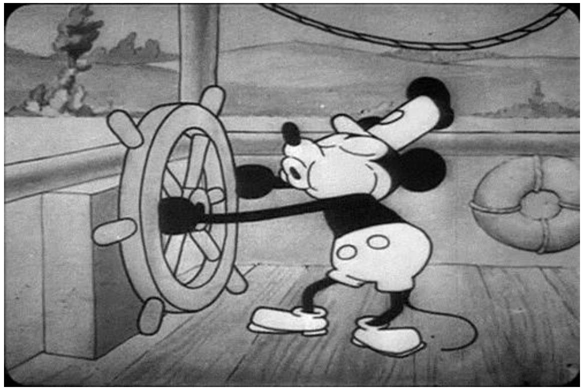
WORCESTER POLYTECHNIC INSTITUTE
MECHANICAL ENGINEERING DEPARTMENT

STRESS ANALYSIS
ES-2502, D'2020

We will get started soon...



07 April 2020

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STRESS ANALYSIS
ES-2502, D'2020

We will get started soon...

Lecture 08:
Unit 6: Stress & Strain/ Hook's Law

07 April 2020

General information

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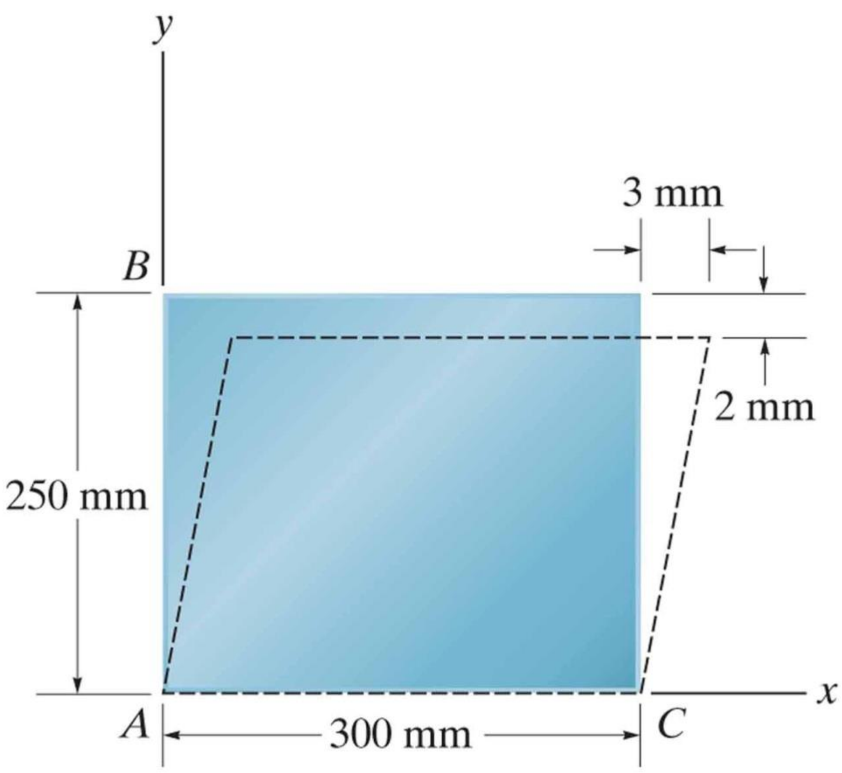
Strain: example F

Due to a loading, the plate is deformed into the dashed shape shown. Determine (a) the average normal strain along the side AB, and (b) the average shear strain in the plate at A relative to the x and y axes.



Approach:

