

Rolling problems:

$$P^* = -(1.2) \frac{2}{\sqrt{3}} \left[\frac{k}{n+1} (\bar{\epsilon})^n \right] w \cdot (R \delta h)^{1/2}$$

Torque estimation on roll is expressed as follows;

$$T = P^* (L/2)$$

The rolling power is obtained by multiplying the rolling torque by the angular speed of roll (ω_n), *rad/sec*, and given as follows;

$$Power = T \omega_n = \left(P^* \frac{L}{2} \right) \omega_n$$

where $\epsilon_1 = \ln(l_f / l_o)$; $\epsilon_2 = 0$; $\epsilon_3 = -\epsilon_1 = \ln(h_f / h_o)$; $\bar{\epsilon} = \frac{2}{\sqrt{3}} \epsilon_1 = -\frac{2}{\sqrt{3}} \epsilon_3$.

$$\omega_n = (2\pi/60) N$$

- 1) A reversing mill having single rolling stand used to roll a strip from $h_o=2.0\text{mm}$ to $h_f=1.5\text{mm}$ and strip-width of $w=500\text{ mm}$, and driven at angular speed of $n=50\text{ rpm}$. Calculate rolling force and torque when roll diameter is changed from $D_1=500\text{ mm}$ to $D_2=300\text{ mm}$. (i.e. $R_1=250\text{ mm}$ to $R_2=150\text{ mm}$), given material follow stress

$$\sigma = 150 (\epsilon)^{0.25} \text{ N/mm}^2 ?$$

- 2) A single stand rolling mill used to roll a strip height from h_o to h_f . Given roll diameter of 500 mm (i.e. $R=250\text{ mm}$), and driven at rolling angular speed of $n=60\text{ rpm}$. If roll width (i.e. strip width $w=1800\text{ mm}$), calculates;

- a) Rolling force from $h_o=1.5\text{ mm}$ to $h_f=1.0\text{ mm}$ and power required? Given material follow stress $\sigma = 150 (\epsilon)^{0.25} \text{ N/mm}^2$.

- b) If the initial strip length is 2 meter calculate the final strip length?

3) A rolling stand has a power of 20 KW, driven at angular speed of 80 rpm. Given roll diameter is 300 mm (i.e. $R=150$ mm), and initial strip thickness is 3 mm and strip-width 300 mm. (Material flow stress $\sigma = 120 (\epsilon)^{0.2}$ N/mm²)

a) Calculate the maximum reduction in strip thickness based on given rolling power ?

b) If the strip length is 3 meter, calculate rolling cost of producing 100 stripes if power cost is 1.5 SR/(KW.Hr)?

4) Tandem mill has two rolling stands with power of 60 and 50 KW, respectively. Given roll diameter is 400 mm for all rolls. Given angular speed for each stand is 80 rpm. The initial strip thickness is 3 mm and its width 300 mm. Calculate maximum reduction of strip thickness on tandem mill? Given material flow stress $\sigma = 120 (\epsilon)^{0.2}$ N/mm² .

Extrusion

a) **Direct round rod extrusion:** $p_e^* = 1.5 \frac{K}{1+n} (\bar{\epsilon})^{n+1} = 1.5 \frac{K}{1+n} (\ln R_e)^{n+1} = 1.5 \frac{K}{1+n} \left(\ln \frac{A_o}{A_f}\right)^{n+1}$,

Where $A_o = \frac{\Pi}{4} D_o^2$, $A_f = \frac{\Pi}{4} D_f^2$ and $R_e = \frac{A_o}{A_f} = \left(\frac{D_o^2}{D_f^2}\right)$.

b) **Indirect round rod extrusion:** $p_{eb}^* = 1.5 \frac{K}{1+n} (\bar{\epsilon})^{n+1} = 1.5 \frac{K}{1+n} (\ln R_{eb})^{n+1} = 1.5 \frac{K}{1+n} \left(\ln \frac{A_o}{A_f}\right)^{n+1}$

Where $A_o = \frac{\Pi}{4} (D_o^2 - D_f^2)$; $A_f = \frac{\Pi}{4} D_f^2$ and $R_{eb} = \frac{A_o}{A_f} = \left(\frac{D_o^2 - D_f^2}{D_f^2}\right) = \frac{D_o^2}{D_f^2} - 1 = R_e - 1$.

c) **Direct round tube extrusion:** $p_{et}^* = 1.5 \frac{K}{1+n} (\bar{\epsilon})^{n+1} = 1.5 \frac{K}{1+n} (\ln R_{et})^{n+1} = 1.5 \frac{K}{1+n} \left(\ln \frac{A_o}{A_f}\right)^{n+1}$

