1 3rd Year Design and Production

Fatigue – Lecture 2

2 Fatigue

2.1 Revision

Fatigue occurs under the action of **fluctuating loads**

- Global stress may be low but at local points it can be high
  - Stress concentrators: e.g. damage, material flaw, geometric feature
- High local stress leads to plastic failure $\Rightarrow$ permanent damage
- Damage is small, but accumulates over repeated cycles and crack grows
- Ultimate failure is generally sudden and catastrophic
  - Fracture occurs in brittle manner, little distortion prior to fracture.

3 SN Curve

3.1 Testing

Typically we characterise fatigue using the SN curve, with data obtained from an R. R. Moore rotating beam test:

4 Fatigue

4.1 SN Curve

The failure load is plotted as a function of the number of cycles to failure (log) as shown. Note, the scatter in fatigue strength for a given life is small, but that the scatter in fatigue life for a given stress is large.

5 Fatigue

5.1 Approximated SN Curve

We can estimate the SN curve if we know the ultimate tensil strength. We can estimate the ultimate tensile strength if

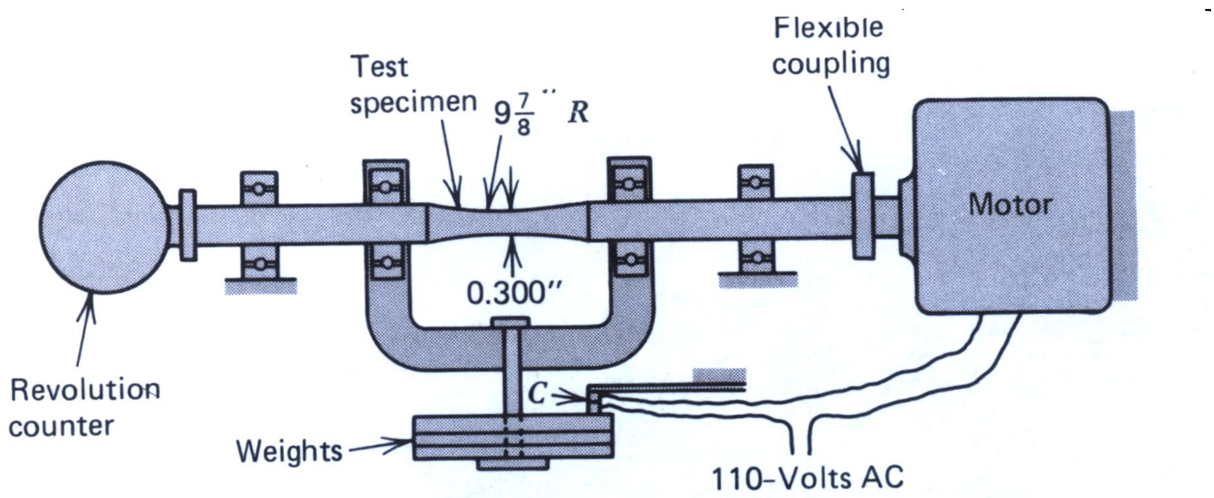

Figure 8.3 R. R. Moore rotating-beam fatigue-testing machine.

