MSE 527 Lab
Mechanical Behavior of Materials

Fall 2019

Website for lecture and lab

http://www.csun.edu/~bavarian/mse_527.htm

MSE 527 - Mechanical Behavior of Materials

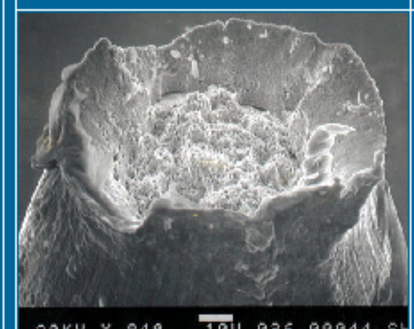
Fall 2011Course Syllabus
Fall 2011 Lab Syllabus
ABET

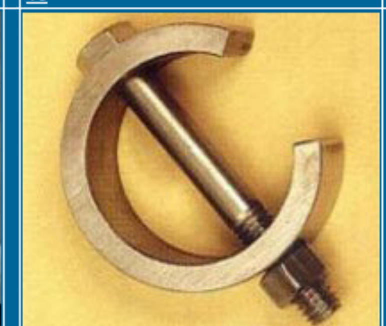
Lectures

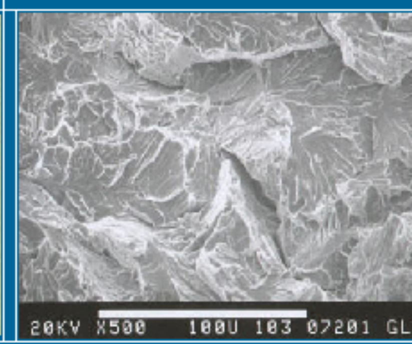
Lecture 1
Dislocations
Plastic Deformation
Strengthening
High Temperature Behavior of Materials
Introduction to Fracture Mechanics
Fracture Toughness
Fatigue Crack Growth
Crack Interaction with Microstructure - Ch 10

Labs

Lab Introduction
Tension Test
Impact Test
Scanning Electron Microscope (SEM)
Metallographic Preparation
Magnesium Deformation







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This site was last updated 08/23/11.

LABS

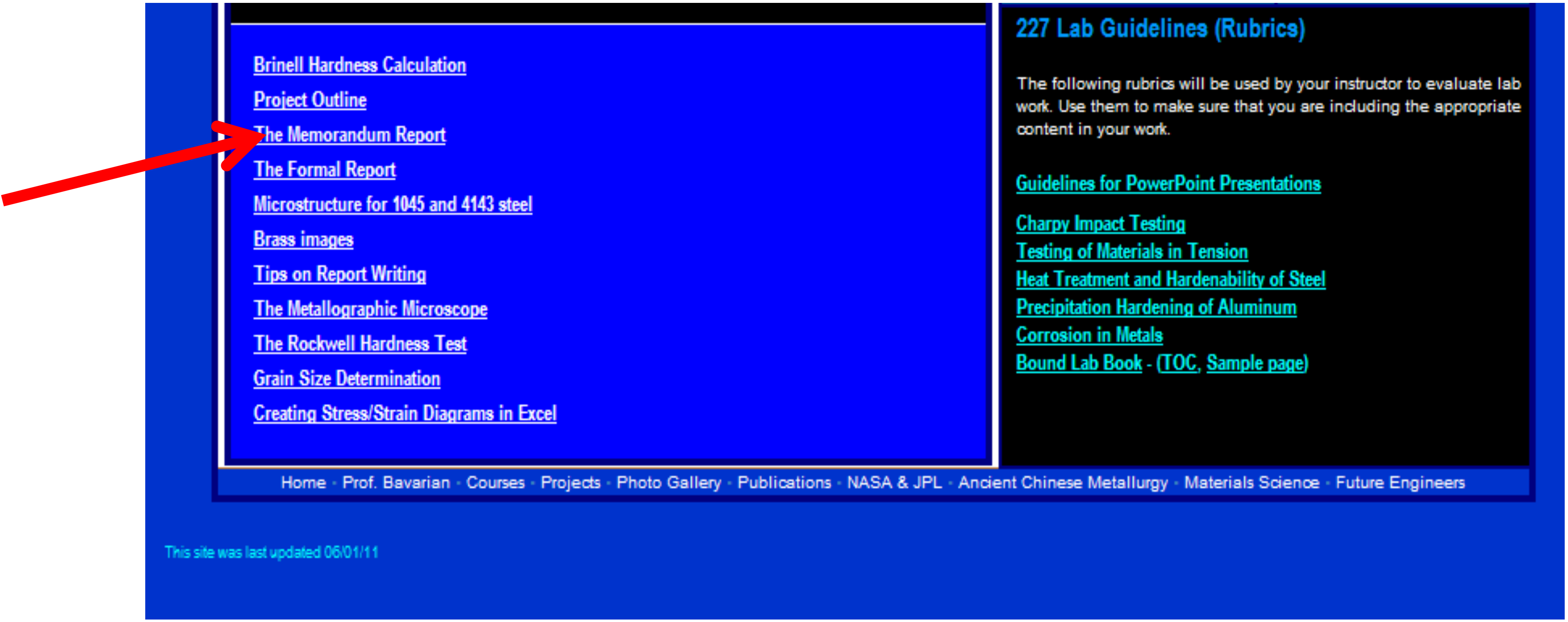
- Tension (Memo report)
- Impact (Memo report)
- Fracture Toughness (Memo report)
- Project I (Formal report)
- Project ll (Formal report)

