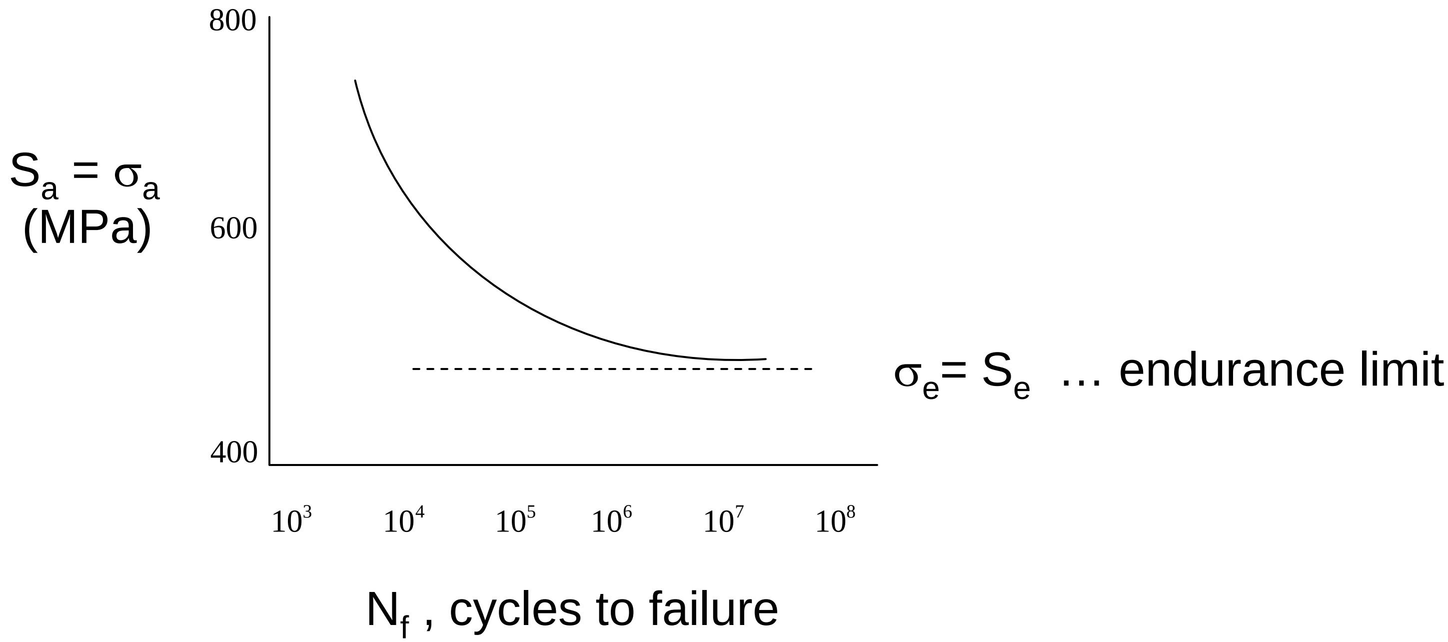
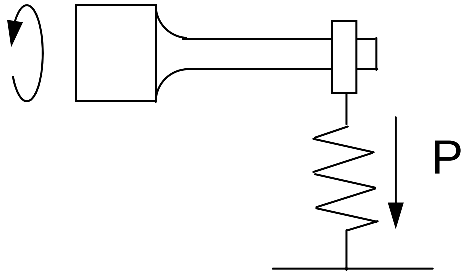
Fatigue Life Evaluation

