9.3.4 Other Shit

9.3.4.1 Worm Gears **Using Mott*

Some useful Shit:

$$N_G = \text{Number of teeth on the gear}$$
$$N_W = \text{Number of worm threads}$$
$$D_G = \text{pitch diameter of the gear (in)}$$
$$D_W = \text{Pitch diameter of the worm}$$
$$p = \text{circular pitch (in)}$$
$$P_d = \text{diametral pitch (teeth/inch)}$$
$$m = \text{module}$$
$$L = \text{Lead angle}$$
$$C = \text{Center distance (in)}$$
$$\phi_n = \text{Normal pressure angle}$$
$$\phi_t = \text{transverse pressure angle}$$
$$a = \text{addendum (in)}$$
$$h_t = \text{whole depth (in)}$$
$$h_k = \text{working depth (in)}$$
$$b = \text{dedendum (in)}$$
$$D_{rW} = \text{Root diameter of worm (in)}$$
$$D_{oW} = \text{Outside diameter of worm (in)}$$
$$D_{rG} = \text{Root Diameter of gear (in)}$$
$$F_G = \text{Face width of wormgear (in)}$$
$$F_W = \text{face length of worm (in)}$$
$$n_W = \text{speed of worm (rpm)}$$
$$n_G = \text{speed of gear (rpm)}$$
$$\nu_{tW} = \text{Pitch line speed for worm (ft/min)}$$
$$\nu_{tG} = \text{Pitch line speed for gear (ft/min)}$$
$$VR = \text{Velocity ratio}$$

Now for some of the formulae to solve for these values:

circular pitch: $p = \frac{\pi D_G}{N_G}$

diametral pitch: $P_d = \frac{N_G}{D_G}$ or $P_d = \frac{\pi}{p}$

module: $m = \frac{D}{N}$

axial pitch: $P_x = p$

lead: $L = N_W P_x$

lead angle: $\tan(\lambda) = \frac{L}{\pi D_W}$

center distance: $C = \frac{D_W + D_G}{2} = \frac{N_W + N_G}{2P_d}$

angle relationship: $\tan\phi_n = \tan(\phi_t)\cos(\lambda)$

addendum: $a = 0.318 P_x = \frac{1}{P_d}$

whole depth: $h_t = 0.6866 P_x = \frac{2.157}{P_d}$

working depth: $h_k = 2a$

dedendum: $b = h_t - a$

root diameter of worm: $D_{rW} = D_W - 2b$

outside diameter of worm: $D_o W = D_W + 2a = D_W + h_k$

root diameter of gear: $D_r G = D_G - 2b$

throat diameter of gear: $D_t = D_G + 2a$

face width of wormgear: $F_G = \sqrt{D_{oW}^2 - D_W^2} = 2p \approx \frac{6}{P_d}$

face length of worm: $F_W = 2\sqrt{(\frac{D_t}{2})^2 - (\frac{D_G}{2-a})^2}$

Speed:

- pitch line speed for worm: $\nu_{tW} = \frac{\pi D_W n_W}{12}$ lb-ft or $\nu_{tW} = \frac{\pi D_W n_W}{60000}$ m/s
- pitch line speed for gear: $\nu_{tG} = \frac{\pi D_G n_G}{12}$ lb-ft or $\nu_{tW} = \frac{\pi D_G n_G}{60000}$ m/s
- Velocity Ratio: $VR = \frac{n_W}{n_G} = \frac{N_G}{N_W}$
- Sliding speed: $\nu_s = \frac{\nu_{tG}}{\sin(\lambda)} = \frac{\nu_{tW}}{\cos(\lambda)}$

Forces:

- Force relationship: $W_{tG} = W_{xW}$, $W_{xG} = W_{tW}$, $W_{rG} = W_{rW}$
- output torque: $T_o = \frac{63000 P_o}{n_G} = \frac{W_{tG} D_G}{2}$
- transmitted force: $W_{tG} = \frac{2T_o}{D_G}$
- axial force: $W_{xG} = W_{tG} \frac{\cos(\phi_n)\sin(\lambda)+\mu\cos(\lambda)}{\cos(\phi_n)\cos(\lambda)-\mu\sin(\lambda)}$
- radial force: $W_{rG} = \frac{W_{tG}\sin(\phi_n)}{\cos(\phi_n)\cos(\lambda)-\mu\sin(\lambda)}$
- friction force: $W_f = \frac{\mu W_{tG}}{\cos(\lambda)\cos(\phi_n)-\mu\sin(\lambda)}$
- power loss due to friction: $P_L = \frac{\nu_s W_f}{33000}$
- input power: $P_i = P_o + P_L$
- $\eta = \frac{P_o}{P_i} = \frac{\cos(\phi_n)-\mu\tan(\lambda)}{\cos(\phi_n)+\frac{\mu}{\tan(\lambda)}}$