(Put data and answer questions in lab book)

- Fatigue/FCG
- SEM
- SCC
- Mg Deformation

Formats for reports

- http://www.csun.edu/~bavarian/mse_227_lab.htm



Course Grades

- 3 Memo reports per group 30%
  - (Tension test, Impact, Fracture toughness)
- 2 Formal project reports per group 50%
- 2 oral presentations per group/ all members present 20%
- Labs are due 2 weeks from the assigned dates.
- No late lab reports accepted.

Time: Tuesday, 7:45 – 10:15 PM, Room JD 1504

MSE 527L Mechanical Behavior of Materials Laboratory

Date	Grp #1	Grp #2	Grp #3	Grp #4
27-Aug	Introduction		Introduction	
3-Sep	Tension	Impact	Kt concent	SEM
10-Sep	Impact	Tension	SEM	Kt concent
17-Sep	Kt concent	SEM	Tension	Impact
24-Sep	SEM	Kt concent	Impact	Tension
1-Oct	Project I	Project I	Project I	Project I
8-Oct	Project I	Project I	Project I	Project I
15-Oct	SCC, plan Project II	Fatigue/FCG	Fract Toughness	Mg Deform
22-Oct	Project I Presentation & Planning Project II			
29-Oct	Fract Toughness	SCC, plan Project II	Mg Deform	Fatigue/FCG
5-Nov	Fatigue/FCG	Mg Deform	SCC, plan Project II	Fract Toughness
12-Nov	Mg Deform	Fract Toughness	Fatigue/FCG	SCC, plan Project II
19-Nov	Project II			
26-Nov	Project II			
3-Dec	Project II			
10-Dec	Project II Presentations			

Project I

- Each lab group, pick 1 ASTM standard. Each group does research and submits a report on a different ASTM standard listed below.

  Volume 03.01
  - E606
  - E399
  - E647
  - E1820

Project ll –Each lab group, pick 1 project topic. Each group does research and submits a formal report on a different topic.

