طراحی اجزای دو

تکلیف سوم ۳

سؤال ۱

$P_t = P_n \cos\psi = 10 \cos(30) = 8.7$ teeth/in

$$d_p = \frac{N_P}{P_t} = \frac{15}{8.7} = 1.7 \text{ in}$$

$$V = \frac{\pi d_p n_p}{12} = \frac{\pi \times 1.7 \times 2000}{12} = 889.7 \text{ ft/min}$$

$$W^t = \frac{33000\,H}{V} = \frac{33000 \times 5}{889.7} = 185.5 \text{ lb}$$

Table: 14-4 $S_t = 23600$ psi

Table: 14-7 $S_c = 65000$ psi

$$\phi_t = \tan^{-1}\left(\frac{\tan\phi_n}{\cos\psi}\right) = \tan^{-1}\left(\frac{\tan 20}{\cos 30}\right) = \tan^{-1}\left(\frac{0.364}{0.866}\right) = \tan^{-1}(0.420) = 23^\circ$$

$$r_p = \frac{d_p}{2} = \frac{1.7}{2} = 0.9 \text{ in}$$

$$m_G = \frac{N_G}{N_P} \longrightarrow N_G = 3 \times 15 = 45 \text{ teeth}$$

$$d_G = \frac{N_G}{P_t} = \frac{45}{8.7} = 5.2 \text{ in}$$

$$r_G = \frac{d_G}{2} = \frac{5.2}{2} = 2.6 \text{ in}$$

$$(r_b)_P = r_p \cos\phi_t = 0.9 \times \cos(23) = 0.8 \text{ in}$$

$$(r_b)_G = r_G \cos\phi_t = 2.6 \times \cos(23) = 2.4 \text{ in}$$

$$a = \frac{1}{P_n} = \frac{1}{10} = 0.1$$

$$Z = \left[(r_p + a)^2 - (r_b)_P^2\right]^{1/2} + \left[(r_G + a)^2 - (r_b)_G^2\right]^{1/2} - (r_p + r_G)\sin\phi_t$$

$$\rightarrow Z = \left[(0.9 + 0.1)^2 - (0.8)^2\right]^{1/2} + \left[(2.6 + 0.1)^2 - (2.4)^2\right]^{1/2} - (0.9 + 2.6)\sin(23)$$

$$\rightarrow Z = 0.6 + 1.2 - 1.4 = 0.4 \text{ in}$$

$$P_N = P_n \cos\phi_n = \frac{\pi}{P_n}\cos\phi_n = \frac{\pi}{10}\cos 20 = 0.3 \text{ in}$$

$$m_N = \frac{P_N}{0.95 Z} = \frac{0.3}{0.95 \times 0.4} = 0.8$$

External Gear $\longrightarrow$ $I = \dfrac{\cos\phi_t \sin\phi_t}{2 m_N} \cdot \dfrac{m_G}{m_G + 1} = \dfrac{\cos(23) \times \sin(23)}{2 \times 0.8} \times \dfrac{3}{3+1} = 0.2$

$$B = 0.25\,(12 - Q_v)^{2/3}$$

$$A = 50 + 56\,(1 - B)$$

$$K_v = \left(\frac{A + \sqrt{V}}{A}\right)^B , \quad V_{max} = [A + (Q_v - 3)]^2$$

Q_v	B	A	K_v	V_{max}
3	1.1	44.4	1.8	1971.4
7	0.7	66.8	1.3	5012.6

✓ OK ← V_{max}

Table: 14–8 $\quad C_p = 1650 \; \sqrt{psi}$

$C_f = 1$

$K_o = 1$ Uniform vibration

$C_H = 1$ The same material for pinion and gear! $\frac{H_{BP}}{H_{BG}} = 1 < 1.2 \; (A' = 0)$

$K_T = 1$ $T < 250\,°F$ $\quad f_p > 64 \; (C_H = 1)$

$$K_s = 1.192 \left(\frac{F\sqrt{Y}}{P_n}\right)^{0.0535}$$

Table: 14–2 → $N_p = 15$ → $Y = 0.290$

$$\rightarrow \quad K_s = 1.192 \left(\frac{2 \times \sqrt{0.290}}{10}\right)^{0.0535} = 0.9$$

