

Mid-Term II (Open-Book, Closed Notes, Homework etc.)

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GEAR DESIGN

Compute the "surface-stress" for a pinion-gear pair. The pressure angle is  $25^\circ$  and the teeth are AGMA full depth with Tip loading. The diametral pitch is 6 teeth per inch, the face width is 2 inches, the transmitted load is 430 lbf and the pitch line velocity is 1527 ft/min. The gear has 26 teeth and is made of ASTM B148 Bronze with Brinell hardness of 190, while the pinion has 17 teeth and is made of grade 1, through hardened steel with Brinell hardness of 200. The gears have solid disks and operate at a temperature of  $180^\circ\text{F}$ .

For Bronze:  $\nu = 0.349$  and  $E = 16.1 \times 10^6$  psi

For Steel:  $\nu = 0.30$  and  $E = 30 \times 10^6$  psi

$\sigma_c = C_p \sqrt{\frac{W_t E}{F I d} \frac{C_a C_m}{C_v}} C_s C_F$  Given uniform load & the load applied force factor  $C_a = 1$

load distribution factor can be estimated from table 11-16

Face width 2 inches  $C_m = 1.6$

$V_t = 1527 \text{ ft/min}$

$B = \frac{(12 - Q_v)^{2/3}}{4} = \frac{(12 - 6)^{2/3}}{4} = 0.825$

$A = 50 + 56(1 - B) = 50 + 56(1 - 0.825) = 59.8$

$C_v = \left( \frac{A}{A + \sqrt{V_t}} \right)^B = \left( \frac{59.8}{59.8 + \sqrt{1527}} \right)^{0.825} = C_v = 0.660$

$C_s = 1$

$C_F = 1$

$$C_p = \sqrt{\pi \left[ \frac{1}{\left( \frac{1-\nu_p^2}{E_p} \right) + \left( \frac{1-\nu_g^2}{E_g} \right)} \right]} = \sqrt{\pi \left[ \frac{1}{\left( \frac{1-0.349^2}{16.1 \times 10^6} \right) + \left( \frac{1-0.3^2}{30 \times 10^6} \right)} \right]}$$

$5.45465 \times 10^9 + 3.033 \times 10^9$

$$C_p = 1936.52$$

$$d_p = \frac{N_p}{P_d} = \frac{17}{6} = 2.8333$$

$$\Gamma_p = 1.41665$$

$$d_g = \frac{N_g}{P_d} = \frac{26}{6} = 4.3333$$

$$\Gamma_g = 2.1667$$

$$P_1 = \sqrt{\left( \Gamma_1 + \frac{1}{P_d} \right)^2 - \Gamma_1^2 \cos^2 \phi} - \frac{\pi}{P_d} \cos \phi$$

$$P_1 = \sqrt{\left( 1.41665 + \frac{1}{6} \right)^2 - \left( 1.41665 \cos 25^\circ \right)^2} - \frac{\pi}{6} \cos 25^\circ$$

$$P_1 = \sqrt{2.50689 - 1.64845} - .474542$$

$$P_1 = .452 \text{ in}$$

$$P_2 = C \sin \phi - P_1 = (\Gamma_1 + \Gamma_2) \sin \phi - P_1$$

$$P_2 = (1.41665 + 2.1667) \sin 25 - .452$$

$$P_2 = 1.062$$

$$I = \frac{\cos \phi}{\left( \frac{1}{P_1} + \frac{1}{P_2} \right) d_1} = \frac{\cos 25^\circ}{\left( \frac{1}{.452} + \frac{1}{1.062} \right) 2.8333} = I = .10143$$

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$$\tau_c = C_p \sqrt{\frac{W_t}{F I d} \frac{C_a C_m C_s C_r}{C_v}} = 1936 \sqrt{\left( \frac{430}{2(.10143)(2.8333)} \right) \frac{(1)(1.6)}{0.660} (1)(1)} = \tau_c$$

$$82.45 \text{ ksi} = \tau_c$$

# SPRING DESIGN

Total coils

Design a helical compression spring for a static load of 400N at a deflection of 45 mm with a safety factor of 2.5. Use  $C=10$  and plain-ground ends. Specify the following parameters necessary to manufacture the spring: Outside Diameter, Total Coils and Free length. Use a wire diameter of 4 mm. Also see if the spring is safe against buckling.