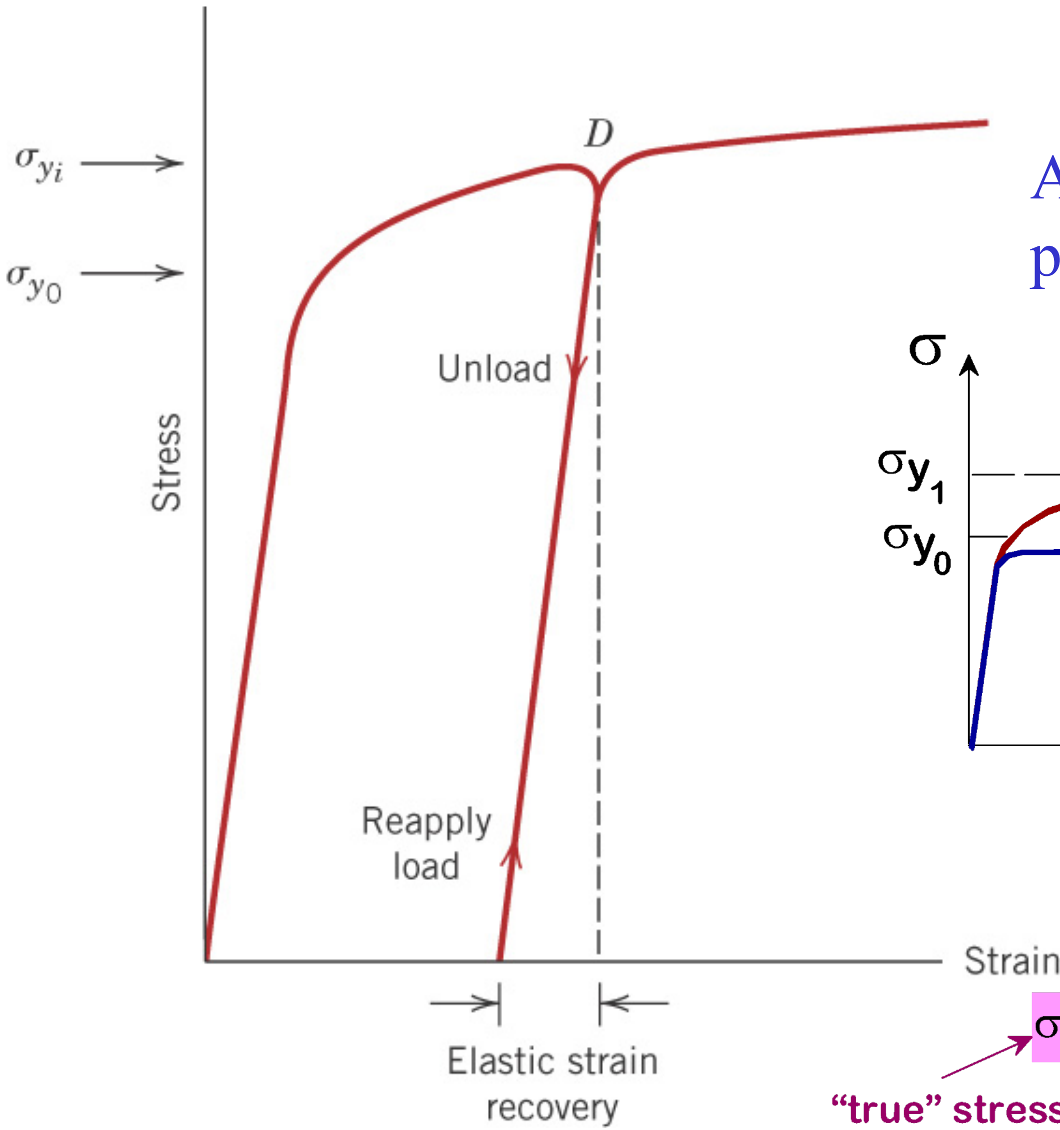
Suggested topics for Lab projects; scope of project must go beyond what was done in lab experiments in terms of complexity:

1. **Impact test**; identify DBTT for different crystal structures
2. **Testing** materials in **tension**; generate stress-strain curve, define elastic modulus, Poisson's ratio, and the strain hardening coefficient.
3. **Fracture behavior** of materials; generate ductile and brittle failure and define their toughness.
4. **Fatigue** of materials, using bending beam, rotating beam; generate S-N curve, effect of surface condition on fatigue behavior, and environmental effects on fatigue (corrosion fatigue).
5. Effects of microstructure on mechanical properties; verify Hall-Petch formula (grain size effects).
6. Environmentally assisted cracking, stress corrosion cracking, hydrogen embrittlement, define K_{1EAC}.
7. Deformation of Mg (slip and twinning mechanisms for plastic deformation).
8. Determine **fracture toughness** (K_{1C}) of a material; design test specimen, perform the test, check test validity, determine factors affecting the fracture toughness.
9. Define fracture toughness using **Charpy impact test**; define K_{1D} and K_{1C}.
10. Failure analysis; prepare a report on a failure case.
11. **Scanning Electron Microscopy (SEM)**: study its application in analyzing fracture behavior.

