Fatigue Failure Prediction

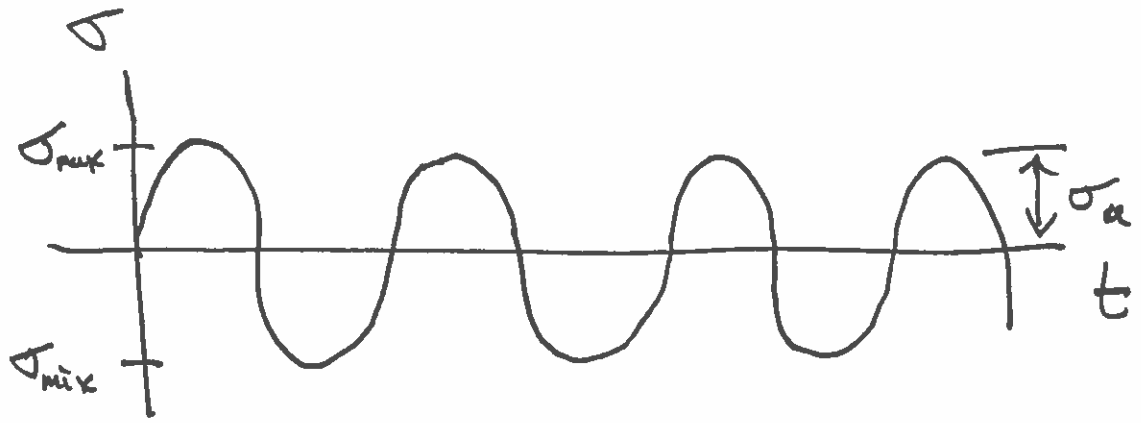
- Up until now we've looked at static and quasi-static loaded.
- Under dynamic loading failure can occur well below either the yield strength or the ultimate strength.
- failure is sudden!
- only testing is sufficient to know if your element will fail.

History

- Dynamic loads became more sig. when steam engines appeared (1800s)
- Railroad cam axles failed after service. The materials were ductile but they had brittle-like failures
- Bending in fully-reversed mode.

