PROBLEM | THE FIGURE SHOWS THE FREE-BODY DIAGRAM OF A CONNECTING-LINK PORTION HAVING STRESS CONCENTRATION AT THREE SECTIONS. THE DIMENSIONS ARE $r = 0.25$ in, $d = 0.40$ in, $h = 0.50$ in, $w_1 = 3.50$ in, AND $w_3 = 3.0$ in. THE FORCES F FLUCTUATE BETWEEN A TENSION OF 5 KIP AND A COMPRESSION OF 16 KIP. NEGLECT COLUMN ACTION AND FIND THE LEAST FACTOR OF SAFETY IF THE MATERIAL IS COLD-DRAWN AISI 1018 STEEL.

GIVEN:

1. CONNECTING LINK WITH DIMENSIONS SHOWN.
2. LOAD FLUCTUATES BETWEEN 5 KIPS TENSION AND 16 KIPS COMP.
3. MATERIAL AISI 1018 STEEL ($S_{ut} = 65.3$ kpsi, 450 MPa ; $S_y = 45.0$ kpsi, 310 MPa)

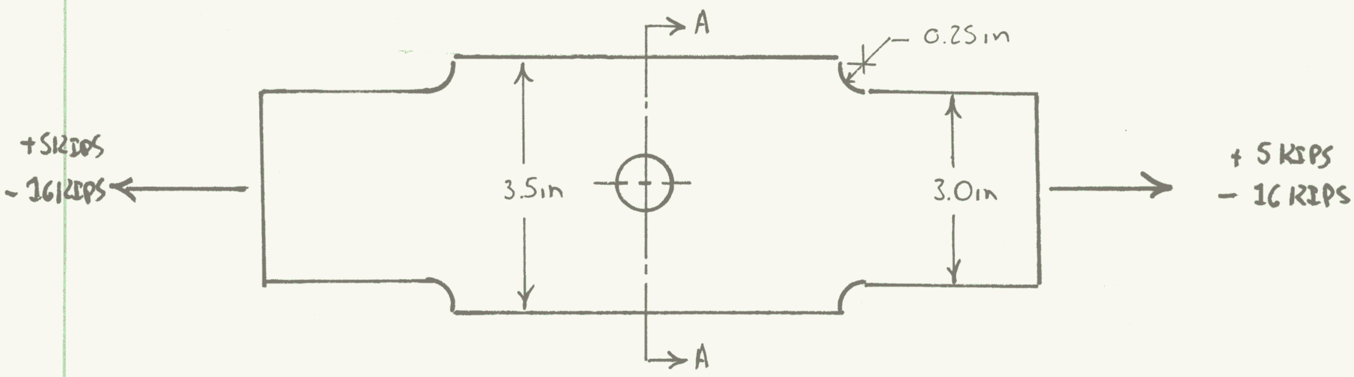
ASSUMPTIONS:

1. LINEAR-ELASTIC MATERIAL
2. NO BUCKLING

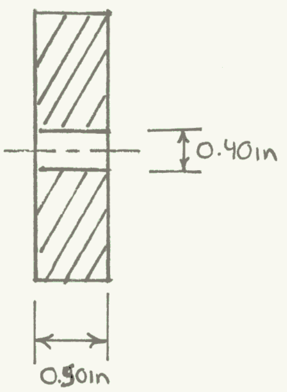
FIND:

1. MINIMUM FACTOR OF SAFETY.

FIGURE:



(a)



SOLUTION:

THE NOMINAL STRESS IN THE SECTION WITH THE FOUR RADII

$$\sigma_{nom,r1} = \frac{5(10^3)\,lb}{(0.5in)(3.0in)} = 3.33\,ksi \quad (1)$$

$$\sigma_{nom,r2} = \frac{-16(10^3)\,lb}{(0.5in)(3.0in)} = -10.67\,ksi \quad (2)$$

THE NOMINAL STRESS IN THE SECTION WITH THE WHOLE

$$\sigma_{nom,H1} = \frac{5(10^3)\,lb}{(3.5in-0.4in)(0.5in)} = 3.23\,ksi \quad (3)$$

$$\sigma_{nom,H2} = \frac{-16(10^3)\,lb}{(3.5in-0.4in)(0.5in)} = -10.32\,ksi \quad (4)$$

