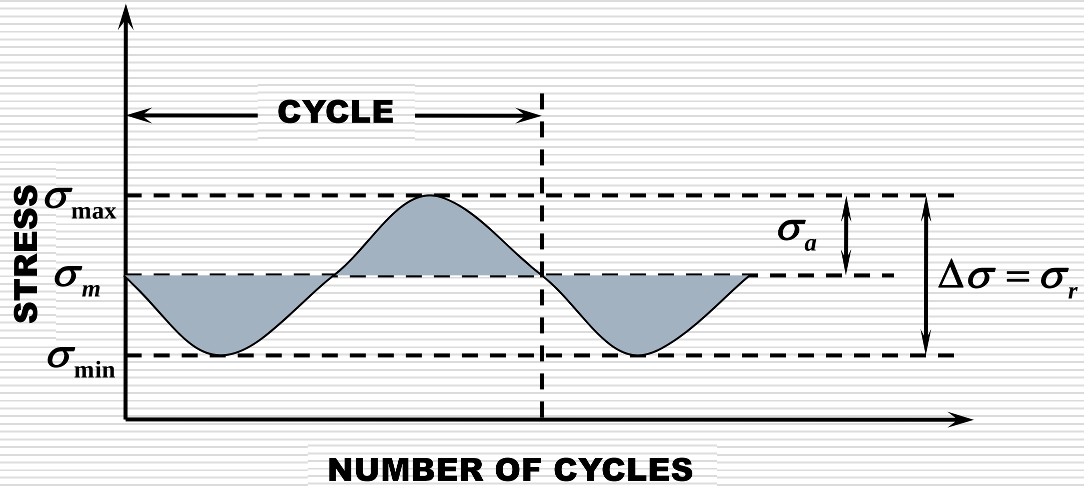
FATIGUE

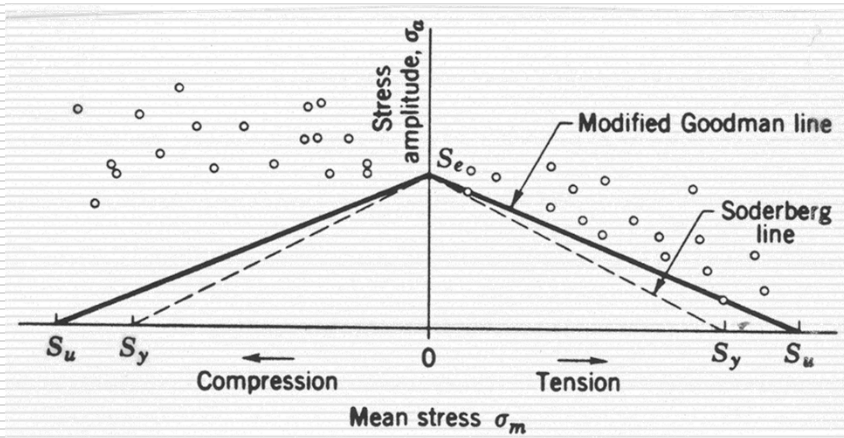
- Fluctuating Stresses

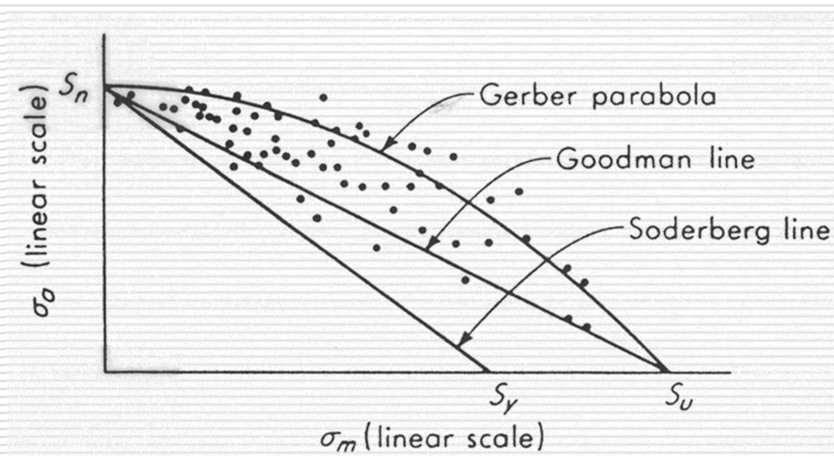
Fatigue Terminology

