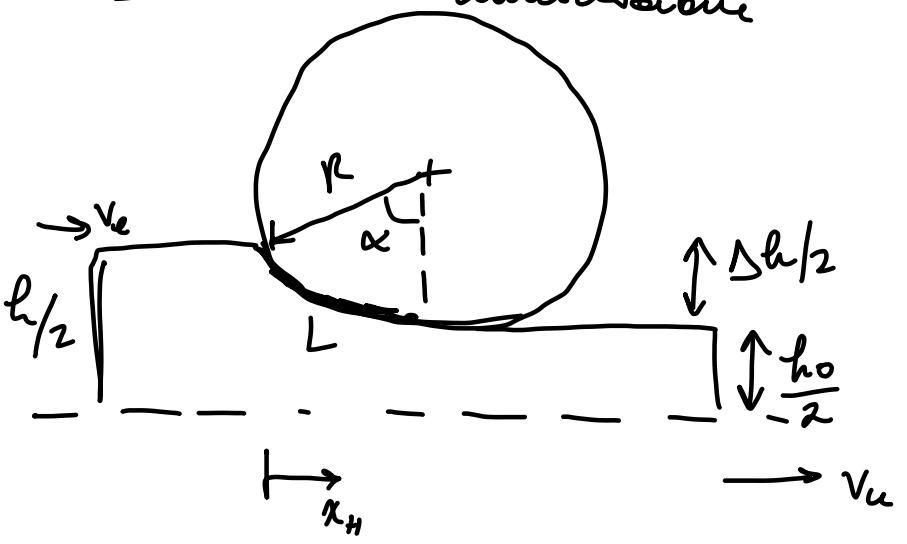
Esercitazione 6 - Laminazione



Riduzione di spessore

$$\Delta h = h - h_0$$

$b_e h_e l_e = b_u h_u l_u$ Costanza Volumetrica

Portata Volumetrica

$$b_e v_e h_e = h_e v_e h_u$$

Allungamento trasversale $b_e = b_u$

$L = \sqrt{R \Delta h}$ Arco di Contatto

$a = \frac{L}{R}$ Angolo di Contatto

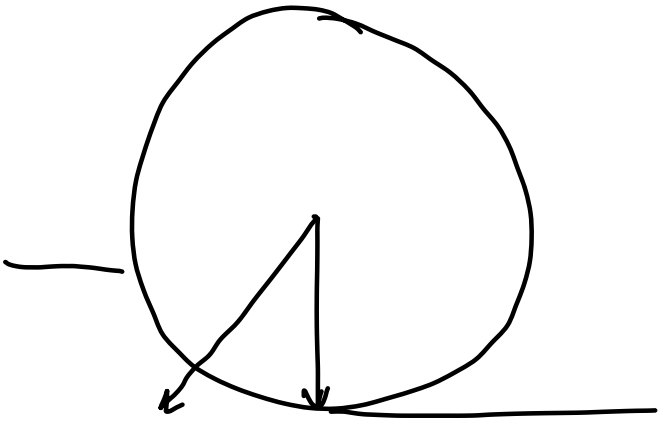
$$\Rightarrow \alpha = \sqrt{\frac{\Delta h}{R}}$$

Condizione d'Imbocco

$$\mu \geq \tan(\alpha)$$

$$\Rightarrow \Delta h \leq \mu^2 R$$

Condizione di Trascinamento



$$F_0 = F_{t,0} - F_{n0}$$

$$F_0 = F_t \cos\frac{\alpha}{2} - F_n \sin\frac{\alpha}{2}$$

$$F_0 = \rho b_e h_e v_e^2 \frac{h_0 - h_e}{h_0}$$

$$F_0 = \frac{2}{\sqrt{3}} \gamma_f \left(1 + \frac{\mu L}{2h_m}\right) b\sqrt{R\Delta h}$$

$$P = \frac{2}{\sqrt{3}} \gamma_f \left(1 + \frac{\mu L}{2h_m}\right) \quad \text{Pressione}$$

