Chapter 16 Equations

Circular pitch of the gear (or pinion) in a plane normal to the teeth

$$p_n = p \cos \psi \tag{16.1}$$

Tangent of pressure angle measured in a plane normal to the teeth

$$\tan \phi_n = \tan \phi \cos \psi \tag{16.2}$$

Diametral pitch in normal plane

$$P_n = P/\cos \psi \tag{16.3}$$

Diameter of a helical gear (at pitch circle)

$$d = N/P = N/(P_n \cos \psi) \tag{16.4}$$

Axial pitch

$$p_a = p/\tan \psi \tag{16.5}$$

Equivalent number of teeth (formative or virtual number of teeth)

$$N_e = N/\cos^3 \psi \tag{16.6}$$

Transmitted force (English)

$$F_t = 33{,}000\dot{W}/V \tag{16.7}$$

Transmitted force (SI)

$$F_t = \dot{W}/V \tag{16.7a}$$

Radial force component

$$F_r = F_t \tan \phi \tag{16.8}$$

Axial force component

$$F_a = F_t \tan \psi \tag{16.9}$$

Transverse normal force component

$$F_b = F_t/\cos \psi \tag{16.10}$$

Helical-gear tooth force

$$F = F_b/\cos \phi_n = F_t/\cos \psi \cos \phi_n \tag{16.11}$$

Gear-tooth-bending stress (refined Lewis equation)

$$\sigma = \frac{F_t P}{bJ} K_v K_o (0.93 K_m) \tag{16.12}$$

Gear fatigue strength

$$S_n = S'_n C_L C_G C_S k_r k_t k_{\text{ms}} \tag{15.18}$$

Surface (Hertz) fatigue stress

$$\sigma_H = C_p \sqrt{\frac{F_t}{b d_p I} \left(\frac{\cos \psi}{0.95\ \text{CR}} \right) K_v K_o (0.93 K_m)} \tag{16.13}$$

(Chapter 16 Equations Continued)

Gear-tooth surface fatigue strength

$$S_H = S_{\text{fe}} C_{\text{Li}} C_R \tag{15.25}$$

Shaft angle of crossed helical gears

$$\Sigma = \psi_1 + \psi_2 \tag{16.14}$$

Virtual number of teeth for pinion and gear (bevel gears)

$$N'_p = \frac{2\pi r_{\text{bp}}}{p} \quad \text{and} \quad N'_g = \frac{2\pi r_{\text{bg}}}{p} \tag{16.15}$$

Virtual number of teeth for pinion and gear (bevel gears)

$$N'_p = 2r_{\text{bp}}P \quad \text{and} \quad N'_g = 2r_{\text{bg}}P \tag{16.15a}$$

Gear ratio

$$\text{Gear ratio} = \frac{\omega_p}{\omega_g} = \frac{N_g}{N_p} = \frac{d_g}{d_p} = \tan \gamma_g = \cot \gamma_p \tag{16.16}$$

Limit on face width

$$b \le \frac{10}{P} \quad \text{and} \quad b \le \frac{L}{3} \quad (L \text{ is defined in Figure 16.9}) \tag{16.17}$$

Average bevel gear diameter (feet)

$$d_{\text{av}} = d - b \sin \gamma \tag{16.18}$$

Average velocity (feet per minute)

$$V_{\text{av}} = \pi d_{\text{av}} n \tag{16.19a}$$

Transmitted force (lb)

$$F_t = 33{,}000 \dot{W} / V_{\text{av}} \tag{16.20a}$$

Average velocity (meters per second)

$$V_{\text{av}} = \pi d_{\text{av}} n \tag{16.19b}$$

Transmitted force (newtons)

$$F_t = \dot{W} / V_{\text{av}} \tag{16.20b}$$

Bevel gear tooth force

$$F = F_t / \cos \phi \tag{16.21}$$

Normal force (to pitch cone) component

$$F_n = F \sin \phi = F_t \tan \phi \tag{f}$$

Axial force component

$$F_a = F_n \sin \gamma = F_t \tan \phi \sin \gamma \tag{16.22}$$

(Chapter 16 Equations Continued)