Lf

$$D = C d \quad (10)(4) = D = 40 \text{ mm}$$

$$l_n = 1020 \text{ mm}$$

$$K_s = 1 + \frac{0.5}{C} = 1 + \frac{0.5}{10} = 1.05 = K_s$$

$$\frac{4 \text{ mm}}{1000 \text{ mm}} = .004$$

$$D = .040$$

$$\gamma = K_s \frac{8 F D}{\pi d^3} = \frac{1.05 (8) (400) (.04)}{\pi (0.004)^3}$$

Info taken from table 13-2

Assume trial diameter 0.167 mm

$$\gamma = 6.68 \times 10^8 \text{ Pa} \quad 6.68 \times 10^2 \text{ MPa}$$

$$S_{UT} = A d^b$$

table 13-4

$$b = -0.1625$$

$$A = 2153.5 \text{ MPa}$$

$$2153.5 \text{ MPa} (0.167)^{-0.1625}$$

$$S_{UT} = 2880.4$$

$$S_{ys} = 0.6 S_{UT} = 0.6 (2880.4) = 1728.24 \text{ MPa}$$

$$N_s = \frac{S_{ys}}{\gamma} = \frac{1728.24 \text{ MPa}}{6.68 \times 10^2 \text{ MPa}}$$

Total # of coils 12

$N_s = 2.59$  spring design will not fail

Outside diameter clearance must be

at least

$$OD = 1.05 D$$

$$OD = (1.05)(40)$$

$$OD = 2 \text{ mm}$$

$$0.05 D \text{ for } D > 13 \text{ mm}$$

Spring Rate

$$k = \frac{F}{\delta} = \frac{400 \text{ N}}{.45 \text{ m}}$$

G for steel is

$$80.86 \text{ Pa}$$

$$k = 889 \text{ N/m}$$

$$N_a = \frac{d^4 G}{8 D^3 k} = \frac{(0.004)^4 (80.86 \text{ Pa})}{8 (40)^3 889} = 4.54$$

$$L_F = L_S + y_{\text{clash}} + y_{\text{work}} + y_{\text{initial}}$$

Act  $k = ? - 0.5$

$$L_S = d N_E$$

Plate grounded  
 $N_a = N_E - 1$

$$L_S = .004 \text{ m} \cdot 12$$

$N_a = 11$

$$L_S = 0.0048 \text{ m}$$

$$L_S = .048 \text{ m}$$

$$y_{\text{initial}} = \frac{F_{\text{initial}}}{k}$$

$$\frac{400}{889} = .45 \text{ m}$$

$$y_{\text{clash}} = 0.15 y = 0.15 (.45 \text{ m}) = 0.068$$

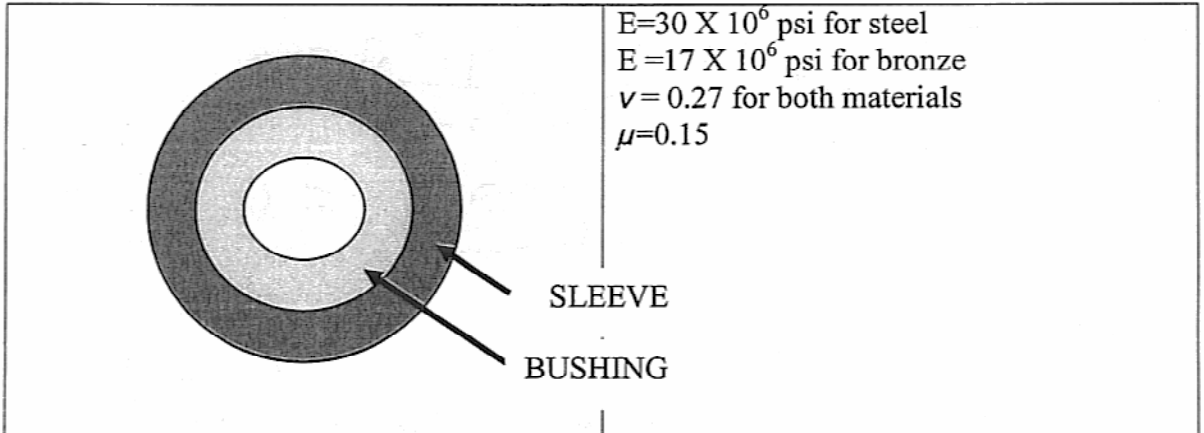
$$L_F = .04 \text{ m} + 0.064 \text{ m} + .45 \text{ m} + .45 \text{ m} =$$

