Update

- What is fatigue?
- Types of Fatigue Loading
- Empirical Data
- Estimating Endurance/Fatigue Strength
- Strategies for Analysis
  - Uniaxial Fully Reversed
  - Uniaxial Fluctuating
  - Multiaxial
Getting Fatigue Data

1) Test a prototype
2) Test the exact material used
3) Published fatigue data
4) Use static data to estimate
Estimating $S_e$, From Static Data

see page 345 in your book...

<table>
<thead>
<tr>
<th></th>
<th>Steel</th>
<th>Iron</th>
<th>Aluminum</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$S_{e'} \cong 0.5S_{ut}$</td>
<td>$S_{e'} \cong 0.4S_{ut}$</td>
<td>$S_{f'<em>{@5E8}} \cong 0.4S</em>{ut}$</td>
</tr>
<tr>
<td></td>
<td>$S_{e'} \cong 100\text{ksi}$</td>
<td>$S_{e'} \cong 24\text{ksi}$</td>
<td>$S_{f'_{@5E8}} \cong 19\text{ksi}$</td>
</tr>
<tr>
<td></td>
<td>for $S_{ut} \leq 200\text{ksi}$</td>
<td>for $S_{ut} \leq 60\text{ksi}$</td>
<td>for $S_{ut} \leq 40\text{ksi}$</td>
</tr>
</tbody>
</table>

**BUT, these are all for highly polished, circular rotating beams of a certain size**
Correction Factors

\[ S_e = C_{load} C_{size} C_{surf} C_{temp} C_{reliab} S_{e}' \]
\[ S_f = C_{load} C_{size} C_{surf} C_{temp} C_{reliab} S_{f}' \]

*pages 348-353 in your book*
Residual Stresses

- Temperature
  - through hardening
  - case hardening

- Surface Treating
  - cold forming
  - shot peening: $C_{\text{surf}}=1$
Constructing Estimated S-N Curves

The material strength at 10^3 cycles, S_m:

\[ S_m = 0.9S_{ut} \quad \text{for bending} \]
\[ S_m = 0.75S_{ut} \quad \text{for axial loading} \]

The line from \( S_m \) to \( S_e \) or \( S_f \), \( S_n = aN^b \)

or \( \log S_n = \log a + b \log N \)
Constructing S-N Curves

\[ S_n = a N^b \]

where \( z = \log N_1 - \log N_2 \)

\[ b = -\frac{1}{z} \log \left( \frac{S_m}{S_e} \right) \]

\[ \log a = \log S_m - b \log N_1 = \log S_m - 3b \]
Fatigue Stress Concentration

\[ K_f = 1 + q(K_f-1) \]

\[ q = \frac{1}{1 + \sqrt[\frac{1}{n}]} \]

- \( q \) – notch sensitivity
- Function of material, \( S_{ut} \), and notch radius
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\[ \sigma_m = 0 \quad \sigma_m \neq 0 \]
Uniaxial, Fully Reversed Strategy
Loading & Stress Half

N (umber of cycles)  Fluctuating Load (F_a)

Tentative Material  Tentative Design

K_t  K_f

σ_a (nominal)

σ_1, σ_2, σ_3 (principal)

σ´ (von Mises)
Uniaxial, Fully Reversed Strategy
Fatigue Half

$S_e$ or $S_f$

$C_{load}$
$C_{surf}$
$C_{size}$
$C_{temp}$
$C_{reliab}$

$S_e$ or $S_f$

Estimated S-N Curve
Uniaxial Fully Reversed Strategy

N (umber of cycles) → Tentative Material → $K_f$

Fluctuating Load ($F_a$) → Tentative Design → $\sigma_a$ (nominal) → $\sigma_1, \sigma_2, \sigma_3$ (principal) → $\sigma'$ (von Mises)

$S_n$ = Fatigue strength at n cycles;
$\sigma'$ = largest von Mises alternating stress;
$N_f = \frac{S_n}{\sigma'}$

$S_e$ or $S_f$

Estimated S-N Curve

$C_{load}$, $C_{surf}$, $C_{size}$, $C_{temp}$, $C_{reliab}$