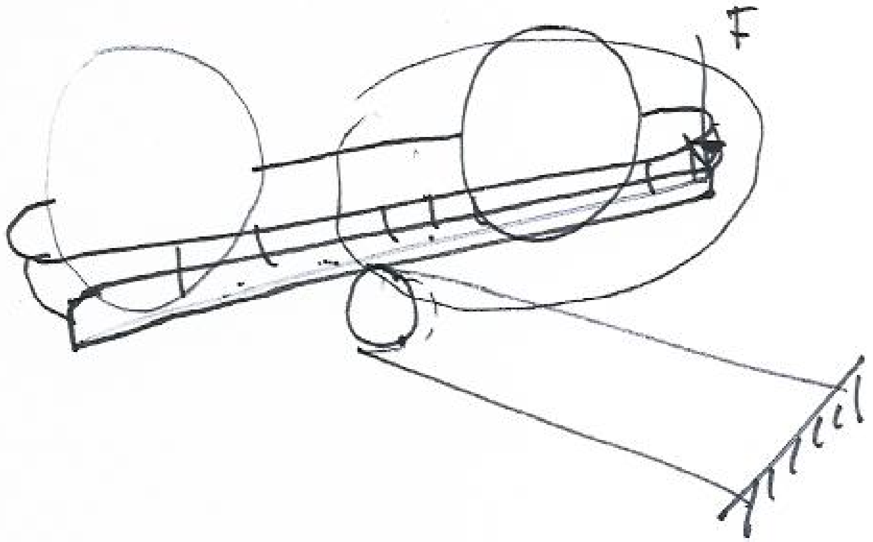
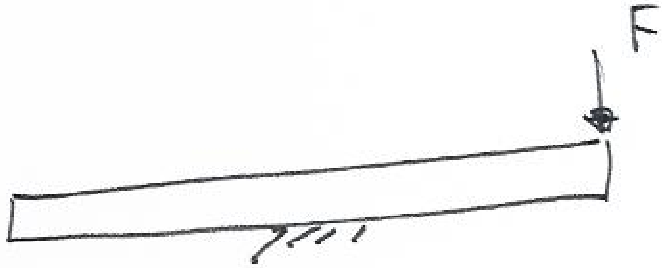
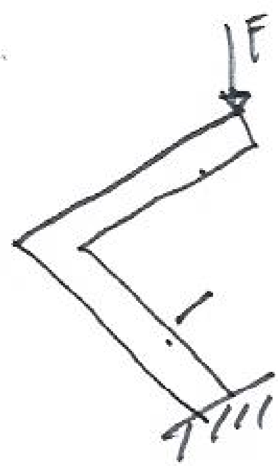
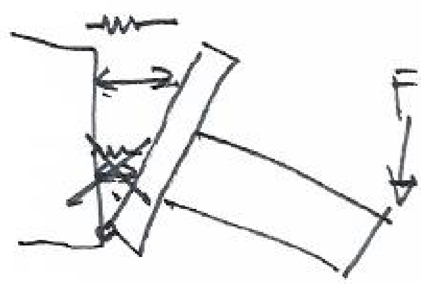
EME 150A FALL 2016 LECTURE 24 Friday, NOV 18, 2016

