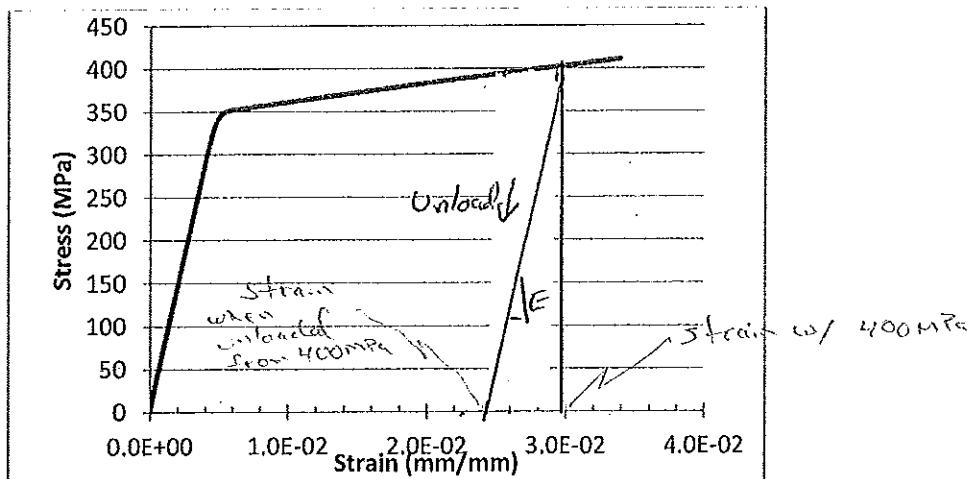


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 EGR 221 Materials Science
 Assignment 6, Fall 2015

- 1) Given a straight round bar made from steel alloy with Young's modulus (E) of 207GPa and yield strength (σ_{ys}) of 400MPa.
 - a) What is the axial strain at yielding? (hint: the answer is close to 0.002mm/mm)
 - b) If a strain gage was used to measure the axial strain to be 0.001mm/mm, can the axial stress be determined? If not, why not? If so, what is the axial normal stress?
 - c) If a strain gage was used to measure the axial strain to be 0.003mm/mm, can the axial stress be determined? If not, why not? If so, what is the axial normal stress?
- 2) A cylindrical metal specimen having an original diameter of 12.8mm (0.505in) and a gage length of 50 mm (~2.0 in) is pulled in tension until fracture occurs. The diameter at the point of fracture is 7.2 mm and the fractured gage length is 74.3 mm. Calculate the ductility in terms of both percent reduction in area (%RA) and percent elongation (%EL).
- 3) The following stress-strain curve is from 2024-T351 aluminum alloy. If a straight bar made of 2024-T351 aluminum had a length of 100mm before loading, what would the length of the bar be with the following:
 - a) 200 MPa axial load applied.
 - b) Loaded to 200 MPa, and then the load is removed.
 - c) 400 MPa axial load applied.
 - d) Loaded to 400 MPa, and then the load is removed.



- 4) Using equation 6-18 in the textbook (RE: tensile strength = 500HB).
 - a) What does HB refer to in this equation?
 - b) Using this equation, what is the hardness of steel with tensile strength of 560MPa?
 - c) Can this equation be used to determine the tensile strength of brass if its hardness was measured to be 120 HB? If not, why not? If so, what would the tensile strength be?
- 5) In words, what is ductility? What is toughness? Would you expect a material with high ductility to also have high toughness? Explain why/why not.

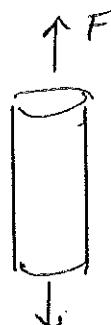
- 6) What happens to the ductility of a chocolate bar when you “freeze” it (and “test” it while cold)? Does something similar happen to most metals? What happens to toughness?
- 7) Speculate – what would have happened to the Titanic had it hit an “iceberg” while sailing in the warm waters of the South Pacific? (okay, probably no icebergs in the warm waters, but something equivalent). Briefly explain.
- 8) Speculate – had the Titanic been made from an FCC metal such as aluminum, what would have happen when it struck the iceberg in the cold North Atlantic? Briefly explain.
- 9) The presence of sulfur in steel causes an increase in the ductile to brittle transition temperature. The sulfur content in the Titanic’s steel exceeded norms for modern steel (which is typically somewhere around up to 0.008% sulfur allowed). Speculate – what would have happen when it struck the iceberg in the cold North Atlantic had the sulfur content been much lower than it was; low enough to meeting today’s norms? Briefly explain.

1) Given: straight round steel bar, $E = 207 \text{ GPa}$
 $\sigma_{ys} = 400 \text{ MPa}$

a) Find: axial strain at yielding

$$E = \frac{\sigma}{\epsilon}$$

assume the σ - ϵ relationship
is linear up until $\sigma = \sigma_{ys}$



$$\epsilon_y = \frac{\sigma_{ys}}{E} = \frac{400 \text{ MPa}}{207,000 \text{ MPa}} = \underline{\underline{0.0019 \text{ mm/mm}}}$$

b) If $\epsilon_{axial} = 0.001 \text{ mm/mm}$ can the axial stress be determined?

Ans: Yes since the material has not yielded.

$$\sigma = E\epsilon = 207 \text{ GPa} (0.001 \text{ mm/mm}) = \underline{\underline{207 \text{ MPa}}}$$

c) If $\epsilon_{axial} = 0.003 \text{ mm/mm}$, can axial stress be determined?

Ans: No, not from the information given,

for this steel if $\epsilon > 0.001 \text{ mm/mm}$

yielding will occur and Hooke's Law ($E = \sigma/\epsilon$) is not valid.

