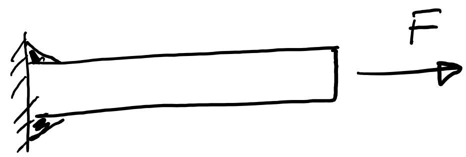
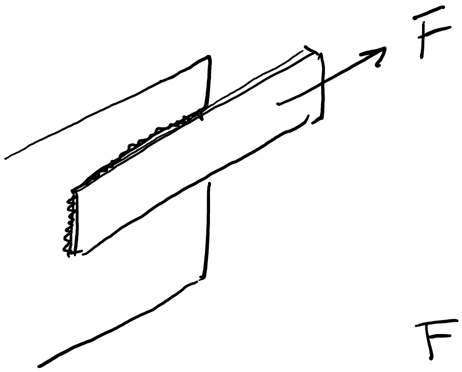
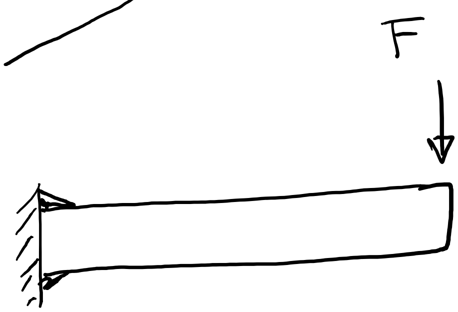
Weld Analysis Review



$$\tau_d = \frac{F}{A_t}$$ OP

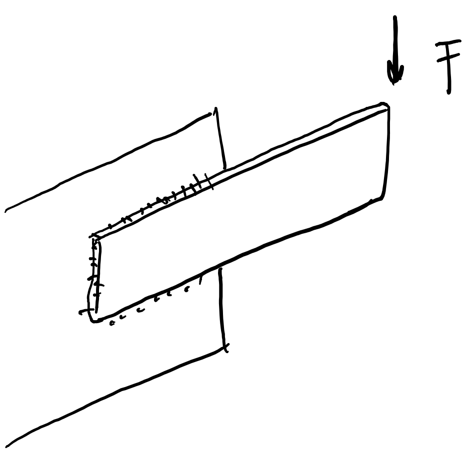


$$\tau_d = \frac{F}{A_t}$$ IP



$$\tau_d = \frac{F}{A_t}$$ IP

$$\tau_b = \frac{Me}{I_t}$$ OP



$$\tau_d = \frac{F}{A_t}$$ IP

$$\tau_t = \frac{Tr}{J_t}$$ IP

Combined loading

vecto sum all in plane stresses τ_{IP}

vector sum all out of plane " τ_{OP}

$$\tau_{Res} = \sqrt{\tau_{IP}^2 + \tau_{OP}^2}$$

Strength

$$S_{ys} = 0.3\ S_{ut}$$

$S_{ut} \equiv$ ultimate strength of the weld or base metal whichever is smaller

Base metal S_{ut} $\equiv$ in Hot Rolled condition

Fatigue Analysis of welds

Scope: Fully alternating stresses

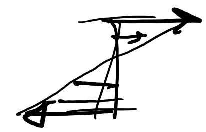
$$n = \frac{S_{es}}{\tau_{alt}} = \frac{\tau_e}{\tau_{alt}}$$

Q: how to estimate endurance limit S_e and endurance limit in-shear S_{es}

$$S_e = K_a K_b K_c K_d K_e K_f S_e'$$

$S_e' \equiv$ endurance limit from rotating bending test

- Normal stress (bending)
- Fully alternating
- Gradient (stress)



For Steels (if we do not have S'_e)

$$S'_e = \frac{1}{2} S_{ut} \qquad (S_{ut} < 200^{ksi})$$

Example: for E70 electrode

$$S'_e = \frac{1}{2}(70) = 35 \text{ ksi}$$

Q: Surface roughness Correction factor

if no data is available about the welding Process, we use the worst surface condition [As forged]

$$K_a = a \, S_{ut}^{b}$$

$$K_a = 39.9 \, (70)^{-0.995}$$

$a = 39.9 \quad b = -0.995 \quad$ As forged

[Table 6-2]

$\Rightarrow K_a = 0.582$

w/o going into details $K_b = 1$ $K_d = 1$

$K_e = 1$ $K_f = 1$

Q: How to convert S_e to S_{es}

by reducing S_e by a factor of 0.58 (experiments show 0.59)

$$K_c = 0.59$$

$$S_{es} = S_e \Big|_{K_c = 0.59}$$

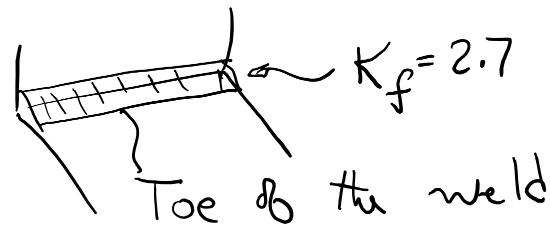
In this case

$$S_{es} = \underbrace{(0.582)}_{K_a}\underbrace{(0.59)}_{K_c}\underbrace{(35)}_{S'_e}$$

$S_{es} \cong 12$ ksi comparable to τ

Q: Assume the nominal shear stress τ is 4714 Psi. Also assume that the

stress concentration factor is 2.1
(Associated with the end of the weld
Table 9-5)



would the factor of safety against eventual fatigue failure be greater than 3?

- Calculate the actual stress

$$\tau_{alt,\,actual} = K_f \tau_{nom}$$

psi

$$= 2.7\,(4714) = 12735$$

$$\Rightarrow n = \frac{S_{es}}{\tau_{alt,act}} = \frac{12000}{12735} = 0.94 \quad \text{NO}$$

Q: if the base metal is AISI 1010

What would be S_e' ?