Modeling Assumptions For Rack Design

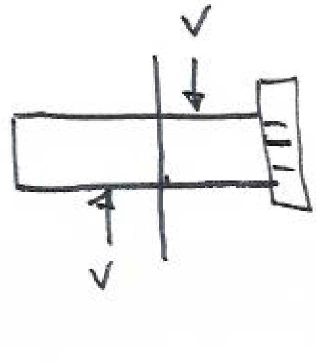


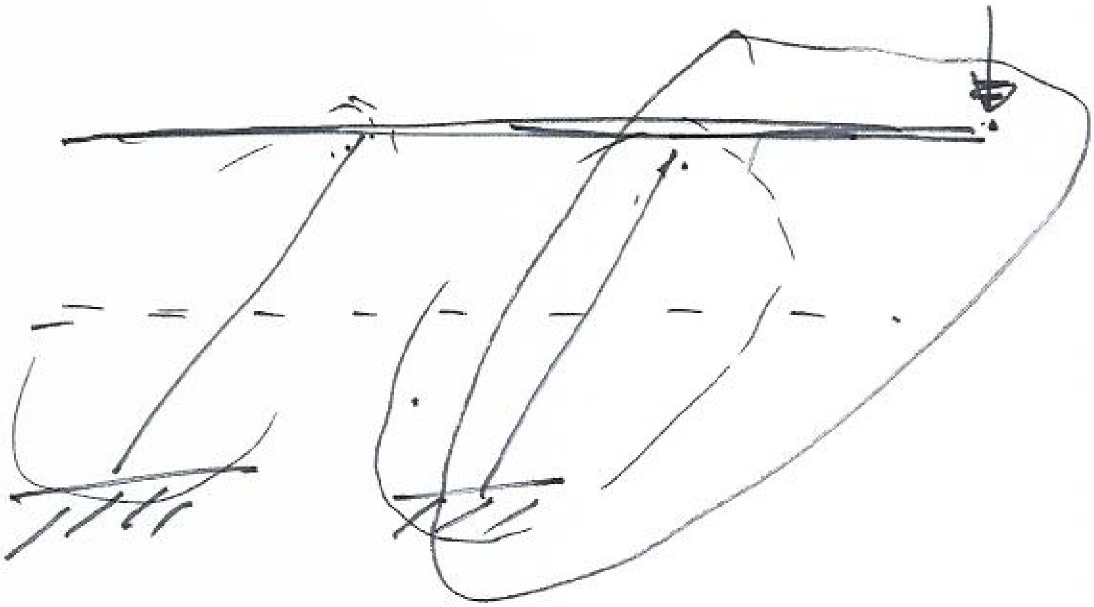


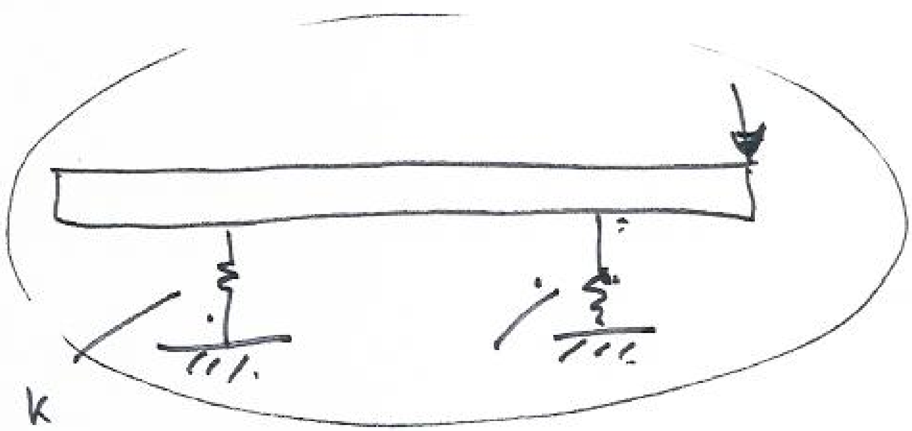




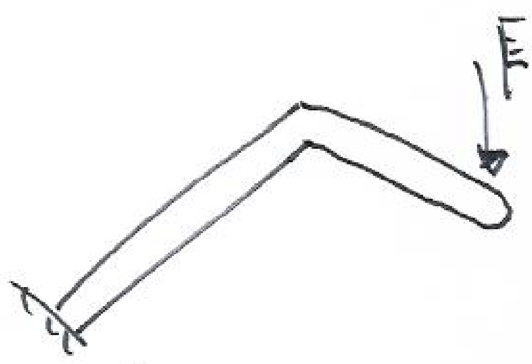
V/4







k
stiffness
the end
of cantilever
beam



Crack Growth

Stage I: Crack Intitiation

- geometric stress concentrations under tensile loads will start cracks
- yielding locally even if it under the overall yield strength of the part
- creates zones of distortion and slip bounds along the crystalline boundarys
- these coalesce into microscopic cracks
- cracks will develop more quickly in brittle materials