Cyclic loading classification

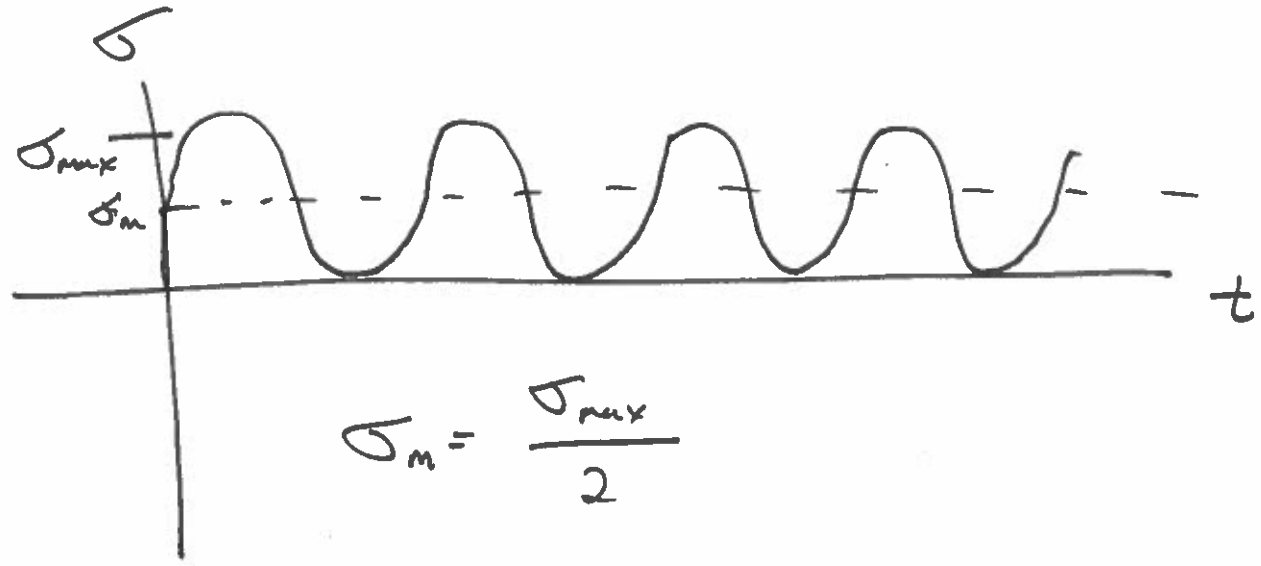
Fully reversed



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

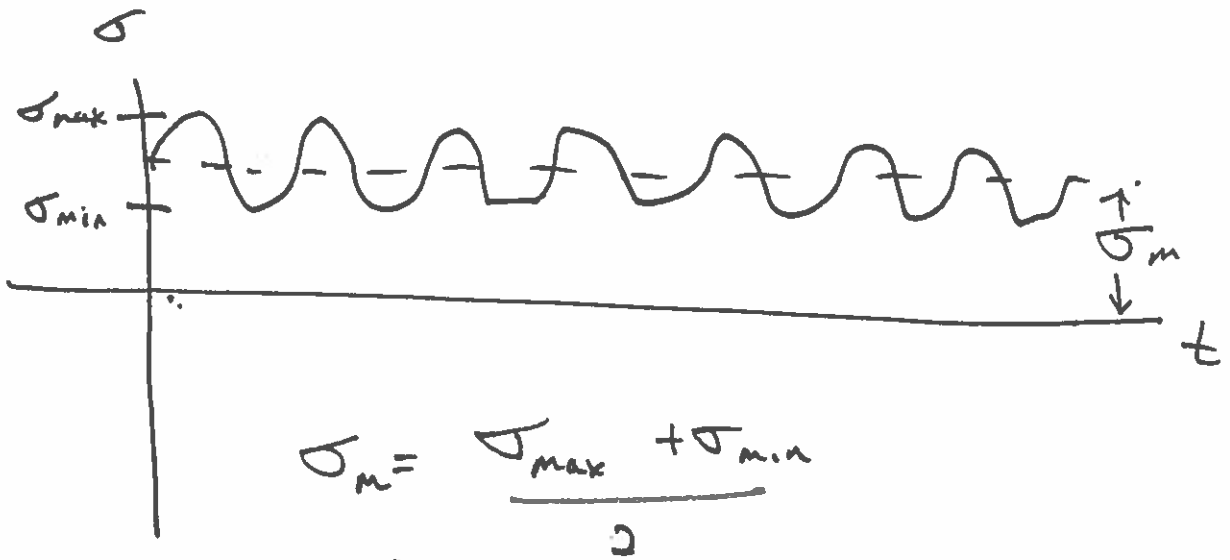
amplitude: $\sigma_a = \frac{\sigma_{max} - \sigma_{min}}{2}$

Repeated stress



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

Fluctuating Stress



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

Design Strategies for fully reversed cass

August Wöhler investigate fatigue failures for ferrous materials in 1860s-1870s.