(1) - (4) ~~ARE~~ CAN BE WRITTEN IN TERMS OF MEAN AND ALTERNATING NOMINAL STRESS. STARTING WITH (1) AND (2)

$$\sigma_{MEAN,r} = \frac{\sigma_{nom,r1}+\sigma_{nom,r2}}{2} = \frac{3.33\,ksi + (-10.67\,ksi)}{2} = -3.67\,ksi \quad (5)$$

$$\sigma_{ALT,r} = \frac{\sigma_{nom,r1}-\sigma_{nom,r2}}{2} = \frac{3.33\,ksi - (-10.67\,ksi)}{2} = 7.0\,ksi \quad (6)$$

FOR (3) AND (4)

$$\sigma_{MEAN,H} = \frac{\sigma_{nom,H1}+\sigma_{nom,H2}}{2} = \frac{3.23\,ksi + (-10.32\,ksi)}{2} = -3.54\,ksi \quad (7)$$

$$\sigma_{amp,H} = \frac{\sigma_{nom,H1}-\sigma_{nom,H2}}{2} = \frac{3.23\,ksi - (-10.32\,ksi)}{2} = 6.78\,ksi \quad (8)$$

(5) - (8) NOW HAVE TO BE CORRECTED TO ACCOUNT FOR THE STRESS CONCENTRATIONS AT THE GEOMETRIC DISCONTINUITY. FOR THE NOMINAL MEAN AND ALTERNATING STRESSES IN THE SECTION WITH THE FOUR RADII ((5) & (6)), THE THEORETICAL STRESS CONCENTRATION IS

$K_{T,r} = 1.8$ (BUDYNAS APP F.2)

- $\frac{D}{d} = \frac{3.5in}{3.0in} = 1.167$
- $\frac{r}{d} = \frac{0.25in}{3.0in} = 0.083$

$q = .8$ (LECTURE 15 PG 22)

$$K_{f,r} = 1 + q(k_T - 1) = 1 + 0.8(1.8-1) = 1.64 \quad (9)$$

$$\sigma_{f,mean,r} = K_{f,r} \cdot \sigma_{MEAN,r} = -3.67\,ksi \cdot 1.64 = \underline{\underline{-6.02\,ksi}}$$ (10)

$$\sigma_{f,amp,r} = K_{f,r} \cdot \sigma_{amp,r} = 7.0\,ksi \cdot 1.64 = \underline{\underline{11.48\,ksi}}$$ (11)

THE MEAN AND AMPLITUDE STRESS CORRECTED FOR FATIGUE IN THE SECTION WITH THE HOLE. (7) & (8)

$K_{T,H} = 2.65$ (BUDYNAS 2ND, APP F.1)

- $\frac{d}{w} = \frac{0.40\,in}{3.5\,in} = 0.114$

$q = 0.8$ (LECTURE 15 PG 22)

$K_{f,H} = 1 + q(K_T - 1) = 1 + 0.8(2.65 - 1) = 2.32$

$$\sigma_{f,mean,H} = K_{f,H} \cdot \sigma_{mean,H} = 2.32 \cdot (-3.54\,ksi) = \underline{-8.21\,ksi}$$ (12)

$$\sigma_{f,amp,H} = K_{f,H} \cdot \sigma_{amp,H} = 2.32\,(6.78\,ksi) = \underline{\underline{15.73\,ksi}}$$ (13)

NOW THE GOODMAN CURVE FOR THIS PART MUST BE CONSTRUCTED. FIRST THE ENDURANCE LIMIT MUST BE CALCULATED

$$S_e' = 0.5 \cdot S_{UT} = 0.5\,(65.3\,ksi) = 32.65\,ksi$$ (14)

$$S_e = k_a \cdot k_b \cdot k_c \cdot k_d \cdot k_e \cdot k_f \cdot S_e'$$

- $k_a = 0.8$ (FINISH - COLD DRAWN)
- $k_b = 0.75$ (SIZE)
- $k_c = 1$ (Reliability)
- $k_d = 1$ (Temperature)
- $k_{e,r} = 1/K_{f,r} = 1/1.65 = 0.606$
  $k_{e,H} = 1/K_{f,H} = 1/2.32 = 0.431$

$$S_{e,r} = (0.8)(0.75)(1)(1)(0.606) \cdot 32.65\,ksi = 11.87\,ksi$$ (15)

