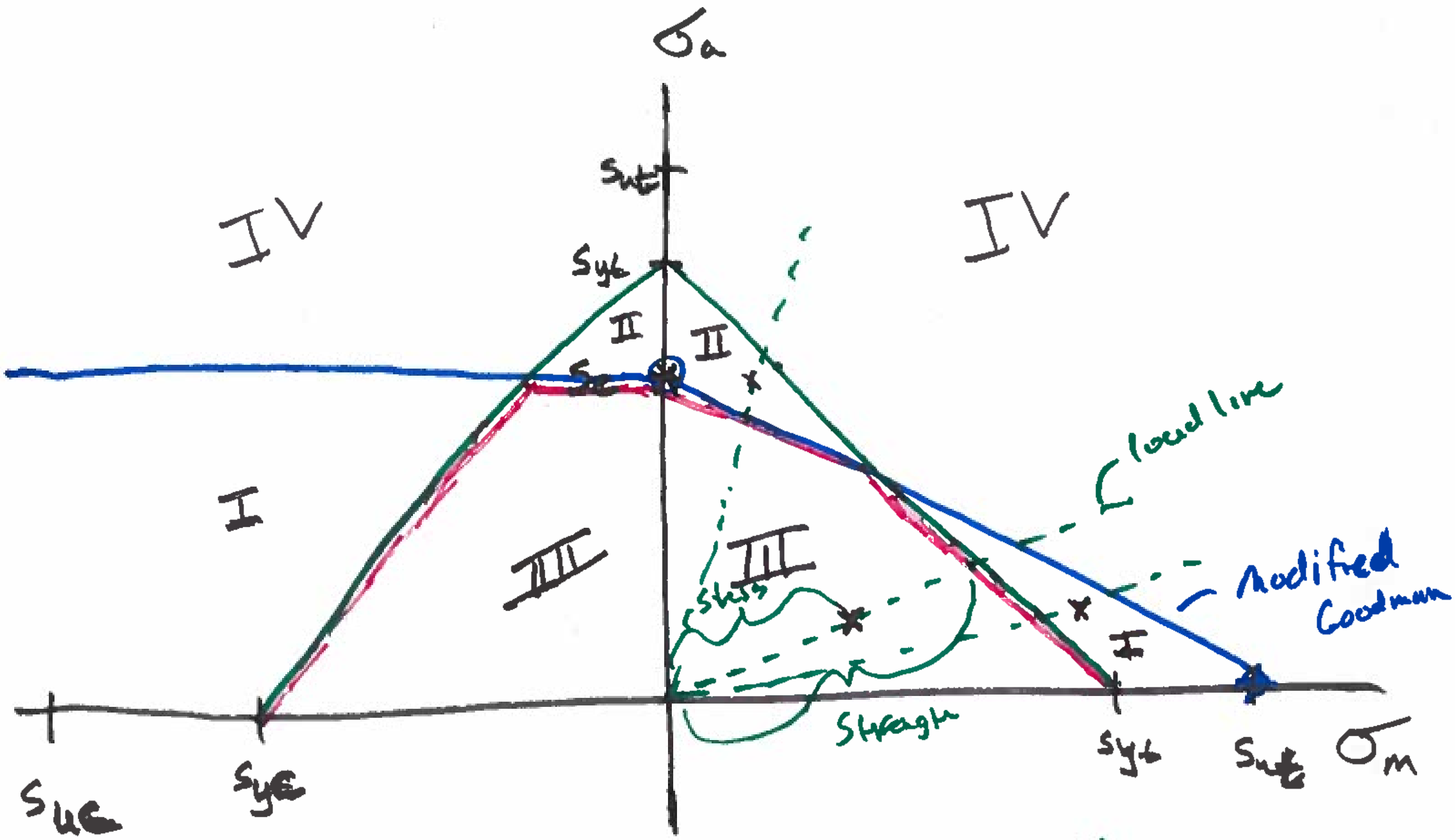
EME 150A FALL 2015 LECTURE 24 NOV 23

Fluctuating Stress

For tensile stress the endurance limit decreases as mean tensile stress increases.

