Quiz 1 - Mechanical Properties and Testing
Chapters 6 and 8 Callister

You need to be able to:

- *Name the properties determined in a tensile test including UTS, .2% offset yield strength, Elastic Modulus, % elongation, and % area reduction and determine their numeric values from a load-elongation or stress-strain graph.*
- Describe what is happening to the microstructure of a metal during a tensile test.
- Use the definitions of stress and strain along with the elastic relationship between them to calculate stress, deflection, or minimum geometry in axial loading.
- Label the elastic and plastic regions of the uniaxial stress-strain curve and describe what is happening at the atomic level in each.
- State what is measured in a fatigue test and list two reasons fatigue is important to designers.
- Name two factors that increase fatigue life and two that decrease fatigue life.
- Define the fatigue limit (endurance limit), state which materials exhibit this limit, and describe how a designer would use the information.
- State what is measured in a hardness test and how it is useful to ME's.
- Describe the difference between Rockwell, Brinell, and Vickers hardness tests and name an application for each.
- State what is measured in an impact test and list two ways the results are used by ME's.
- Be able to match such "general" terms as *stiffness, hardness*, *toughness, strength, and ductility* with their particular material property (e.g. stiffness is measured by Elastic Modulus).
- List two visual and one microscopic indicator(s) for ductile, brittle, and fatigue failures.
- Describe the difference between stress concentration and stress intensity factor, including applications and units.

Vocabulary Chapter 6:

Ductility	Hardness	Resilience
Elastic deformation	Modulus of Elasticity	Tensile Strength
Elastic Recovery	Plastic Deformation	Toughness
Engineering strain	Poissons' Ratio	Yielding
Engineering stress	Proportional Limit	Yield Strength

Vocabulary Chapter 8:

Brittle fracture	Fatigue	Stress Intensity factor
Charpy Test	Fatigue limit	Stress raiser
Creep	Fracture Mechanics	Thermal Fatigue
Ductile Fracture	Fracture toughness	
Ductile to brittle transition	Impact Energy	

Mechanical Properties and Testing
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Hardness: Resistance to penetration/indentation/scratching

Procedure: Press penetrator in - measure dimple *diameter* or *depth*

Advantages	Disadvantages
• can predict strength, wear resistance • inexpensive, easy • relatively nondestructive • common designer specification	• strength prediction only quantitative for hard steel • predictions are qualitative (no design numbers)

Types	Indentor	Load	Measure	Notable
Rockwell	Diamond Brale or Ball (1/16, 1/8, 1/4/ 1/2)	60-150 kg	Depth	Common - R_A,R_B,R_C
Brinnell	10 mm Ball	500-3000kg	Diameter	500*BHN=UTS (hard steel)
Knoop/Vickers	Pyramidal Diamond	1-1000g	"Diameter"	can measure individual grains

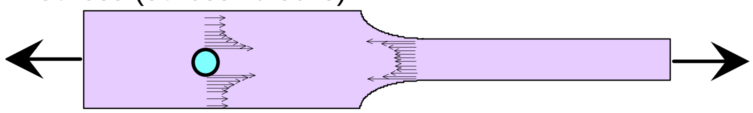
Fracture

Type	Visual Indicators	Microscopic Indicators
Ductile	• Macroscopic deformation (bending, twisting, stretching, necking) • shear lips (45° to principal tension) • nonreflective fracture surfaces	microvoid formation and coalescence (dimples)
Brittle	• pieces fit back together with no deformation • sparkly reflective surfaces • fracture is perpendicular to principal tension • "chevrons"	Flat cleavage planes (planes separate rather than slide)
Fatigue	• "beach" marks or clamshell marks indicating progressive crack growth • polished surfaces next to rapid fracture (surfaces rubbed before failure)	Fatigue striations due to repeated crack extensions (often missing)

Stress Concentrations:

What is it?

Changes in geometry (holes, fillets, threads, notches) can cause local increases in stress (stress raisers)



For example: Near a small hole in a large plate, the stress at the edge of the hole is three times as high as the stress away from the hole.

Importance:

- high-strength, low ductility materials can crack
- cyclic stress coupled with stress concentration is typical for fatigue failures

Quantifying:

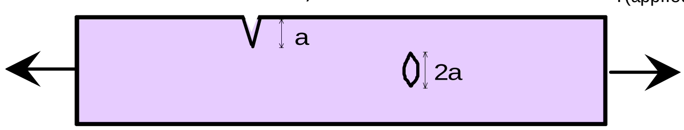
Stress Concentration Factor, $K = \sigma_{max} / \sigma_{nominal}$

where:

- K is from published charts
- $\sigma_{nominal}$ is the stress ignoring the stress concentration
- σ_{max} is the highest local stress due to the concentration

Fracture Mechanics

For notched members, failure occurs when $K_{I(applied)} > K_{I(critical)}$.



Importance: Can quantify"strength" of flawed members.