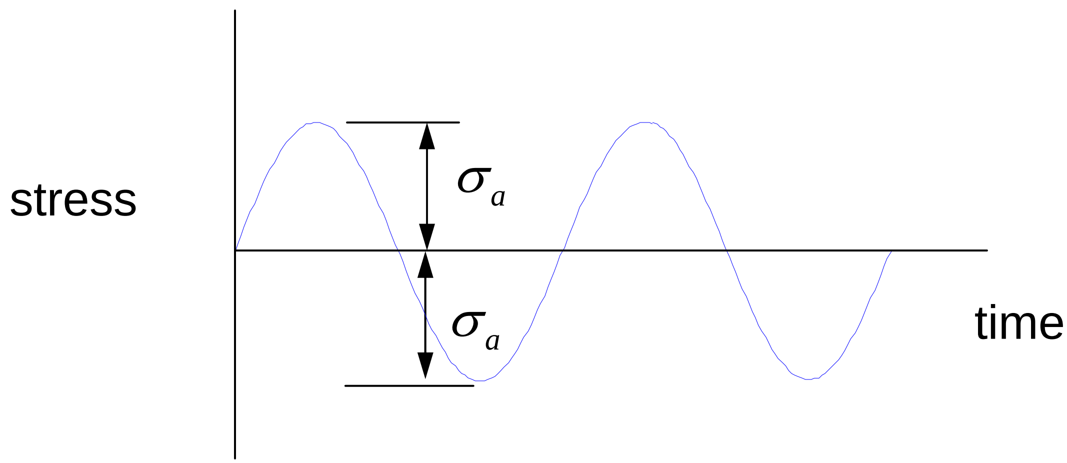
S-N Curve (alternating stress amplitude (S_a) versus number of cycles (N_f) to failure)



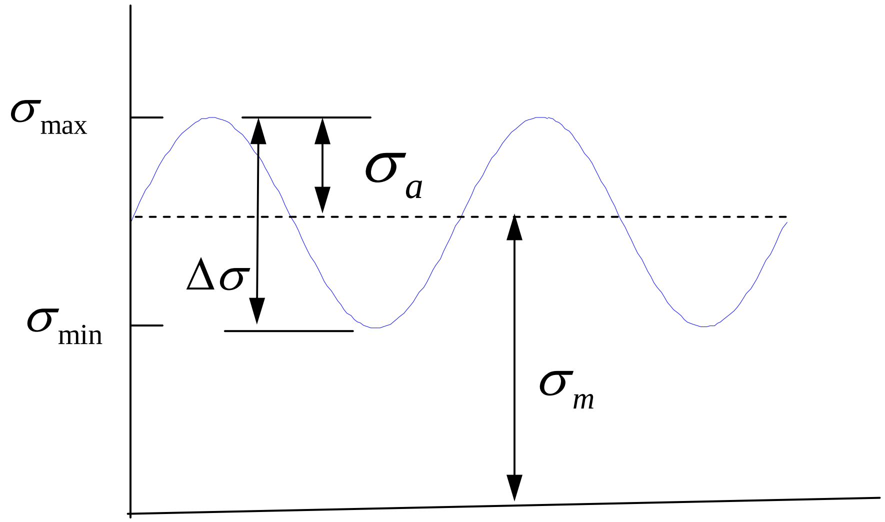
Some materials, such as steel, show an endurance limit stress below which the fatigue life is essentially infinite. Other materials may not show such behavior but an effective endurance limit may be specified at some large number of cycles



S-N testing is done under alternating (completely reversed) loading and stress



Mean Stress Effects



$$\Delta\sigma = \sigma_{\max} - \sigma_{\min}$$ stress range

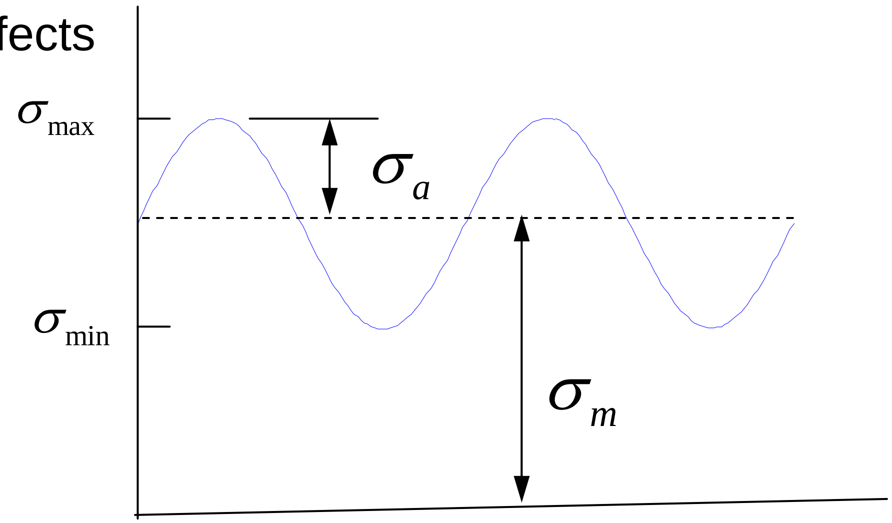
$$\sigma_a = \frac{\Delta\sigma}{2} = \frac{\sigma_{\max} - \sigma_{\min}}{2}$$ alternating stress