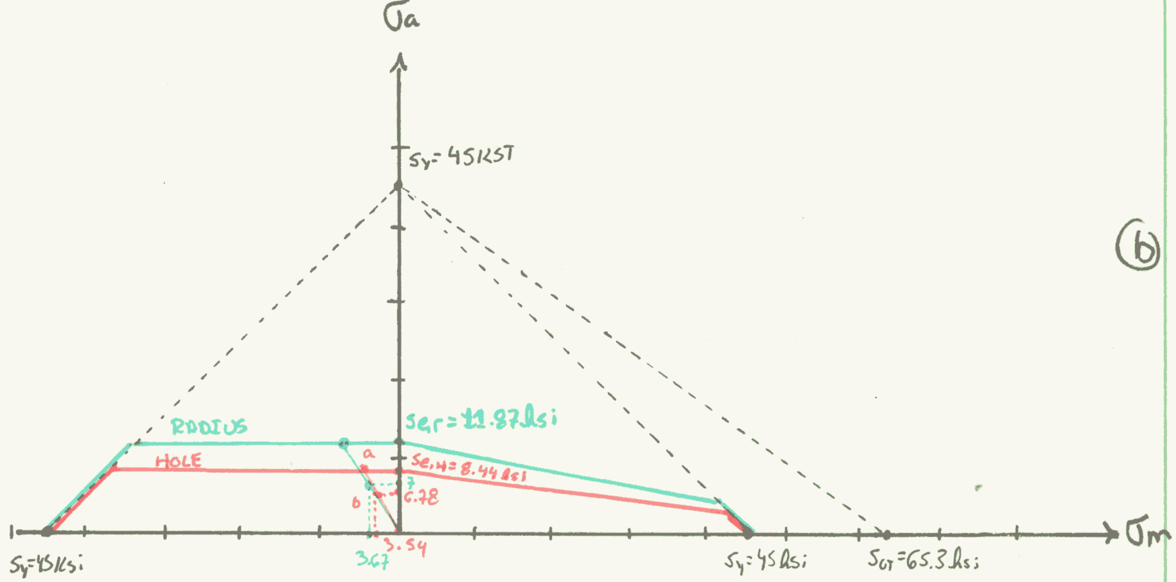
$$S_{e,H} = (0.8)(0.75)(1)(1)(0.431) \cdot 32.65\,ksi = 8.44\,ksi$$ (16)

VALUES OF THE ENDURANCE LIMIT WITHOUT FATIGUE CORRECTION

$$S^*_{e,r} = (0.8)(0.75)\,32.65\,ksi = 19.59$$ (17)