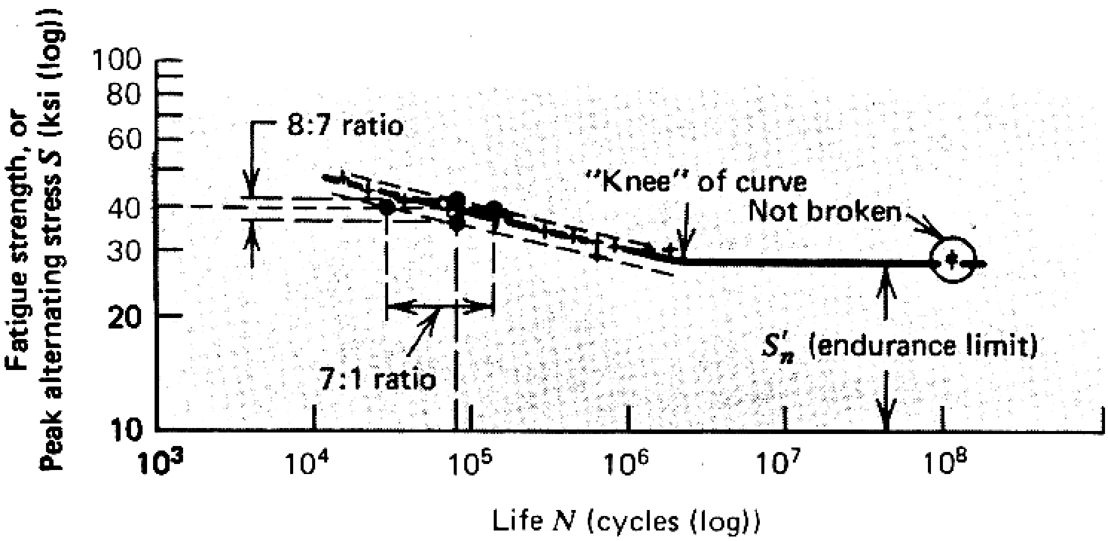

Figure 1: Representative S–N curve for 120 Bhn steel

we know Brinell Harness.

6 Fatigue

6.1 SN Curve Approximations

For Steel we approximate SN curve as

- $S_3 \approx (0.9)(S_u)$
- $S'_n \approx (0.5)(S_u)$

We can estimate S_u as

- $S_u = 0.450 \times$ Brinell Hardness (kpsi)
- $S_u = 3.1 \times$ Brinell Hardness (MPa)
- Valid for Bhn ≤ 400, though **may** apply at higher hardnesses