$C_{mc} = 0.8$ crowned teeth

$$C_{pf} = \frac{F}{10 d_p} - 0.0375 + 0.0125 F \qquad 1 < F \leq 17 \text{ in}$$

$$\rightarrow C_{pf} = \frac{2}{10 \times 1.7} - 0.0375 + 0.0125 \times 2 = 0.1$$

$C_{pm} = 1.1$ straddle-mounted $S_1/S \geq 0.175$

$$C_{ma} = A + BF + CF^2$$

Table 14–9 : Commercial → $A = 0.127,\ B = 0.0158,\ C = -0.930 \times 10^{-4}$

$$\rightarrow C_{ma} = 0.127 + 0.0158 \times 2 - 0.930 \times 10^{-4} \times (2)^2 = 0.2$$

$C_e = 0.8$ adjusted at assembly!

$$K_m = 1 + C_{mc}\,(C_{pf} C_{pm} + C_{ma} C_e)$$

$$\rightarrow K_m = 1 + 0.8\,(0.1 \times 1.1 + 0.2 \times 0.8) = 1.2$$

$$Y_N = 1.356\,N^{-0.018} = 1.356(10^8)^{-0.018} = 0.973$$

$$Z_N = 1.449\,N^{-0.023} = 1.449(10^8)^{-0.023} = 0.949$$

$$K_R = 0.50 - 0.109\ln(1-R) = 0.50 - 0.109\ln(1-0.999) = 1.25$$ Table 14-10

$m_B = 1.2 \longrightarrow K_B = 1$

Figure 14-7 → $J' = 0.44$
Figure 14-8 → $MF = 0.93$
} $J = 0.4$

Bending stress:

$$\sigma = W^t K_o K_v K_s \frac{P_d}{F}\frac{K_m K_B}{J}$$

$$S_F = \frac{S_t Y_N / K_T K_R}{\sigma}$$

$$\Rightarrow S_F = \frac{\dfrac{23600 \times 0.973}{1\times 1.25}}{185.5\times 1\times K_v \times 0.9 \times \dfrac{10}{2}\times\dfrac{1.2\times 1}{0.4}} = \frac{7.336}{K_v}$$

→ $Q_v = 3 \rightarrow S_F = 4.1$

→ $Q_v = 7 \rightarrow S_F = 5.6$

Contact stress:

$$\sigma_c = C_p\left(W^t K_o K_v K_s \frac{K_m}{d_p F}\frac{C_f}{I}\right)^{1/2}$$

$$S_H = \frac{S_c Z_N C_H / K_T K_R}{\sigma_c}$$

$$\Rightarrow S_H = \frac{\dfrac{65000\times 0.949\times 1}{1\times 1.25}}{1650\left(185.5\times 1\times K_v\times 0.9\times\dfrac{1.2}{1.7\times 2}\times\dfrac{1}{0.2}\right)^{1/2}} = \frac{1.806}{(K_v)^{1/2}}$$

→ $Q_v = 3 \rightarrow S_H = 1.3$, $S_H^2 = 1.8$

→ $Q_v = 7 \rightarrow S_H = 1.6$, $S_H^2 = 2.5$

برای کیفیت پایین تر نیز مشکل به وجود نخواهد آمد چرا که ضریب اطمینان در همه حالات بیشتر از یک است!

