FATIGUE FAILURE CRITERIA

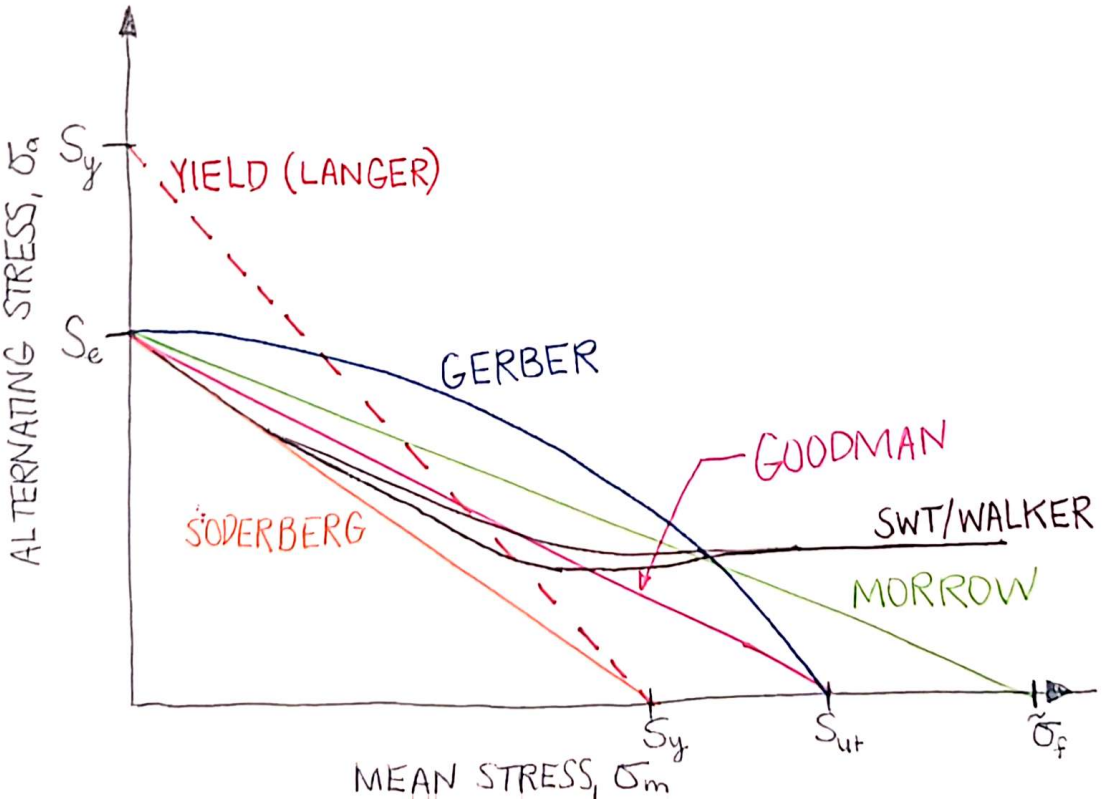
THE S-N DIAGRAM IS NORMALLY GENERATED WITH COMPLETELY REVERSED STRESSES ($\sigma_m = 0$).

WE WANT TO DETERMINE THE EXPECTED LIFE OF A COMPONENT FOR ANY GIVEN COMBINATION OF MEAN AND ALTERNATING STRESS.

FIRST, WE CHECK IF INFINITE LIFE IS EXPECTED.

- FOR COMPLETELY REVERSED LOADING ($\sigma_m = 0$), FAILURE IS PREDICTED AT THE ENDURANCE LIMIT (S_e).
- FOR STATIC LOADING ($\sigma_a = 0$), FAILURE IS PREDICTED AT THE MATERIAL'S YIELD STRENGTH (S_y), ULTIMATE STRENGTH (S_{ut}) OR TRUE FRACTURE STRENGTH ($\tilde{\sigma}_f$).

THERE ARE MANY THEORIES THAT CAN BE USED TO REPRESENT THE INFINITE LIFE BOUNDARY FOR VARIOUS COMBINATIONS OF σ_a AND σ_m.



YIELD (LANGER)

EVEN IF INFINITE LIFE IS PREDICTED, IT IS NECESSARY TO CHECK FOR FIRST-CYCLE YIELDING. COMPARING THE MAXIMUM STRESS TO THE YIELD STRESS, WE FIND THE FACTOR OF SAFETY GUARDING AGAINST YIELD TO BE

$$n_y = \frac{S_y}{\sigma_{max}} = \frac{S_y}{\sigma_a + |\sigma_m|}$$

GOODMAN

THE GOODMAN LINE IS SIMPLE, CONSERVATIVE AND COMMONLY USED FOR DESIGN PURPOSES.

FOR $\sigma_m > 0$, THE FACTOR OF SAFETY FOR INFINITE LIFE IS

$$\frac{1}{n_f} = \frac{\sigma_a}{S_e} + \frac{\sigma_m}{S_{ut}}$$

FOR $\sigma_m < 0$, EXPERIMENTS HAVE SHOWN THAT COMPRESSIVE MEAN STRESS IS NOT DETRIMENTAL TO FATIGUE LIFE. IN THIS CASE, THE FACTOR OF SAFETY FOR INFINITE LIFE IS

$$n_f = \frac{S_e}{\sigma_a}$$

MORROW

THE MORROW LINE IS IDENTICAL IN NATURE TO THE GOODMAN LINE, EXCEPT THAT IT REPLACES THE ULTIMATE STRENGTH WITH THE TRUE FRACTURE STRENGTH $\tilde{\sigma}_f$ OR THE FATIGUE STRENGTH COEFFICIENT σ_f'. IT TENDS TO GIVE A BETTER, LESS CONSERVATIVE FIT TO THE DATA AS COMPARED TO THE GOODMAN LINE. THE FACTOR OF SAFETY FOR INFINITE LIFE IS

$$\frac{1}{n_f} = \frac{\sigma_a}{S_e} + \frac{\sigma_m}{\tilde{\sigma}_f} \quad \text{OR} \quad \frac{1}{n_f} = \frac{\sigma_a}{S_e} + \frac{\sigma_m}{\sigma_f'}$$

IF NEEDED, A CRUDE ESTIMATE OF σ_f' FOR STEELS ($HB \leq 500$) IS GIVEN BY THE SAE FATIGUE DESIGN HANDBOOK:

$$\sigma_f' = S_{ut} + 50 \text{ ksi} \quad \text{OR} \quad \sigma_f' = S_{ut} + 345 \text{ MPa}$$

HOWEVER, IF THIS ESTIMATE IS USED, THE CURVE COULD BE ANYWHERE BETWEEN CONSERVATIVE AND NONCONSERVATIVE.

WE WILL FOCUS OUR ATTENTION ON THE GOODMAN CRITERIA, BUT EACH OF THE CRITERIA LABELED IN THE FIGURE HAS VALUE FOR DIFFERENT APPLICATIONS.

FATIGUE FAILURE ANALYSIS

THE GENERAL RECIPE TO PERFORM FATIGUE FAILURE ANALYSIS IS:

1. DETERMINE THE LIFE OF THE COMPONENT
   (a) IS INFINITE LIFE PREDICTED? IF SO, FIND THE FACTOR OF SAFETY FOR INFINITE LIFE (n_f).
   (b) IF INFINITE LIFE IS NOT PREDICTED ($n_f < 1$), FIND THE PREDICTED NUMBER OF CYCLES TO FAILURE.
2. CHECK FOR FIRST-CYCLE YIELDING.