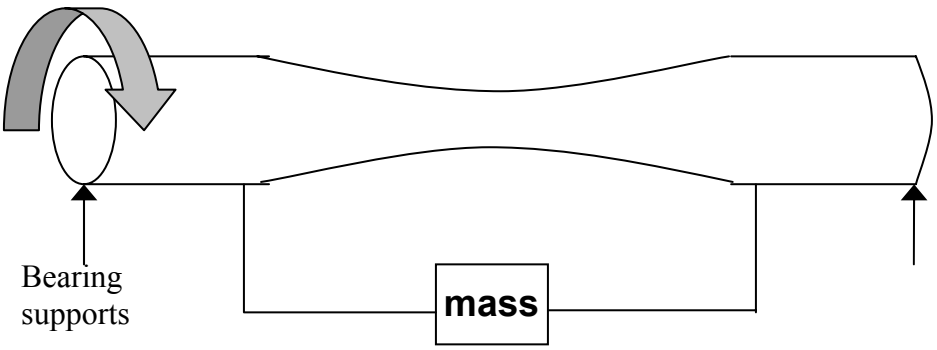
FATIGUE

Fatigue – fracture that occurs due to a repeated, cyclic stress.

- Yielding is required to initiate a fatigue crack
- Fatigue cracking begins locally at stress concentrations
- Cracks can grow slowly over time at $\sigma_{nom}<S_y$ until $K>K_{IC}$ or $\sigma_{reduced}>S_u$. Can result in unexpected, catastrophic failure!

Measuring the Fatigue Strength of Materials

Rotating Beam Fatigue Test is the baseline fatigue data published for many materials



Test conditions:

At a point on the outer surface:

How do you calculate the maximum stress in the specimen?

Stress as a function of time at a point on the outer surface:

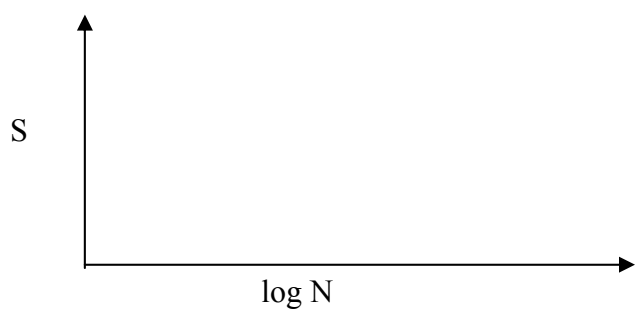
$$mean\ stress = \sigma_m = \frac{\sigma_{\max} + \sigma_{\min}}{2}$$

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

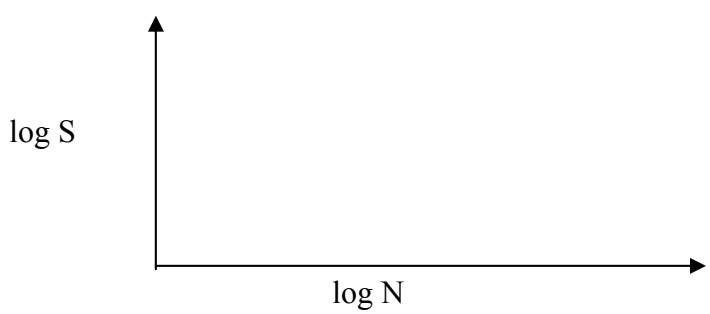
$$stress\ ratio = R = \frac{\sigma_{\min}}{\sigma_{\max}}$$

For rotating beam:
$\sigma_m =$
$\sigma_a =$
$R =$

Test procedure:
-For a given mass measure number of cycles (N) until failure for each.
-Use mass to calculate the stress that caused failure in each case (S).
-Plot S versus N to obtain "S-N curve"



$S = \sigma_{max}$ that results in failure at a particular number of cycles; called *fatigue strength*



S'_n = endurance limit = stress below which fatigue failure will not occur. Not observed in all materials.

Fatigue Strength Information for Various Materials

- Experimental data obtained under simulated or actual service conditions is best.
- Handbooks like MIL-HDBK-5H tabulate S-N fatigue data for various materials.

STEELS

- Endurance limit is observed at 10^6 cycles; below this stress value you obtain "infinite life".
- Endurance limit (S'_n) scales with S_u. For steel with *Brinell hardness less than 400:*

$$S'_n = 0.5S_u$$

Recall that for steels S_u (ksi) = 0.5(Brinell hardness)

- Low cycle fatigue strength (S at 10^3 cycles) scales with S_u:

$$S = 0.9S_u$$

- For Brinell hardness greater than 400 see Fig. 8.6 in text.

ALUMINUM ALLOYS

- There is no sharply defined endurance limit for these alloys. Therefore, the fatigue strength at $5x10^8$ or 10^8 cycles is commonly used for "infinite life".
- See Figures 8.8, 8.9 in text.

OTHERS

- See Fig. 8.10 for magnesium alloys.

Next topic: How do we use this data for design?