Stage II Crack propogation

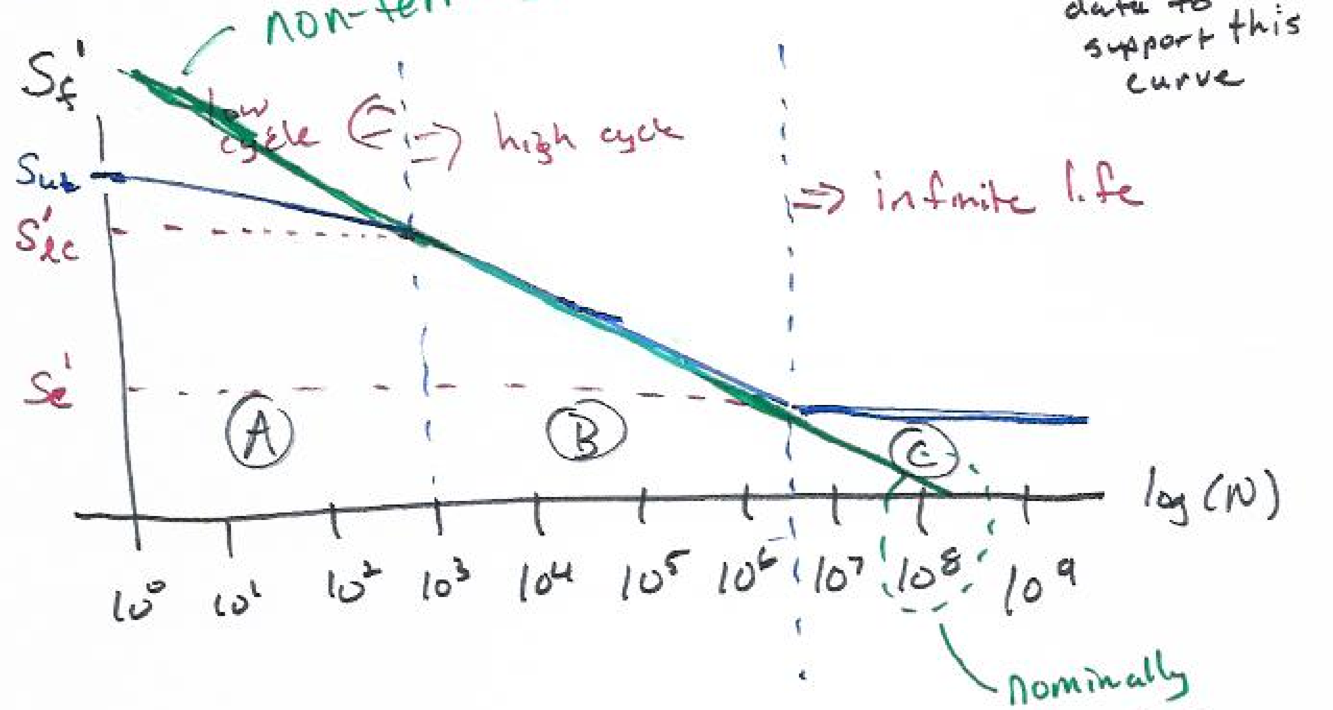
- crack growth primarily due to tensile loads
- reptitive compressive load will not cause cracks to propogate
- if is corrosive enviroment ⇒ faster propogation
- frequency and amplitude of loading plays important roles in crack growth

Stage III : Fracture

cracks will grow until its size increases past the toughness of the material, at some next cycle the part fractures