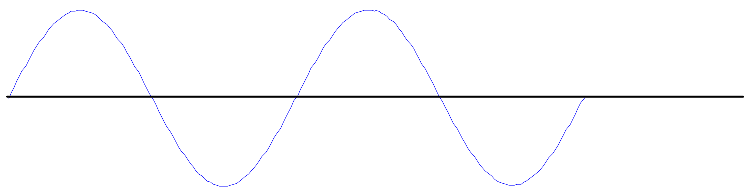
$$\sigma_m = \frac{\sigma_{\max} + \sigma_{\min}}{2}$$ mean stress

Mean Stress Effects

$$R = \frac{\sigma_{min}}{\sigma_{\max}}$$ stress ratio

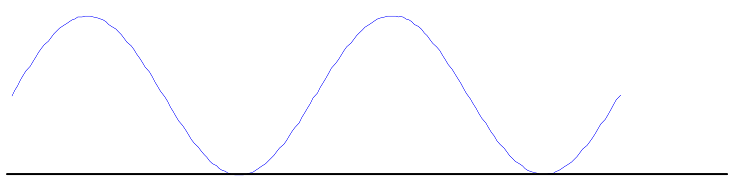
$$A = \frac{\sigma_a}{\sigma_m}$$ amplitude ratio





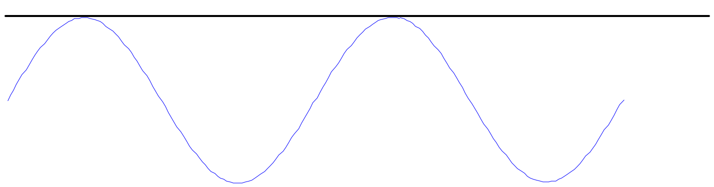
fully reversed

$R = -1 \quad A = \infty$



zero to max

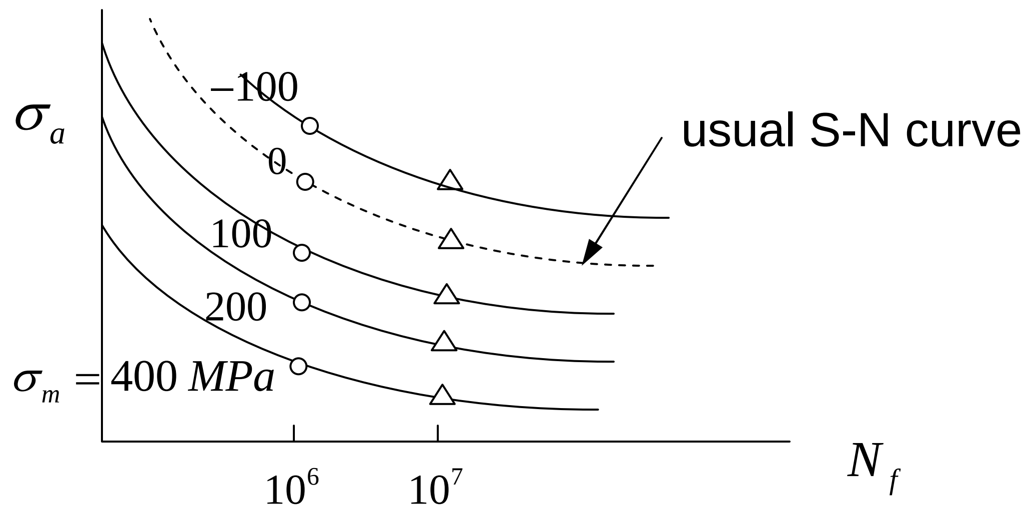
$R = 0 \quad A = 1$



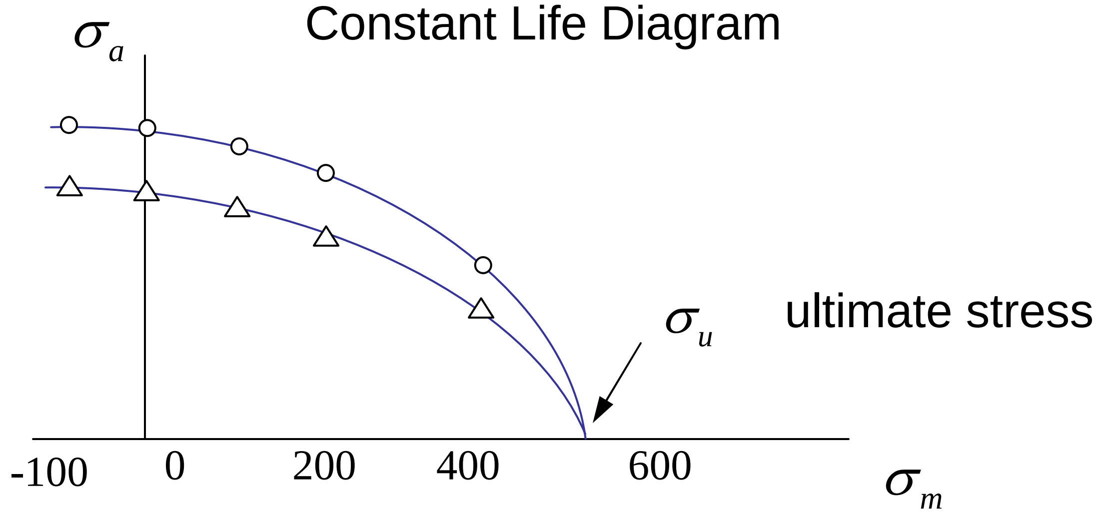
zero to min

$R = \infty \quad A = -1$

