UNIVERSITY OF HOUSTON
Cullen College of Engineering

Fundamentals of Engineering Spring 2005 Review

Materials Science

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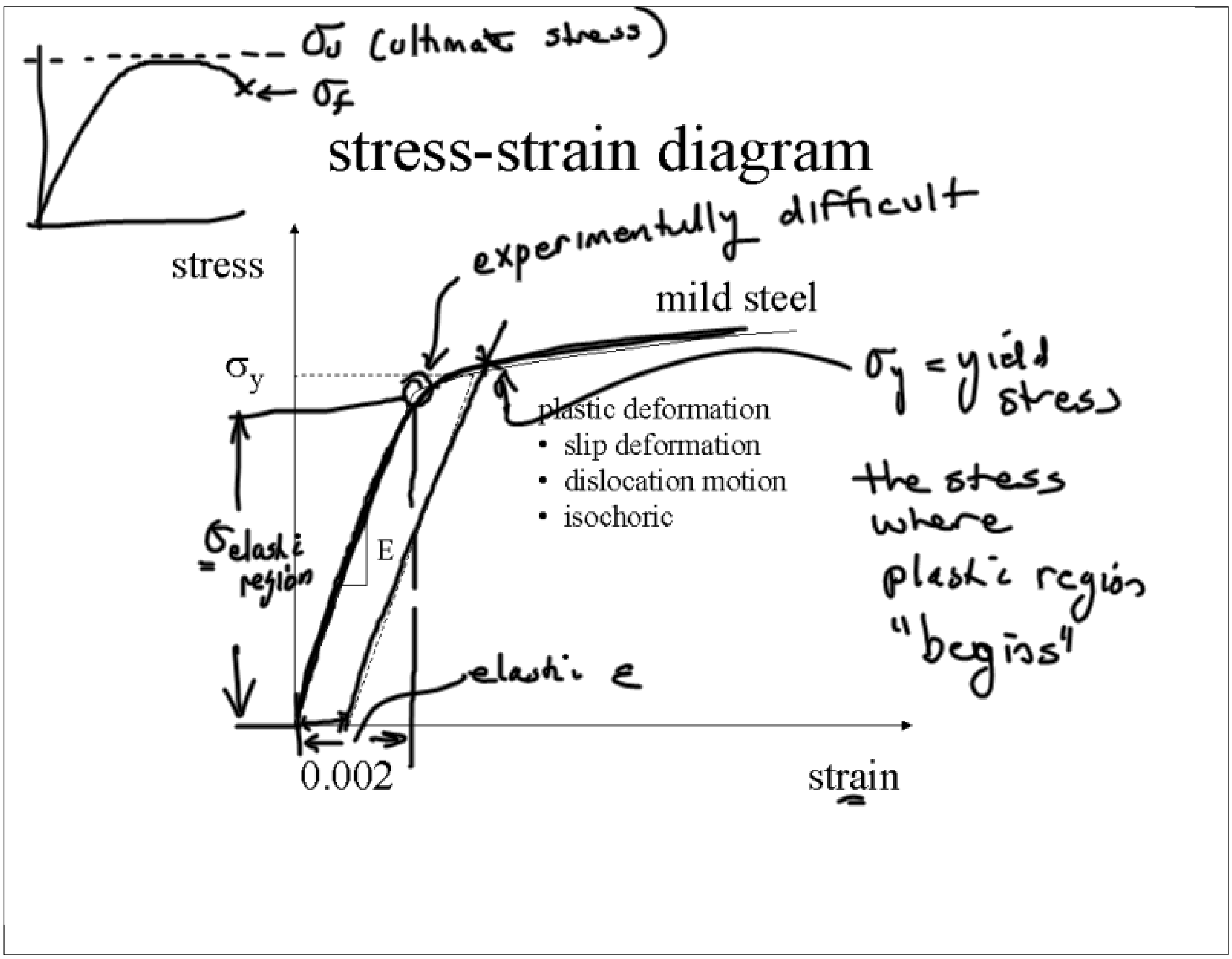
problem distribution