- Stress
  - σ_{max}, σ_{min}
  - σ_m, σ_a
  - σ_r

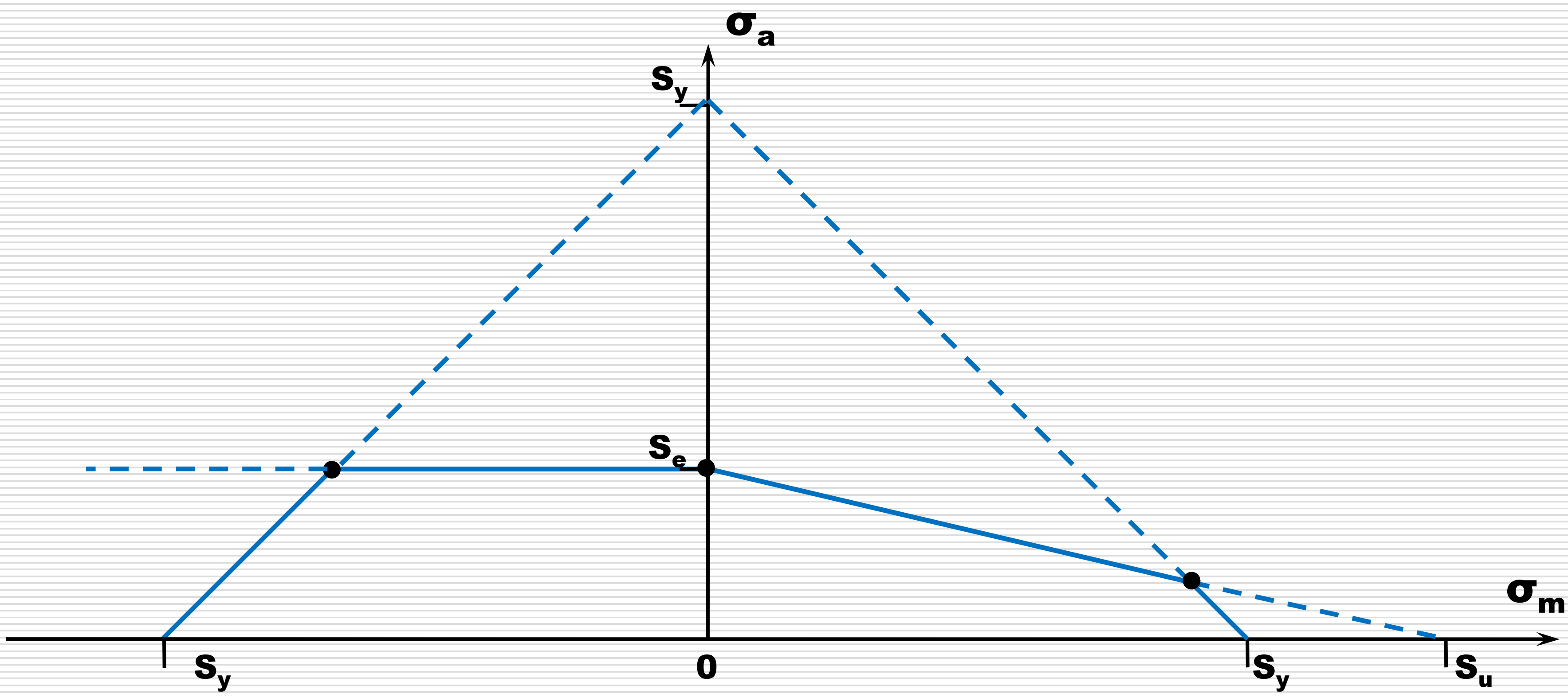


σ_m-σ_a Diagrams for Axial and Bending Loads

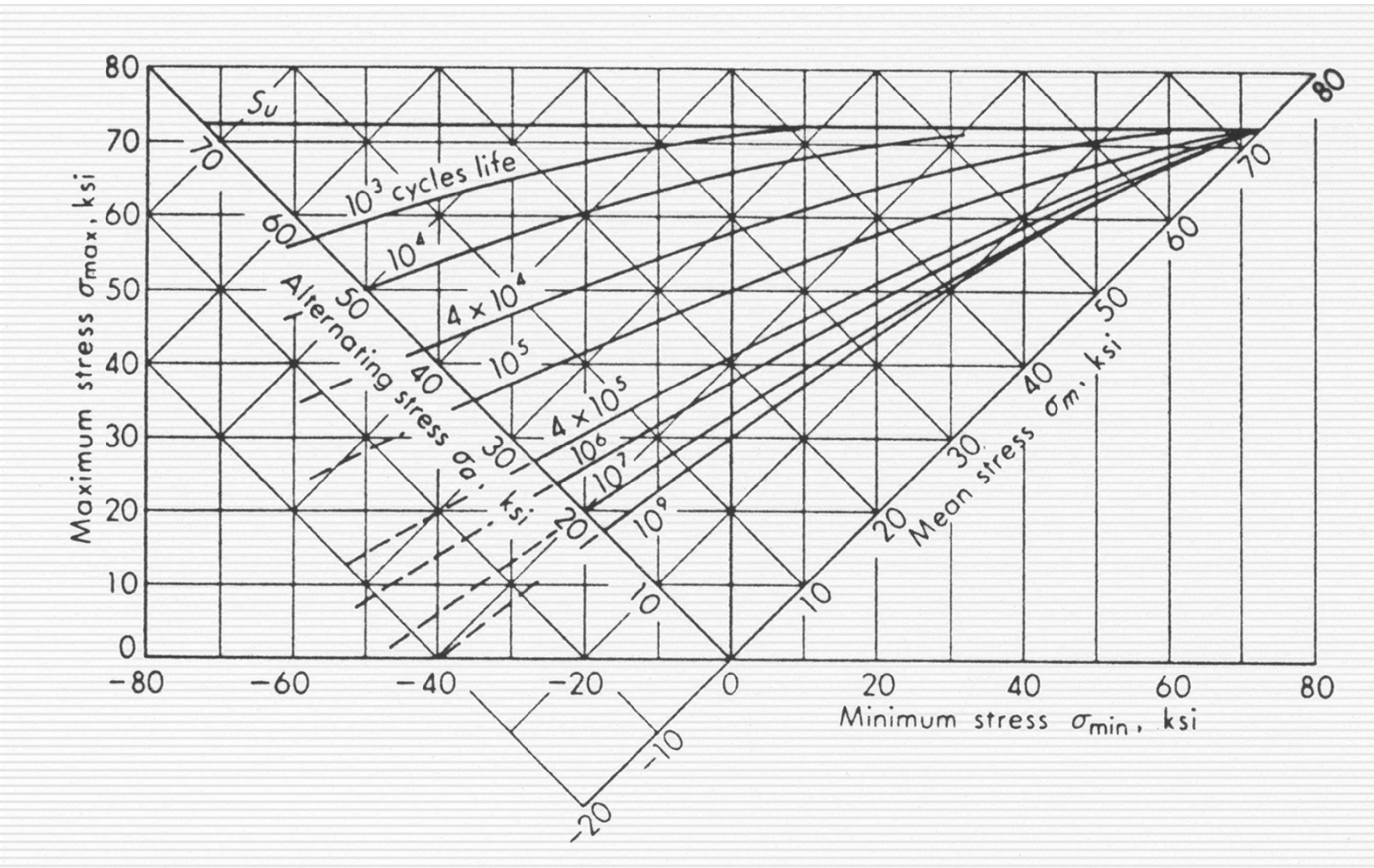




