

— Midterm —

Close book – Total: 20 marks

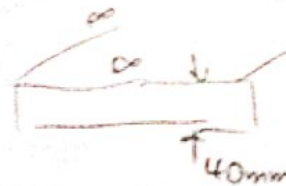
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Problem:

You have a 40 mm thick plate available (can be cut to size as needed) and your company possesses equipment with the following capabilities:

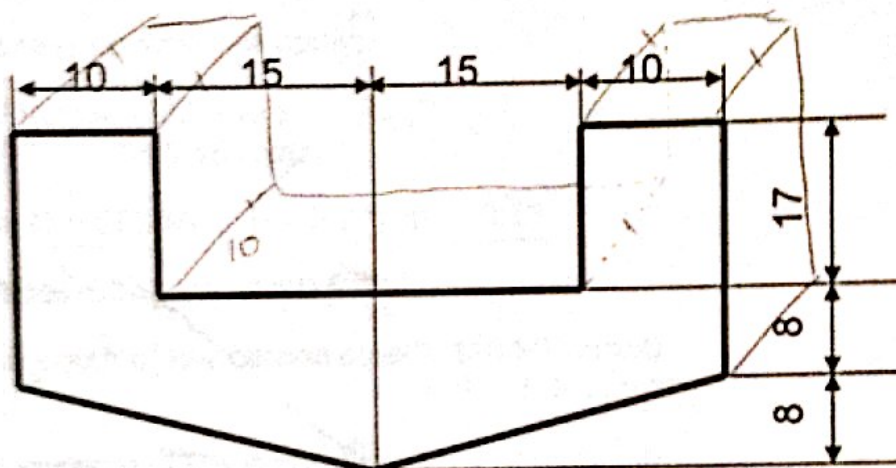
1. Hot closed die forging (MF = 4)
2. Hot open die forging (MF = 1.5)
3. Cold flat rolling (MF = 3)
4. Hot flat rolling (MF = 4)
5. Cold extrusion
6. Hot extrusion
7. Cold wire drawing



- a) Select a combination of two sub-processes from the list above for the manufacture of the component shown in figure 1 on page 2! There is no requirement for the surface finish. (4 pts) Hot process.
- b) For each sub-process, calculate the required processing force! Material parameters and a list of equations are provided on following pages. (12 pts)
- c) Indicate 2 methods to reduce the force requirement for each sub-process! (4 pts)

- add steps
- heat die
- lubricate

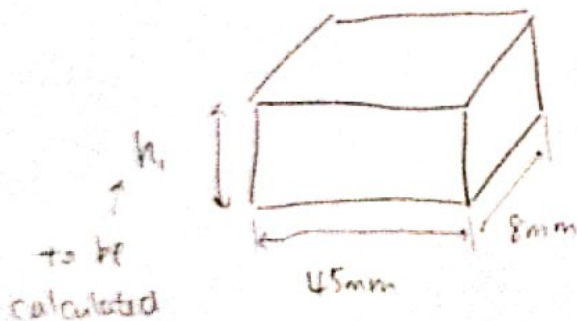
Name :
Student number :



- All dimensions are in mm
- Length in third direction = 10 mm

Figure 1

OPTIONAL INTERMEDIARY STATE



MCG4323
DEPARTMENT OF MECHANICAL ENGINEERING
Close book

Name :
Student number :

Material:

Low carbon steel

Following process parameters apply:

Coefficient of friction = 0.6 (hot)
= 0.15 (cold)

$K = 600 \text{ MPa}$; $C = 300 \text{ MPa}$; $n = 0.27$; $m = 0.13$

Radius of rolls in rolling stand = 0.6 m

Shear yield strength of low carbon steel = 110 MPa (hot)
= 320 MPa (cold)

Tensile yield strength of low carbon steel = 210 MPa (hot)
= 620 MPa (cold)

Ultimate tensile strength of low carbon steel = 410 MPa (hot)
= 820 MPa (cold)

Forging speed = 0.25 m/sec

Roll surface speed = 1.2 m/sec

Extrusion speed = 0.12 m/sec.

Max. length of extruder = 5 m.

$\alpha = 14$ (for drawing)

Equations

$$\sigma_{Taverage} = \frac{K \epsilon_T^n}{n+1}$$

$$\sigma_T = K \epsilon_T^n$$

$$\sigma_T = C \dot{\epsilon}_T^m$$

$$\epsilon_T = \left| \ln \left(\frac{h_f}{h_0} \right) \right|$$

$$L = \sqrt{R(h_0 - h_f)}$$

$$\dot{\epsilon}_T = \frac{V}{h_f}$$

$$A = L \times w$$

$$\tau_s \geq \frac{\sigma_{yield}}{2}$$

$$F = \sigma_{Taverage} * \mu R * w * MF$$

$$F = \sigma * A * MF$$

$$\epsilon_T = \left| \ln \left(\frac{h_{faverage}}{h_0} \right) \right|$$

$$\epsilon_T = \ln \left(\frac{A_{original}}{A_{final}} \right)$$

$$F_{average} = 1.7 * A_0 * \sigma_{Taverage} * \ln \left(\frac{A_0}{A_f} \right)$$

$$h_{faverage} = \frac{V_0}{A_{fprojected}}$$

$$\dot{\epsilon}_{Taverage} = \frac{\left| \ln \left(\frac{h_{faverage}}{h_0} \right) \right| V_r}{L}$$

$$F_{average} = C \left[\frac{\left[6V \ln \left(\frac{A_{original}}{A_{final}} \right) \right]}{D_0} \right]^m A_{original} \left[0.8 + 1.2 \ln \left(\frac{A_{original}}{A_{final}} \right) \right]$$

Max Draft $h_0 - h_f = \mu^2 R$

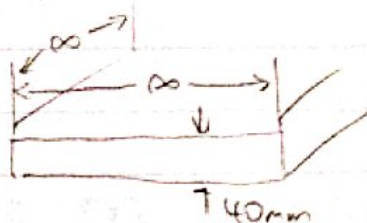
2
4
b) Since there is no requirement for surface finish, hot processes are okay to use.

