EME 150A FALL 2015 LECTURE 21 NOV 16

Fatigue Failure Prediction

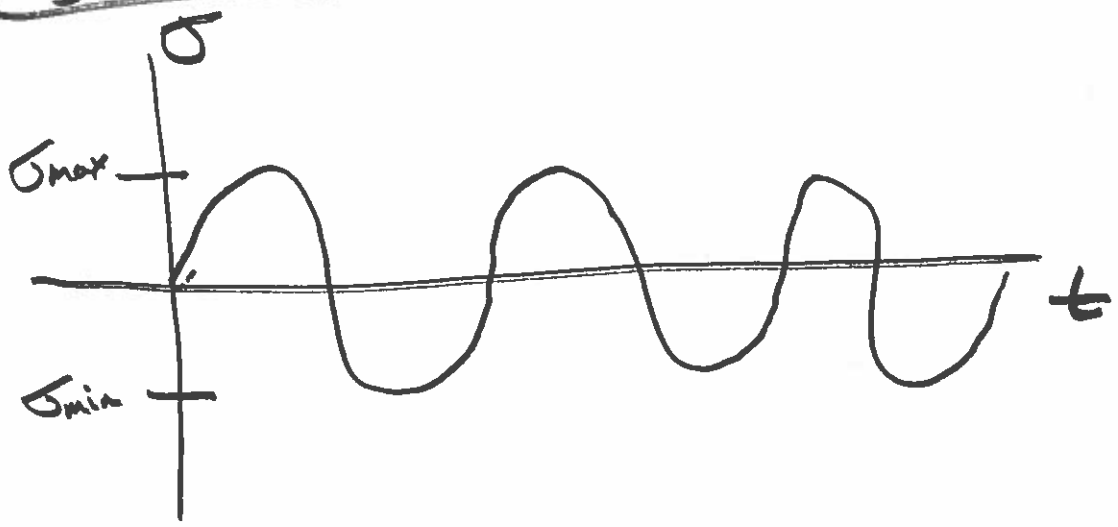
- Up to now we've looked static and quasi-static loadings.
- under dynamic loading failure can occure well below eithe the yield Streyth or the ultimate tensile strength
- failure sudden!!
- only testing is sufficient to know if your element will fail.

History

- Dynamic loads became more significant with the introduction of steam engines in late 1800s.
- Railroad car axles failed after service period. Materials were ductile, they had brittle-like failure.
- Bending in fully-reversed mode