σ_m-σ_a Diagrams, A Closer Look
Modified Goodman Diagram

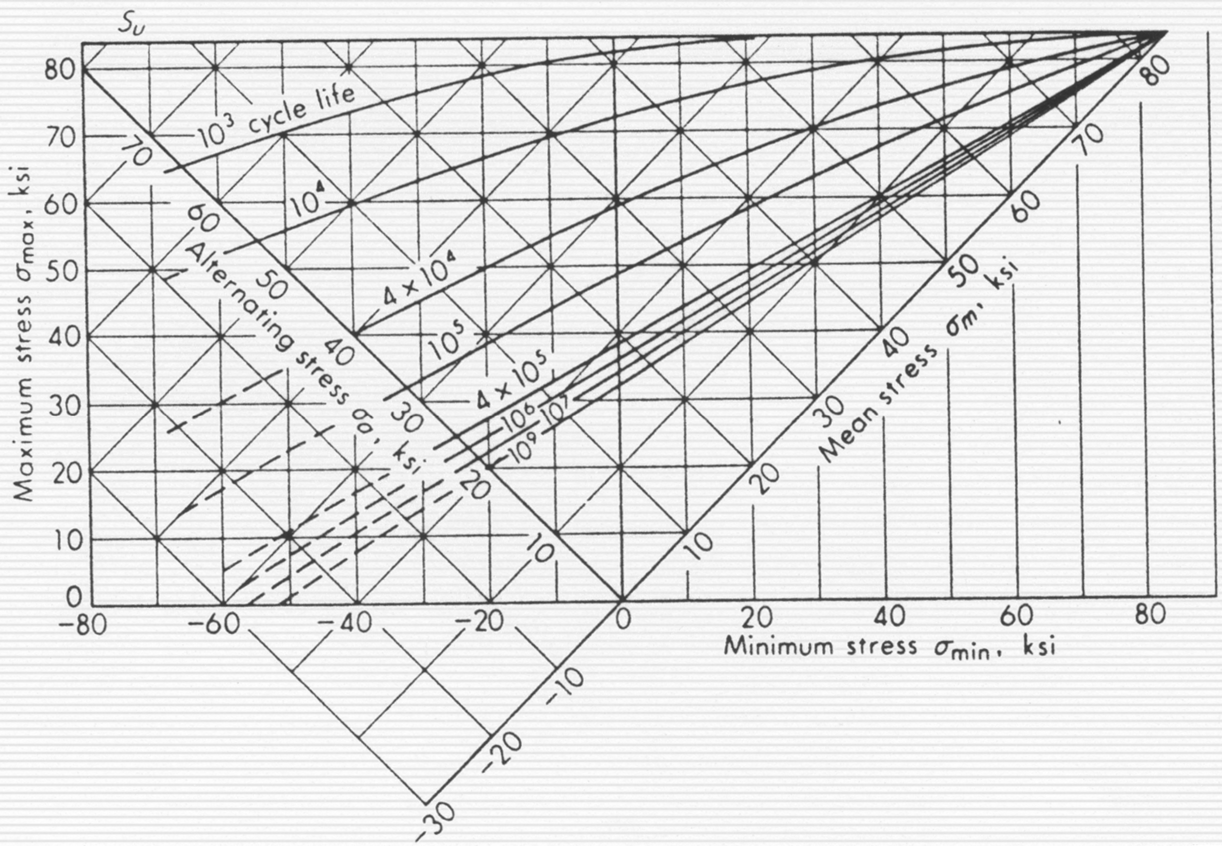


2024 Al



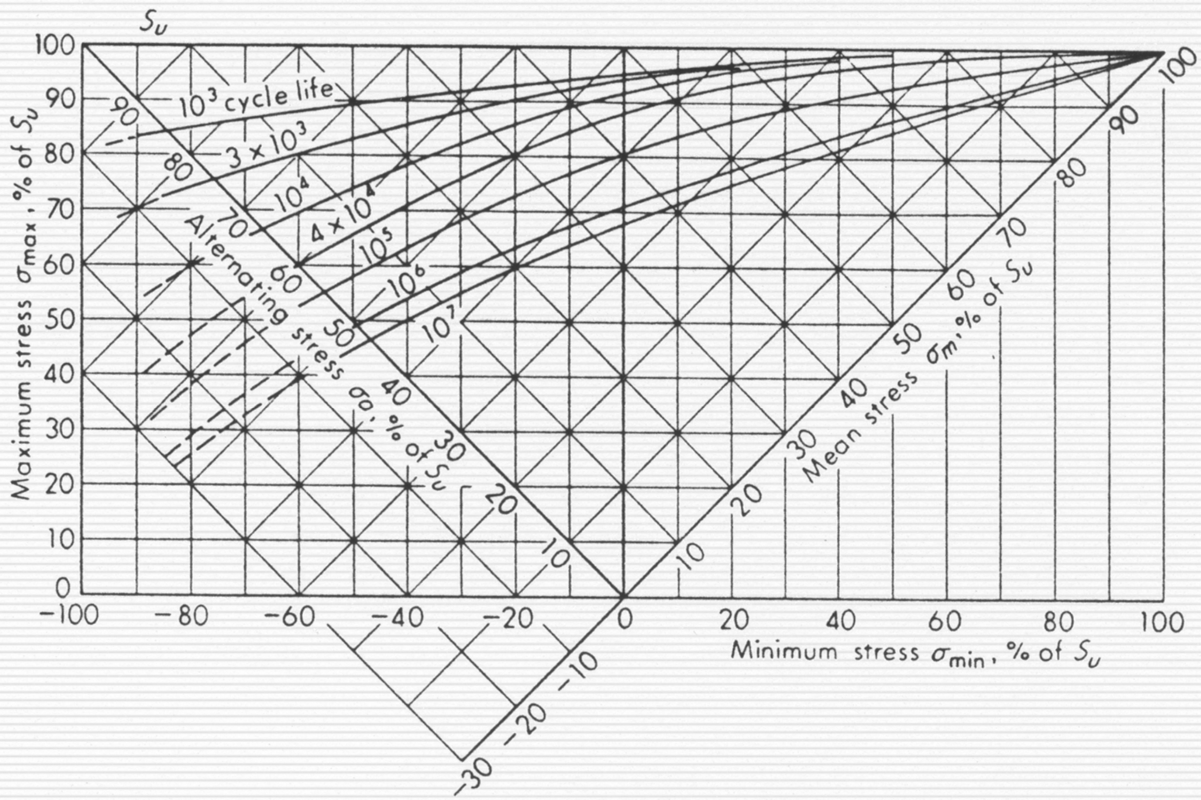
Maximum stress σ_{max}, ksi
Minimum stress σ_{min}, ksi
Mean stress σ_m, ksi
Alternating stress σ_a, ksi
S_u
10^3 cycles life
10^4
4×10^4
10^5
4×10^5
10^6
10^7
10^9

7075 Al



S_U
Maximum stress σ_{max}, ksi
Minimum stress σ_{min}, ksi
Alternating stress σ_a, ksi
Mean stress σ_m, ksi
10^3 cycle life
10^4
4×10^4
10^5
4×10^5
10^6
10^7
10^9