compression ⇐ ⇒ tension



$$n = \frac{\text{strength}}{\text{stress}}$$

I: failure due to yielding

II: finite life

III: infinite life, will not fail

IV: failure due to yielding, fracture, or fatigue

Steps for design based on stress life theory

1. Determine S_e' from test data or

$$S_e' = \begin{cases} 0.5\,S_{ut} & S_{ut} \le 200\,\text{kpsi}\ (1400\,\text{MPa}) \\ 100\,\text{kpsi}\ (700\,\text{MPa}) & S_{ut} > 200\,\text{kpsi} \end{cases}$$

ferrous materials

2. Find S_e using Marin parameters

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

Surface finish

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

Size

$$k_b = \begin{cases} 0.879\,d_e^{-0.107} & 0.11 \le d < 2\,\text{in} \\ 0.91\,d_e^{-0.157} & 2\,\text{in} \le d \le 10\,\text{in} \\ 1.24\,d_e^{-0.107} & 2.79 \le d \le 51\,\text{mm} \\ 1.51\,d_e^{-0.157} & 51 \le d \le 245\,\text{mm} \end{cases}$$

$k_{b_{axial}} = 1$

d_e: equivalent diameter

non-rotating, for odd shapes

Load

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

Temp

$$K_d = 0.975 + 0.432(10^{-3})T_F - 0.115(10^{-5})T_F^2$$
$$+ 0.104(10^{-8})T_F^3 - 0.595(10^{-12})T_F^4$$

Table 6-4 $\qquad K_d = 1$ room temperature

reliability

K_e from Table 6-5 or $K_e = 1 - 0.08 z_a$

Stress concentration factors

$$K_f = 1 + q(K_t - 1) \qquad K_{fs} = 1 + q(K_{ts} - 1)$$

q: notch sensitivity Fig 6-20 or 6-21

$$\sigma = K_f \sigma_0 \qquad \tau = K_{fs} \tau_0$$

E

Low cycle fatigue strength

$S_{ec} = f\, S_{ut}$ f: ~~Table~~ Fig 6-18 or test data

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

High cycle

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

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

Fluctuating

Find σ_m and σ_a (K_f applied to both)

$\sigma_m = \frac{\sigma_{max} + \sigma_{min}}{2}$ $\sigma_a = \left|\frac{\sigma_{max} - \sigma_{min}}{2}\right|$

Apply failure criteria:

mod-Goodman $\frac{\sigma_a}{S_e} + \frac{\sigma_m}{S_{ut}} = \frac{1}{n}$

$\sigma_m \geqslant 0$

Gerber line

$$\frac{n\sigma_a}{S_e} + \left(\frac{n\sigma_m}{S_{ut}}\right)^2 = 1$$

If have torsion!

for $\tau_m \geq 0$

τ_m, τ_a $\quad K_c = 0.59$

$$S_{sy} = 0.577\, S_y$$

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

Check for yielding!

$$\sigma_a + \sigma_m = \frac{S_{yt}}{n}$$

$$\tau_a + \tau_m = \frac{0.577\, S_{yt}}{n}$$

Finite life

Example 6-12

A steel bar under cyclic loading with $\sigma_{max} = 60$ Ksi and $\sigma_{min} = -20$ Ksi