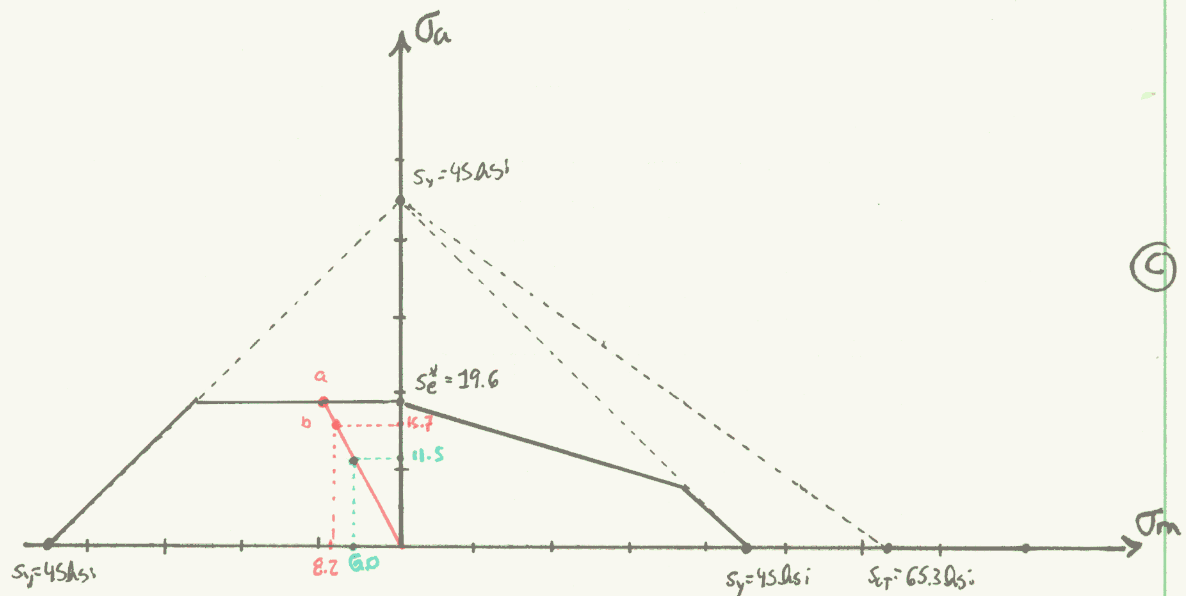
$$S^*_{e,H} = (0.8)(0.75)\,32.65\,ksi = 19.59$$ (18)

(b)



GOODMAN DIAGRAM WHERE S_e IS CORRECTED FOR THE STRESS CONCENTRATION, (15), (16) ARE USED FOR SE AND (5) - (8) ARE USED FOR σ_a & σ_m

(c)



GOODMAN DIAGRAM WHERE σ_a AND σ_m ARE CORRECTED FOR THE STRESS CONCENTRATION, (17)/(18) ARE USED FOR SE AND (10) - (13) ARE USED FOR σ_a & σ_m

BOTH FIGURES INDICATE THAT THE HOLE IS THE LEAST SAFE CONDITION. THE FACTOR OF SAFETY AT THE HOLE WILL BE COMPUTED USING BOTH (b) AND (c). STARTING WITH (b)

FROM (b) THE LOCATION OF POINT a MUST BE FOUND, KNOWING THE EQUATION OF THE LINE

$$\sigma_a = m \cdot \sigma_m$$

$$m = \frac{6.78\ ksi}{-3.54\ ksi} = -1.92$$

$$\sigma_a = -1.92 \cdot \sigma_m$$

THE VALUE OF σ_m WHEN $\sigma_a = 8.44\ ksi$

$$8.44\ ksi = -1.92 \cdot \sigma_m \Rightarrow \sigma_m = \frac{8.44\ ksi}{-1.92} = 4.41\ ksi$$

THE S.F. CAN NOW BE CALCULATED

$$S.F. = \frac{[(8.44\ ksi)^2 + (4.41\ ksi)^2]^{1/2}}{[(6.78\ ksi)^2 + (3.54\ ksi)^2]^{1/2}} = \boxed{1.24}$$

NOW THE SAFETY FACTOR IS CALCULATED FROM (c). STARTING WITH THE EQUATION OF THE LINE.

$$\sigma_a = m \cdot \sigma_m$$

$$m = \frac{15.7\ ksi}{-8.2\ ksi} = -1.91$$

$$\sigma_a = -1.91 \cdot \sigma_m$$

THE VALUE OF σ_m WHEN $\sigma_a = 19.6\ ksi$

$$19.6\ ksi = -1.91 \cdot \sigma_m \Rightarrow \sigma_m = \frac{19.6\ ksi}{-1.91} = -10.24\ ksi$$

THE S.F. CAN NOW BE CALCULATED

$$S.F. = \frac{[(19.6\ ksi)^2 + (-10.24\ ksi)^2]^{1/2}}{[(15.7\ ksi)^2 + (-8.2\ ksi)^2]^{1/2}} = \boxed{1.24}$$

SUMMARY

THE KEY IS THAT YOU ONLY CORRECT FOR THE STRESS CONCENTRATION IN ONE PLACE.