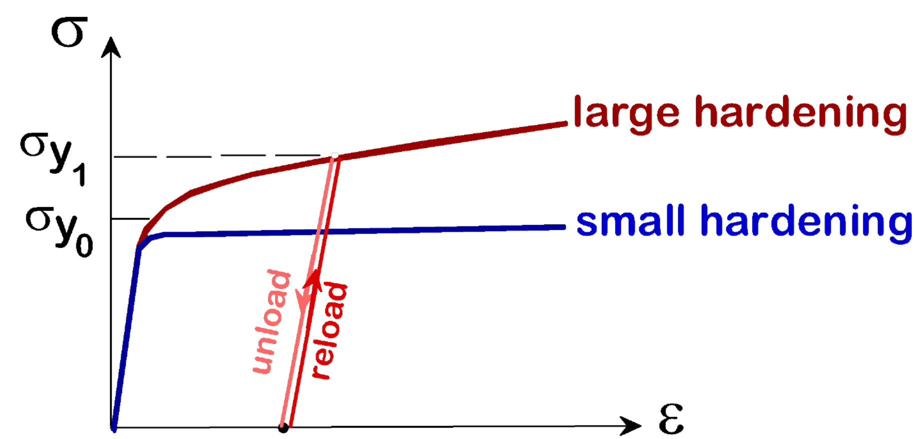
Tension Test

- Conduct tensile tests (steel/aluminum) samples using crosshead and laser
- Create Engineering and True stress-strain curves
- Define TS, YS, % Elongation, Elastic modulus (E)
- Compare E results from two different methods of displacement measurement (Crosshead and Laser)
- Based on True stress-strain, calculate strain hardening coefficient (n).

Strain Hardening



An increase in sy due to plastic deformation.



$$\sigma_T = C(\varepsilon_T)^n$$

"true" stress (F/A)

"true" strain: $\ln(L/L_o)$

hardening exponent:
n=0.15 (some steels)
to n=0.5 (some copper)

Strain Hardening (n, K or C values)

Table 7.4 Tabulation of *n* and *K* Values (Equation 7.19) for Several Alloys

		K	
Material	***n***	***MPa***	***psi***
Low-carbon steel (annealed)	0.21	600	87,000
4340 steel alloy (tempered @ 315°C)	0.12	2650	385,000
304 stainless steel (annealed)	0.44	1400	205,000
Copper (annealed)	0.44	530	76,500
Naval brass (annealed)	0.21	585	85,000
2024 aluminum alloy (heat treated—T3)	0.17	780	113,000
AZ-31B magnesium alloy (annealed)	0.16	450	66,000

$$\sigma_T = C(\varepsilon_T)^n$$

hardening exponent:
n=0.15 (some steels)
to n=0.5 (some copper)

"true" stress (F/A)

"true" strain: $\ln(L/L_o)$

Impact Test

- Conduct Charpy impact tests on two sets of samples (steel and aluminum)
- Define DBTT using three methods (Chapter 9)
- Using shear lip, calculate K_c (approx) value for each material.

- $D = 1/(2\pi) * (K/\sigma_{YS})^2$
- D = Charpy sample width (measured) * shear lip % (estimated)
- Ex: width = 0.37 in, shear lip % = 20%   D = 0.37 * 0.20 = 0.074 in
- 1018 steel, σ_{YS} = 60 ksi 2024 Al , σ_{YS} = 52 ksi

K_t Concentration

- Conduct tensile tests on three different types of stress raisers.
- Using both stress and strain calculate $K_{t.}$
- Using Handbook of stress concentration, calculate K_t, compare with your experimental results and explain any differences.

