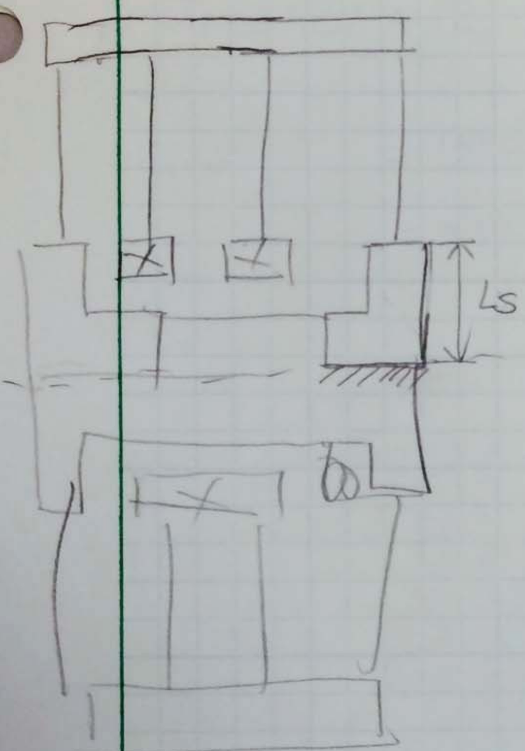
$L_s = \frac{L_i}{2} = \frac{L_o}{2}$



2.8 poly   0.5 → substrate

$(\alpha_f - \alpha_s) \cdot \Delta T$ 160 GPa

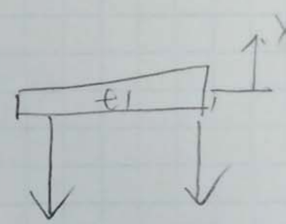
$= (2.8 - 0.5)(650° - 25°C) \cdot \left(\frac{E_{poly}}{1-\nu}\right) =$ $1-0.2$

$= 287.5\,MPa$

the amount of expansion or contraction when beams are free to move

$L_x' = (\alpha_s - \alpha_f) \cdot \Delta T \cdot L_x$ $650°C - 25°C$

$\Delta L_s = (\alpha_s - \alpha_f) \cdot \Delta T \cdot L_s$



$$E \cdot A \frac{(X_t - L_i')}{L_i} + EA \frac{(X_t - L_o' - \Delta L_s)}{L_o} = 0$$

$$\frac{X_t - L_i'}{L_i} + \frac{X_{t_1} - L_o' - \Delta L_s}{L_o} = 0$$

$L_i = L_o$

$$2X_t = L_o' + L_i' + \Delta L_s$$

$$X_t = \frac{L_o' + L_i'}{2} + \frac{\Delta L_s}{2}$$

$$= L_o' + \frac{\Delta L_s}{2}$$

stress in outside beam

$$\sigma_o = E \cdot \varepsilon_o = E \cdot \frac{L_o' + \frac{\Delta L_s}{2} - L_o' - \Delta L_s}{L_o} = E \cdot \left(-\frac{\frac{\Delta L_s}{2}}{L_o}\right) = -E \cdot \frac{(\alpha_s - \alpha_f)\Delta T \cdot L_s}{2L_o}$$

$$= -160\,GPa \cdot \frac{(0.5-2.8)\times 10^{-6} \times (650-25)°}{4} = 57.5\,MPa$$

inside beam

$$\sigma_i = E \cdot \frac{L_o' + \frac{\Delta L_s}{2} - L_i'}{L_i} = E \cdot \frac{\Delta L_s}{2L_i} = 160 \times \frac{(0.5-2.8)\times 10^{-6} \times (650-25)}{4} = -57.5\,MPa$$

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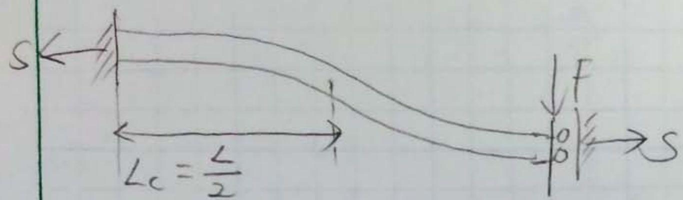
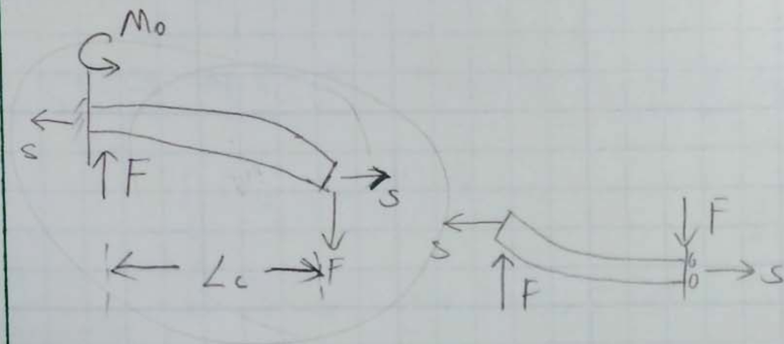
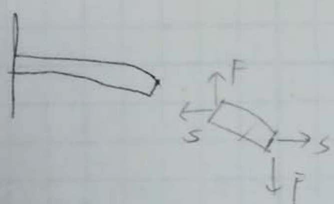
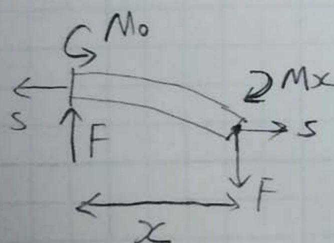