$$h_m = \frac{h_e + h_u}{2}$$

Punto di Inversione della collina delle pressioni

$$x_H = \frac{R \sin\alpha}{2} + \frac{1}{4}\frac{\Delta h}{\mu}$$

Coppia della lamiera

$$M = F_v \cdot \frac{L}{2}$$

$$P = M\omega \qquad \omega = \frac{v_c}{R}$$

$P_{tot} = 2P$ ↳ 2 molle

$$P = F_v L \frac{v_c}{R}$$

$$P = \rho_m b_m L^2 \frac{v_c}{R}$$

$$L^2 = R\Delta h$$

$$= \rho_m b_m v_c \Delta h$$

$W = P_v t_{lam}$ ↳ Energia

Esercizio 1

$$h_e l_e b_e = h_u l_u b_u$$

$$h_e v_e b_e = h_u v_u b_u$$

$$b_e = b_u$$

$$v_e = \frac{h_u v_u}{h_e} = 1{,}2 \text{ m/s}$$

$\mu = 0{,}3$

$R = 40\,mm$

$h_e = 5\,mm$

$V_u = 2\,m/s$

$V_c = 1{,}5\,m/s$

$$\alpha = \sqrt{\frac{\Delta h}{R}} = \sqrt{\frac{5 \cdot 3}{40}} = 0{,}27\,rad = 15{,}7\,rad$$

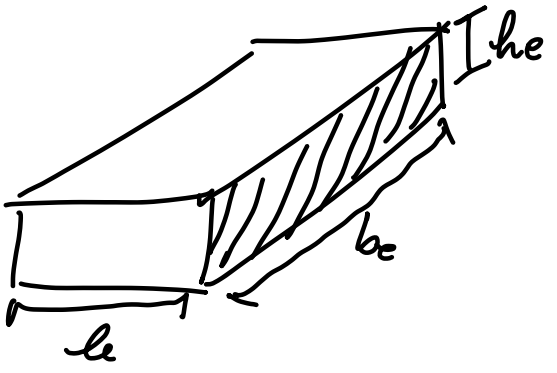
$$h_m = \frac{h_u V_u}{V_c} = 4\,mm$$

$$x_H = \frac{R \sin\alpha}{2} + \frac{1}{4} \cdot \frac{\Delta h}{\mu} = 7{,}07\,mm$$

Esercizio 2

350×120

$l_c = 4000\,mm$



Riduzione di Sezione

↳ $z = 12\%$

$\mu = 0{,}35$ $\quad V_e = 1{,}85\,m/s$

$b_e = b_u$

$$z = \frac{h_e b_e - h_u b_u}{h_e b_e} = \frac{h_e - h_u}{h_e} = \frac{\Delta h}{h_e}$$

$$\Delta h = z h_e = 14{,}4\,mm$$

$$h_u = h_e - \Delta h = 105{,}6\,mm$$

$\mu > \tan\alpha$

$\Delta h \leq \mu^2 R$

1) $\rightarrow R \geq \frac{\Delta h}{\mu^2} = \frac{14,4}{0,35^2} = 117,55\ mm$

2)

$h_e \cancel{b_e} l_e = h_u \cancel{b_u} l_u$

$l_u = \frac{h_e l_e}{h_u} = 4545\ mm$

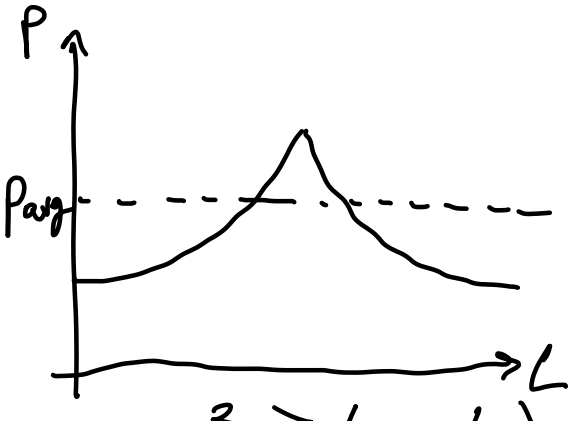
3) $h_e v_e \cancel{b_e} = h_e v_u \cancel{b_u}$

$v_u = \frac{h_e v_e}{h_u} = 2,1 \frac{m}{s}$

Esercizio 3

$L = \sqrt{\Delta h \cdot R} = 4,472\ mm$

$h_m = \frac{h_e + h_u}{2} = \frac{5+4}{2} = 4,5\ mm$



Per calcolare ci interessa il valore medio

$p_{avg} = \frac{2}{\sqrt{3}} \bar{Y}_f \left(1 + \frac{\mu L}{2 h_m}\right) = 357\ MPa$