Scanning Electron Microscope (SEM)

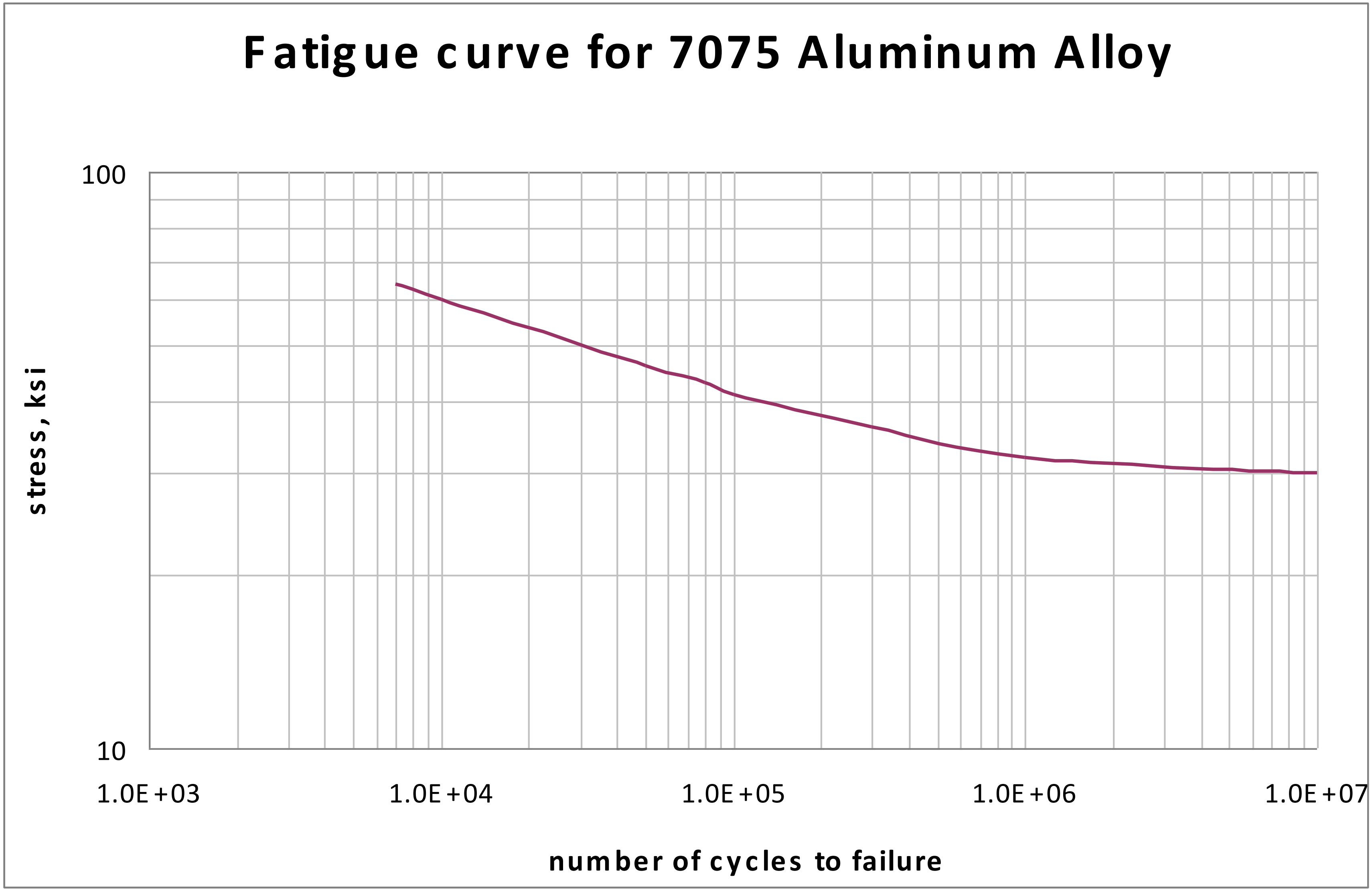
- Fractographic analysis of ductile and brittle failure.
- Intergranular cracking
- Transgranular cracking
- Fatigue failure

