Recitation #1

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Nominal (Engineering) σ & ε

- $\sigma = P/A_o$ Force/Original x-sectional area
  - Tensile stress (+)
  - Compressive stress (-)
  - Only valid if uniformly distributed force over entire area, A.
- $\varepsilon = \delta/L_o$, elongation/original length
  - Ratio of two lengths (unitless)
  - Also, $\varepsilon = L - L_o/L_o = L/L_o - 1 = \lambda - 1$

Normal (True) σ & ε

- σ=P/A Force/Area ←A changes with time
  - Tensile stress (+)
  - Compressive stress (-)
  - Only valid if uniformly distributed force over entire area, A.
- $\varepsilon=\delta/L'$ elongation/length ←This changes with time
  - Ratio of two lengths (unitless)
  - ε = int(dL/L) from Lo to L = ln(L/Lo)

Small ε (strain) condition

- $\varepsilon \sim \varepsilon_{nominal}$
  - Because, $\varepsilon = \ln(1+ \varepsilon_{nominal})$
- $\sigma \sim \sigma_{nominal}$
  - Because, $\sigma = \sigma_{nominal} (1+\varepsilon_{nominal})$
- This shows that when dealing w/ elastic strains (not rubbers), it doesn't matter whether true or normal or nominal stresses/strains are used in calculation

Hooke's Law

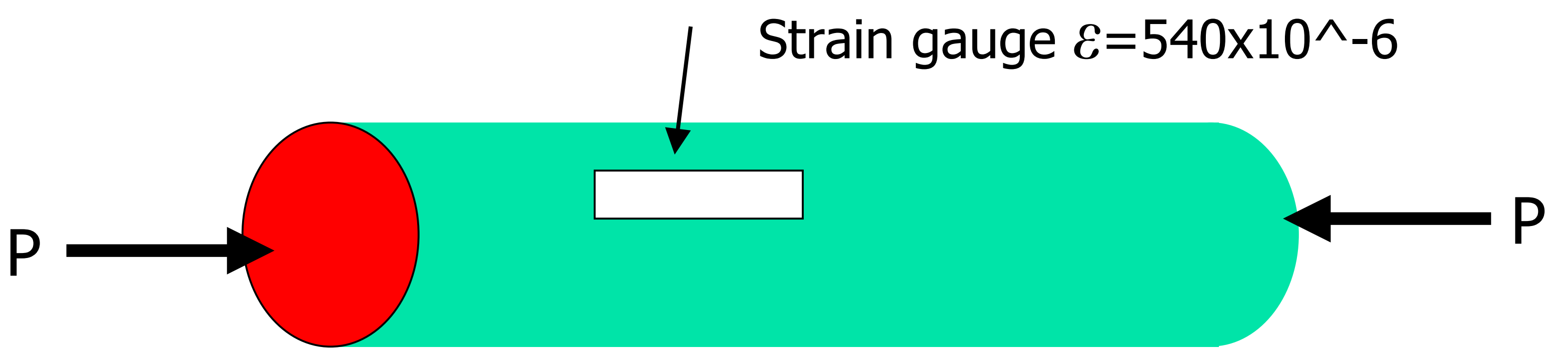
- Linear Elasticity – allows conversion from raw data to stress vs. strain curves
- σ=Eε
- E= Young's Modulus (Elastic Modulus)
- Similarly,
  - F=kd (force = constant*distance)
  - P=k δ (force = spring constant*displacement)

Elasticity & Poisson’s ratio

- Linear (metals, ceramics)→ALL mat’ls exhibit elastic behavior at ε<0.001%
- Nonlinear (polymers, rubbers)→Some mat’ls exhibit large strain elasticity
- $\nu = -\varepsilon' / \varepsilon$ (if bar stretched in x-direction)
  - ε is axial strain (the x-related strain)
  - ε' is lateral (either y or z strain)

Example Problem 1

A circular aluminum tube of length L=500mm is loaded in compression by forces P. The outside & inside diameters are 60mm & 50mm, respectively. A strain gage is placed on the outside to measure normal strains in the longitudinal direction.



Problem 1 Continued…

(a) If the measured strain is ε=540x10^-6, what is the shortening δ of the bar?

$\delta = \varepsilon L = 0.270mm$

(b) If the compressive stress in the bar is intended to be 40 MPa, what should be the load, P ?