Quantifying: $K_I = Y\sigma\sqrt{\pi a}$ **Units:** ksi√in, MPa√m

Geometry factor (Y); stress (nominal) (σ); flaw size (a)

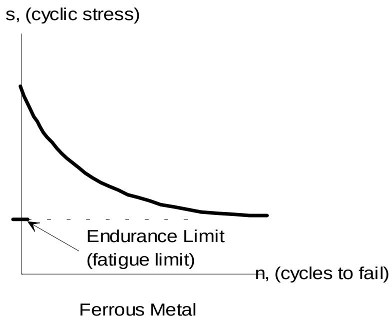
Advantage:

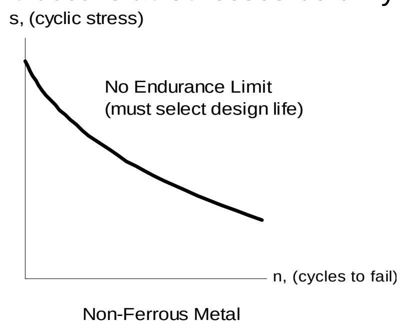
- can use parts with subcritical flaws
- can set inspection standards

Stress Concentration Factor	Stress Intensity Factor
• multiplier of nominal stress • no units • can't quantitatively predict failure stress	• measure of local stress field • units of: ksi√in, MPa√m • can predict failure stress for discovered flaws

Fatigue

Definition: Crack initiation and propagation due to repeated (cyclic) stresses. Fracture is often unexpected since it occurs at stresses below yield strength.



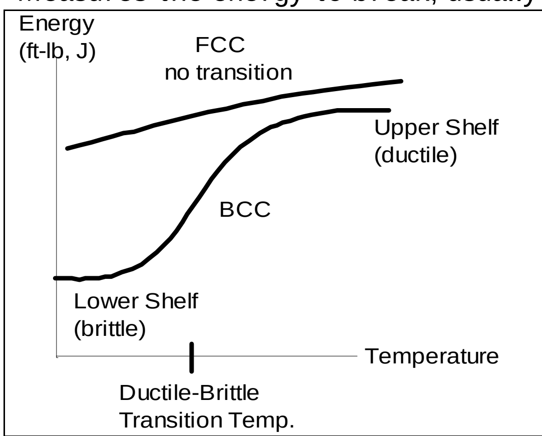


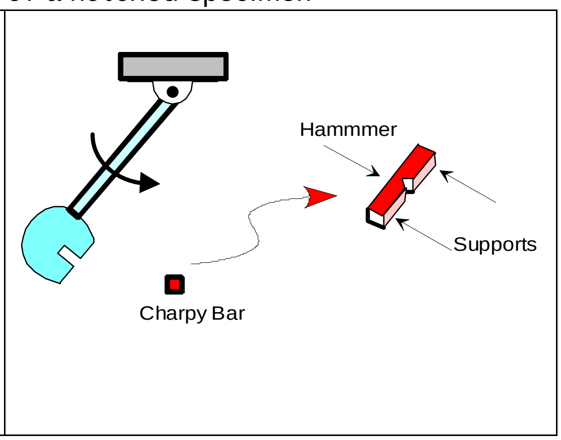
Prevention:

- Keep stress below endurance limit (≈1/3 UTS for steel)
- Avoid stress concentrations (e.g. fillets with small radii)
- Shot peen, case harden, polish to "improve" surface
- Avoid corrosive environments

Impact Testing

Measures the energy to break, usually of a notched specimen





Advantages	Disadvantages
• Determine minimum temperature of use • Finds "notch sensitive" materials	• Difficult to apply quantitatively in design • Addresses temperature, not stress or flaw size

Tensile Test Review

Concept	Conceptual Definition	Engineering Term	Symbols	Units	Usefulness	Microstructure
	Load per unit area	Stress	$\sigma = \frac{P}{A_0}$	lb/in^2, psi, N/m^2, Pa	Normalizes load for geometry.	
	Deflection w.r.t.length	Strain	$\varepsilon = \frac{\Delta l}{l_0}$	in/in, mm/mm,	Normalizes deflection for geometry	
Strength	Stress to bend (permanently deform)	Yield Strength	YS, σ_{ys}, 0.2%offset YS Yield Point	psi, MPa	Limit of useful design. Beginning of range for some processing.	End of bond stretching, beginning of planer slip
Strength	Max Stress before failure	Ultimate Tensile Strength	UTS, σ_{uts}	psi, MPa	Limit for some manufacturing. part breaks	Plane separation, cleavage (brittle) or sliding (ductile)
Stiffness	Deflection per unit load, normalized for geometry	Young's Modulus, Elastic Modulus	$E = \frac{\sigma}{\varepsilon}$	psi, MPa	Essentially constant for metals regardless of processing. Can predict deflections given load	Atomic attraction. depends only on bonds between atoms
Ductility	Amount material bends/stretches/ twists prior to breaking	% Elongation % Reduction in Area	$\left(\frac{l_{fract} - l_0}{l_0}\right)100\%$ $\left(\frac{A_0 - A_{fract}}{A_0}\right)100\%$	% %	What does your design do upon overload.	Planer slip
Elastic energy storage	Energy per unit volume	Modulus of Resilience Strain Energy Density	$U = \frac{1}{2}\sigma_y \varepsilon_y = \frac{\sigma_y^2}{2E}$	in-lb/in^3, psi, MPa	Spring design Fracture Mechanics Manufacturing	bond stretching
Toughness	Energy to fail	Toughness	area under σ-ε curve		Collision protection	bond stretching and planer slip

Tensile Test of a Ductile Metal