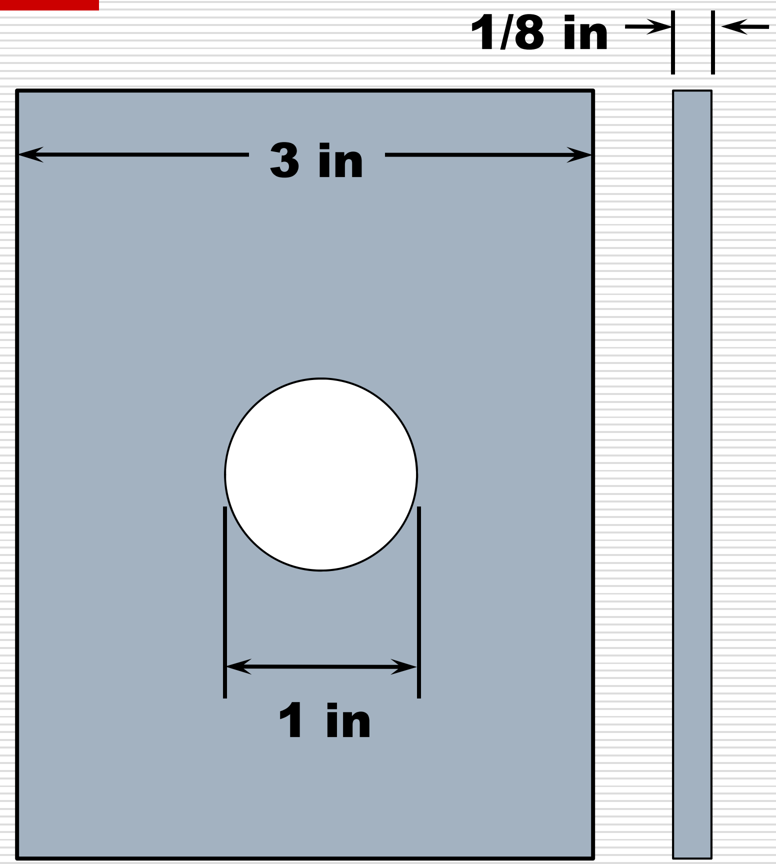
Steel



S_u
10^3 cycle life
3×10^3
10^4
4×10^4
10^5
10^6
10^7
Maximum stress σ_{max}, % of S_u
Alternating stress σ_a, % of S_u
Mean stress σ_m, % of S_u
Minimum stress σ_{min}, % of S_u
100
90
80
70
60
50
40
30
20
10
0
−100
−80
−60
−40
−20
−10
−30

Example

A part made of 1/8in thick 7075-T6 aluminum alloy. It is subjected to a tensile load that fluctuates between 1000 and 5000lb. Determine its estimated life.



Example

It is desired to determine the size of a UNS G10500 cold drawn steel bar to withstand a tensile preload of 8kips and a fluctuating tensile load varying from 0 to 16kips. Owing to the design of the ends, the bar will have a geometric stress concentration factor of 2.02 corresponding to a fillet whose radius is 3/16in. Determine a suitable diameter for an infinite life and a factor of safety of at least 2.0.