Fracture Toughness

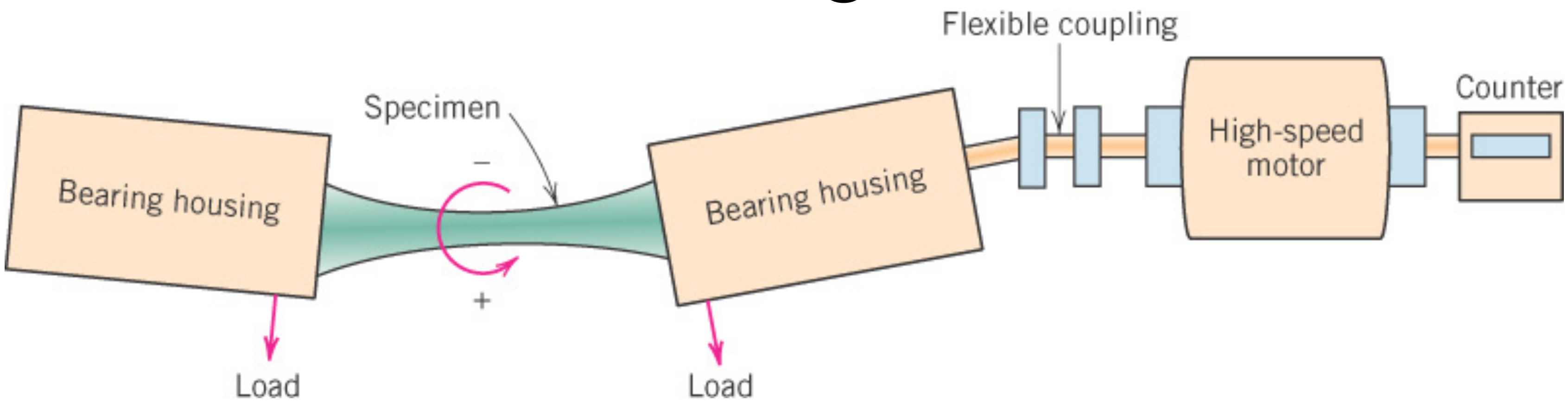
- Using ASTM E399, measure K_c for an aluminum sample.
- Validate if this K_c is K_{1c}.

Fatigue/Fatigue Crack Growth (FCG)

- Using the rotating beam machine, conduct 4 fatigue tests at different stress levels (90%, 80%, 70%, 60% of yield stress) and superimpose your results on the S-N curve of the alloy tested (7075 Al). σ_y is roughly 80,000 psi.
- $M = 0.0982SD^3$ (weight applied to rotating beam)
  - M= bending moment, S=stress, D=diameter of reduced area
- Use ASTM E647, conduct Fatigue Crack Growth (FCG) test and establish Paris Equation for the alloy.


Fatigue curve for 7075 Aluminum Alloy
100
10
stress, ksi
1.0E+03
1.0E+04
1.0E+05
1.0E+06
1.0E+07
number of cycles to failure

Fatigue



Fatigue testing apparatus for rotating bending test

- Fatigue is a form of failure that occurs in structures subjected to dynamic stresses over an extended period.
- Under these conditions it is possible to fail at stress levels considerably lower than tensile or yield strength for a static load.
- Single largest cause of failure in metals; also affects polymers and ceramics.
- Common failure in bridges, aircraft and machine components.

Fatigue Mechanism

- Crack grows *incrementally*

$$\frac{da}{dN} = \left(\Delta K\right)^m$$

typ. 1 to 6

$\sim (\Delta\sigma)\sqrt{a}$

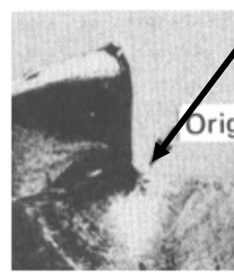
increase in crack length per loading cycle

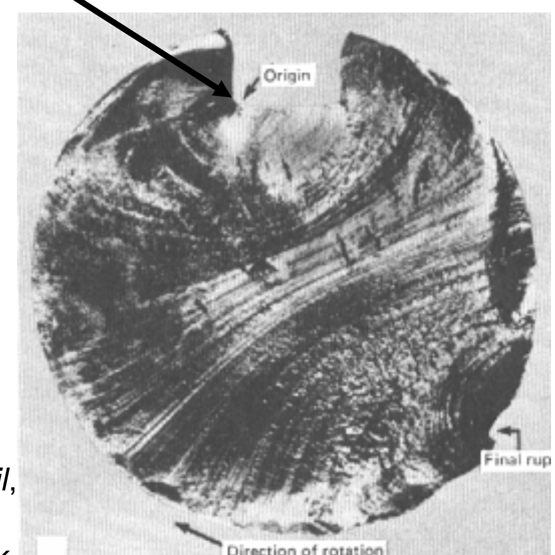
- Failed rotating shaft
  -- crack grew even though