$F_r = p_{avg} \cdot b \cdot l = 405{,}5\,kN$

Agisce a metà dell'arco di contatto in questo caso

$M = F_r \cdot \frac{L}{2} = 904{,}7\,Nm$

Esercizio 4

$R = 530\,MPa$

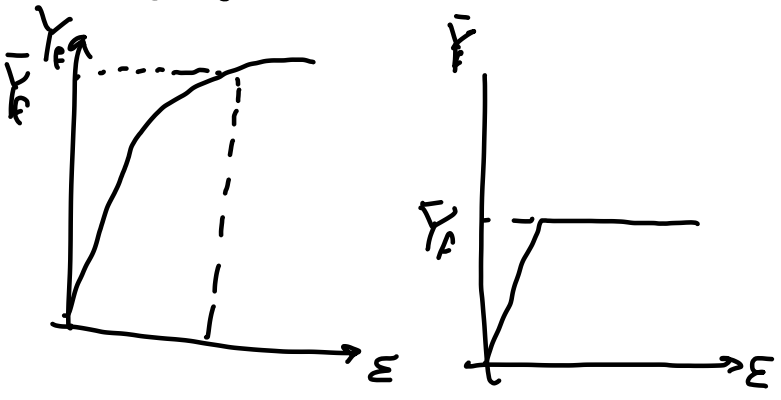
$n = 926$

$L = \sqrt{\Delta h \cdot R'} = 28{,}32\,mm$

$\varepsilon = \ln \frac{h_e}{h_m} = 0{,}5108$

$\bar{Y}_f = \frac{k\varepsilon^n}{n+1}$

Abrecodes



$\bar{Y}_f = 353{,}2\,MPa$

$p_m = \frac{2}{\sqrt{3}} \bar{Y}_f \left(1 + \frac{\mu L}{2h_m}\right) = 479{,}93\,MPa$

$h_m = \frac{h_e + h_u}{2}$

$F_v = p_m \cdot L \cdot b = 274{,}4\,kN$

$P = M_w = F \frac{L}{2} \omega = 805{,}02\,kW$

$P_{TOT} = 2P = 1610{,}04\,kW$

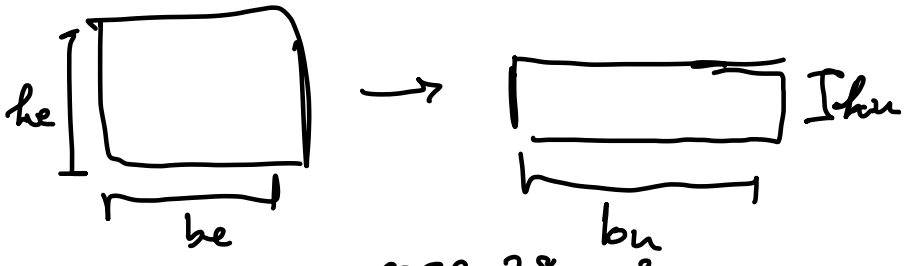
Esercizio 5

$$\Delta h = \mu^2 R = 0{,}3^2 \cdot 300 = 27\,mm$$

$$h_u = h_e - \Delta h = 123\,mm$$

$$b_e \neq b_u \qquad \Delta b = \frac{\Delta h}{6}\sqrt{R/h_e} = 6{,}3$$

$$b_u = b_e + \Delta b = 156{,}36\,mm$$



$$S_u = b_u h_u = 19232{,}28\,mm^2$$

$$\varepsilon = \ln \frac{S_e}{S_u} \qquad S_e = h_e b_e$$

$$F_v = p_m b_m L$$

$$b_m = \frac{b_e + b_u}{2} = 153{,}18\,mm$$

$$h_m = \frac{h_e + h_u}{2} = 136{,}5\,mm$$

$$\bar{Y}_f = \frac{K\varepsilon^n}{n+1} = 147{,}77\,MPa$$

$$L = \sqrt{\Delta h \cdot R} = 90\,mm$$

$$p_m = \frac{2}{\sqrt{3}}\bar{Y}_f\left(1 + \frac{\mu L}{2h_m}\right) = 187{,}5\,MPa$$