Fatigue Failure Due to Combined Stresses

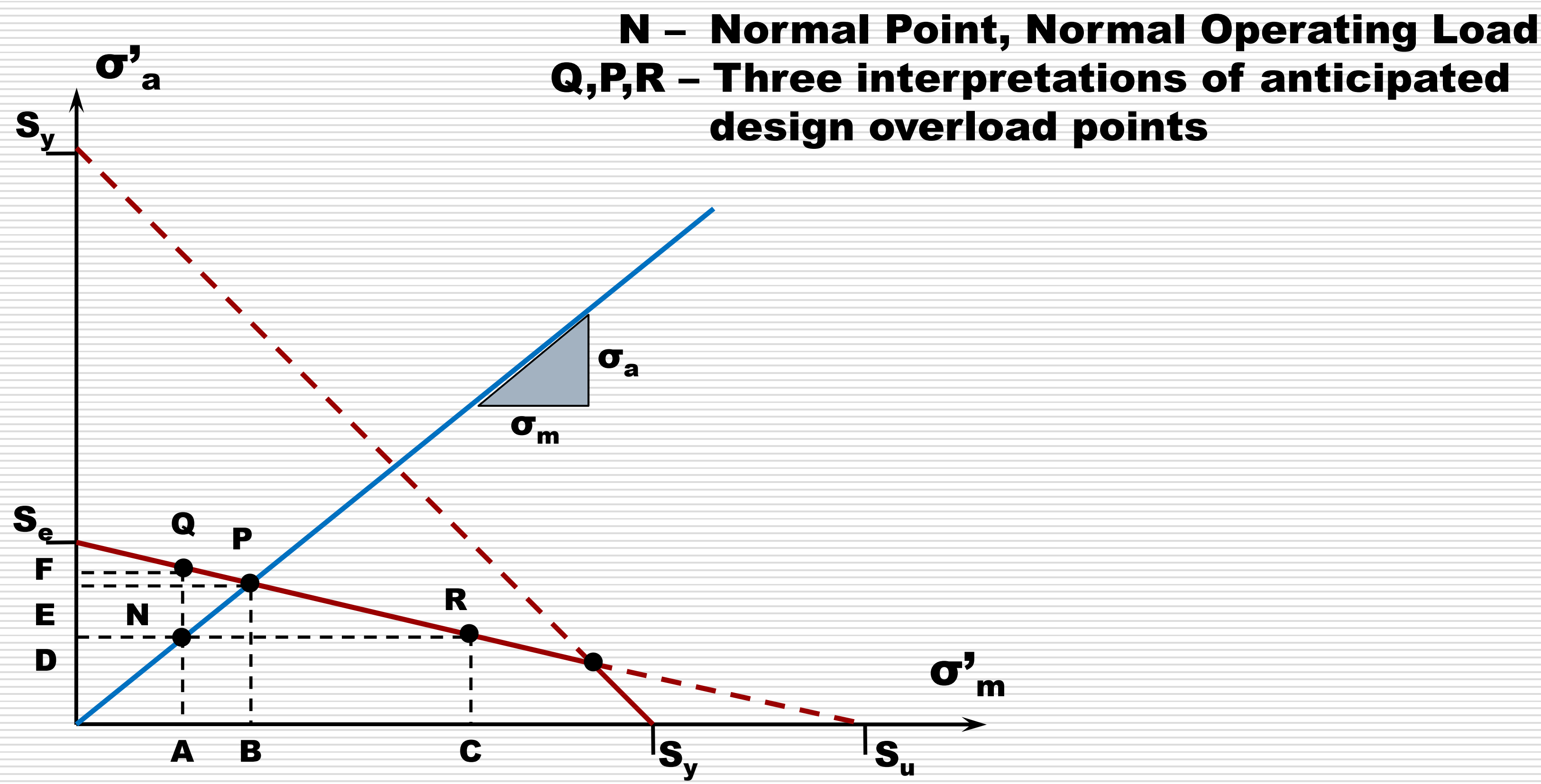
- Distortional Energy Method
  - Mean von Mises Stresses

$$\sigma_{vM,m} = \sqrt{\frac{1}{2} \cdot \left[\left(\sigma_{1,m} - \sigma_{2,m} \right)^2 + \left(\sigma_{2,m} - \sigma_{3,m} \right)^2 + \left(\sigma_{3,m} - \sigma_{1,m} \right)^2 \right]}$$

  - Alternating von Mises Stresses

$$\sigma_{vM,a} = \sqrt{\frac{1}{2} \cdot \left[\left(\sigma_{1,a} - \sigma_{2,a} \right)^2 + \left(\sigma_{2,a} - \sigma_{3,a} \right)^2 + \left(\sigma_{3,a} - \sigma_{1,a} \right)^2 \right]}$$

Factor of Safety: Three Interpretations



Example

A bar of steel has S_u=700MPa, S_y=500MPa, and a fully corrected endurance limit of S_3=200MPa. For each case below find the factor of safety which guards against static and fatigue failures.

1. $\tau_m = 140MPa$
2. $\tau_m = 140MPa, \quad \tau_a = 70MPa$
3. $\tau_{xy,m} = 100MPa, \quad \sigma_{x,a} = 80MPa$
4. $\sigma_{x,m} = 60MPa, \quad \sigma_{x,a} = 80MPa$

   $\tau_{xy,m} = 70Mpa, \quad \tau_{xy,a} = 35MPa$