  $K_{max} < K_c$

  -- crack grows faster as
  - $\Delta\sigma$ increases
  - crack gets longer
  - loading freq. increases.

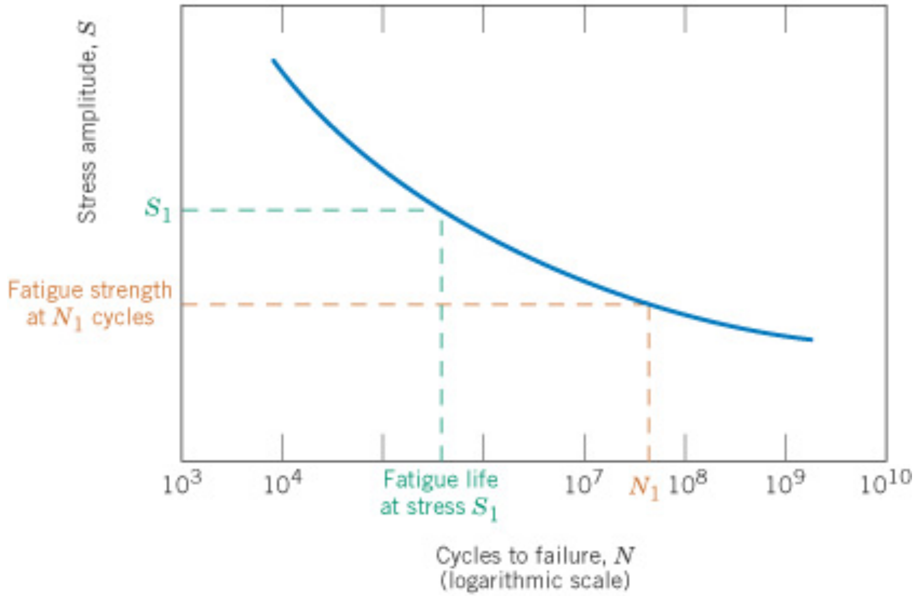
crack origin





Adapted from Fig. 9.28, *Callister & Rethwisch 3e.* (Fig. 9.28 is from D.J. Wulpi, *Understanding How Components Fail*, American Society for Metals, Materials Park, OH, 1985.)

S-N Curves



- A specimen is subjected to stress cycling at a maximum stress amplitude; the number of cycles to failure is determined.
- This procedure is repeated on other specimens at progressively decreasing stress amplitudes.
- Data are plotted as stress S versus number N of cycles to failure for all the specimen.
- Typical S-N behavior: the higher the stress level, the fewer the number of cycles.

Mg Deformation

- See detailed description on MSE 527 webpage for Mg deformation and metallography).
- Observe slip bands and twinning
- Prepare 3 polished Mg sample, etch and observe grain structure.
- Deform 3 polished Mg samples at different temp (0° C, 25 °C, and 100 °C)
- Observe grain structure and look for slip band and twinning, re-etch and re-examine your samples (twinning cannot be removed by etching.

Stress Corrosion Cracking (SCC)

- Prepare 4 C-ring samples by polishing both perimeter edges (using sandpaper grits 240 thru 600, and polishing wheel 1 micron powder).
- Use ASTM G-38, Vol 03.02, specifically the equation to determine OD_f and Δ.
- Measure OD and t (wall thickness).
- Load (and label for identification) the C-rings at four different stress levels (80%, 65%, 50%, 35% of the yield stress. The alloy is 7050 Al: σ_Y is roughly 80,000 psi; E = 10 million psi.
- Expose these samples to CCT (salt spray corrosion).
- Examine your samples on a weekly basis to inspect for crack initiation.