- morning: 6% (7 out of 120 problems)
- afternoon: 5% (3 out of 60 problems)

subject areas

- 30% stress-strain diagram (3) ✓
- 20% creep/fatigue (2) ✓
- 20% processing/properties (2) ✓
- 20% phase diagram (2) ✓
- 10% other (1)


σ_u (ultimate stress)
σ_f
stress-strain diagram
experimentally difficult
stress
mild steel
σ_y
σ_y = yield stress
plastic deformation
• slip deformation
• dislocation motion
• isochoric
the stess where plastic region "begins"
$\sigma_{elastic}$ region
E
elastic ε
0.002
strain

32. What does the non-linear portion of a stress-strain diagram represent?

- Plastic region
- Strain is not linear wrt. stress

$$\varepsilon = f(\sigma)$$

Elastic

$$f(\sigma) = E\sigma + \varepsilon_0$$

Plastic

$$f(\sigma) \neq E\sigma + \varepsilon_0$$

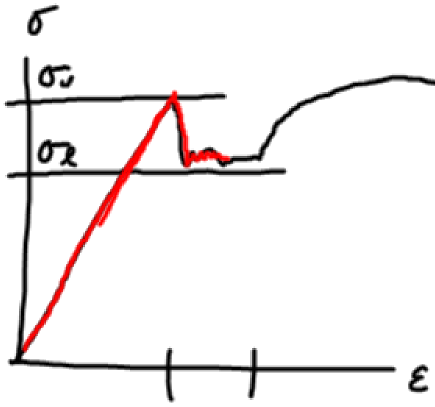
some non-linear

33. What is the 0.2% offset yield stress?

- Convention (agreement) wher yield stress is defined because its experimentally dificult to determine σ_y.

∴ A line || to elastic behavior at 0.002 strain is used to id. a "working" value of σ_y

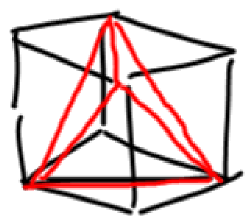
34. What metal exhibits upper and lower yield points?



steel (any Iron alloy)

Attributed to carbon atoms & iron atoms

C (4)   Fe (3, 5)



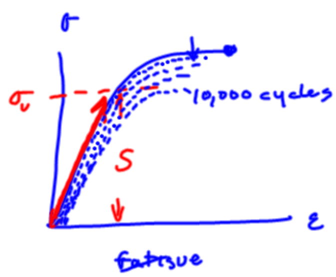
creep and fatigue

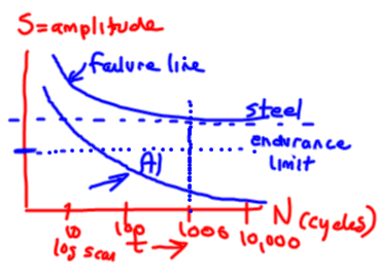
creep
- deformation at constant stress and high temperature
- grain boundary sliding, formation of voids (failure)

fatigue
- failure in cyclic loading due to surface defects
- sensitive to surface properties (corrosion, finish)
- endurance limit for steels (unlimited life)

40% or higher MP (melting point)

– Creep is significant at high T





~~Steel~~
Steel is alloy
Al is an element
Ti, Fe, C, Vn

~~Creep~~
Fatigue
generates "heat"
→ creep like behavior
crystalline structure rearranges
becomes brittle
Starts at material surface (propogate inward)

Cold rolling – surface polish
Shot peen (bead blasting)
polish
case hardening

Corrosion fatigue
– corrosive environment + cyclic loading

35. What is the cause of creep failure?

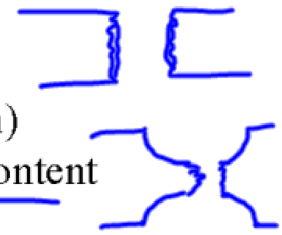
- Deformation of material under constant stress.
- Temperature matters ($T > 40\%$ MP)

internal thermal energy ~~so~~ allows dislocations C, Fe to rearrange & allow slip

