PROBLEM 1.2

Two solid cylindrical rods $AB$ and $BC$ are welded together at $B$ and loaded as shown. Knowing that the average normal stress must not exceed 150 MPa in either rod, determine the smallest allowable values of the diameters $d_1$ and $d_2$.

SOLUTION

(a) Rod $AB$:

Force: $P = 60 \times 10^3$ N

Stress: $\sigma_{AB} = 150 \times 10^6$ Pa

Area: $A = \frac{\pi}{4} d_1^2$

$$\sigma_{AB} = \frac{P}{A} \quad \therefore A = \frac{P}{\sigma_{AB}}$$

$$\frac{\pi}{4} d_1^2 = \frac{P}{\sigma_{AB}}$$

$$d_1^2 = \frac{4P}{\pi \sigma_{AB}} = \frac{(4)(60 \times 10^3)}{\pi(150 \times 10^6)} = 509.30 \times 10^{-6} \text{ m}^2$$

$$d_1 = 22.568 \times 10^{-3} \text{ m} \quad d_1 = 22.6 \text{ mm}$$

(b) Rod $BC$:

Force: $P = 60 \times 10^3 - (2)(125 \times 10^3) = -190 \times 10^3$ N

Stress: $\sigma_{BC} = -150 \times 10^6$ Pa

Area: $A = \frac{\pi}{4} d_2^2$

$$\sigma_{BC} = \frac{P}{A} = \frac{4P}{\pi d_2^2}$$

$$d_2^2 = \frac{4P}{\pi \sigma_{BC}} = \frac{(4)(-190 \times 10^3)}{\pi(-150 \times 10^6)} = 1.61277 \times 10^{-3} \text{ m}^2$$

$$d_2 = 40.159 \times 10^{-3} \text{ m} \quad d_2 = 40.2 \text{ mm}$$
PROBLEM 1.5

A strain gage located at $C$ on the surface of bone $AB$ indicates that the average normal stress in the bone is 3.80 MPa when the bone is subjected to two 1200-N forces as shown. Assuming the cross section of the bone at $C$ to be annular and knowing that its outer diameter is 25 mm, determine the inner diameter of the bone’s cross section at $C$.

SOLUTION

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

Geometry:

\[ A = \frac{\pi}{4}(d_1^2 - d_2^2) \]

\[
\begin{align*}
    d_2^2 &= d_1^2 - \frac{4A}{\pi} = d_1^2 - \frac{4P}{\pi\sigma} \\
    d_2^2 &= (25 \times 10^{-3})^2 - \frac{(4)(1200)}{\pi(3.80 \times 10^6)} \\
    &= 222.92 \times 10^{-6} \text{ m}^2 \\
    d_2 &= 14.93 \times 10^{-3} \text{ m} \\
\end{align*}
\]

\[ d_2 = 14.93 \text{ mm} \]
**PROBLEM 1.7**

Each of the four vertical links has an $8 \times 36$-mm uniform rectangular cross section and each of the four pins has a 16-mm diameter. Determine the maximum value of the average normal stress in the links connecting (a) points $B$ and $D$, (b) points $C$ and $E$.

**SOLUTION**

Use bar $ABC$ as a free body.

\[
\sum M_C = 0: \quad (0.040) F_{BD} - (0.025 + 0.040)(20 \times 10^3) = 0
\]

\[F_{BD} = 32.5 \times 10^3 \text{ N} \quad \text{Link } BD \text{ is in tension.}\]

\[\sum M_B = 0: \quad -(0.040) F_{CE} - (0.025)(20 \times 10^3) = 0
\]

\[F_{CE} = -12.5 \times 10^3 \text{ N} \quad \text{Link } CE \text{ is in compression.}\]

Net area of one link for tension $= (0.008)(0.036 - 0.016) = 160 \times 10^{-6} \text{ m}^2$

For two parallel links, $A_{\text{net}} = 320 \times 10^{-6} \text{ m}^2$

\[\sigma_{BD} = \frac{F_{BD}}{A_{\text{net}}} = \frac{32.5 \times 10^3}{320 \times 10^{-6}} = 101.563 \times 10^6 \quad \sigma_{BD} = 101.6 \text{ MPa}\]

Area for one link in compression $= (0.008)(0.036) = 288 \times 10^{-6} \text{ m}^2$

For two parallel links, $A = 576 \times 10^{-6} \text{ m}^2$

\[\sigma_{CE} = \frac{F_{CE}}{A} = \frac{-12.5 \times 10^3}{576 \times 10^{-6}} = -21.701 \times 10^{-6} \quad \sigma_{CE} = -21.7 \text{ MPa}\]
**PROBLEM 1.11**

For the Pratt bridge truss and loading shown, determine the average normal stress in member $BE$, knowing that the cross-sectional area of that member is $5.87 \text{ in}^2$.

**SOLUTION**

Use entire truss as free body.

\[ + \sum M_H = 0: \quad (9)(80) + (18)(80) + (27)(80) - 36A_y = 0 \]
\[ A_y = 120 \text{ kips} \]

Use portion of truss to the left of a section cutting members $BD$, $BE$, and $CE$.

\[ \begin{align*}
  + \sum F_y &= 0: \quad 120 - 80 - \frac{12}{15}F_{BE} = 0 \\
  \therefore F_{BE} &= 50 \text{ kips}
\end{align*} \]

\[ \sigma_{BE} = \frac{F_{BE}}{A} = \frac{50 \text{ kips}}{5.87 \text{ in}^2} \]

\[ \sigma_{BE} = 8.52 \text{ ksi} \]

\[ \begin{align*}
  \Delta &= 0 \quad \text{(balance of moments about point F)} \\
  \Delta &= \frac{F_{BD}}{120 \text{ kips}} \\
  F_{BD} &= 120 \text{ kips} \\
  F_{BE} &= 80 \text{ kips} \\
  F_{CE} &= 80 \text{ kips}
\end{align*} \]