Radial force component

$$F_r = F_n \cos\gamma = F_t \tan\phi \cos\gamma \qquad \textbf{(16.23)}$$

Axial force component (spiral bevel gear)

$$F_a = \frac{F_t}{\cos\psi}(\tan\phi_n \sin\gamma \mp \sin\psi \cos\gamma) \qquad \textbf{(16.24)}$$

Radial force component (spiral bevel gear)

$$F_r = \frac{F_t}{\cos\psi}(\tan\phi_n \cos\gamma \pm \sin\psi \sin\gamma) \qquad \textbf{(16.25)}$$

Bevel gear-tooth-bending stress

$$\sigma = \frac{F_t P}{bJ} K_v K_o K_m \qquad \textbf{(15.17)}$$

Bevel gear-tooth surface fatigue strength

$$\sigma_H = C_p \sqrt{\frac{F_t}{b d_p I} K_v K_o K_m} \qquad \textbf{(15.24)}$$

Pitch diameter of worm gear

$$d_g = N_g p/\pi \qquad \textbf{(15.2, modified)}$$

Velocity ratio of worm gear set

$$\frac{\omega_w}{\omega_g} = \frac{N_g}{N_w} \qquad \textbf{(16.26)}$$

Guideline for worm gear set design

$$N_w + N_g > 40 \qquad \textbf{(16.27)}$$

Guideline for maximum power-transmitting capacity of worm gear set

$$\frac{c^{0.875}}{3.0} \le d_w \le \frac{c^{0.875}}{1.7} \qquad \textbf{(16.28)}$$

Minimum diameter for shell worm

$$d_w = 2.4p + 1.1 \text{ (in.)} \qquad \textbf{(16.29)}$$

Guideline for gear face width design

$$b \le 0.5 d_{w,\text{out}} \qquad \textbf{(16.30)}$$

Worm lead angle

$$\tan\lambda = L/\pi d_w \qquad \textbf{(10.1, modified)}$$

Tangential force on worm gear

$$F_{\text{gt}} = F_{\text{wa}} = F_n \cos\phi_n \cos\lambda - f F_n \sin\lambda \qquad \textbf{(g)}$$

(Chapter 16 Equations Continued)

Tangential force on worm

$$F_{wt} = F_{ga} = F_n \cos \phi_n \sin \lambda + f F_n \cos \lambda \quad \textbf{(h)}$$

Radial force on gear

$$F_{gr} = F_{wr} = F_n \sin \phi_n \quad \textbf{(i)}$$

Ratio of tangential velocity of gear to tangential velocity of worm

$$V_g / V_w = \tan \lambda \quad \textbf{(16.33)}$$

Efficiency of worm gear set

$$e = \frac{\cos \phi_n - f \tan \lambda}{\cos \phi_n + f \cot \lambda} \quad \textbf{(16.34)}$$

Sliding velocity

$$V_s = V_w / \cos \lambda = V_g / \sin \lambda \quad \textbf{(16.35)}$$

Worm gear set coefficient of friction condition for self-locking

$$f \geq \cos \phi_n \tan \lambda \quad \textbf{(16.36)}$$

Dynamic load

$$F_d = F_{gt} K_v = F_{gt} \frac{1200 + V_g}{1200} \quad \textbf{(16.39)}$$

Maximum allowable value of dynamic load (bending fatigue)

$$F_s = S_n b p y \quad \textbf{(16.40)}$$

Maximum allowable value of dynamic load (surface fatigue)

$$F_w = d_g b K_w \quad \textbf{(16.41)}$$

Rate of heat dissipation

$$H = CA(t_o - t_a) \quad \textbf{(13.13)}$$

External area of conventional worm gear housing

$$A = 0.3c^{1.7} \quad \textbf{(16.42)}$$