① Hot closed die forging (MF=4) ~~MF=4~~

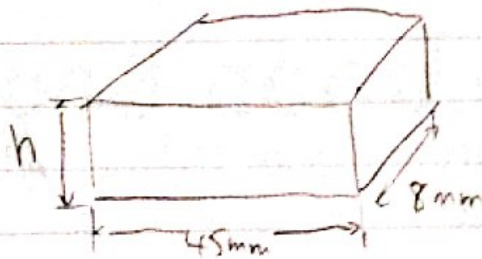
② Hot open die forging (MF=1.5) x -2

b) Assume hot closed die forging no flash

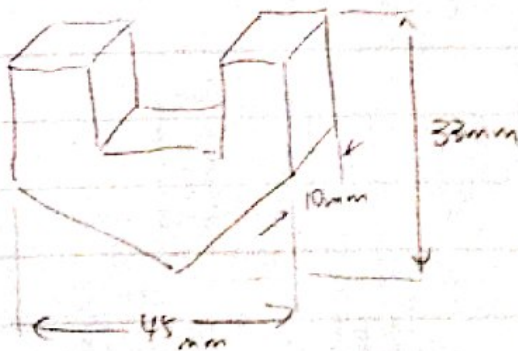
• Assume 40mm thick plate as shown



to be cut and hot open die forged to the intermediary state as shown.



↓ Hot Closed Die forging



Assume constant volume: $V_i = V_f$

$$V_f = 45 \cdot 33 \cdot 10 = 50 \cdot 17 \cdot 10 = 8 \cdot 25 \cdot 10 = 7750 \text{ mm}^3 \quad \times \textcircled{-1}$$

$$V_o = l \cdot w \cdot h \Rightarrow h = \frac{V_o}{l \cdot w} = \frac{7750}{45 \cdot 8} \approx 21.53 \text{ mm}$$

Hot Open Die forging

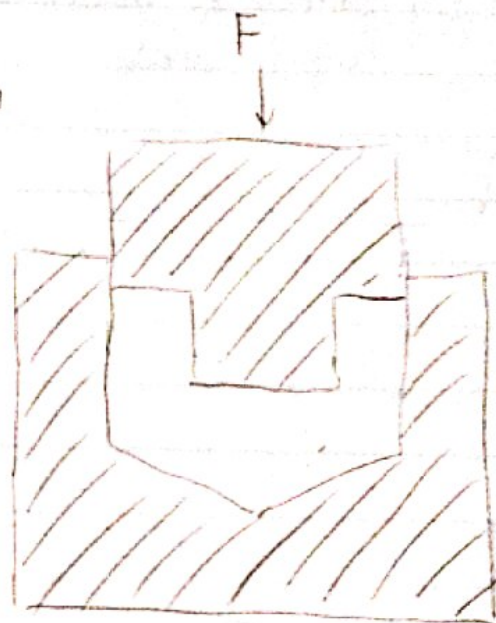
$$F = \sigma_{\text{tend}} \cdot A_{\text{proj}} \cdot MF$$

$$MF = 1.5$$

$$A_{\text{proj}} = 45 \cdot 8 = 360 \text{ mm}^2 \quad \times \textcircled{-1}$$

$$\sigma_{\text{tend}} = C \dot{\epsilon}_T^m, \quad C = 300 \text{ MPa}, \quad m = 0.13$$

$$\dot{\epsilon}_T = \frac{V}{h_f} = \frac{0.25 \times 1000 \text{ mm/s}}{21.53 \text{ mm}} = 11.61 \frac{\text{mm}}{\text{mm} \cdot \text{s}}$$



$\textcircled{-2}$ wrong piece

$$F = (300 \text{ MPa}) (11.61 \frac{\text{mm}}{\text{mm} \cdot \text{s}})^{0.13} \times 360 \text{ mm}^2 \times 1.5 = 222814.33 \text{ N}$$

$$F = 223 \text{ kN} \quad \checkmark$$

12 Hot Closed die forging

$$F = \sigma_{\text{tend}} \cdot A_{\text{proj}} \cdot MF$$

$$MF = 4$$

$$A_{\text{proj}} = 45 \cdot 10 = 450 \text{ mm}^2 \quad \checkmark$$

$$\sigma_{\text{tend}} = C \dot{\epsilon}_T^m, \quad C = 300 \text{ MPa}, \quad m = 0.13$$

$$\dot{\epsilon}_T = V/h_f, \quad V = 0.25 \text{ m/s}, \quad h_f \text{ not obvious, must use } h_{\text{forg}} = \frac{V_o}{A_{\text{proj}}}$$

$$\dot{\epsilon}_T = \frac{V \cdot A_{\text{proj}}}{V_o} = \frac{(0.25 \times 1000 \text{ mm/s})(450 \text{ mm}^2)}{7750 \text{ mm}^3} = 14.52$$

$$F = (300)(14.52)^{0.13} \times 450 \times 4 = 764626.63 \text{ N}$$

$$F = 765 \text{ kN} \quad \checkmark$$