Cyclic Loading Classifications

Fully reversed

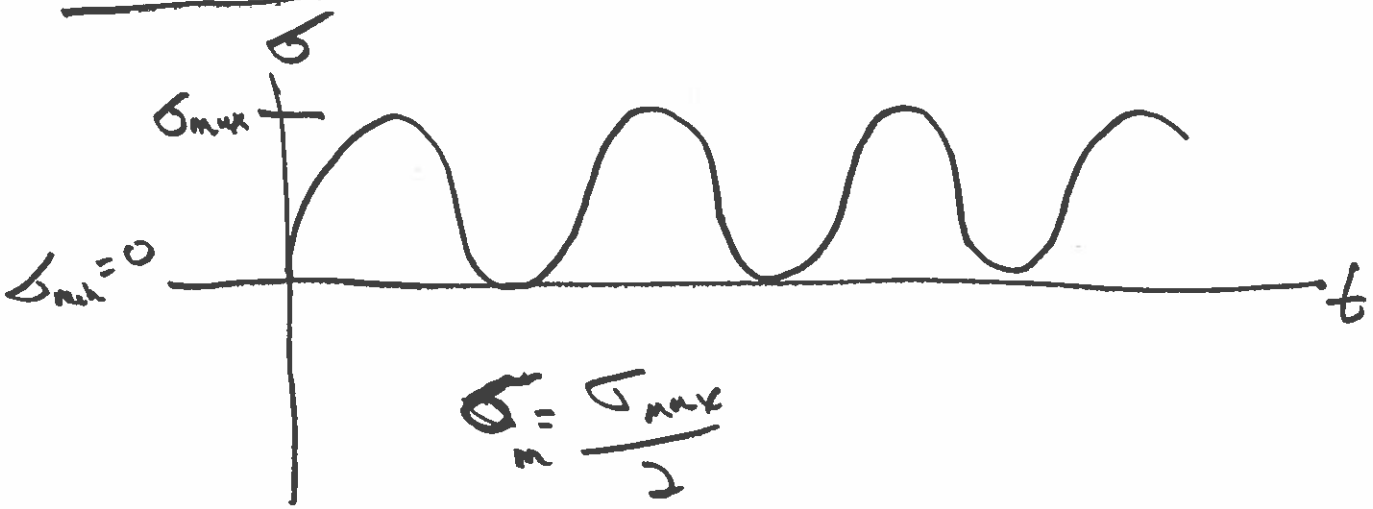


$$\text{mean stress: } \sigma_m = \frac{\sigma_{max} + \sigma_{min}}{2} = 0$$

amplitude stress

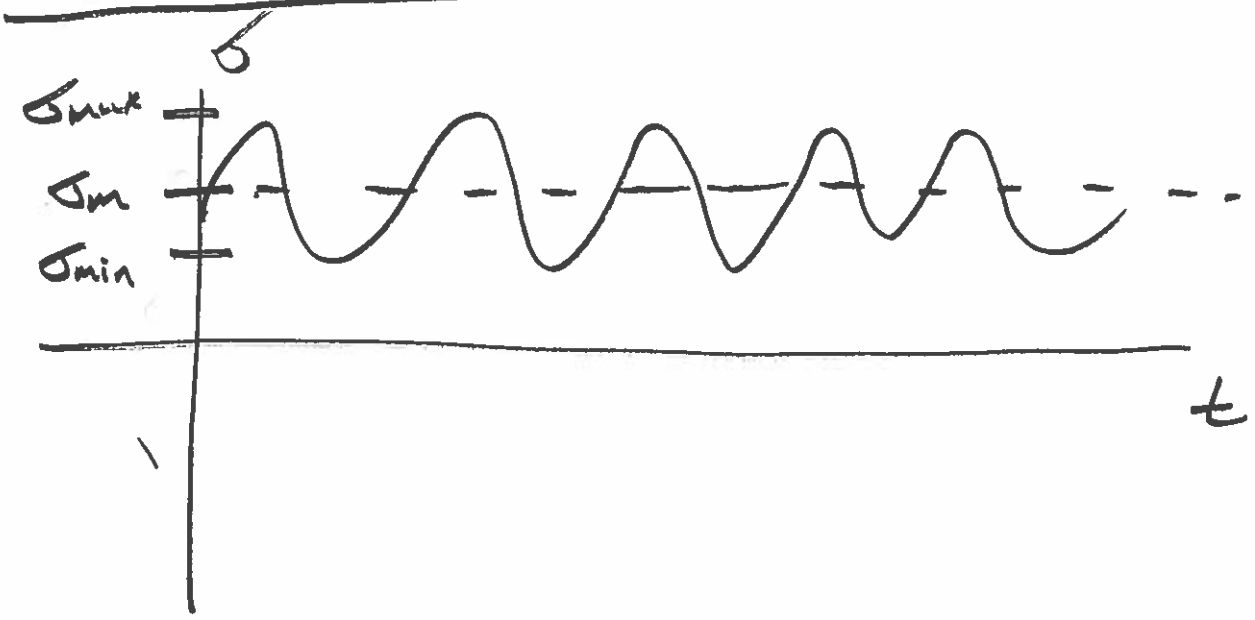
$$\sigma_a = \frac{\sigma_{max} - \sigma_{min}}{2}$$