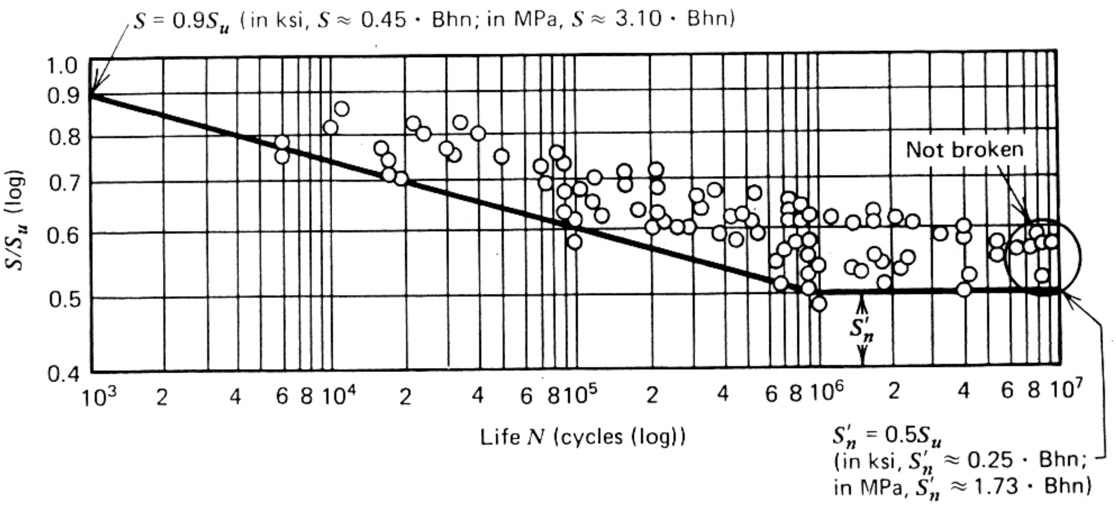

Figure 2: Generalized S–N curve for wrought steel with superimposed data points

Note 1 kpsi=6.890 MPa

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7 Fatigue

7.1 Dependence of S'_n on Hardness

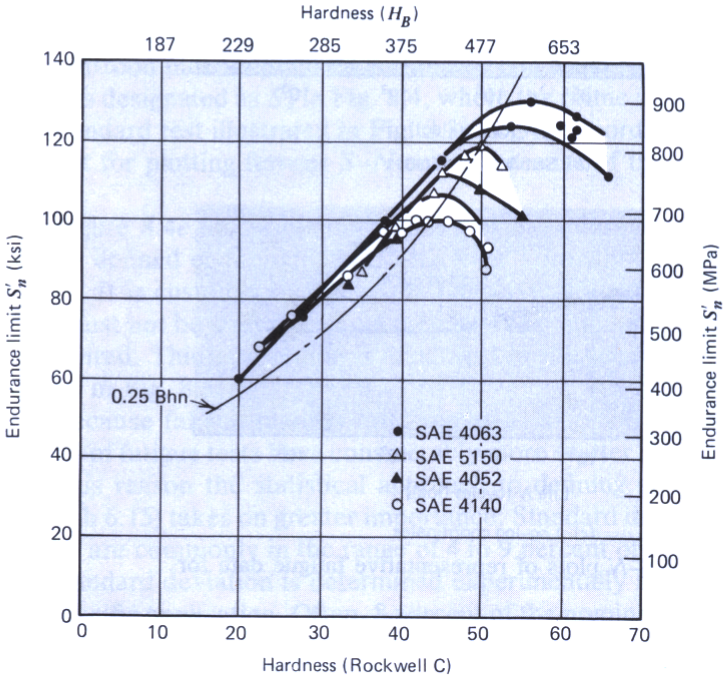

Figure 8.6 Endurance limit versus hardness for four alloy steels. (From M. F. Garwood, H. H. Zarburg, and M. A. Erickson, *Interpretation of Tests and Correlation with Service*, American Society for Metals, 1951, p. 13.)

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8 Actual Fatigue Strength

The actual fatigue strength of a **component** depends on mode of loading, surface finish, component dimension, etc., Typically we use an expression like

$$S_n = S'_n C_L C_G C_S$$

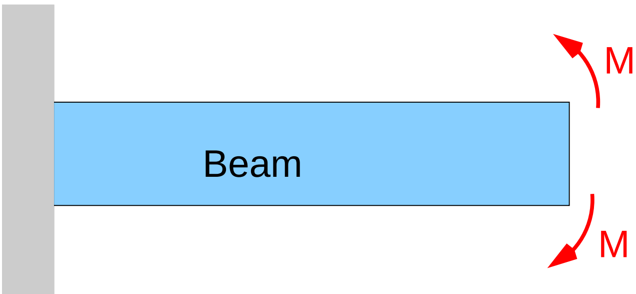
- S_n is the actual (calculated) fatigue strength
- S'_n is data from SN curve (experiment or estimate)
- C_L modifying factor for **loading type**
- C_G modifying factor for **gradient/size**
- C_S modifying factor for **surface finish**

In general $S_n < S'_n$

9 Loading

9.1 Reversed Bending

Clamp one end, and apply up and down loading on the other end

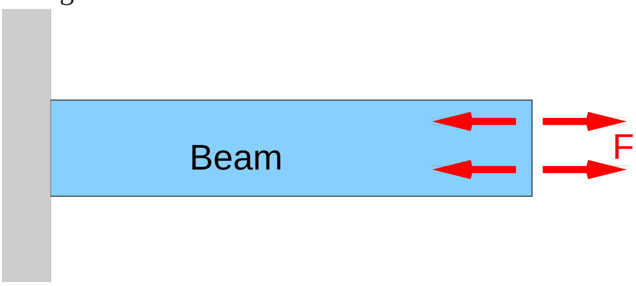


Different to the rotating bending of the R. R. Moore test
What will effect be?
Slight increase in fatigue strength, usually ignored

10 Loading

10.1 Reversed Axial Loading

Again, different to rotating bending



Effect is to reduce fatigue strength (about 10%). Usually this is conservatively factored in as a 20–30% reduction.

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11 Loading

11.1 Reversed Torsional Loading

- Fatigue is associated with localised yielding
- Yielding of ductile materials correlates with the distortion energy theory
- $\Rightarrow$ Endurance Limit is 58% of that found for reversed bending
- 10^3 limit is 0.9 times the ultimate **shear strength**,
  - $S_{us} \approx 0.8S_u$ for steel
  - $S_{us} \approx 0.7S_u$ for other ductile metals

12 Correction Factors

12.1 Dimension/Gradient Factor

- Reflects the effect of changes in the dimension of a component
- Thinner sections have more favourable stress gradients
- Thicker sections have poorer gradients $\Rightarrow$ reduce the estimate of endurance limit
  - Thicker relative to R. R. Moore sample's 0.3 inch diameter.
- V. thick specimens also suffer due to heat treatment flaws etc.,

12.2 Surface Finish

Surface finish and material strength combine to give another correction factor.

13 Surface Finish