37. Define metal fatigue?

- Failure of material, starts at surface under cyclic loading

ductility, hardness, toughness



ductility

- deformation without fracture (% elongation)
- increases with temperature, lower carbon content

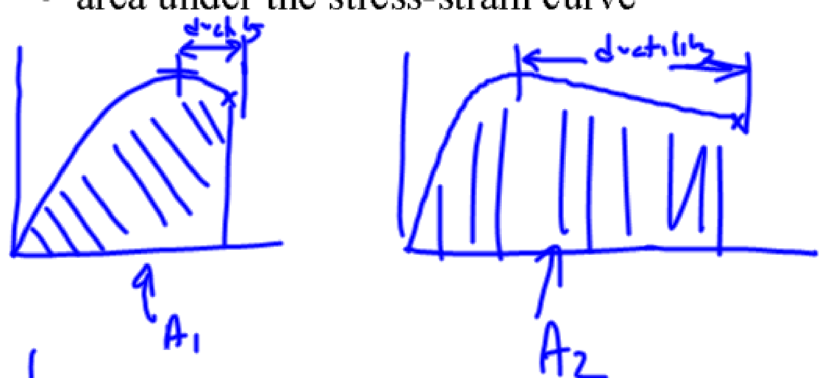
hardness

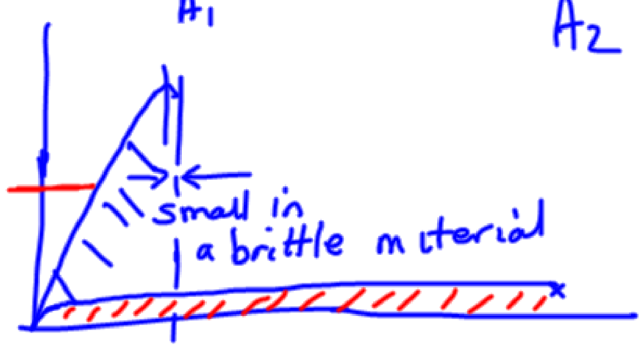
- resistance to penetration (Brinell, Rockwell tests) 601 C3
- increases with carbon content, smaller grain size

working material

toughness

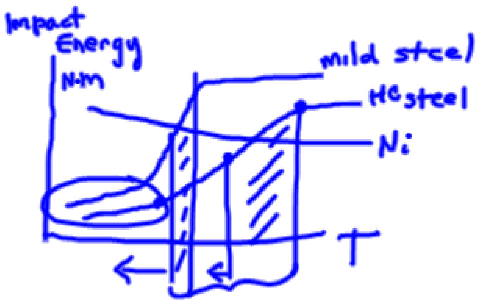
- energy absorbed before fracture (Charpy test)
- area under the stress-strain curve





36. Which statement regarding ductile-brittle transition is false?

- sudden loss of ductility below a critical temperature (true)
- loss of toughness at lower temperatures (true)
- carbon steels less susceptible to this transition (False)
- some pure metals (aluminum, copper, nickel) do not exhibit this transition (true)



Occur at terrestrial temperatures

processing

→ chemistry
* microstructure

annealing
- heat and slowly cool (relieves internal stresses)
- increases ductility, lowers yield, softens the material

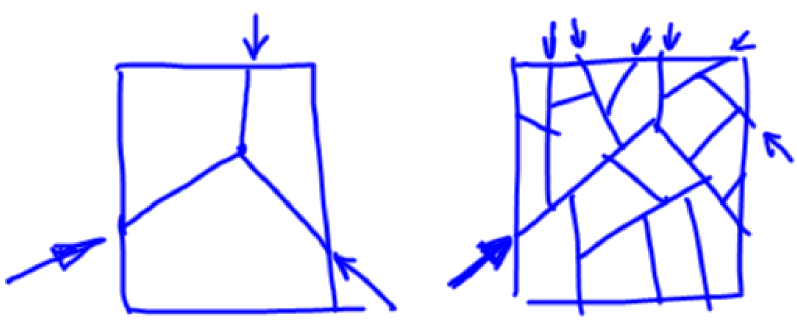
cold working
- stressing past the yield point (reduces grain size)
- increases toughness, hardness, yield strength

quenching
- rapid cooling that promotes hardening
- strong but brittle material (low toughness)