σ= 40MPa, A = $\pi/4[d_2^2-d_1^1]$ = 863.9mm^2,

P = σA = 40MPa*863.9mm^2 = 34.6kN

Example Problem 2

Imagine a long copper wire hangs virtically from a high-altitude balloon.

(a) What is the greatest length (feet) it can have without yielding if the copper yields at 25 ksi?

(b) If the same wire hangs from a ship at sea, what is the greatest length?

γc = wt. Density of copper = 556 lb/ft^3 γw = wt density of sea water = 63.8lb/ft^3

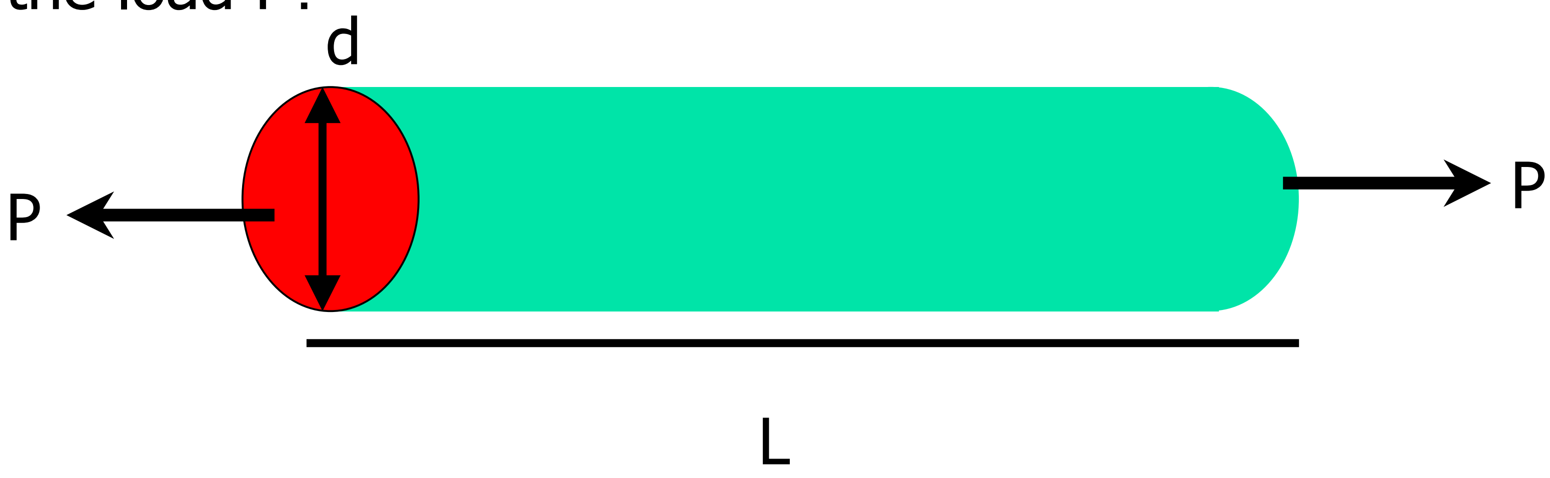
Problem 2 Continued…

(a) W = total weight of copper wire = $\gamma_c AL$, σmax = W/A = γcL, Lmax = σmax/γc = 25,000psi/556lb/ft^3 (b/c 1,000psi in 1ksi)

(b) F = tensile force at top of wire, F= (γc- γw)AL, σmax =F/A = (γc- γw)L, Lmax = σmax/ (γc- γw) = 7310 ft.

Example Problem 3

A prismatic bar of circular cross section is loaded by tensile forces, P. The bar has length, L=3.0m and diameter d=30mm. It is made of an aluminum alloy with modulus of elasticity E=73 GPa. And Poissons ratio ν =1/3. If th bar elongates by 7.0mm, what is the decrease in diameter Δd? What is the magnitude of the load P?



Problem 3 Continued…

Axial strain: $\varepsilon = \delta/L$ = 7mm/3m = 0.002333

Lateral strain: $\varepsilon' = -\nu\,\varepsilon$ = -1/3 (0.002333) = -0.000778

(Minus sign means shortening)

Decrease in diameter: $\Delta d = |\varepsilon'|d$ = (0.000778)(30mm)

Tensile loads: Axial stress $\sigma = E\,\varepsilon$ = 73GPa*0.002333 = 170.3MPa

(This stress is less than the yield stress, so Hooke's law is applicable)

$P = \sigma A$ = (170.3MPa)(π/4)(30mm)^2 = 120kN