Solu

2) Given: metal tensile bar, $D_o = 12.8 \text{ mm}$ $L_o = 50 \text{ mm}$
 Pulled in tension until fracture

$$D_{\text{fract}} = 7.2 \text{ mm} \quad L_{\text{fract}} = 74.3 \text{ mm}$$

Determine: ductility in terms of %EL & %RA

Solu: $\% \text{EL} = \frac{l_{\text{fract}} - l_o}{l_o} \times 100 \%$

$$= \frac{74.3 \text{ mm} - 50 \text{ mm}}{50 \text{ mm}} \times 100 \%$$

$$\% \text{EL} = 48.6 \% \quad (\text{very ductile})$$

$$\% \text{RA} = \frac{A_o - A_{\text{fract}}}{A_o} \times 100 \%$$

$$A_o = \frac{\pi}{4} D_o^2 = \frac{\pi}{4} (12.8 \text{ mm})^2$$

$$A_o = 128.7 \text{ mm}^2$$

$$A_{\text{fract}} = \frac{\pi}{4} D_f^2 = \frac{\pi}{4} (7.2 \text{ mm})^2$$

$$\% \text{RA} = \frac{(128.7 - 40.72) \text{ mm}^2}{128.7 \text{ mm}^2} A_{\text{fract}} = 40.72 \text{ mm}^2$$

$$\underline{\underline{\% \text{RA} = 68.4 \% \quad (\text{very ductile})}}$$

So (n)

- 3) Given: σ - ϵ curve (attached) for 2024-T35
 long bar of 2024-T35, 100 mm long before testing

How long will it be?

- a) w/ 200 MPa axial load

Assume: $E = 69 \text{ GPa}$

From σ - ϵ curve, $\sigma_y \approx 350 \text{ MPa}$

Since applied stress will not cause yielding:

$$\epsilon = \frac{\sigma}{E} = \frac{350 \text{ MPa}}{69,000 \text{ MPa}} = 0.0051 \text{ mm/mm}$$

$$\epsilon = \frac{l - l_0}{l_0} = 0.0051 \text{ mm/mm}$$

$$l = l_0 \epsilon + l_0 = l_0(1 + \epsilon)$$

$$l = 100 \text{ mm} (1.0051) = \underline{\underline{100.51 \text{ mm}}}$$

(Assume $l_0 = 100.00 \text{ mm}$)

- b) Loaded to 200 MPa, then unloaded

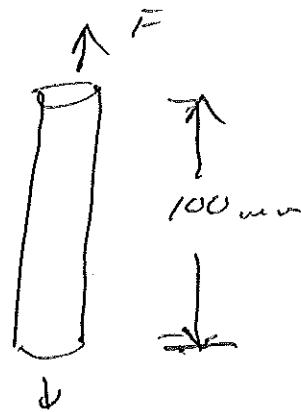
ANS: Since the mat'l did not yield, it will return to its original length (100 mm)

- c) Loaded to 400 MPa

The mat'l has yielded so Hooke's law is not valid. From σ - ϵ curve,

$$\text{at } \sigma = 400 \text{ MPa}, \epsilon = 0.03 \text{ mm/mm}$$

$$l = l_0(1 + \epsilon) = 100 \text{ mm} (1 + 0.03) = \underline{\underline{103 \text{ mm}}}$$



d) loaded to 400 MPa, then unloaded

Unloaded strain (from σ - ϵ curve)
is about 0.022 mm/mm

$$l = l_0(1 + \epsilon) = 100 \text{ mm} (1 + 0.022) = \underline{\underline{102.2 \text{ mm}}}$$

ANSWER

4 RE! eq 6-18: tensile strength = 500 HB

a) what does 'HB' refer to?

ANS: Brinell Hardness (sort of a "unit" for hardness - it is in reference to a method of measuring hardness)

b) Using eq 6-18, what is the hardness of a steel w/ $\sigma_{UTS} = 560 \text{ MPa}$?

ANS: eq 6-18 requires σ_U to be in psi:

$$560 \text{ MPa} \left(\frac{1000 \text{ psi}}{6.89 \text{ MPa}} \right) = 80,200 \text{ psi}$$

$$80,200 \text{ psi} = 500 \text{ HB}$$

$$\text{Hardness} = \frac{80,200}{500} = \underline{\underline{160 \text{ HB}}}$$

c) Can this eq'n (6-18) be used w/ brass?

ANS: NO - as mentioned in the text,
eq 6-18 is for steel only

5) in words what is ductility, what is toughness?

Ductility: a measure of strain in a material at fracture (ex: %EL, %RA)

Toughness: amount of energy required to fracture a material.

- Would a mat'l w/ ↑ ductility also have ↑ toughness? ALWAYS in most cases, yes.

Plastic strain "absorbs" energy - so more strain, the greater the toughness.

This is not always the case, but generally so.

ANSWER

6) What happens when chocolate is cooled?

ANS: It becomes less tough & ductile.

What about metals?

ANS: They may lose toughness if cold.

7) Speculate: would the Titanic have sunk if it was warm?

ANS: The hull may have dented rather than fractured \therefore not sunk.

8) Speculate: if the Titanic was aluminum or other FCC - would it have sunk when it hit the iceberg?

ANS: FCC metals (such as aluminum) do not lose toughness when cold. If dented not fractured — not sink.

9) Speculate: if the titanic were made to modern steel standards (0.008% sulfur max), would it have sunk?

ANS: most modern steel remains tough at 0°C .
 \therefore NOT SINK.