(martensite) → tools

37. Which statement regarding carbon steel is false?

- a steel can be hardened without carburizing (true)
- yield strength can be increased by cold rolling (true)
- ductility decreases for steels with more carbon (true)
- steels with larger grain size are stronger (false)



reactions

- eutectic: liquid → two solid phases
- eutectoid: solid → two solid phases
- peritectic: liquid + solid → solid
- peritectoid: two solid phases → solid

solid

W % = weight fraction of alloy

A% = molar fraction of a alloy

$$W\%\text{-}A = \frac{W\text{-}A}{W\text{-}A + W\text{-}B} \times 100\%$$

$$A\% = \frac{\text{mol } A}{\text{mol } A + \text{mol } B} \times 100\%$$

$$\text{mol } A = \frac{W\text{-}A}{MW_A}$$

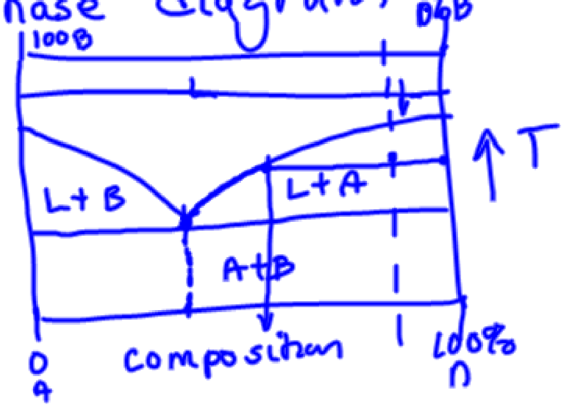
phases

given
\# constituents
\# possible mixtures

$P + F = C + 2$ ← # thermodynamic controls
(p, T)

Some alloys are completely miscible

Phase diagram



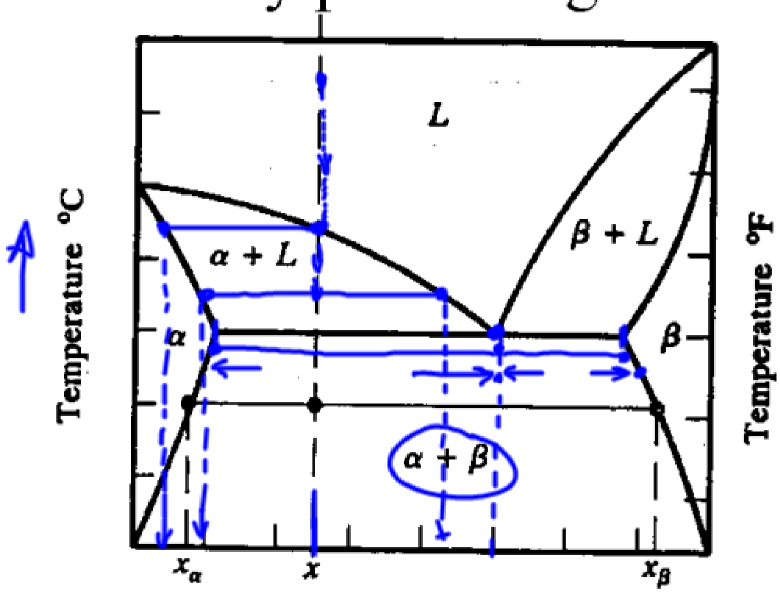
18. What is a peritectoid reaction?