S-N Curve

Fig 6-10 shows data to support this curve



Ferrous

(A) Low Cycle $10^0 \leq N \leq 10^3$

$$S_{ec}' = f\, S_{ut}$$

$S_{ut} < 70$ kpsi $f = 0.9$

$S_{ut} > 70$ kpsi ⇒ see Fig 6-18

(C) Infinite Life $N \geq 10^6$ and 10^7 cycles

$$S_e' = 0.5\, S_{ut} \quad \begin{cases} S_{ut} \leq 200 \text{ kpsi} \\ S_{ut} \leq 1400 \text{ MPa} \end{cases}$$

see Fig 6-17

$$S_e' = 100 \text{ kpsi} \quad S_{ut} \geq 200 \text{ kpsi}$$

$$700 \text{ MPa} \quad S_{ut} \geq 1400 \text{ MPa}$$

(B) High Cycle

$$S_f = a N^b \qquad N = \left(\frac{\sigma_{rev}}{a}\right)^{1/b}$$

stress of fully reversed cycles

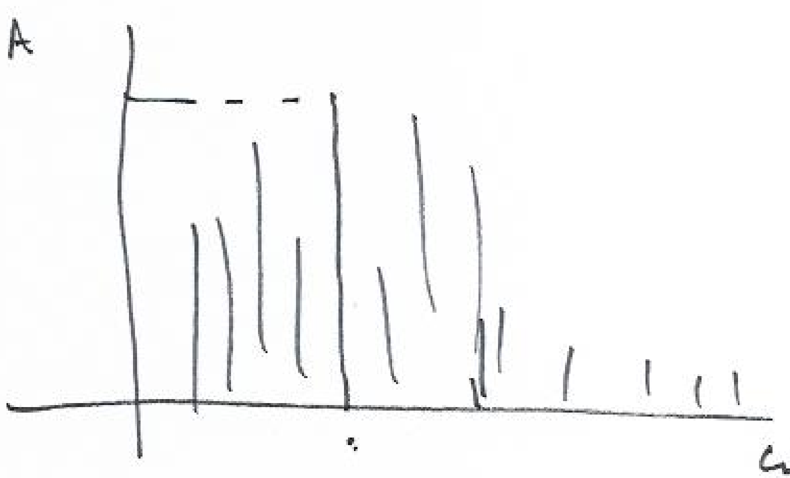
$$a = \frac{(\overbrace{f S_{ut}}^{S_{ec}'})^2}{S_e'} \qquad b = -\frac{1}{3}\log\left(\frac{f S_{ut}}{S_e'}\right)$$

$$S_{ec}' = f S_{ut}$$

How to interpret bus data

FFT: Fast Fourier transform

Transforms an time signal into frequency domain.



Non-ferrous

Use High Cycle (B) for $N > 10^{6}$

$N = 5 \times 10^{8}$ => typically consider sufficient for an "infinite life" design

Marin Parameters

S_e': endurance limit of ideal R.R. Moore test specimen for fully reversed

S_e: endurance limit of your non-ideal part under specific conditions

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

Surface Finish

$K_a = a S_{ut}^{\,b}$ Table 6-2

Size Factor : K_b

equivalent diameter

$$K_b = \begin{cases} 0.87\, d_e^{-0.107} & 0.11\text{in} \le d_e \le 2\text{in} \\ 0.91\, d_e^{-0.157} & 2\text{in} \le d_e \le 10\text{in} \end{cases}$$

Eq 6-20

Table 6-3 for d_e ↑ ..

This is only used for bending and torsion!
For axial $K_b = 1$.

Load Factor K_c

$$K_c = \begin{cases} 1 & \text{bending} \\ 0.85 & \text{axial} \\ 0.59 & \text{torsion} \end{cases}$$

If you have combined loads use $K_c = 1$ and use von mises stress technique in sec 6-14.

