PROBLEM 2.1

A nylon thread is subjected to a 8.5-N tension force. Knowing that $E = 3.3 \text{ GPa}$ and that the length of the thread increases by 1.1%, determine (a) the diameter of the thread, (b) the stress in the thread.

SOLUTION

(a) Strain: \[ \varepsilon = \frac{\delta}{L} = \frac{1.1}{100} = 0.011 \]

Stress: \[ \sigma = E \varepsilon = (3.3 \times 10^9)(0.011) = 36.3 \times 10^6 \text{ Pa} \]

\[ \sigma = \frac{P}{A} \]

Area: \[ A = \frac{P}{\sigma} = \frac{8.5}{36.3 \times 10^6} = 234.16 \times 10^{-9} \text{ m}^2 \]

Diameter: \[ d = \sqrt{\frac{4A}{\pi}} = \sqrt{\frac{(4)(234.16 \times 10^{-9})}{\pi}} = 546 \times 10^{-6} \text{ m} \quad d = 0.546 \text{ mm} \]

(b) Stress: \[ \sigma = 36.3 \text{ MPa} \]
**PROBLEM 2.17**

The specimen shown has been cut from a $\frac{1}{4}$-in.-thick sheet of vinyl ($E = 0.45 \times 10^6$ psi) and is subjected to a 350-lb tensile load. Determine (*a*) the total deformation of the specimen, (*b*) the deformation of its central portion $BC$.

---

**SOLUTION**

\[
\delta_{AB} = \frac{PL_{AB}}{EA_{AB}} = \frac{(350 \text{ lb})(1.6 \text{ in.})}{(0.45 \times 10^6 \text{ psi})(1 \text{ in.})(0.25 \text{ in.})} = 4.9778 \times 10^{-3} \text{ in.}
\]

\[
\delta_{BC} = \frac{PL_{BC}}{EA_{BC}} = \frac{(350 \text{ lb})(2 \text{ in.})}{(0.45 \times 10^6 \text{ psi})(0.4 \text{ in.})(0.25 \text{ in.})} = 15.556 \times 10^{-3} \text{ in.}
\]

\[
\delta_{CD} = \delta_{AB} = 4.9778 \times 10^{-3} \text{ in.}
\]

(*a*) Total deformation:

\[
\delta = \delta_{AB} + \delta_{BC} + \delta_{CD}
\]

\[
\delta = 25.511 \times 10^{-3} \text{ in.}
\]

\[
\delta = 25.5 \times 10^{-3} \text{ in.} \blacktriangleleft
\]

(*b*) Deformation of portion $BC$:

\[
\delta_{BC} = 15.56 \times 10^{-3} \text{ in.} \blacktriangleleft
\]
PROBLEM 2.35

The 4.5-ft concrete post is reinforced with six steel bars, each with a $1 \frac{1}{8}$-in. diameter. Knowing that $E_s = 29 \times 10^6$ psi and $E_c = 4.2 \times 10^6$ psi, determine the normal stresses in the steel and in the concrete when a 350-kip axial centric force $P$ is applied to the post.

SOLUTION

Let $P_c$ = portion of axial force carried by concrete.

$P_s$ = portion carried by the six steel rods.

$$
\delta = \frac{P_c L}{E_c A_c} \quad P_c = \frac{E_c A_c \delta}{L}
$$

$$
\delta = \frac{P_s L}{E_s A_s} \quad P_s = \frac{E_s A_s \delta}{L}
$$

$$
P = P_c + P_s = \left(\frac{E_c A_c + E_s A_s}{E_c A_c + E_s A_s}\right) \delta
$$

$$
\varepsilon = \frac{\delta}{L} = \frac{-P}{E_c A_c + E_s A_s}
$$

$$
A_s = 6\frac{\pi}{4}d_s^2 = \frac{6\pi}{4}(1.125 \text{ in.})^2 = 5.9641 \text{ in}^2
$$

$$
A_c = \frac{\pi}{4}d_c^2 - A_s = \frac{\pi}{4}(18 \text{ in.})^2 - 5.9641 \text{ in}^2
$$

= 248.51 \text{ in}^2

$L = 4.5 \text{ ft} = 54 \text{ in.}$

$$
\varepsilon = \frac{-350 \times 10^3 \text{ lb}}{(4.2 \times 10^6 \text{ psi})(248.51 \text{ in}^2) + (29 \times 10^6 \text{ psi})(5.9641 \text{ in}^2)} = -2.8767 \times 10^{-4}
$$

$$
\sigma_s = E_s \varepsilon = (29 \times 10^6 \text{ psi})(-2.8767 \times 10^{-4}) = -8.3424 \times 10^3 \text{ psi} \quad \sigma_s = -8.34 \text{ ksi} \uparrow
$$

$$
\sigma_c = E_c \varepsilon = (4.2 \times 10^6 \text{ psi})(-2.8767 \times 10^{-4}) = 1.20821 \times 10^3 \text{ psi} \quad \sigma_c = -1.208 \text{ ksi} \uparrow
$$
PROBLEM 2.41

Two cylindrical rods, one of steel and the other of brass, are joined at C and restrained by rigid supports at A and E. For the loading shown and knowing that $E_s = 200 \text{ GPa}$ and $E_b = 105 \text{ GPa}$, determine (a) the reactions at A and E, (b) the deflection of point C.