$F_V = p_m b_m L = 2585\,kN$

$M = F_V \frac{L}{2} = 118224\,Nm$

$P = 2Mw = 2365\,kW$

$w = \frac{V_c}{R}$

Esercizio 6

$b = 200\,mm$

$\alpha = 18°$

$D = 300\,mm$

$R = 150\,mm$

$p_m = 50\,MPa$

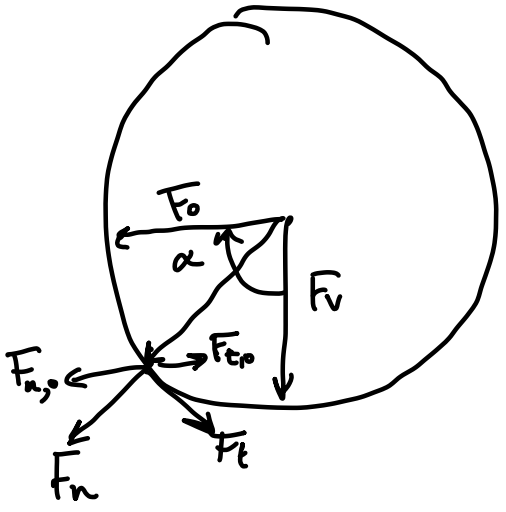
$\mu = 0{,}35$

$L = R\alpha = 47{,}124\,mm$

$F_n = pbL = 50 \cdot 200 \cdot 47{,}124 = 471{,}24\,N$

$F_t = \mu F_n = 174{,}84\,N$

$F_o = F_{t,o} - F_{n,o} = F_t \cos\frac{\alpha}{2} - F_n \sin\frac{\alpha}{2} = 81{,}2\,N$



$\cos\alpha = \frac{R - \frac{\Delta h}{2}}{R} =$

$\Delta h = 2(R - \cos\alpha) = 14{,}68\,mm$

r_{max}:

$\Delta h = \mu^2 R = 18{,}375\,mm$

$\Delta h = \Delta h_{max} \Rightarrow \alpha$ } ioll

$$r = \frac{S_e - S_u}{S_e} \overset{b_e = b_u}{=} \frac{h_e - h_u}{h_e} = \frac{\Delta h}{h_e} = r_h$$

$$h_e = \frac{\Delta h}{r_h} = 9 \pm 1{,}878 \text{ mm}$$

$$S_e l_e = S_u l_u$$

$$\frac{l_e}{l_u} \cdot \frac{S_u}{S_e} \longrightarrow \frac{h_u}{h_e}$$

$$\frac{l_u}{l_e} = \frac{h_e}{h_e - \Delta h} = 1{,}25$$

$$l_u = 2{,}5 \text{ m}$$

Esercizio TdE 14/7/19

$\bar{Y}_f = 400 \text{ MPa}$

$D = 8 \text{ mm}$

$R = 4 \text{ mm}$

$\mu = 0{,}15$

$l_e = 100 \text{ mm}$

$b_e = 50 \text{ mm}$

$h_e = 1 \text{ mm}$

1) $\Delta h_{max} = \mu^2 R = 0{,}15^2 \cdot 4 = 0{,}09 \text{ mm}$

$h_u = h_e - \Delta h = 0{,}91 \text{ mm}$

$l = \sqrt{R \Delta h_{max}} = 0{,}6 \text{ mm}$

$h_m = \frac{h_e + h_u}{2} = \frac{1 + 0{,}91}{2} = 0{,}955 \text{ mm}$

$$p_m = \frac{2}{\sqrt{3}} \bar{Y}_f \left(1 + \frac{\mu l}{2 h_m}\right)$$

$= 483{,}64\ MPa$

$F_v = p_m b_m L = 14509\ N$

$M = F_v \cdot \frac{L}{2} = 4{,}35\ Nm$

$P = 2M\omega = 2M\frac{v_t}{R} = 2\frac{Mv}{R} = 10875\ W$

$t_{lam} = ?\quad l_m = ?$

$l_m = \frac{h_e l_e}{h_m} = 104{,}7\ mm$

$t_{lam} = \frac{l_m}{v_c} =$

$W = P\, t_{lam} = 227225\ J$

Esercizio 8 10/2/23

$M_{max} = 5000\ Nm$

$\mu = 0{,}2$

$M = F_v \cdot L/2 = p_m \cdot b_m \cdot L \cdot \frac{L}{2} = \frac{p_m b_m R\Delta h}{2}$