Mean Stress Effects



Constant Life Diagram



Empirical curves to estimate mean stress effects on fatigue life

a. Soderberg (USA, 1930) $$\frac{\sigma_a}{\sigma'_e} + \frac{\sigma_m}{\sigma_y} = 1$$

b. Goodman (England, 1899) $$\frac{\sigma_a}{\sigma'_e} + \frac{\sigma_m}{\sigma_u} = 1$$

c. Gerber (Germany, 1874) $$\frac{\sigma_a}{\sigma'_e} + \left(\frac{\sigma_m}{\sigma_u}\right)^2 = 1$$

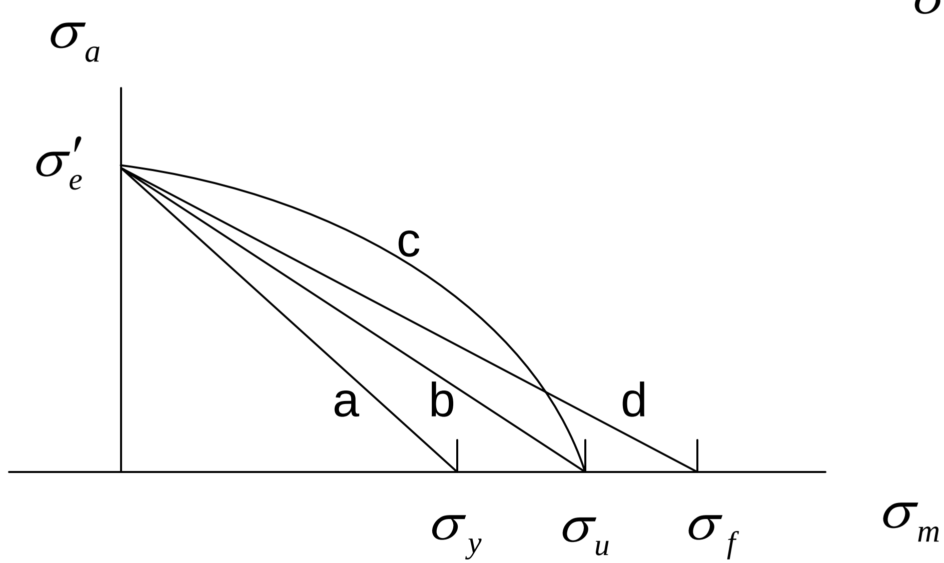
d. Morrow (USA, 1960s) $$\frac{\sigma_a}{\sigma'_e} + \frac{\sigma_m}{\sigma_f} = 1$$

