Introduction to Engineering Bike Lab 2 - 1

Agenda

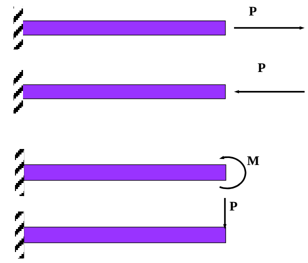
- Begin Bike Lab #2

Part I - Bicycle Design
Material as Structural Components

How Materials Are Loaded

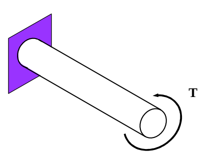
TENSION / COMPRESSION

BENDING



How Materials Are Loaded

TORSION



Most practical applications are combinations of tension/compression, bending, and torsion

Characterization of Stiffness and Strength of Materials

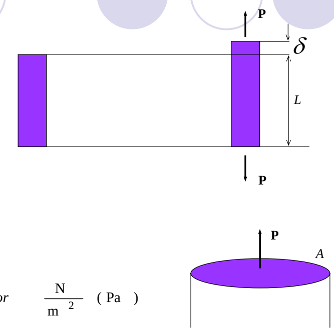
The tension test:

Strain: $\varepsilon = \frac{\delta}{L}$

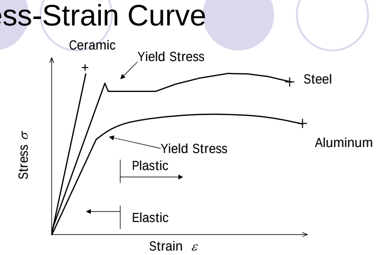
Stress: $\sigma = \frac{P}{A}$

Units of stress:

$\frac{lb}{in^2}$ (psi) *or* $\frac{N}{m^2}$ (Pa)



Stress-Strain Curve



In the elastic (linear) portion of the stress-strain curve:

$$\sigma = E \varepsilon$$ (Hooke's Law)

Modulus of Elasticity (slope of *s* - *e*) curve) (**Material Stiffness**)

Stress-Strain

Yield Stress is the limit of the elastic region. Materials that are loaded within the elastic region will return to their original dimensions upon unloading

Typical values:

	Steel	Aluminum	Copper	Titanium
Modulus of Elasticity (psi)	$29x10^6$	$10.1x10^6$	$17x10^6$	$16.5x10^6$
Yield Stress (psi)	36,000 - 100,000	14,000 - 73,000	10,000- 53,000	25,000- 120,000

Stress-Strain

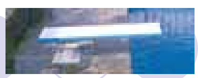
Structural components are designed to deform (change dimensions) when used. For Example:

The top floor of the Sears tower in Chicago can sway 6 inches due to the force applied by the wind

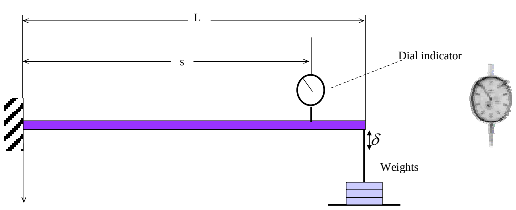
Stress-Strain

The tips of the wings of a Boeing 747 Jumbo jet deflect up 14 feet as the aircraft takes off.

Part II
Bending of a Cantilever Beam



Experimental setup:



Part II
Bending of a Cantilever Beam

<u>The deflection of the beam depends on:</u>

- The load F. More deflection with larger load.
- The length of the beam. The deflection of the end increases with the length.
- Material stiffness. Higher stiffness produces less deflection.
- The geometry of the cross section. Higher moment of inertia (defined in the next slide), results in less deflection.

Bending of a Cantilever Beam

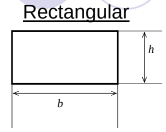
Theoretically, the deflection of the beam at the location of the dial indicator is given by

$$\delta = \frac{F s^2}{6 E I}(3L - s)$$

Where ***E*** is the modulus of elasticity of the beam’s material, and ***I*** is the moment of inertia of the cross section.

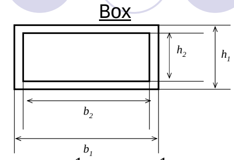
Moment of Inertia of a Cross Section

<u>Rectangular</u>



$$I_{rect} = \frac{1}{12} b\, h^3$$

<u>Box</u>



$$I_{box} = \frac{1}{12} b_1 h_1^3 - \frac{1}{12} b_2 h_2^3$$

In the lab we will set up three cantilever beams and we will compare their deflection. Two of the beams have the same cross section geometry (rectangle), but one is made of steel and the other is made of aluminum. The third beam is made up of aluminum with a smaller cross sectional area than the first two beams, but with a box cross section.

In Lab

For each of the three beams (steel rectangular, aluminum rectangular, aluminum box):

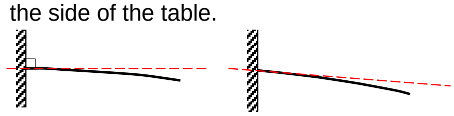
1. Clamp the beam and position the dial indicator such that:
   ***L* = 12.5 in. and *s* = 11.5 in**.
2. Load (by placing 2.5 lb weights in the bucket) incrementally (5 increments) up to:
   ***F*max = 12.5 lb.**

In Lab

3. Record the deflection δ for each load .
4. Measure the beam's cross section dimensions and calculate moment of inertia I.
5. Record all measurements and calculations in Worksheet A.

NOTE:

- The deflection measured in the lab is greater than theory predicts. This is mainly due to how the beams are clamped. The clamped end is not a true 'fixed' end as assumed by theory, and the beam is not perpendicular to the side of the table.



ASSUMED BEAM ACTUAL BEAM

After Lab

For each of the three beams (steel rectangular, aluminum rectangular, aluminum box):

- Plot the theoretically expected deflection (δ) versus load (F) for $0 \le F \le F_{max}$
- Overlay the four data points (experimental measured load and deflection).
- Put all curves and data points for the three beams on one plot. Remember to label the curves.

After Lab

Prepare a team Lab Report using the standard format given and include the following:

- Worksheet A
- Graph of the results
- Answer the following:
  - Compare the theoretical prediction with the measurements. Explain any discrepancies that exist.
  - Why are tubes used for the bicycle frame?
- Calculations

Bike Lab 2: Worksheet A

	E, Modulus of Elasticity (psi)	Width, *b* (in.)	Height, *h* (in.)	Wall Thickness (in.)	*I*, Moment of Inertia (in^4)
Steel Beam	29×10^6			N.A	
Aluminum Beam	10.1×10^6			N.A	
Aluminum Box	10.1×10^6				

Steel rectangular:

Load *F*, (lb)						
Deflection δ (in.)						

Aluminum rectangular:

Load *F*, (lb)						
Deflection δ (in.)						

Aluminum box:

Load *F*, (lb)						
Deflection δ (in.)						

Assignment

- Read Bike Lab #2 materials