$\text{solid}_1 + \text{solid}_2 \rightarrow \text{solid}_3$

peritectic

$\text{liquid} + \text{solid}_1 \rightarrow \text{solid}_2$

binary phase diagram



Tool to predict mixture composition

- Equilibrium diagram

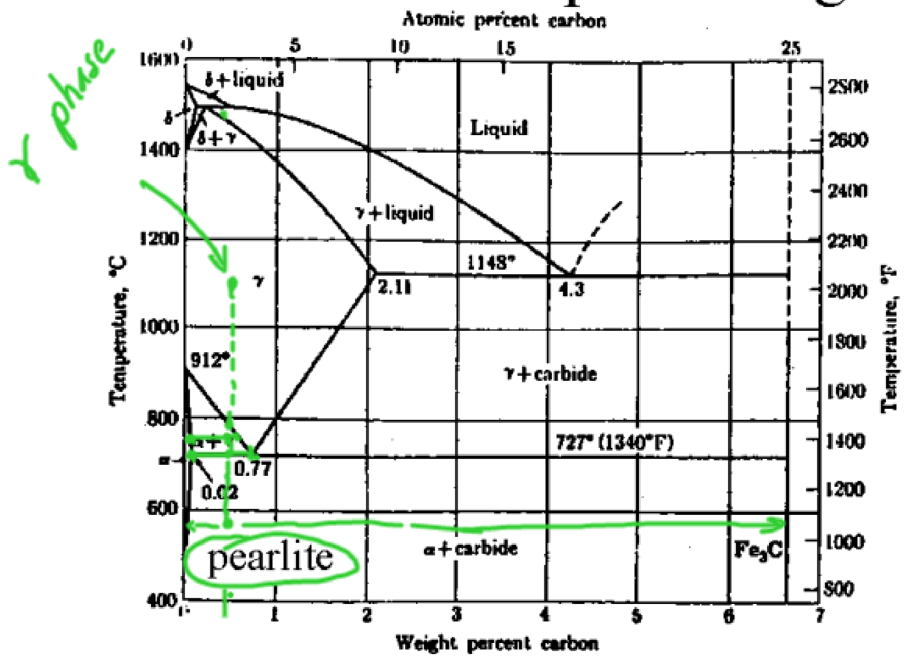
2 components

3 possible solids

α, α+β, β

$$\alpha\,\text{wt\%} = \frac{X_\beta - X}{X_\beta - X_\alpha} \times 100\ ;\ \beta\,\text{wt\%} = \frac{X - X_\alpha}{X_\beta - X_\alpha} \times 100$$

iron - iron carbide phase diagram



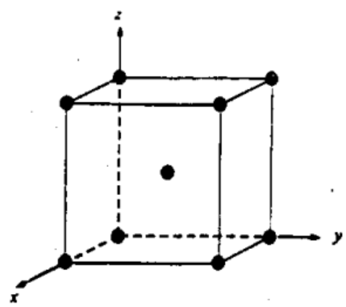
α ferrite (BCC), δ iron (BCC), γ austenite (FCC)

17. A steel with 0.18 wt% carbon is heated to 1100°C and then slowly cooled to room temperature. What is the phase composition?

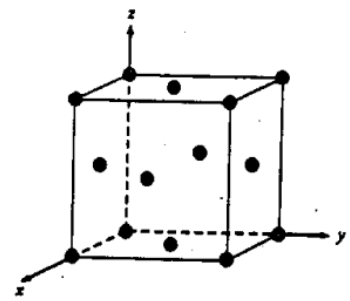
16. Which condition does not lead to stronger metals and alloys?

- presence of second phase precipitates stronger
- presence of dispersed fibers or particles stronger
- presence of martensite phase in steel stronger
- annealing of cold worked metal above its recrystallization temperature weaker

crystal structures



BCC body-centered cubic



FCC face-centered cubic

Volumes / Densities

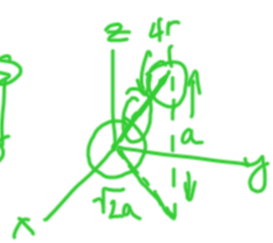
BCC, FCC, Simple cubic ←

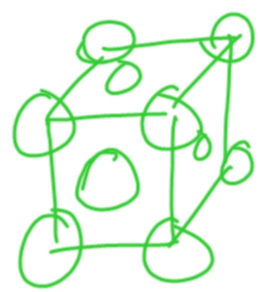
HP
HCP

$$\frac{1 \text{ atom}}{(2r)^3}$$

=

⇒ density of cubic structure





be able to recognize