Round
$= 5 \times 1\,min = 5\,min$

2.) Cut Part ② with tool ⓓ with cutting condition $DOC = 1\,mm \ \& \ f = 200\,mm/min$ or $W = 1\,mm$



There are many L in this case

even you have to cut multiple layer just use largest D since D↑ MRR↑ P_c↑

- $MRR = A \cdot f = \left[\frac{\pi D^2}{4} - \frac{\pi (D - 2DOC)^2}{4}\right] \cdot f = 24{,}505\ mm^3/min$
- Assume $SE = 3$

$P_c = \frac{MRR \cdot SE}{60} = 1225.25\ W$ > 1000 W ∴ not satisfy $\xrightarrow{\text{Change DOC to 0.5mm}}$ $P_c = \frac{1225.25}{2} = 612.625\ W$ < 1000W ∴ satisfy

There are 20 different L

- Cutting Time: → Round $= \frac{deep}{DOC} = \frac{10}{0.5} = 20$ rounds

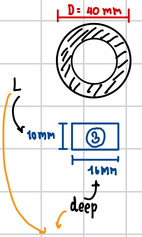
new

→ Total Cutting Time (T_2) $= \sum_{i=1}^{20} \frac{L_i}{f}$

* Ajarn will give picture in scale 1:1 so you just measure it by yourself.

Assume 1 mm of the cutting tool tips

3.) Cut Part ③ with tool ⓐ with cutting condition DOC = 1mm & f = 200 mm/min or W = 1mm



- $MRR = A \cdot f = \left[\frac{\pi D^2}{4} - \frac{\pi(D-2DOC)^2}{4}\right] \cdot f = 24{,}505\ mm^3/min$ ⟶ $P_c = \frac{MRR \cdot SE}{60} = 1225.25\ W$ > 1000 W ∴ not satisfy $\xrightarrow[\text{DOC to 0.5m}]{\text{Change}}$ $P_c = 612.625\ W$ < 1000 W ∴ satisfy
- Assume SE = 3
- Cutting Time: ⟶ $Round = \frac{deep}{DOC} = \frac{16}{0.5} = 32$ rounds (new DOC)

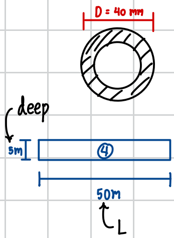
  ⟶ Cutting Time per Round : $\frac{L}{f} = \frac{10}{200} = 0.05\ min = 3\ sec$

  Total Cutting Time (T_3)
  = Round × Cutting Time per Round
  = 32 × 3 = 96 sec = 1 min 36 sec

why?: ⓐ tool is cutting in this pattern

4.) Swap the side so we can do turning the section ④

5.) Cut Part ④ with tool ⓓ with cutting condition DOC = 1mm & f = 200 mm/min or W = 1mm



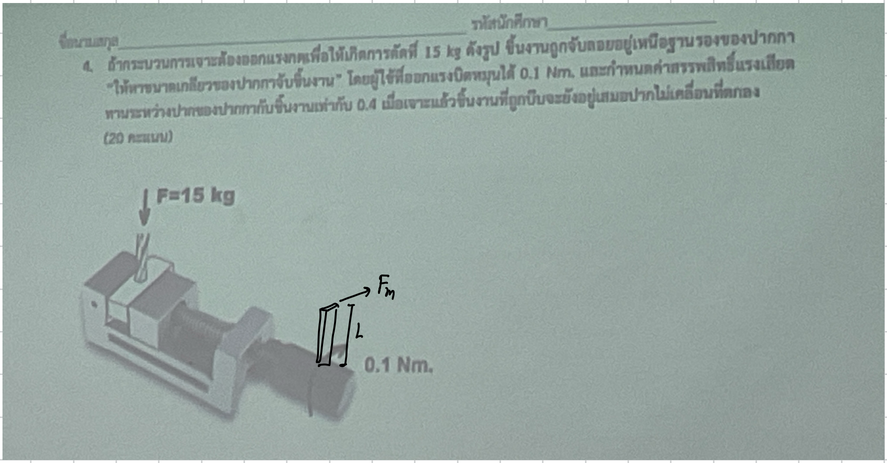
- $MRR = A \cdot f = \left[\frac{\pi D^2}{4} - \frac{\pi(D-2DOC)^2}{4}\right] \cdot f = 24{,}505\ mm^3/min$ ⟶ $P_c = \frac{MRR \cdot SE}{60} = 1225.25\ W$ > 1000 W ∴ not satisfy $\xrightarrow[\text{DOC to 0.5m}]{\text{Change}}$ $P_c = 612.625\ W$ < 1000 W ∴ satisfy
- Assume SE = 3
- Cutting Time : ⟶ $Round = \frac{deep}{DOC} = \frac{5}{0.5} = 10$ rounds (new DOC)

  ⟶ Cutting Time per Round = $\frac{L}{f} = \frac{50}{200} = 0.25\ min = 15\ sec$

  Total Cutting Time (T_4)
  = Round × Cutting Time per Round
  = 10 × 15
  = 150 sec = 2 min 30 sec

- $T_c = T_1 + T_2 + T_3 + T_4 = \ldots$
- Total Preparing Time = T_c + $\underbrace{\text{Preparing Time + Gauging Time}}_{\text{Can assign the value by yourself}}$

Clamping Force


ชื่อนามสกุล______________________ รหัสนักศึกษา______________________

4. ถ้ากระบวนการเจาะต้องออกแรงกดเพื่อให้เกิดการตัดที่ 15 kg ดังรูป ชิ้นงานถูกจับลอยอยู่เหนือฐานรองของปากกา
"ให้หาขนาดเกลียวของปากกาจับชิ้นงาน" โดยผู้ใช้ที่ออกแรงบิดหมุนได้ 0.1 Nm. และกำหนดค่าสัมประสิทธิ์แรงเสียด
ทานระหว่างปากของปากกากับชิ้นงานเท่ากับ 0.4 เมื่อเจาะแล้วชิ้นงานที่ถูกบีบจะยังอยู่เสมอปากไม่เคลื่อนที่ตกลง
(20 คะแนน)

Step 1 : Check Load of Clamping

- $\tau = F_m \cdot L$
- Normal Force : $N = \dfrac{2\tau\pi}{Pitch}$
- Friction : $F_f = \mu N$

Cl

$\ast$ Check : $F_f > F_{load}$

$\rightarrow N > \dfrac{F_{load}}{\mu}$

F_{load}: 15 × 9.8 N

μ: 0.4

Condition so clamp can handle force

Step 2 : Find Pitch at Load Limit

- $N = \dfrac{2\tau\pi}{Pitch}$ Size of the screw

$\dfrac{F_{load}}{\mu} = \dfrac{2\tau\pi}{Pitch}$

- $Pitch = (2\tau\pi)\left(\dfrac{\mu}{F_{load}}\right) = (2 \times 0.1 \times \pi)\left(\dfrac{0.4}{15 \times 9.8}\right) = 0.0017 \text{ m}$

$= 0.0017 \times 1000 \text{ mm}$

$= 1.7 \text{ mm}$ //