FATIGUE FAILURE OF HELICAL COMPRESSION SPRINGS

SPRINGS ARE ALMOST ALWAYS SUBJECT TO FATIGUE LOADING. MANY ARE SUBJECT TO HIGH CYCLES (E.G. THE VALVE SPRING OF AN ENGINE), SO THESE MUST BE DESIGNED FOR INFINITE LIFE.

SHOT PEENING IS A MECHANICAL SURFACE TREATMENT USED TO IMPROVE FATIGUE STRENGTH. IT INVOLVES BOMBARDING THE SURFACE OF A MATERIAL WITH SMALL SPHERICAL MEDIA, USUALLY STEEL, GLASS, OR CERAMIC BEADS, AT HIGH VELOCITY.

THE BEST DATA FOR THE TORSIONAL ENDURANCE LIMITS OF SPRING STEELS WERE PUBLISHED BY ZIMMERLI IN 1957. HE DISCOVERED THE SURPRISING FACT THAT SIZE, MATERIAL, AND TENSILE STRENGTH HAVE NO EFFECT ON THE ENDURANCE LIMITS FOR WIRE DIAMETERS LESS THAN 3/8 in (10 mm).

<u>FOR UNPEENED SPRINGS</u>: $S_{sa} = 35$ ksi (241 MPa) AND $S_{sm} = 55$ ksi (379 MPa)

<u>FOR PEENED SPRINGS</u>: $S_{sa} = 57.5$ ksi (398 MPa) AND $S_{sm} = 77.5$ ksi (534 MPa)

FROM THESE FLUCTUATING STRESS VALUES, WE CAN ESTIMATE AN EQUIVALENT COMPLETELY REVERSED STRESS (USING GOODMAN CRITERIA):

$$S_{se} = \frac{S_{sa}}{1 - \frac{S_{sm}}{S_{su}}}$$

ANY OF THE OTHER FATIGUE FAILURE CRITERIA COULD BE USED IN A SIMILAR FASHION.

THE TORSIONAL MODULUS OF RUPTURE S_{su} IS APPROXIMATELY:

$$S_{su} = 0.67 S_{ut}$$

WHERE S_{ut} IS A FUNCTION OF THE WIRE DIAMETER d.

THE FACTOR OF SAFETY FOR INFINITE LIFE CAN BE FOUND USING THE GOODMAN CRITERION, ADAPTED FOR THE PURE SHEAR CASE.

$$\frac{1}{n_f} = \frac{\tau_a}{S_{se}} + \frac{\tau_m}{S_{su}}$$

THE SHEAR STRESSES τ_a AND τ_m ARE:

$$\tau_a = K_B \frac{8 F_a D}{\pi d^3}$$

$$\tau_m = K_B \frac{8 F_m D}{\pi d^3}$$

WHERE F_a AND F_m ARE:

$$F_a = \frac{F_{max} - F_{min}}{2}$$

$$F_m = \frac{F_{max} + F_{min}}{2}$$

NOTE THAT, BECAUSE COMPRESSION SPRINGS SHOULD NEVER BE SUBJECTED TO TENSILE LOADS, $F_{min} = 0$ OR $F_{min} = F_i$, WHERE F_i IS THE PRE-LOAD.

CRITICAL FREQUENCY OF HELICAL SPRINGS

WHEN COMPRESSED, HELICAL COMPRESSION SPRINGS DO NOT DEFORM UNIFORMLY. INSTEAD, THE DEFORMATION RESEMBLES A WAVE MOVING THROUGH THE SPRING. THIS PHENOMENON IS CALLED SPRING SURGE!

TO AVOID RESONANCE, THE NATURAL FREQUENCY OF THE SPRING SHOULD BE 15-20 TIMES HIGHER THAN THE FORCING FREQUENCY OF THE APPLICATION.

$$f = \frac{1}{4}\sqrt{\frac{kg}{W}}$$

IF SPRING HAS ONE END AGAINST A FLAT PLATE AND THE OTHER FREE.

$$f = \frac{1}{2}\sqrt{\frac{kg}{W}}$$

IF SPRING ENDS ARE ALWAYS IN CONTACT WITH FLAT PLATES.

WHERE W IS THE WEIGHT OF THE ACTIVE PART OF A HELICAL SPRING

$$W = AL\gamma = \frac{\pi d^2}{4}(\pi D N_a)\gamma = \frac{\pi^2 d^2 D N_a \gamma}{4}$$

WHERE γ IS THE SPECIFIC WEIGHT OF THE WIRE MATERIAL (FOUND IN TABLE A-5 IN SHIGLEY).

FOR STEELS, $\gamma = 0.282\ \text{lbf}/\text{in}^3 = 487\ \text{lbf}/\text{ft}^3 = 76.5\ \text{kN}/\text{m}^3$.