σ_y … yield stress

σ_u … ultimate stress

σ_f … true fracture stress

σ'_e … effective alternating stress at failure for a lifetime of N_f cycles



General observations

1. Most actual test data tend to fall between the Goodman and Gerber curves.

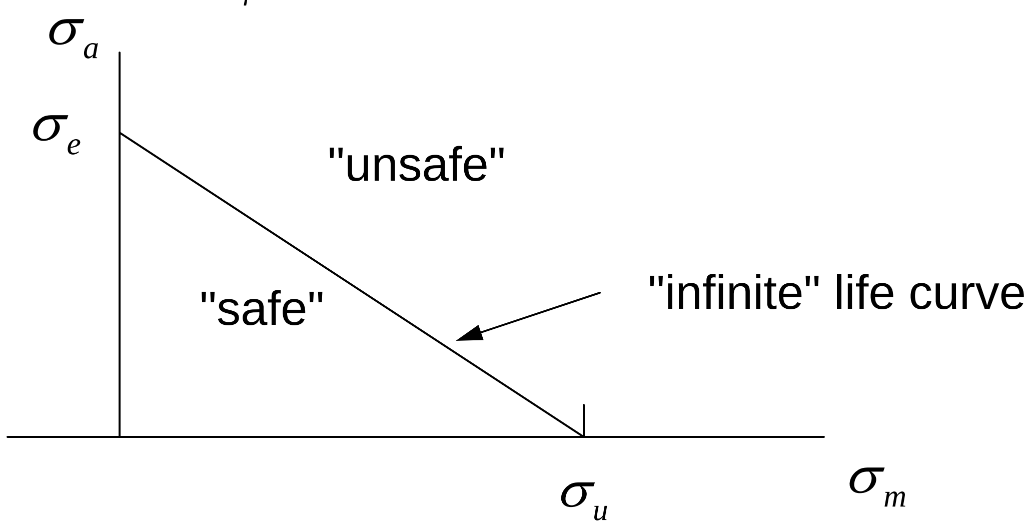
2. For most fatigue situations $R<1$ (i.e. small mean stress in relation to alternating stress), there is little difference in the theories

3. In the range where the theories show large differences (i.e. R values approaching 1) there is little experimental data. In this case the yield stress may set the design limits.