Where $A_o = \frac{\Pi}{4} (D_o^2 - D_p^2)$; $A_f = \frac{\Pi}{4} (D_f^2 - D_p^2)$; $R_{et} = \frac{A_o}{A_f}$, where D_p mandrel diameter.

d) **Indirect round tube extrusion:** $p_{ebt}^* = 1.5 \frac{K}{1+n} (\bar{\epsilon})^{n+1} = 1.5 \frac{K}{1+n} (\ln R_{ebt})^{n+1} = 1.5 \frac{K}{1+n} \left(\ln \frac{A_o}{A_f}\right)^{n+1}$

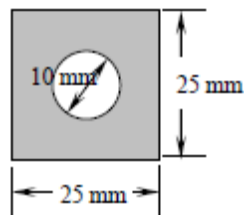
Where $A_o = \frac{\Pi}{4} (D_o^2 - D_f^2)$; $A_f = \frac{\Pi}{4} (D_f^2 - D_p^2)$; $R_{ebt} = \frac{A_o}{A_f} = R_{et} - 1$

e) **Can extrusion:** $p_{ec}^* = 1.5 \frac{K}{1+n} (\bar{\epsilon})^{n+1} = 1.5 \frac{K}{1+n} (\ln R_{ec})^{n+1} = 1.5 \frac{K}{1+n} \left(\ln \frac{A_o}{A_f}\right)^{n+1}$

Where $A_o = \frac{\Pi}{4} (D_p^2)$; $A_f = \frac{\Pi}{4} (D_o^2 - D_p^2)$; $R_{ec} = \frac{A_o}{A_f} > 1$.

Extrusion Problems:

1) Calculate the extrusion ratio for manufacturing the following section using direct and indirect extrusion processes. Given a billet diameter of 80 mm, and a mandrel diameter 10 mm. Calculate the effective strain for both cases?



2) Calculate the extrusion ratio for direct extrusion process of a square cross-section rod having dimensions of 25x25 mm. Given billet diameter 100 mm and material follows the Relationship $\sigma = 100\epsilon^{0.1} N/mm^2$, deformation efficiency $\eta=75\%$.

- a) What is the effective strain?
- b) If the billet length is 500 mm, what is the final length of the rod?
- c) What is the required power, when the extruded product speed is 3 m/s.
- d) If the power cost is 3 SR/KW.Hr what is the production cost of producing 100 bars having 6 meter length each from the same cross-section?

3) Resolve problem 5.2 for indirect extrusion process and compare the results?

4) A soft aluminum billet of 50 mm diameter is to be can extruded. The can has a 1 mm wall thickness and a 3 mm bottom thickness and height of 100 mm. If the material follows:

$\sigma = 120\epsilon^{0.2} N/mm^2$ and the deformation efficiency $\eta=0.8$, determine:

- a) The extrusion ratio?
- b) The effective strain?
- c) The extrusion force?
- d) The energy consumption needed for the manufacturing of 10,000 cans of this material?

5) Calculate the extrusion ratio for the following process:

- a) Direct rod extrusion: with $D_o=10mm$ and extrusion of square section of rectangular cross-section 20x25mm.
- b) The force needed to complete the process for each technique?
- c) The total plastic work in each case?
- d) Discuss your results?

Drawing problems

$$r_m = 1 - e^{-\eta(n+1)}$$

$$\bar{\varepsilon} = \ln\left(\frac{A_o}{A_f}\right) = \ln\left(\frac{1}{1-r_m}\right) = \eta(1+n)$$

$$A_o L_o = A_f L_f \Rightarrow \frac{A_o}{A_f} = \frac{L_f}{L_o} = \frac{D_o^2}{D_f^2} : \text{ then } \bar{\varepsilon} = \varepsilon_1 = \ln(D_f^2 / D_o^2)$$

$$P_d^* = \frac{1}{\eta} \frac{K}{1+n} (\bar{\varepsilon})^{n+1}$$

Drawing power: $Power = P_d v_d$

- 1) Calculate the maximum reduction in area, r_m , for copper wire, $\sigma = 440\epsilon^{0.38} N/mm^2$ given the deformation efficiency $\eta=0.8$?
- 2) Consider a copper rod of $L_o=100mm$, $D_o=15 mm$, $\sigma = 500\epsilon^{0.4} N/mm^2$. This rod is to be deformed to maximum possible reduction in area by two different methods t:
 - Simple tension.
 - Rod drawing.Determine:
 - a) The maximum possible reduction in area in each technique?
 - b) The force needed to complete the process for each technique?
 - c) The total plastic work in each case?
 - d) Discuss your results?