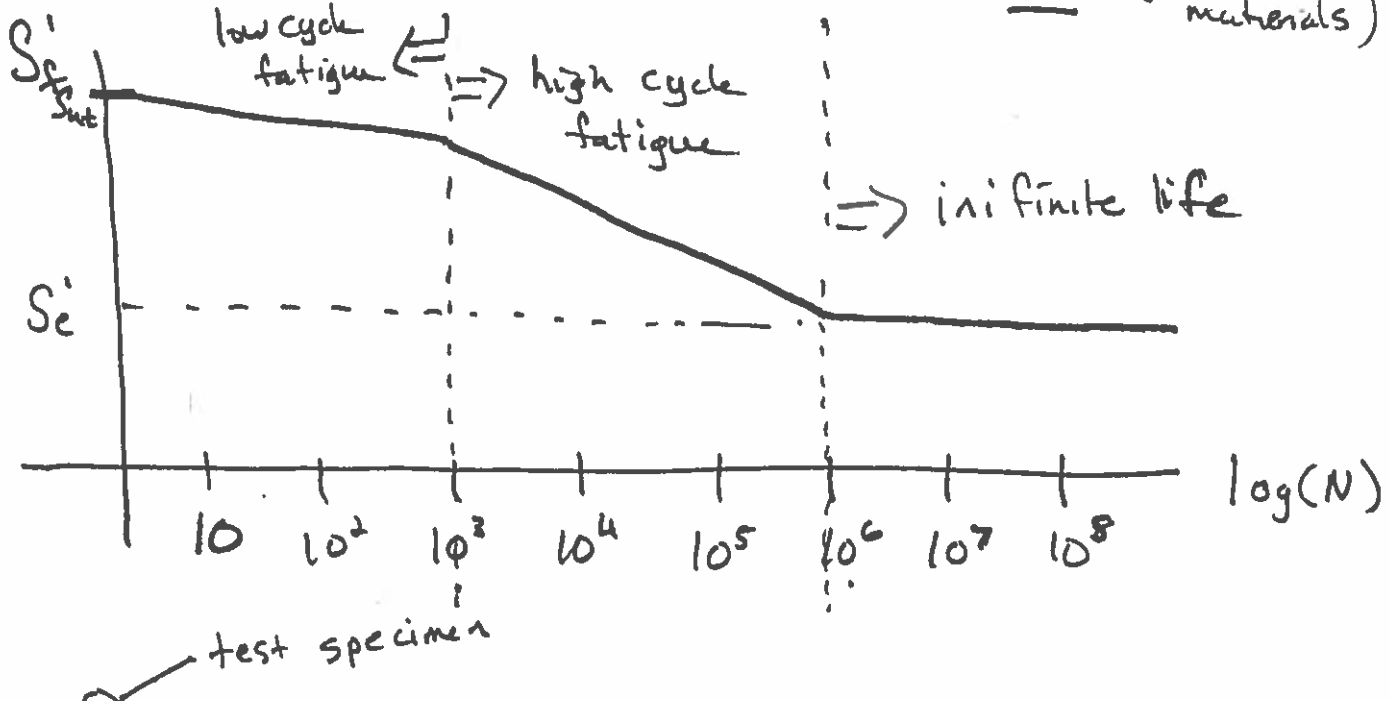
Found:

- number of cycles was the main culprit for failure
- steels have an endurance limit

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

S-N

Steel (ferrous materials)



S_f' : unmodified fatigue strength limit for a test specimen

S_e' : unmodified endurance limit of the test specimen

ferrous materials

empirically found

$S_e' = 0.5 S_{ut}$ $\quad S_{ut} < 200$ kpsi

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

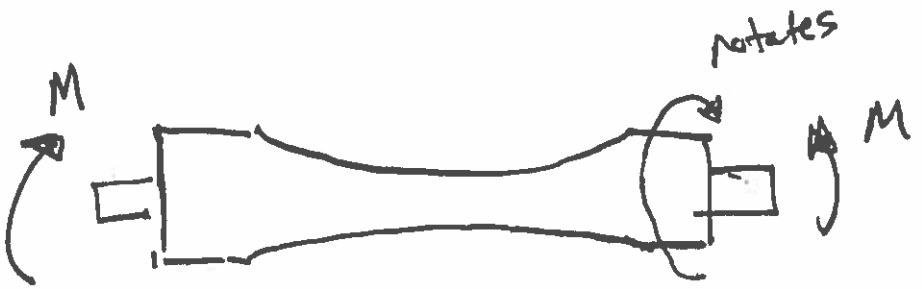
$10^0 < N < 10^3$: low cycle fatigue

$N > 10^3$: high cycle fatigue

$N > 10^6$: infinite life

Test specimen

R.R. Moore : high speed beam bending machine



highly polished : axial polishing

S_e' and S_f' $\Rightarrow$ only for exactly the test specimen

Main Parameters

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

S_e: endurance limit of your actual part

S_e': test specimen

Fatigue failure starts at a crack!

Mechanisms for fatigue failure

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

Stages of Fatigue failures

Stage I : crack initiation

Stage II : crack propagation

Stage III : sudden unstable crack growth resulting in fracture