$S_{ut} = 80$ ksi $S_e = 40$ ksi

$S_{yt} = 65$ Ksi $f = 0.9$

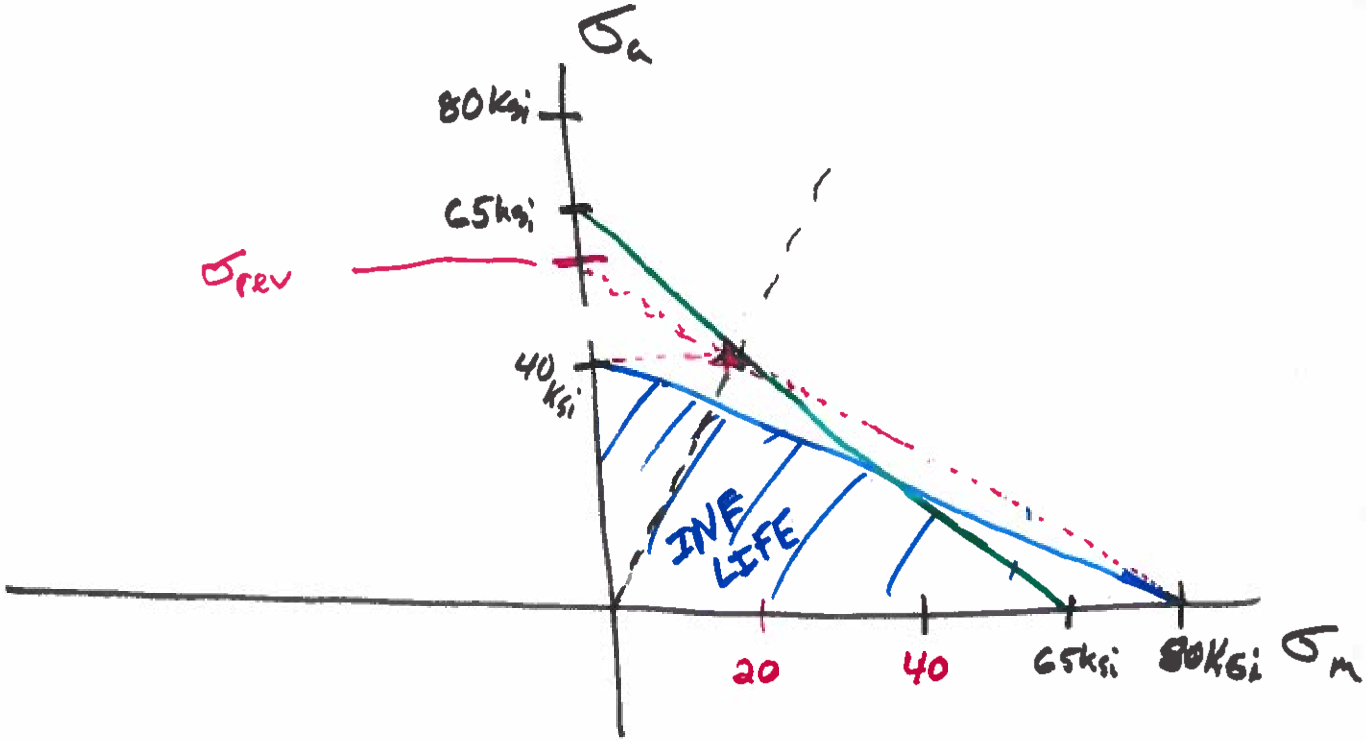
Find: number of cycles to fatigue failure using modified Goodman line.

$$\sigma_a = \frac{60-(-20)}{2} = 40 \text{ Ksi}$$

$$\sigma_m = \frac{60+(-20)}{2} = 20 \text{ Ksi}$$

Goodman line

$$n = \frac{1}{\frac{\sigma_a}{S_e} + \frac{\sigma_m}{S_{ut}}} = \frac{1}{\frac{40}{40} + \frac{20}{80}} = 0.8$$



$$n_{yield} = \frac{S_{yt}}{\sigma_a + \sigma_m} = \frac{65 \text{ kpsi}}{60 \text{ kpsi}}$$

not yielding!

Finite life!

Need equivalent fully reversed stress that would cause as much damage as the fluctuating stress

$$\sigma_{rev} = \frac{\sigma_a}{1 - \frac{\sigma_m}{S_{ut}}} = \underline{\underline{53.3 \text{ Ksi}}}$$

$$a = \frac{(f\,S_{ut})^2}{S_e} = 129.6\text{ ksi}$$

$$b = -\frac{1}{3}\log\left(\frac{f\,S_{ut}}{S_e}\right) = -0.0851$$

$$N = \left(\frac{\sigma_{rev}}{a}\right)^{1/b} = 3.4 \times 10^4 \text{ cycles}$$