SOLUTION

A to C: $E = 200 \times 10^9 \text{ Pa}$

$A = \frac{\pi}{4} (40)^2 = 1.25664 \times 10^3 \text{ mm}^2 = 1.25664 \times 10^{-3} \text{ m}^2$

$EA = 251.327 \times 10^6 \text{ N}$

C to E: $E = 105 \times 10^9 \text{ Pa}$

$A = \frac{\pi}{4} (30)^2 = 706.86 \text{ mm}^2 = 706.86 \times 10^{-6} \text{ m}^2$

$EA = 74.220 \times 10^6 \text{ N}$

A to B: $P = R_A$

$L = 180 \text{ mm} = 0.180 \text{ m}$

$\delta_{AB} = \frac{PL}{EA} = \frac{R_A (0.180)}{251.327 \times 10^6}$

$= 716.20 \times 10^{-12} R_A$

B to C: $P = R_A - 60 \times 10^3$

$L = 120 \text{ mm} = 0.120 \text{ m}$

$\delta_{BC} = \frac{PL}{EA} = \frac{(R_A - 60 \times 10^3)(0.120)}{251.327 \times 10^6}$

$= 447.47 \times 10^{-12} R_A - 26.848 \times 10^{-6}$

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PROBLEM 2.41 (Continued)

C to D:  \[ P = R_A - 60 \times 10^3 \]
\[ L = 100 \text{ mm} = 0.100 \text{ m} \]
\[ \delta_{BC} = \frac{PL}{EA} = \frac{(R_A - 60 \times 10^3)(0.100)}{74.220 \times 10^6} \]
\[ = 1.34735 \times 10^{-9} R_A - 80.841 \times 10^{-6} \]

D to E:  \[ P = R_A - 100 \times 10^3 \]
\[ L = 100 \text{ mm} = 0.100 \text{ m} \]
\[ \delta_{DE} = \frac{PL}{EA} = \frac{(R_A - 100 \times 10^3)(0.100)}{74.220 \times 10^6} \]
\[ = 1.34735 \times 10^{-9} R_A - 134.735 \times 10^{-6} \]

A to E:  \[ \delta_{AE} = \delta_{AB} + \delta_{BC} + \delta_{CD} + \delta_{DE} \]
\[ = 3.85837 \times 10^{-9} R_A - 242.424 \times 10^{-6} \]

Since point E cannot move relative to A,  \[ \delta_{AE} = 0 \]

(a)  \[ 3.85837 \times 10^{-9} R_A - 242.424 \times 10^{-6} = 0 \]
\[ R_A = 62.831 \times 10^3 \text{ N} \]
\[ R_E = R_A - 100 \times 10^3 = 62.8 \times 10^3 - 100 \times 10^3 = -37.2 \times 10^3 \text{ N} \]

(b)  \[ \delta_C = \delta_{AB} + \delta_{BC} = 1.16367 \times 10^{-9} R_A - 26.848 \times 10^{-6} \]
\[ = (1.16367 \times 10^{-9})(62.831 \times 10^3) - 26.848 \times 10^{-6} \]
\[ = 46.3 \times 10^{-6} \text{ m} \]
\[ \delta_C = 46.3 \mu\text{m} \]
PROBLEM 2.51

A rod consisting of two cylindrical portions \( AB \) and \( BC \) is restrained at both ends. Portion \( AB \) is made of steel \( (E_s = 200 \text{ GPa}, \alpha_s = 11.7 \times 10^{-6}/^\circ\text{C}) \) and portion \( BC \) is made of brass \( (E_b = 105 \text{ GPa}, \alpha_b = 20.9 \times 10^{-6}/^\circ\text{C}) \). Knowing that the rod is initially unstressed, determine the compressive force induced in \( ABC \) when there is a temperature rise of \( 50^\circ\text{C} \).

SOLUTION

\[
A_{AB} = \frac{\pi}{4} d_{AB}^2 = \frac{\pi}{4} (30)^2 = 706.86 \text{ mm}^2 = 706.86 \times 10^{-6} \text{m}^2
\]
\[
A_{BC} = \frac{\pi}{4} d_{BC}^2 = \frac{\pi}{4} (50)^2 = 1.9635 \times 10^3 \text{ mm}^2 = 1.9635 \times 10^{-3} \text{m}^2
\]

Free thermal expansion:
\[
\delta_T = L_{AB} \alpha_s (\Delta T) + L_{BC} \alpha_b (\Delta T)
\]
\[
= (0.250)(11.7 \times 10^{-6})(50) + (0.300)(20.9 \times 10^{-6})(50)
\]
\[
= 459.75 \times 10^{-6} \text{m}
\]

Shortening due to induced compressive force \( P \):
\[
\delta_P = \frac{PL}{E_s A_{AB}} + \frac{PL}{E_b A_{BC}}
\]
\[
= \frac{0.250P}{(200 \times 10^9)(706.86 \times 10^{-6})} + \frac{0.300P}{(105 \times 10^9)(1.9635 \times 10^{-3})}
\]
\[
= 3.2235 \times 10^{-9} P
\]

For zero net deflection, \( \delta_P = \delta_T \)
\[
3.2235 \times 10^{-9} P = 459.75 \times 10^{-6}
\]
\[
P = 142.624 \times 10^3 \text{ N}
\]
\[
P = 142.6 \text{ kN}
\]