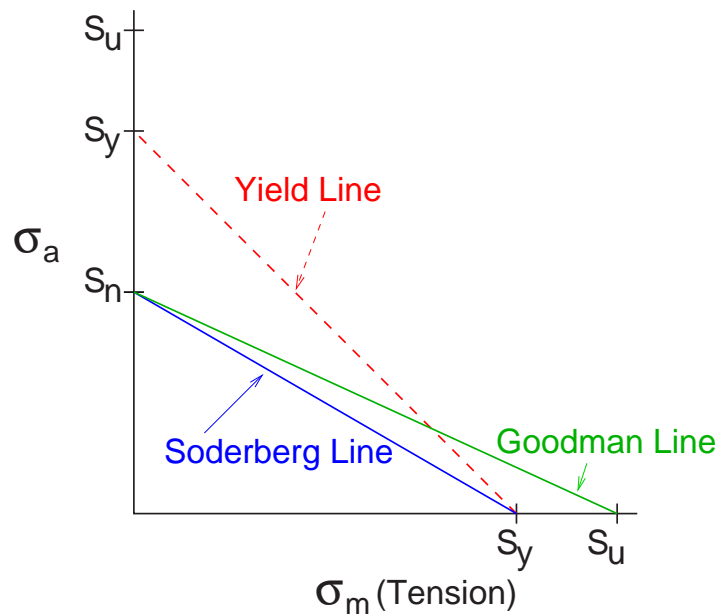

1 3rd Year Design and Production

Fatigue – Lecture 4

2 Constant Life Fatigue Diagrams



3 Constant Life Fatigue Diagrams

3.1 Equations

- Soderberg Line is based on S_y and S_n

$$\rightarrow S_a/S_n + S_m/S_y = 1$$

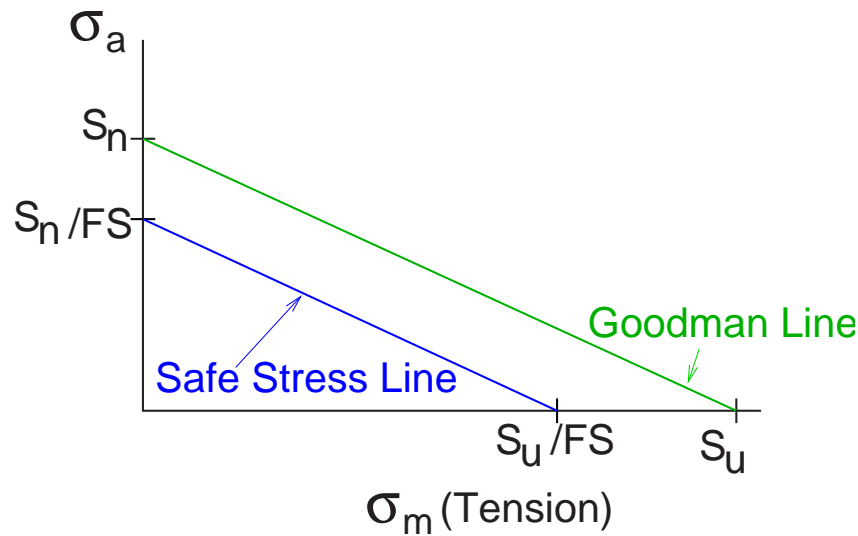
- Goodman Line is based on S_u and S_n

$$\rightarrow S_a/S_n + S_m/S_u = 1$$

4 Factor of Safety

- Illustrated here for Goodman Criteria (can use Soderberg, etc., also).
- FS is the factor of safety
- Safe stress line is parallel to original Goodman line

$$\frac{S_a}{S_n} + \frac{S_m}{S_u} = \frac{1}{FS}$$



5 Summary of CLF Diagrams

- Four straight lines relevant for infinite life:
 - Soderberg, Goodman, Yield-line, Load-line
 - Which failure criteria to use?:
 - If no yielding allowed, Soderberg will be conservative
 - If we don't know S_u , then use Soderberg
 - If S_u is known, and we want to find infinite life, with yielding permitted, then use Goodman line
 - If S_u is known, and we want to find infinite life, with yield onset permitted, then use Goodman line and yield line to define the safe zone (Modified Goodman Criterion).
-

6 Stress Concentration – Geometry

- Surface features and flaws can lead to locally elevated stresses
- Tables/charts allow us to look up K_t
 - Theoretical or Geometric stress concentration factors
- Materials have different **notch sensitivities**: q
 - Material with a lot of flaws already are not damaged much by one more
⇒ low notch sensitivity
 - Very perfect material is significantly damaged by addition of a notch or flaw
⇒ high notch sensitivity
- Calculate **Fatigue Stress Concentration Factor** K_f using K_t and q :

$$K_f = 1 + q(K_t - 1)$$

7 Stress Concentration

Now that we have K_f what do we do with it?

- Ductile Materials
 - Nominal Mean Stress Method
 - Apply K_f only to alternating stress
 - Brittle Materials
 - Residual Stress Method
 - Apply K_f to both alternating stress and mean stress
-

8 Stress Concentration

8.1 Applied to Goodman Criteria

- Nominal Mean Stress Method (ductile material)

Apply K_f only to alternating component

$$\frac{[K_f S_a]}{S_n} + \frac{S_m}{S_u} = \frac{1}{FS}$$

- Residual Stress Method (brittle material; adjust for yielding and resultant residual stress if predicted stress $> S_y$)

Apply K_f to alternating **and** mean components

$$\frac{[K_f S_a]}{S_n} + \frac{[K_f S_m]}{S_u} = \frac{1}{FS}$$

Different texts will make different recommendations on this.

9 Equivalent Stress Equations

To account for situation where there is a combination of bending, shear, and/or axial stresses it is necessary to determine the equivalent stress that is created. Different forms are possible. . .

- Maximum Shear Stress

$$\tau_{\max} = \sqrt{\left(\frac{\sigma_{\text{eq}}}{2}\right)^2 + \tau_{\text{eq}}^2}$$

- Maximum Normal/Principle Stress

$$\sigma_{\max} = \frac{\sigma_{\text{eq}}}{2} + \sqrt{\left(\frac{\sigma_{\text{eq}}}{2}\right)^2 + \tau_{\text{eq}}^2}$$

- Von-Mises / Distortion Energy Theory

$$\sigma_{\max} = \sqrt{\sigma_{\text{eq}}^2 + 3\tau_{\text{eq}}^2}$$

10 Equivalent Stress Equations

10.1 How to Use these Relations

Juvinall recommends the following policy:

- Find the **equivalent alternating bending stress** using distortion energy theory as:

$$\sigma_{ea} = \sqrt{\sigma_a^2 + 3\tau_a^2}$$

- Find the **equivalent mean bending stress** as the maximum principle stress:

$$\sigma_{em} = \frac{\sigma_m}{2} + \sqrt{\left(\frac{\sigma_m}{2}\right)^2 + \tau_m^2}$$

Shigley recommends the application of the distortion energy equation to both alternating and mean stresses.
