

MTE321 Formulas

Stresses

Deformation Elongation

$$\delta = \frac{FL}{EA}$$

$$\delta = \frac{\sigma L}{E}$$

Torsional Formulas

Stress

R is the radial distance

$$\tau = \frac{Tr}{J}$$

$$Z_p = \frac{J}{c}$$

$$\tau_{max} = \frac{T}{Z_p}$$

Deformation

θ is the angle of twist across L

For non-circular shafts K is section polar second moment of area and

Q the section polar modulus

$$T = \frac{P}{\omega} \quad T_{lb-in} = 63000 \frac{P}{\omega}$$

$$\theta = \frac{TL}{GJ}$$

$$\text{Non-Circular } \tau = \frac{T}{Q}$$

$$\text{Non-Circular } \theta = \frac{TL}{GK}$$

Thin-Walled Closed Tubes

A = median area boundary, U is length of median boundary

$$K = \frac{4A^2t}{U}$$

$$Q = 2tA$$

Shear Stress

V section shear force, Q is the first moment area, and t is the section thickness

$$\tau_{(y)} = \frac{VQ}{It}$$

$$\text{Rectangular Beam } \tau_{max} = \frac{3V}{2A}$$

$$\text{Solid Round Beam } \tau_{max} = \frac{4V}{3A}$$

$$\text{Hollow Round Beam } \tau_{max} = \frac{2V}{A}$$

Beam Bending

M is the moment at the section, y is the distance from the neutral axis

$$\sigma_y = -\frac{My}{I}$$

Stress Concentrations

Stress Concentration Factor

K_t is material and loading dependent, values greater than 3 are a waste

$$\sigma_{max} = K_t \sigma_{nom}$$

Curved Beam Bending

$$R = \frac{A}{ASF}$$

r = distance to required stress location

r_c = centroid distance

A = cross-sectional area

$$\sigma_{(r)} = \frac{M(\theta)(R-r)}{Ar(r_c-R)}$$

Thermal Strain

$$\epsilon_x^m = -\alpha \delta T$$

Principle Stresses

$$\tan 2\theta_\sigma = \frac{2\tau_{xy}}{\sigma_x - \sigma_y}$$

$$\sigma_{1,2} = \frac{\sigma_x + \sigma_y}{2} \pm \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$$

$$\text{Max } \sigma_{norm} = \frac{1}{2}(\sigma_x + \sigma_y) + \sqrt{\left[\frac{1}{2}(\sigma_x - \sigma_y)\right]^2 + \tau_{xy}^2}$$

$$\text{Min } \sigma_{norm} = \frac{1}{2}(\sigma_x - \sigma_y) - \sqrt{\left[\frac{1}{2}(\sigma_x - \sigma_y)\right]^2 + \tau_{xy}^2}$$

Design Factors

A₉₅ Equivalence

$$\text{Equivalent Diameter: } D_e = 0.370D$$

$$\text{General: } 0.766D_e^2$$

Design: Dynamic Loads

Loading

$$\sigma_m = \text{mean stress} = \frac{\sigma_{max} + \sigma_{min}}{2}$$

$$\sigma_a = \text{stress amplitude} = \frac{\sigma_{max} - \sigma_{min}}{2}$$

$$R = \text{stress ratio} = \frac{\sigma_{min}}{\sigma_{max}}$$

$$A = \text{stress ratio} = \frac{\sigma_a}{\sigma_m}$$

$$\text{Loading Cycle: period between peaks}$$

Stress

Periodic

Fluctuating $\sigma_m \neq 0$, R = -1

Pulsating $\sigma_m = 0$, R = 1

Endurance Limit

s_a = Stress Amplitude Level

N: number of cycles to failure

s_n = fatigue limit

Assume s_n = 0.5s_u if no data

$$s_a = s_n N^b$$

$$s_n' = C_m C_{st} C_R C_S s_n$$

s_n from table appendix 3

C_m material flaws

C_R Reliability Factor

C_s = size factor (5-12, 5-4 circular), (5-13 for other)

4. Apply a material factor, C_m, from the following list.

Wrought steel: C_m = 1.00

Cast steel: C_m = 0.80

Powdered steel: C_m = 0.76

Malleable cast iron: C_m = 0.80

Gray cast iron: C_m = 0.70

Ductile cast iron: C_m = 0.66

5. Apply a type-of-stress factor: C_{st} = 1.0 for bending stress; C_{st} = 0.80 for axial tension.

6. Apply a reliability factor, C_R, from Table 5-3.

7. Apply a size factor, C_s, using Figure 5-12 and Table 5-4 as guides.

Goodman Method

Dynamic Loads Ductile

$$(\sigma_m < 0)$$
$$Von\ Mises: N_1 = \frac{s_n^i}{K_t \sigma_a^i}$$
$$Tresca: N_1 = \frac{s_n^i}{K_t \sigma_a^i}$$

Dynamic Loads Tensile

$$(\sigma_m > 0)$$
$$Von\ Mises: \frac{K_t \sigma_a^i}{s_n^i} + \frac{\sigma_m^i}{s_u} = \frac{1}{N_1}$$
$$Tresca: \frac{2K_t}{s_n^i} (\tau_a)_{max} + \frac{4}{3s_u} (\tau_m)_{max} = \frac{1}{N_1}$$

Dynamic Yield Test

$$for\ low\ \sigma_a\ high\ \sigma_m$$
$$Von\ Mises: \frac{K_t \sigma_a^i}{s_y} + \frac{K_t \sigma_m^i}{s_y} = \frac{1}{N_2}$$
$$Tresca: \frac{2K_t}{s_{sy}} (\tau_a)_{max} + \frac{2K_t}{S_{sy}} (\tau_m)_{max} = \frac{1}{N_2}$$

Effective safety factor is i of N₁ and N₂

Gears

Table 8-1

Pitch Line Speed

$$V_T = \frac{\pi D \cdot n_p}{12}$$

Gears

Spur Gears

$$Speed\ of\ Gears: \frac{n_p}{n_G} = \frac{N_G}{N_P}$$
$$Common\ Speed: v_T = R_1 \omega_1 = R_2 \omega_2$$
$$Tangential\ Acceleration: a_T = R_1 \alpha_1 = R_2 \alpha_2$$
$$Velocity\ Ratio: VR = \frac{R_G}{R_P} \geq 1$$
$$Circular\ Pitch: p = \frac{\pi D}{N}$$
$$Contact\ Ratio:$$

Helical Gears

$$Transverse\ Pitch: \frac{\pi}{P_d}$$
$$Normal\ Circular: p_n = p \cos \psi$$
$$Axial\ Pitch: p_x = \frac{p_t}{\tan \psi}$$