Temperature Factor K_d

$$K_d = \frac{S_T}{S_{RT}} = \frac{\text{Tensile strength at actual operating temp}}{\text{Tensile strength at room temperature}}$$

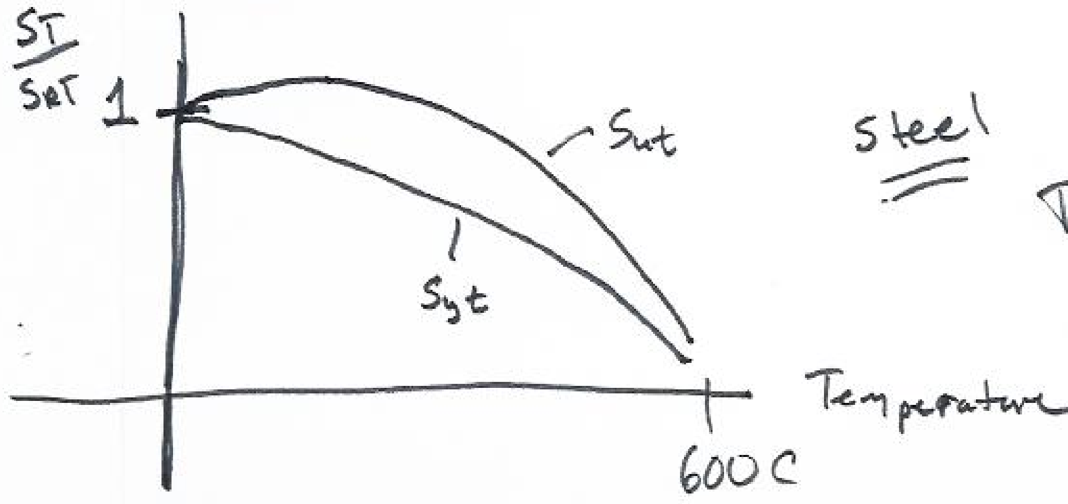


Table 6-4 or eq 6-27

K_e : reliability factor

$$K_e = 1 - 0.08 z_a$$

Table 6-5
and
A-10

K_f : Misc Effects Factor

You want to lower the endurance limit if:

- residual stress from manufacturing
- Corrosion
- plating : reduces endurance limit
- metal spray : " " "
- stress concentration factors :
  for fatigue these factors are
  important for <u>both</u> ductile and brittle.

Stress Concentration Factors for Fatigue

- Stress concentration for static loading (of brittle materials): K_t, K_{ts}

K_t ↑ normal stress K_{ts} ↑ shear stress

- in fatigue, Some materials are not fully sensitive to the presence of notches and reduced stress con. factor is used

$$\sigma_{max} = K_f \sigma_o \qquad \tau_{max} = K_{fs} \tau_o$$

- K_f, K_{fs}: fatigue stress consentration factors

$$K_f = \frac{\text{max stress in notched specimen}}{\text{max ~~stress~~ in notch-free specimen}}$$