4. The Soderberg line is very conservative and seldom used

Use of empirical curves for an infinite life design

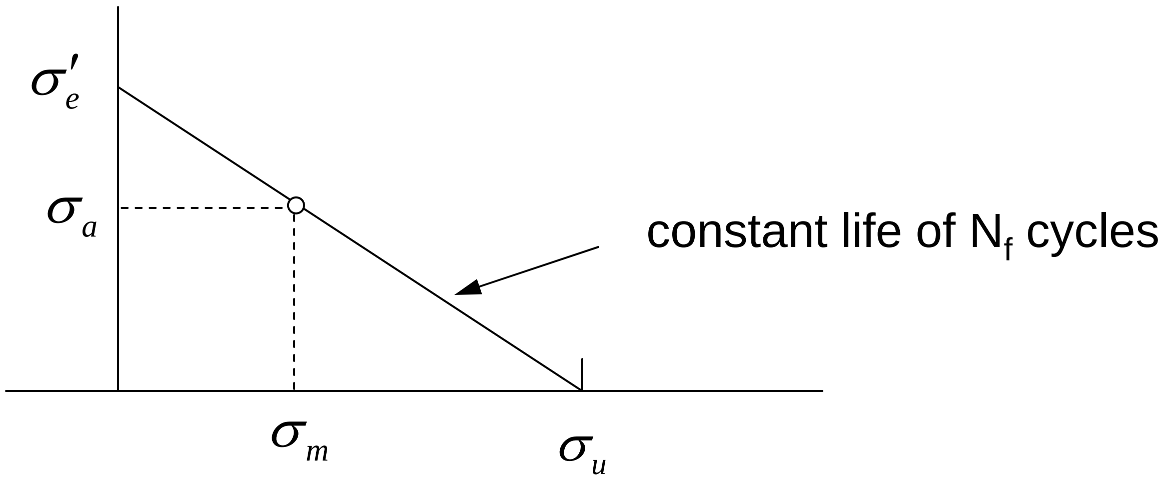
Use a particular curve such as the Goodman with $\sigma_e' = \sigma_e$ (the endurance limit, $N_f = \infty$)



any combination of mean and alternating stresses that are to the left of the curve are deemed safe, those to the right are not

Use of empirical curves and S-N data for an finite life design

1. A given combination of mean and alternating stresses is taken to lie on a constant life curve such as the Goodman line:

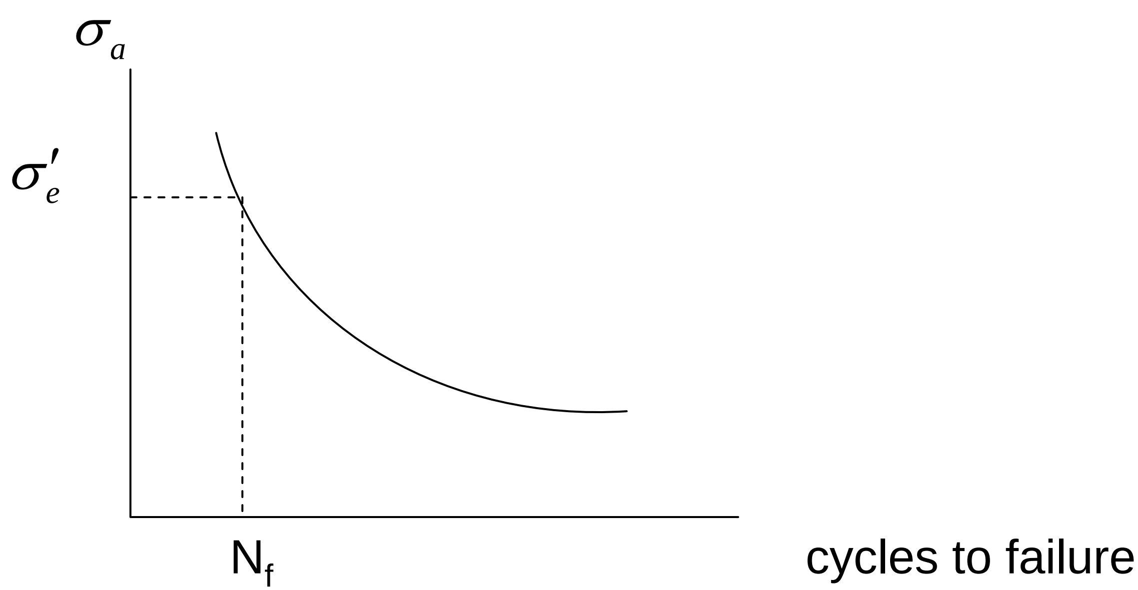


2. That curve is then used to solve for the effective purely alternating stress, σ'_e , that will cause failure at this same lifetime:

$$\frac{\sigma_a}{\sigma'_e} + \frac{\sigma_m}{\sigma_u} = 1$$

solve for

3. Using this effective alternating stress, determine the lifetime for this stress (and the corresponding original alternating and mean stresses) from the S-N diagram for the given material:



Some References on Fatigue Design

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