Helical Compression Spring Design

QUESTION 1) A helical compression spring must give a minimum force of 500 N and a maximum force of 750 N over an adjustment range of 2 cm static deflection. The spring material is A227 cold drawn wire; the loading is static. Design the spring. (G=79.6 Gpa)

Solution:

$$S_{ut} = A * d^b \qquad \text{(table 13-4 pp. 816)}$$

$$A = 1753.3$$

$$b = -0.1822$$

$$S_{ut} = 1753.3 * d^{-0.1822}$$

$$S_{ys} = 0.6 * S_{ut} = 1051.98 * d^{-0.1822} \qquad \text{(d is in mm), (table 13-6 pp.816)}$$

$$\tau_{max} = K_s \frac{8 * F * D}{\pi * d^3}$$

$$K_s = \frac{2 * C + 1}{2 * C} \Rightarrow \quad \text{assume C=8,} \quad 4 \le C \le 12$$

$$K_s = \frac{17}{16} \qquad\qquad \frac{D}{d} = 8 \Rightarrow D = 8 * d$$

$$\tau_{max} = \frac{17}{16} * \frac{8 * (750) * 8 * d}{\pi * d^3} = \frac{16242}{d^2}$$

$$N = \frac{S_{ys}}{\tau_{max}} = \frac{1051 * 98 * d^{-0.1822}}{\frac{16242}{d^2}} \ge 1$$

$$\Rightarrow 0.0648 * d^{2-0.1822} \ge 1$$

$$d^{1.8178} \ge 15.44$$

$$d \ge 4.5 \text{ mm}$$

$$\text{Choose A227} \Rightarrow d = 5 \text{ mm}$$

$$D = 8 * 5 = 40 \text{ mm}$$

$$N \ge 1$$

$$k = \frac{\Delta F}{y} = \frac{750 - 500}{2 * 10^{-2}} = 12500 \text{ N/m}$$

$$k = \frac{d^4 * G}{8 * D^3 * N_a} \Rightarrow \quad N_a = \frac{d^4 * G}{8 * D^3 * k} = \frac{\left(5 * 10^{-3}\right)^4 * 79.6 * 10^9 \text{ N/m}^2}{8 * \left(40 * 10^{-3}\right)^3 * 12500}$$

$$N_a = 7.77 \Rightarrow N_a = 8$$

$$k = 1214.6 \text{ N/m}$$

Assume squared and ground ends,

$$N_t = 8 + 2 = 10$$

$$L_s = N_t * d = 5 * 10 = 50\text{mm}$$

$$y_{initial} = \frac{F_{initial}}{k} = \frac{500}{12140.6} = 0.041\text{m} = 41\text{mm}$$

$$y_{clash} = 0.15 * y = 0.15 * (20\text{mm}) = 3\text{mm}$$

$$L_f = L_s + y_{clash} + y_{working} + y_{initial} = 50 + 3 + 20 + 41 = 114\text{mm}$$

$$y_{shut} = L_f - L_s = 114 - 50 = 64$$

$$F_{shut} = k * y_{shut} = 1214.6 * 64 * 10^{-3} \;\; \Rightarrow F_{shut} = 777 \text{ N}$$

$$\tau_{shut} = K_s \frac{8 * F * D}{\pi * d^3} = \frac{1.06 * 8 * (777) * \left(40 * 10^{-3}\right)}{\pi * \left(5 * 10^{-3}\right)^3} = 671.5 \text{ MPa}$$

$$N_{s_{shut}} = \frac{S_{sy}}{\tau_{shut}} = \frac{783.88}{671.5} = 1.16 > 1$$

Check for Buckling: $\frac{L_f}{D} = \frac{114}{40} = 2.85 < 4$

Inside Coil Diameter: $D_i = D - d$

$$= 40 - 5 = 35\text{mm}$$

$$D_o = D + d = 45\text{mm}$$

<u>The smallest hole:</u>

if $D < 13\text{mm} \Rightarrow \;\; hole_{min} = D_o + 0.05 * D$

$$= 45 + 0.05 * (40) = 47\text{mm}$$

Clearance $= 0.1 * D$

if $D > 13\text{mm}$

Clearance $= 0.05 * D$

<u>The largest pin:</u>

$$pin_{max} = D_i - 0.05 * D$$

$$= 35 - 0.05 * (40)$$

$$pin_{max} = 33\text{mm}$$