Repeated Stress



$$\sigma_m = \frac{\sigma_{max}}{2}$$

Fluacting Stress



Design Strategies for full reversal

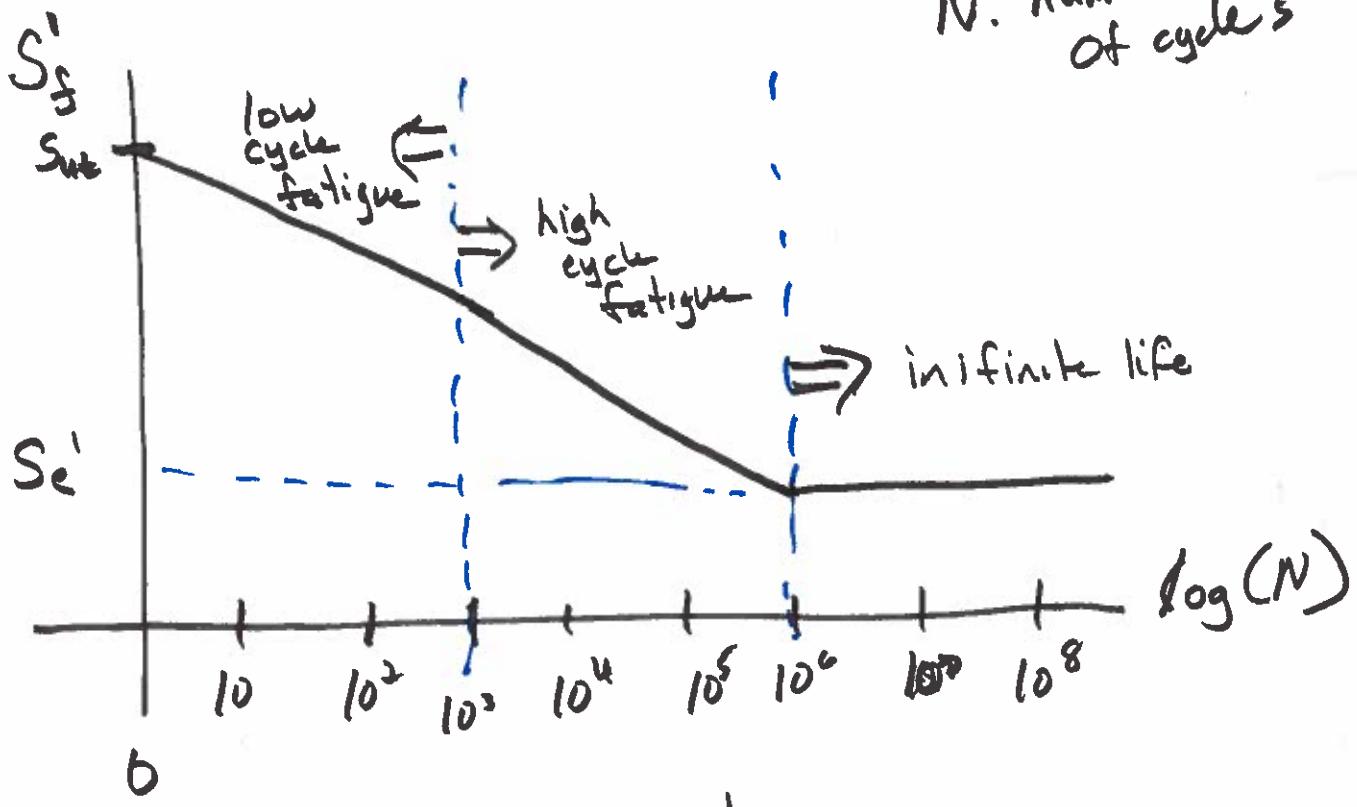
August Wöhler ~~[illegible]~~ investigated fatigue failures for ferrous metals in 1860s-1870s.

Found:

- number of cycles was main culprit
- Steels have an endurance limit

Endurance: value stress that is tolerable for many millions of cycles (infinite cycles)

S-N Curve



Typical Steel

S_f' (1): unmodified fatigue strength limit for test specimen

S_e': unmodified endurance limit
- ferrous materials
  - $S_e' \simeq 0.5\, S_{ut}$ $S_{ut} < 200$ Kpsi
  - $S_e' \equiv 100$ Kpsi $S_{ut} > 200$ Kpsi

$10^0 < N < 10^3$: low cycle fatigue

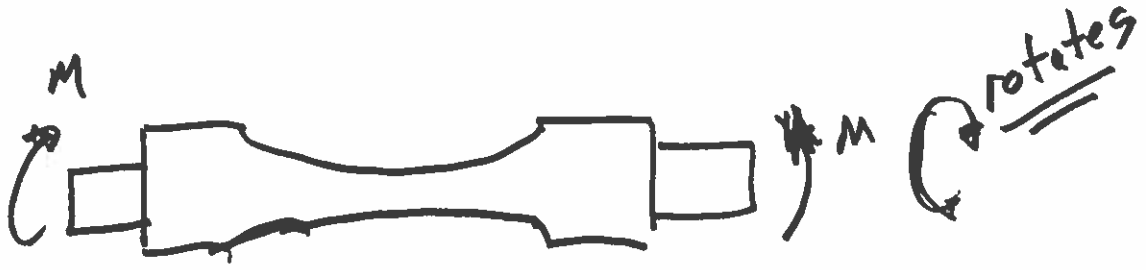
$N > 10^3$: high cycle fatigue

$N > 10^6$: infinite life

$N < 10^7$: finite life

Test specimen

R.R. Moore high speed beam machine



highly polished => axial polishing

Use of S-N curve for design:

stress-life theory

$S_e' + S_f'$ => only for test specimen

Marin parameters: Marin

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

S_e: endurance limit of your part

S_e': endurance limit of test specimen

Fatigue starts at a crack

Mechanisms for fatigue failure

- cracks are ever present in all materials
- develop over time due to cyclic loading
- all materials have micro- and macroscopic discontinuities

Stages of Fatigue Failures

Stage I: Crack initration

Stage II: crack propogation

Stage III: sudden unstable crack growth resulting in fracture

Memo 3: Static Failure

- Identify elements highest stresses. due static loading.
- Requirement: 250lb on the end of rack There other places your may fail!
- Show individual factor of safety for critical points
- overall factor of safety
- Justify material and geometry choices in terms of strength
- Explanations on redesign based on findings