$$\text{Free length } L_F = 1.008 \text{ m}$$

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## Interference Fit

A steel bushing is to be installed into a bronze sleeve as shown. The bushing has an inside diameter of 2.500 in and a nominal outside diameter of 3.000 in. The sleeve has a nominal inside diameter of 3.000 in. and an outside diameter of 4.000 in.



Find: a) pressure developed at the interface b) stresses in the sleeve and bushing and c) Torque that may be safely transmitted.

$$\delta = 0.001 \times 3.0 \text{ inches}$$

$$\delta = 0.003$$

$$D_i = 2.5 \text{ inches} \quad r_i = 1.25$$

$$\text{nominal OD} = 3.0 \text{ inches} = r_o^N =$$

$$\text{Nominal ID} = 3.0 \text{ inches} = r_i^N$$

$$D_o = 4.00 \text{ inches} \quad r_o = 2$$

$$p = \frac{0.5 \delta}{\frac{E_o}{r_o} \left( \frac{r_o^2 + r^2}{r_o^2 - r^2} + \nu_o \right) + \frac{E_i}{r_i} \left( \frac{r^2 + r_i^2}{r^2 - r_i^2} - \nu_i \right)}$$

$$p = \frac{(0.5)(0.003)}{}$$

$$p = \frac{1.5}{17 \times 10^6 \text{ psi} \left( \frac{2^2 + 1.5^2}{2^2 - 1.5^2} + 0.28 \right) + \frac{1.5}{30 \times 10^6 \text{ psi} \left( \frac{1.5^2 + 0}{1.5^2 - 0} - 0.28 \right)}$$

$$p = \frac{0.0015}{3.39832 \times 10^{-7} + 3.6 \times 10^{-8}}$$

$$p = 3991 \text{ psi} \times -0.5$$

stress in the sleeve and bushing

b) Bushing  $\sigma_{\theta t} = -p \frac{r^2 + r_1^2}{r^2 - r_1^2} = -3991 \frac{1.5^2 + 0^2}{1.5^2 - 0^2} \sigma_{r_1} = -3991 \text{ psi}$

Bushing  $\sigma_r = -p = -3991 \text{ psi}$  -0.5

sleeve  $\sigma_t = p = \frac{r_0^2 + r^2}{r_0^2 - r^2} \cdot 3991 \frac{2^2 + 1.5^2}{2^2 - 1.5^2} = 14254 \text{ psi}$

sleeve  $\sigma_r = -p = -3991 \text{ psi}$

$$\gamma = \frac{\pi r \mu \sigma}{E_0 \left( \frac{r_0^2 + r^2}{r_0^2 - r^2} + 0.28 \right) + \frac{1}{r_1} \left( \frac{r^2 + r_1^2}{r^2 - r_1^2} - 0.28 \right)}$$

$\nu_c = 0.28$

$$\gamma = \frac{(\pi)(1.5)(1.25)(0.15)(0.003)}{17 \times 10^6 \left( \frac{2^2 + 1.5^2}{2^2 - 1.5^2} + 0.28 \right) + 30 \times 10^6 \left( \frac{1.5^2 + 0}{1.5^2 - 0} - 0.28 \right)}$$

chose = 1.5 inches length

$$\gamma = \frac{0.002651}{2.2656 \times 10^{-7} + 2.4 \times 10^{-8}}$$

$$\gamma = \frac{0.002651}{2.2656 \times 10^{-7} + 2.4 \times 10^{-8}}$$

Torque = 10580 in-lb

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-0.5