Chapter 4 Equations

Axial tensile stress

\[ \sigma = \frac{P}{A} \]  \hspace{1cm} (4.1)

Average direct shear stress

\[ \tau = \frac{P}{A} \]  \hspace{1cm} (4.2)

Torsional shear stress at radius \( r \) (round bar)

\[ \tau = \frac{Tr}{J} \]  \hspace{1cm} (4.3)

Surface torsional shear stress for round bar of diameter \( d \)

\[ \tau = 16T/\pi d^3 \]  \hspace{1cm} (4.4)

Maximum torsional shear stress for rectangular bar

\[ \tau_{\text{max}} = T(3a + 1.8b)/a^2b^2 \]  \hspace{1cm} (4.5)

Normal stresses for beam loaded in bending

\[ \sigma = \frac{My}{I} \]  \hspace{1cm} (4.6)

Maximum normal stresses for beam loaded in bending (section modulus \( Z \))

\[ \sigma_{\text{max}} = \frac{M}{Z} \]  \hspace{1cm} (4.7)

Maximum normal stresses for solid round bar loaded in bending

\[ \sigma_{\text{max}} = \frac{32M}{\pi d^3} \]  \hspace{1cm} (4.8)

Tensile and compressive stresses for curved beam in bending

\[ \sigma_i = \frac{Mc_i}{eA_{ri}} \quad \text{and} \quad \sigma_o = -\frac{Mc_o}{eA_{ro}} \]  \hspace{1cm} (4.9)

Distance between the neutral axis and the centroidal axis

\[ e = \bar{r} - \frac{A}{\int dA/\rho} \]  \hspace{1cm} (4.10)

Tensile and compressive stresses for curved beam in bending

\[ \sigma_i = K_iMc/I = K_iM/Z \quad \text{and} \quad \sigma_o = -K_oMc/I = -K_oM/Z \]  \hspace{1cm} (4.11)

Transverse shear stress in beam

\[ \tau = \frac{V}{Ib} \int_{y=y_0}^{y=c} y \, dA \]  \hspace{1cm} (4.12)

Maximum transverse shear stress in beam (solid round section)

\[ \tau_{\text{max}} = \frac{3}{2}V/A \]  \hspace{1cm} (4.13)

Maximum transverse shear stress in beam (solid rectangular section)

\[ \tau_{\text{max}} = \frac{3}{2}V/A \]  \hspace{1cm} (4.14)
(Chapter 4 Equations Continued)

Maximum transverse shear stress in beam (thin-wall tubing)

\[ \tau_{\text{max}} = \frac{2V}{A} \]  \hfill (4.15)

Principal normal stresses

\[ \sigma_1, \sigma_2 = \frac{\sigma_x + \sigma_y}{2} \pm \sqrt{\tau_{xy}^2 + \left(\frac{\sigma_x - \sigma_y}{2}\right)^2} \]  \hfill (4.16)

Principal directions—angle between the principal axes and the \(x\) and \(y\) axes (or the angle between the principal planes and the \(x\) and \(y\) planes)

\[ 2\phi = \tan^{-1}\left(\frac{2\tau_{xy}}{\sigma_x - \sigma_y}\right) \]  \hfill (4.17)

Maximum shear stress

\[ \tau_{\text{max}} = \pm \sqrt{\tau_{xy}^2 + \left(\frac{\sigma_x - \sigma_y}{2}\right)^2} \]  \hfill (4.18)

Normal stress on a plane oriented at angle \(\phi\) from the #1 principal plane

\[ \sigma_\phi = \frac{\sigma_1 + \sigma_2}{2} + \frac{\sigma_1 - \sigma_2}{2} \cos 2\phi \]  \hfill (4.19)

Shear stress on a plane oriented at angle \(\phi\) from the #1 principal plane

\[ \tau_\phi = \frac{\sigma_1 - \sigma_2}{2} \sin 2\phi \]  \hfill (4.20)

Maximum normal stress; maximum shear stress

\[ \sigma_{\text{max}} = K_t\sigma_{\text{nom}} \quad \text{and} \quad \tau_{\text{max}} = K_t\tau_{\text{nom}} \]  \hfill (4.21)

Strain for unrestrained homogeneous, isotropic body

\[ \epsilon = \alpha \Delta T \]  \hfill (4.22)