$$K_f = 1 + q(K_t - 1)$$

q: notch sensitivity

Fig 6-20: q for normal stress

Fig 6-21: q for shear stress

Process for fatigue analysis

1. Calculate the max stress at critical points in your design.

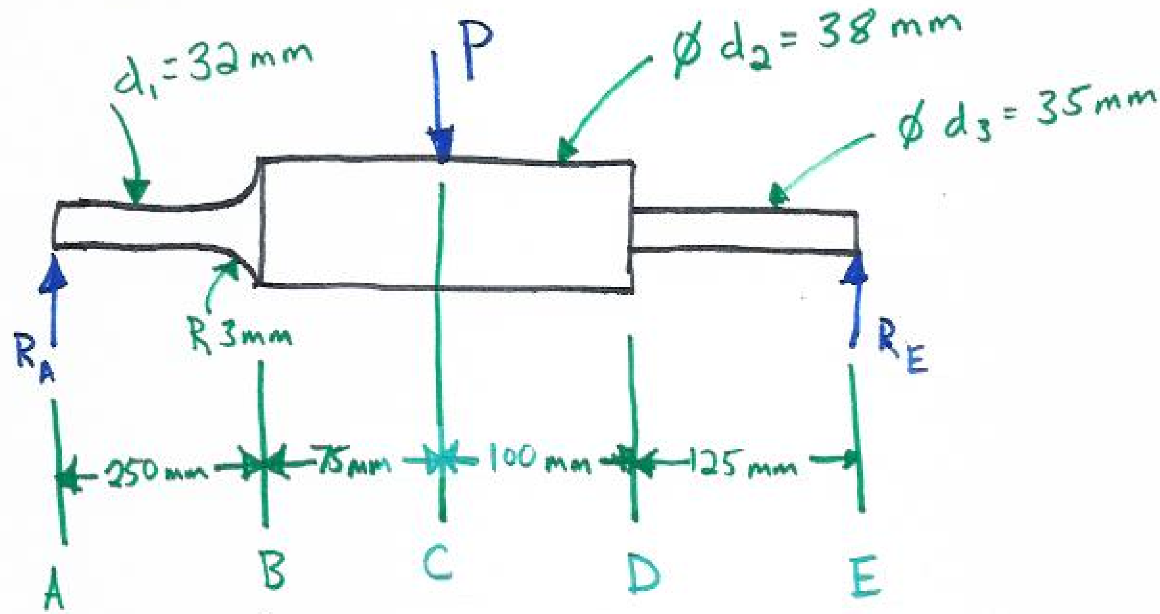
2. For a given material: $\underbrace{S_{ut}, S_e', S_{ec}'}_{\text{ideal specimen}}$

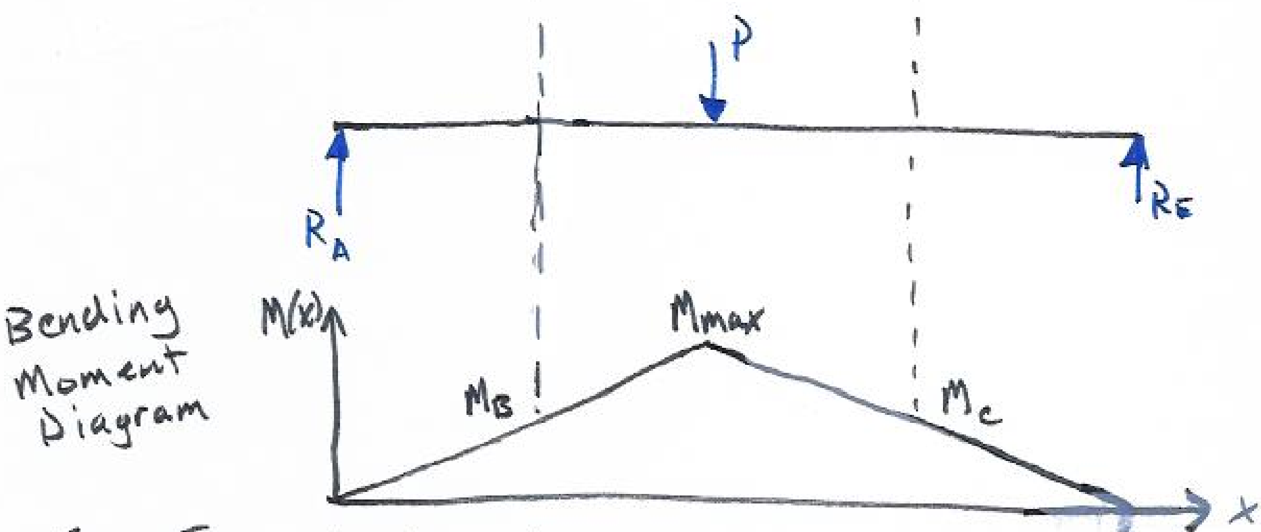
3. Determine if you have low cycle, high cycle, or infinite. Characterize your dynamic stresses.

4. Calculate actual S_e, S_{ec} ~~be~~ with Marin parameters. (many effects, including stress concentrations)

Example

Given a rotating beam which is simply supported at A & E with P=6.8 KN and is going through fully reversed cycles, what is the life of the part if the material is CD 1050 steel?