ادامه

(سوال ۲)

$$d_p = \frac{N_P}{P_d} = \frac{15}{10} = 1.5 \quad in$$

$$V_t = \frac{\pi d_p n_p}{12} = \frac{\pi \times 1.5 \times 500}{12} = 196.3 \quad ft/min$$

Table : 15-2 : $K_o = 1.75$ Medium shock

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

$$B = 0.25(12 - Q_v)^{2/3}$$

$$(V_t)_{max} = [A + (Q_v - 3)]^2 = 10,000 \quad ft/min$$

OK ✓

$$K_v = \left(\frac{A + \sqrt{V_t}}{A}\right)^B$$

تمرین کنید → $Q_v = 11 \rightarrow B = 0.25(12 - 11)^{2/3} = 0.25$

$\rightarrow A = 50 + 56(1 - 0.25) = 92$

$\rightarrow K_v = \left(\frac{92 + \sqrt{196.3}}{92}\right)^{0.25} = 1.04$

$$C_s = 0.125F + 0.4375 \qquad 0.5 \leq F \leq 4.5 \ in$$

$\rightarrow C_s = 0.125 \times 1.5 + 0.4375 = 0.6$

$$K_s = 0.4867 + \frac{0.2132}{P_d} \qquad 0.5 \leq P_d \leq 16 \ teeth/in$$

$\rightarrow K_s = 0.4867 + \frac{0.2132}{10} = 0.5$

$K_{mb} = 1$ both straddle-mounted

$$K_m = K_{mb} + 0.0036F^2 = 1 + 0.0036 \times (1.5)^2 = 1.01$$

$C_{xc} = 1.5$ crowned teeth

$K_x = 1$

Figure : 15-6 → $N_p = 15$, $N_G = 15 \times 2 = 30 \rightarrow I = 0.07$

Figure : 15-7 → $N_p = 15$, $N_G = 15 \times 2 = 30 \rightarrow J = 0.22$

[illegible]

$N_L = 10^4$ cycles

$C_L = 3.4822\, N_L^{-0.0602} = 3.4822\,(10^4)^{-0.0602} = 2.0001$

$K_L = 6.1514\, N_L^{-0.1192} = 6.1514\,(10^4)^{-0.1192} = 2.0520$

$C_H = 1$ Carburized steel

$K_T = \dfrac{460+t}{710} = \dfrac{460+300}{710} = 1.07$

Table: 15-3 → 1 failure over 10 → $C_R = 0.92$, $K_R = 0.85$

Table: 15-4 → $S_{ac} = 200{,}000$ psi

Table: 15-6 → $S_{at} = 30{,}000$ psi

$C_p = 2290\ \sqrt{psi}$ for steel

Bending stress:

$$\sigma = \frac{W^t}{F} P_d K_o K_v \cdot \frac{K_s K_m}{K_x J}$$

$$\sigma_{all} = \frac{S_{at} K_L}{S_F K_T K_R}$$

$$S_F = \frac{\sigma_{all}}{\sigma} = 1 \Rightarrow \frac{W^t}{1.5} \times 10 \times 1.75 \times 1.04 \times \frac{0.5 \times 1.01}{1 \times 0.22} = \frac{30{,}000 \times 2.0520}{1 \times 1.07 \times 0.85}$$

$\Rightarrow W^t = 2430.2$ lb

$$\Rightarrow H = \frac{W^t V_t}{33000} = \frac{2430.2 \times 196.3}{33000} = 14.5 \text{ hp}$$

Contact stress:

$$\sigma_c = C_p \left(\frac{W^t}{F d_p I} K_o K_v K_m C_s C_{xc} \right)^{1/2}$$

$$(\sigma_c)_{all} = \frac{S_{ac} C_L C_H}{S_H K_T C_R}$$

$$S_H = \frac{(\sigma_c)_{all}}{\sigma_c} = 1 \Rightarrow 2290 \left(\frac{W^t}{1.5 \times 1.5 \times 0.07} \times 1.75 \times 1.04 \times 1.01 \times 0.6 \times 1.5 \right)^{1/2} = \frac{200{,}000 \times 2.0001 \times 1}{1 \times 1.07 \times 0.92}$$

$\Rightarrow W^t = 2997.7$ lb

$$\Rightarrow H = \frac{2997.7 \times 196.3}{33000} = 17.8 \text{ hp}$$

در این سیستم مکانیکی در ابتدا خستگی خمشی رخ می‌دهد! توان قابل انتقال نیز همان 14.5 اسب بخار است!