$L = \sqrt{R\Delta h}$

$$k = \frac{M_0}{R_0} = \frac{8000}{0,15} = 53300\,N$$

$D_{min} = 188\,mm$

Verifica d'Imbocco

$$\alpha = \sqrt{\frac{\Delta h}{R_{max}}} = 0,231$$

$\tan\alpha = 0,235$

Condizione limite

$\mu \geq \tan\alpha$

Non è verificato dato che $\mu = 0,2$

Esercizio 9

$\bar{Y}_f = 500\,MPa$

che be — han b
$500 \cdot 500 \Rightarrow 450 \cdot 500$

$\Delta h = 50$

$D = 800\,mm \rightarrow R = 400\,mm$

$n = 20\,giri/min$

$\mu = 0,2$

$l_m = 457,3\,mm$

$p_{max} = 630 MPa$

$\mu \geq \tan\alpha$

$\alpha_{lim} = \tan^{-1}(\mu) = 31,9°$

$\alpha = \sqrt{\frac{\Delta h}{R}} = 20,2° < \alpha_{lim}$ → ~~sabbocco~~ Verificato

$V_n = V_c = \omega R$

$\omega = \frac{2\pi n}{60} =$

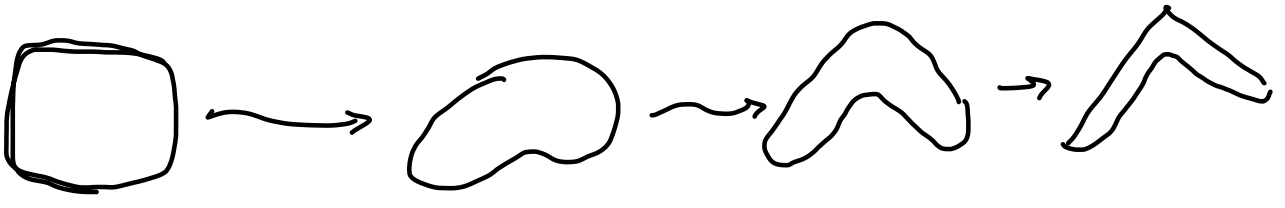
$V_n = \frac{2\pi n}{60} \cdot R = 0,837 \frac{m}{s}$

$F_r = p_m b_m \cdot L = p_M \cdot b_m \cdot \sqrt{\Delta h R}$
$= 4,45 \cdot 10^7 N$

$M = F_r \cdot \frac{L}{2} = 3150 kNm$

$P = 2M\omega = 2M \frac{v_t}{R} = 13,2 MW$

Calibratura



Diversi passaggi per portare ad una forma specifica

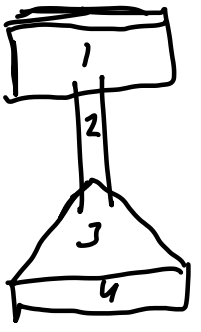
$$\lambda_i = \frac{A_{n-1}}{A_n} \qquad 1{,}25 < \lambda_i < 1{,}8$$

$$A_0 = \lambda_m^n A_n$$
↳ Medio

$$n = \frac{\ln A_0 - \ln A_n}{\ln \lambda_m}$$

Esercizio 1

λ_m = circa 1,5



$A_1 = A_n B = 1140$

$A_2 = S(D - B - a - b) = 1036\ mm^2$

$A_3 = C\frac{b}{2} = 900 mm^2$

$A_4 = C \cdot a$

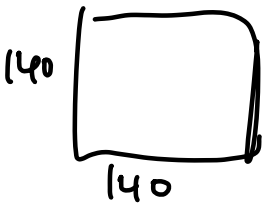
$A_n = A_1 + A_2 + A_3 + A_4 = 4576 mm^2$

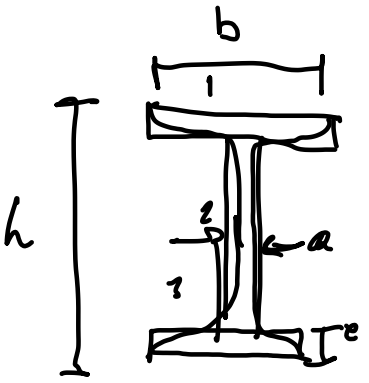
$A_0 = 150 \cdot 150 = 22500\ mm^2$

$n = \frac{\ln A_0 - \ln A_n}{\ln \lambda_m} = 3{,}93 \rightarrow n = 4$

↳ Arrotondiamo sempre per eccesso

Exercício 2





$h = 180$ $\quad b = 82m$ $\quad a = 6,9$ $\quad b = 10,4$

$\lambda_m = 1,5$

$A_1 = b \cdot e = 852,8\ mm^2$

$A_3 = A_1$

$A_2 = (h - 2e)a = 1098,68\ mm^2$

$A_n = 2804,08\ mm^2$

$A_0 = 19600\ mm^2$

$$n = \frac{\ln A_n - \ln A_0}{\ln \lambda_m} = 4,8 \rightarrow n = 5$$