Now design selection for worm gears:

1. **Calculate the lead L and the lead angle λ**

$$p = \frac{\pi}{P_d} = \frac{\pi D_G}{N_G}$$

$$P_x = p$$

$$L = N_W P_x$$

$$\lambda = \arctan(\frac{L}{\pi D_W}$$

2. **Find Center Distance CD**

$$CD = \frac{D_G + D_W}{2}$$

3. **Calculate the pitch line speed of the gear**

$$\nu_{tG} = \frac{\pi D_G n_G}{12}$$

4. **Calculate the sliding speed**

$$\nu_s = \frac{\nu_{tG}}{\sin(\lambda)} = \frac{\nu_{tW}}{\cos(\lambda)}$$

5. **Calculate the coefficient of friction:**

$$\mu = \begin{cases} 0.15 & ,\nu = 0 \\ 0.124e^{-0.074\nu_s^{0.645}} & ,0 < \nu_s < 10 \\ 0.103e^{-0.11\nu_s^{0.45}} + 0.012 & ,\nu_s > 10 \end{cases}$$

6. **Find the forces on the gear:**

$$T_o = \frac{63000P_o}{n_G} = \frac{W_{tG}D_G}{2}$$

$$W_{tG} = \frac{2T_o}{D_G}$$

$$W_{xG} = W_{tG}\frac{\cos(\phi_n)\sin(\lambda) + \mu\cos(\lambda)}{\cos(\phi_n)\cos(\lambda) - \mu\sin(\lambda)}$$

$$W_{rG} = \frac{W_{tG}\sin(\phi_n)}{\cos(\phi_n)\cos(\lambda) - \mu\sin(\lambda)}$$

7. **Find the friction force:**

$$W_f = \frac{\mu W_{tG}}{\cos(\lambda)\cos(\phi_n) - \mu\sin(\lambda)}$$

8. **Find the power loss due to friction:**

$$P_L = \frac{\nu_s W_f}{33000}$$

9. **Compute the input power:**

$$P_i = P_o + P_L$$

10. **Calculate efficiency:**

$$\eta = \frac{P_o}{P_i} = \frac{\cos(\phi_n) - \mu\tan(\lambda)}{\cos(\phi_n) + \frac{\mu}{\tan(\lambda)}}$$