Sum Forces & Moments

$$\Sigma F = 0 = R_A + R_E - P$$
$$\Sigma M_A = 0 = (550\,mm) R_E - (325\,mm) P$$

$R_A = 2.782$ KN
$R_E = 4.018$ KN
reaction forces

The highest bending normal stresses will be at $\underline{B}$.

$$M_B = (250mm)\, R_A \Rightarrow M_B = 695.5\, Nm$$

1) Calculate nominal max stress.

$$\sigma_{Bo} = \frac{M_B c}{I} = \frac{M_B\, d_1/2}{\frac{\pi d_1^4}{64}} = \frac{32 M_B}{\pi d_1^3} = \frac{32(695.5\, Nm)}{\pi (0.032m)^3}$$

σ_{Bo} ← nominal

$$\boxed{\sigma_{Bo} = 216.2\, MPa}$$

See Figure A-15-9 in appendix.

2) Calculate the specimen endurance limit.

$S_e' = 0.5\, S_{ut}$ for $S_{ut} < 1400\, MPa$

From Table A-20 $S_{ut} = 690\, MPa$ and $S_y = 580\, MPa$

$$\boxed{S_e' = 345\, MPa}$$

3) Calculate Marin parameters so that the part's endurance limit can be found.

- Surface Finish, K_a

$K_a = a\, S_{ut}^{\,b}$ From table 6-2 the cold drawn row gives $a = 4.51$, $b = -0.265$

$$K_a = (4.51)(690\, MPa)^{-0.265}$$

$$\boxed{K_a = 0.798}$$

- Size Factor, K_b

We have rotating + bending so $d_e = d_1$

$d_1 < 51\text{mm}$ so using eq 6-20

$$K_b = \left(\frac{d_1}{7.62}\right)^{-0.107} = \boxed{0.858}$$

- loading factor, K_c

We have bending so $K_c = 1$

- temperature, K_d

Nothing is said about temperature, so $K_d = 1$.

- reliability, K_e

Nothing said: $K_e = 1$

- misc factors, $K_f = 1$

3) We need to account for the stress concentration due to the fillet.

$$K_f = 1 + q(K_t - 1)$$

From Chart A-15-9 and $\left.\begin{array}{l} r/d = 0.093 \\ D/d = 1.19 \end{array}\right\} K_t = 1.65$

From Fig 6-20

$$q \approx 0.85$$

$$\sigma_B = K_f \sigma_{B0} = (1 + 0.85[1.65 - 1])(216.2\text{ MPa}) = \boxed{335.7\text{ MPa}}$$

4) Find S_e

$$S_e = (0.798)(0.858)\,S_e' = (0.798)(0.858)(345\text{ MPa})$$

$$\boxed{S_e = 236\text{ MPa}}$$

5) $\sigma_B > S_e$ and $\sigma_B < S_y < S_{ut}$

$$S_{N=10^3} = S'_{\ell c} = f\,S_{ut} = (0.84)(690\text{ MPa}) = \underline{579.6\text{ MPa}}$$

f : from Fig 6-18

690 MPa = 100 kpsi , so $f = 0.84$

$\sigma_B < S_{N=10^3}$

So we have high cycle fatigue!

$$N = \left(\frac{\sigma_B}{a}\right)^{1/b} \qquad a = \frac{(f\,S_{ut})^2}{S_e} \qquad b = -\frac{1}{3}\log\left(\frac{f\,S_{ut}}{S_e}\right)$$

$$a = \frac{\left[(0.84)(690\text{ MPa})\right]^2}{S_e} = 1423\text{ MPa}$$

$$N = \left(\frac{335.7\text{ MPa}}{1423\text{ MPa}}\right)^{1/-0.1308} \qquad b = -\frac{1}{3}\log\left(\frac{579.6}{236}\right) = -0.1308$$

$$\boxed{N = 68 \times 10^3}$$

The part will fail after this many cycles.