AISI 1010 $\quad S_y = 26 \quad S_{ut} = 47$ Hot Rolled

$$S_e' = \frac{47}{2} = 23.5 \text{ ksi}$$

Spring Design

Scope

- Helical Compression Springs
- static & cyclic loading
- Steel springs
- Buckling

Review from Statics

Q: A spring has a $K = 100$ lbs/in and free length of 5 inches. What force (F^*) would reduce the length to 3".

$$F = KX$$

$$F^* = 100(5-3) \Rightarrow F^* = 200 \text{ lbs}$$

Develop the habit of writing

$$\underbrace{\Delta F}_{\text{change in force}} = K \underbrace{\Delta \bar{X}}_{\text{change in length}}$$

state-1 ≡ Free length $X_1 = 5$ $F_1 = 0$

state-2 ≡ Final length $X_2 = 3$ $F_2 = ?$

[everything is positive]

$$F_2 - 0 = K(X_1 - X_2)$$

$$F_2 \equiv F^* = 100(5-3) = 200 \text{ lbs}$$

Q: A spring with $K = 100$ N/mm is compressed to 100 mm with a force of 20 N. What force would compress the spring to 80 mm

$$\Delta F = K \Delta X$$

state-1 $X_1 = 100$ mm $F_1 = 20$ N

state-2 $X_2 = 8$ mm $F_2 = ?$

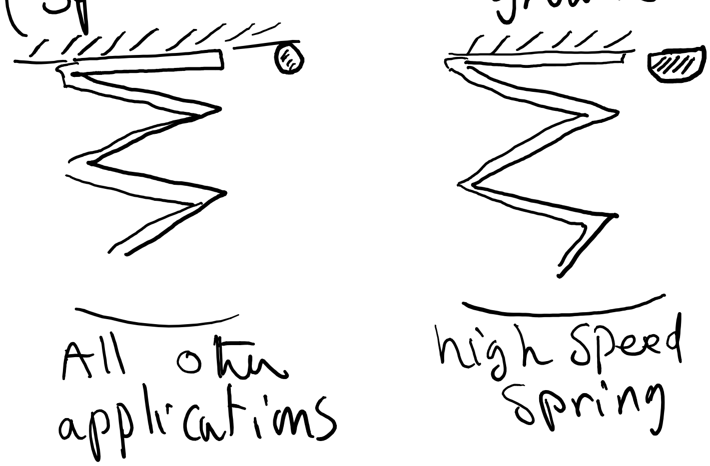
$$F_2 - F_1 = K\ (X_1 - X_2)$$

$$F_2 - 20 = 100\ (100 - 80)$$

$$\Rightarrow \overline{F_2} = F^* = 2020\ N$$

Q: What parameters do we need to specify to order a compression spring

- Free length
- Total Number of Coils
- material
- wire size (diameter)
- Coil diameter (mean Coil diameter)
- end Condition (Square or Square and ground



- Set-Removal (Set removed or not)

A little more expensive (higher strength)

Q: Relationship between K spring constant and geometry & material information

$$K = \frac{G d^4}{8 N_a D^3}$$

$G \equiv$ Shear modulus $\quad G = \frac{E}{2(1+\nu)}$

for steels $G \doteq 11.5 \times 10^6$ psi

$N_a \equiv$ The number of active coils

$D \equiv$ mean coil diameter

Example: Mechanical Pencil Spring

Given: $D_o = 0.16$ inch

wire diameter (guess) $= 0.015$ inch

State-1 Minimum force = 140 grams

Length at minimum force = 1 inch

State-2 Maximum force = 450 grams

Length at Maximum force = 0.5 inch

material = Cheapest A 227 (Plain Carbon Steel)

End Condition = closed (one coil)

Set-removed = NO

Find: Free length L_o or L_f

Total # of Coils N_t

Solution

Calculate K from forces

state-1 : F_{min} , $L_{F_{min}}$

state-2 : F_{max} , $L_{F_{max}}$

$$\Delta F = K \Delta X$$

$$F_{max} - F_{min} = K\left(L_{F_{min}} - L_{F_{max}}\right)$$

$F_{min} = 140$ grams $\equiv 0.31$ lbs

$F_{max} = 450$ " $\equiv 0.99$ lbs

$$(0.99 - 0.31) = K\,(1 - 0.5)$$

$\Rightarrow K = 1.36$ lbs/in

Calculate the number of active coils from K

$$K = \frac{d^4 G}{8 N D^3} \qquad (EQ\ 10\text{-}9)$$

$$1.36 = \frac{(0.015)^4 \cdot (11.5 * 10^6)}{8 N\,(0.145)^3} \qquad (I)$$

where $D = D_o - d \equiv$ mean coil diameter

$= 0.16 - 0.015$

$D = 0.145$

from (I) $\Rightarrow$ $N = 17.5$ Turns

Calculate the total # of coils

For both ends square

$$N_t = N + 2$$

$$N_t = 19.5 \text{ Turns}$$ ←

Calculate free length

$$\Delta F = K \, \Delta X$$

state-1 : free length $F_1 = 0$ $L_1 = L_0$

state-2 : maximum force

$F_2 = 0.99$ $L_2 = 0.5''$

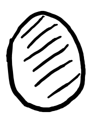
$$0.99 - 0 = 1.36 \, (L_0 - 0.5)$$

$$\Rightarrow L_0 = 1.23''$$

Check to make sure the spring is adequate

- check for Set (that the sring wire would not go beyond yielding)

[Determine factor of safety guarding against yielding of spring wire subjected to the maximum force they can possibly be subjected to]



$$\tau = \frac{Tr}{J}$$