11. **Find the Lewis form factor y from the table below using your ϕ_n value:**

TABLE 10-5 Approximate Lewis Form Factor for Wormgear Teeth

ϕ_n	y
$14\frac{1}{2}°$	0.100
20°	0.125
25°	0.150
30°	0.175

12. **Find the normal circular pitch:**

$$p_n = p\cos(\lambda) = \frac{\pi\cos(\lambda)}{P_d}$$

13. **Find the dynamic factor K_v:**

$$K_v = \frac{1200}{1200 + \nu_{tG}}$$

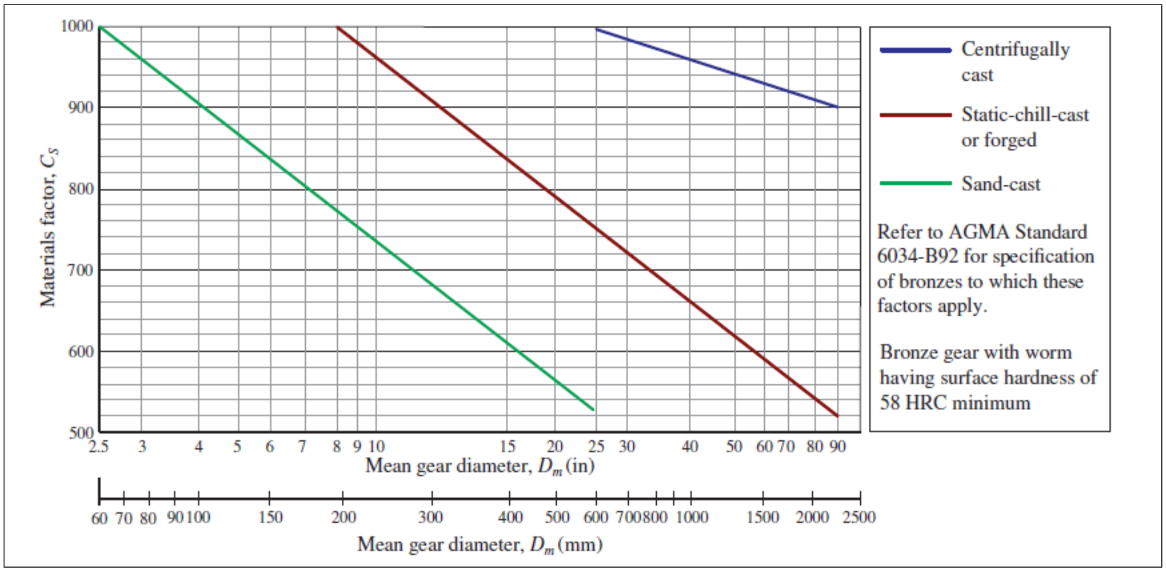
14. **Find the dynamic load, W_d:**

$$W_d = \frac{W_{tG}}{K_v}$$

15. **Find the stress σ in the gear teeth:**

$$\sigma = \frac{W_d}{yFp_n}$$

16. **Find the materials factor C_s using this figure:**



For sand-cast bronzes:

$$C_s = \begin{cases} 1189.636 - 476.545 \log_{10}(D_p) & D_G > 2.5 \\ 1000 & D_G < 2.5 \end{cases}$$

For static-chill-cast or forged bronze:

$$C_s = \begin{cases} 1411.651 - 455.825 \log_{10}(D_p) & \\ 1000 & D_G < 8 \end{cases}$$

For centrifugally cast bronze:

$$C_s = \begin{cases} 1251.291 - 179.75 \log_{10}(D_p) & \\ 1000 & D_G < 25 \end{cases}$$

17. **Find the ration correction factor C_m:**

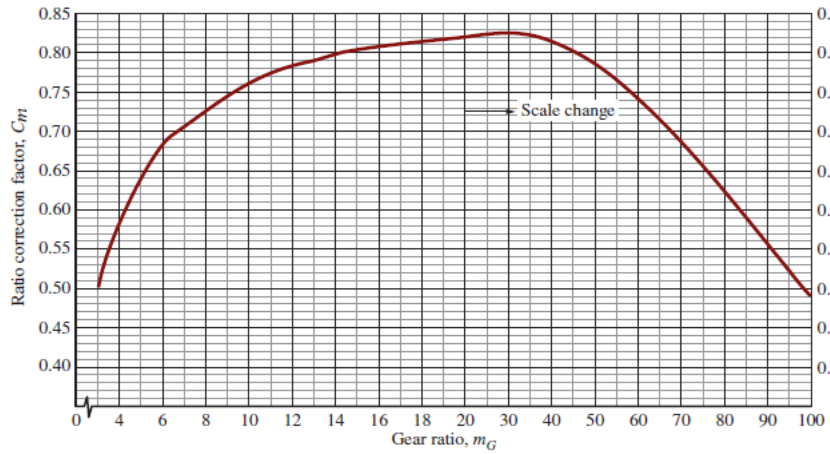


FIGURE 10–28 Ratio correction factor, C_m, versus gear ratio, m_G

Remember that m_G is the gear ratio which is $m_G = \frac{N_G}{N_p}$

$$C_m = \begin{cases} 0.02\sqrt{-m_G^2 + 40m_G - 76} + 0.46 & 6 < m_g < 20 \\ 0.0107\sqrt{m_G^2 + 56m_G + 5146} & 20 < m_G < 76 \\ 1.1483 - 0.00658m_G & m_G > 76 \end{cases}$$

18. **Find the Worm gear velocity factor C_v:**

$$C_v = \begin{cases} 0.659e^{-0.0011\nu_s} & 0 < \nu_s < 700 \\ 13.31\nu_s^{-0.571} & 700 < m_G < 3000 \\ 65.52\nu_s^{-0.774} & \nu_s > 3000 \end{cases}$$

19. **Find the effective face width F_e:**

$$F_e = \begin{cases} F & , F < \frac{D_W}{3} \\ \frac{D_W}{3} & , F > \frac{D_W}{3} \end{cases}$$

20. **Find the rated tangential load W_{tR}:**

$$W_{tR} = C_s D_G^{0.8} F_e C_m C_v$$

21. **Check if the design is satisfactory to resist pitting:**
If $W_{tR} > W_{tG}$ then the design is satisfactory