$$F \cdot L_c - S \cdot y(L_c) - M_0 = 0$$

$$\Rightarrow M_0 = F \cdot L_c - S \cdot y(L_c)$$



$$M_x + F \cdot x - S \cdot y(x) - M_0 = 0$$

$$\Rightarrow M_x = -F \cdot x + S \cdot y(x) + F \cdot L_c - S \cdot y(L_c)$$

$$= S \cdot y(x) - F \cdot x + F \cdot L_c - S \cdot y(L_c)$$

$$EI \frac{d^2y}{dx^2} = S \cdot y(x) - F \cdot x + F \cdot L_c - S y \cdot (L_c)$$

$$EI y'' = Sy - F \cdot x + [F L_c - S y(L_c)] \quad y'' = \frac{S}{EI} y - \frac{F}{EI} x + \frac{[F \cdot L_c - S \cdot y(L_c)]}{EI}$$

$$y = C_1 \cos px + C_2 \sin px + C_3 x + C_4$$

$$y'' = -C_1 \cdot p^2 \cos px - C_2 p^2 \sin px = \frac{S}{EI} C_1 \cos px + \frac{S}{EI} C_2 \sin px$$

$$\Rightarrow p = \sqrt{\frac{-S}{EI}}$$

$$y = C_1 \cos px + C_2 \sin px + C_3 x + C_4$$

$$EIy'' = C_1 \cdot S \cdot \cos px + C_2 \cdot S \cdot \sin px$$

$$= C_1 S \cdot \cos px + C_2 \cdot S \sin px + \underline{C_3 \cdot S \cdot x} + \underline{C_4 \cdot S} \underline{- Fx} + \underline{F \cdot L_c} - \underline{S \cdot y(L_c)}$$

$$\Rightarrow \begin{cases} (C_3 \cdot S - F)\, x = 0 \\ F \cdot L_c - S \cdot y(L_c) + C_4 \cdot S = 0 \end{cases} \Rightarrow \begin{cases} C_3 = \dfrac{F}{S} & (3) \\ C_4 = -\dfrac{FL_c}{S} + y(L_c) & (4) \end{cases}$$

Boundary condition

$$y(0) = 0 \Rightarrow C_1 + C_4 = 0 \quad (5)$$

$$\left.\frac{dy}{dx}\right|_{x=0} = 0 \Rightarrow -C_1 p \cdot \sin px + C_2 p \cos px + C_3 = 0 \quad (6)$$

$$C_2 p + C_3 = 0$$

$$\Rightarrow \begin{cases} C_2 = -\dfrac{C_3}{p} = -\dfrac{F}{S \cdot p} \\ C_1 = -C_4 = -\left[-\dfrac{FL_c}{S} + y(L_c)\right] \\ C_3 = \dfrac{F}{S} \\ C_4 = -\dfrac{FL_c}{S} + y(L_c) \end{cases}$$

$$y(L_c) = C_1 \cdot \cos(p \cdot L_c) + C_2 \sin(p \cdot L_c) + C_3 \cdot L_c + C_4$$

$$y(L_c) = \left[\frac{FL_c}{S} - y(L_c)\right] \cos(pL_c) - \frac{F}{Sp} \cdot \sin(p \cdot L_c) + \frac{F}{S} \cdot L_c - \frac{FL_c}{S} + y$$

$$\frac{FL_c}{S} \cos(pL_c) - y(L_c) \cos(pL_c) - \frac{F}{S \cdot p} \sin(pL_c) = 0$$

$$\Rightarrow y(L_c) = \frac{FL_c}{S} \frac{\cos(pL_c)}{\cos(pL_c)} - \frac{F}{Sp} \cdot \frac{\sin(pL_c)}{\cos(pL_c)} = \frac{FL_c}{S} - \frac{F}{Sp} \tan$$

$$\boxed{K_c = \frac{F}{y(L_c)} = \frac{F}{\frac{FL_c}{S} - \frac{F}{Sp}\tan(pL_c)} = \boxed{\frac{p \cdot S}{p \cdot L_c - \tan(pL_c)}}}$$

$$, \quad p = \sqrt{\frac{-S}{EI}} = \sqrt{-1}\; i \cdot \sqrt{\frac{S}{EI}}$$

$$K_c = \frac{i \cdot \sqrt{\frac{S}{EI}} \cdot S}{\sqrt{\frac{S}{EI}} \cdot i \cdot L_c - \tan\left(\sqrt{\frac{S}{EI}} \cdot i \cdot L_c\right)}$$

$$= \frac{\sqrt{\frac{S}{EI}}}{\sqrt{\frac{S}{EI}} \cdot L_c + i \cdot \tan\left[i \sqrt{\frac{S}{EI}} \cdot L_c\right]}$$

$$\tanh(x) = -i \tan(i \cdot x)$$

$$= \frac{\sqrt{\frac{S}{EI}} \cdot S}{\sqrt{\frac{S}{EI}} \cdot L_c - \tanh\left[\sqrt{\frac{S}{EI}} \cdot L_c\right]}$$