1) Define geometry
2) Determine change in geometry
3) Compute required strains

Strain: example F

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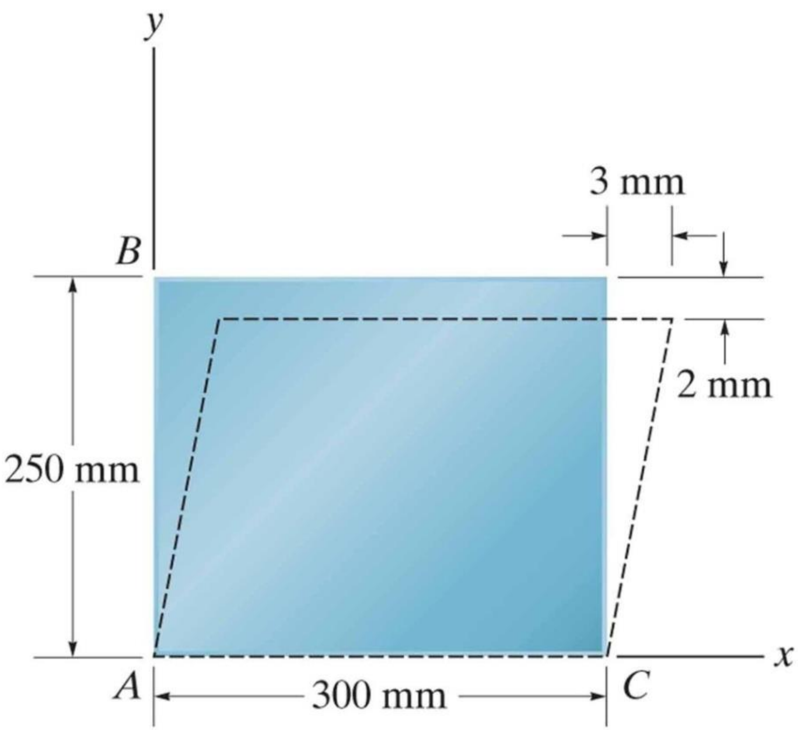
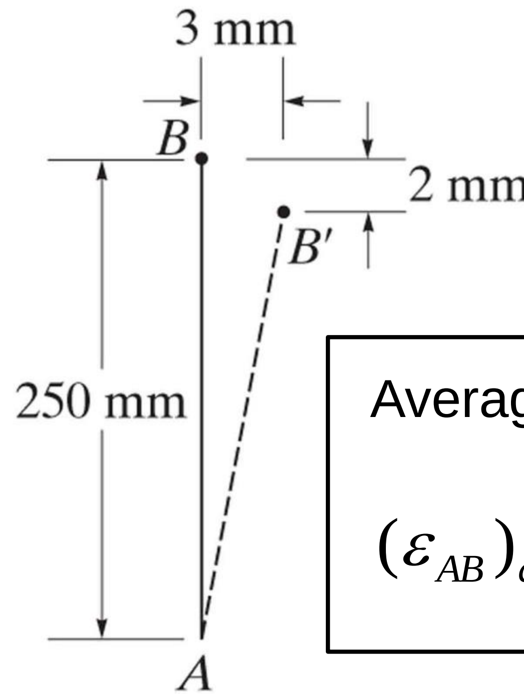




Average normal strain:

$$(\varepsilon_{AB})_{avg} = \frac{AB' - AB}{AB}$$

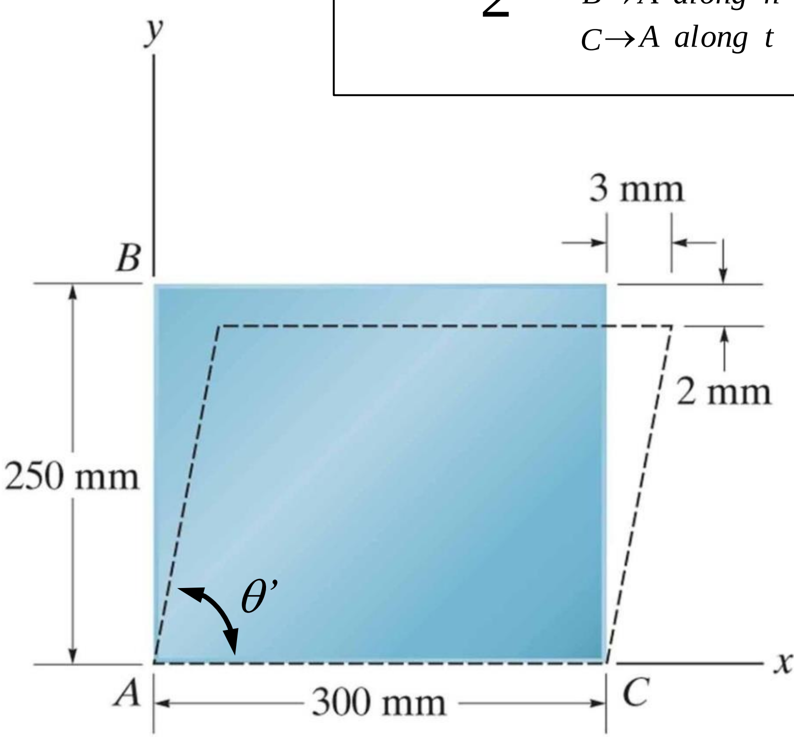
Strain: example F

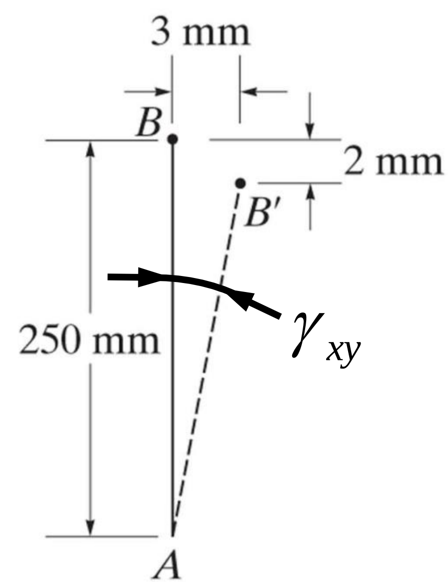
Due to a loading, the plate is deformed into the dashed shape shown. Determine (a) the average normal strain along the side AB, and (b) the average shear strain in the plate at A relative to the x and y axes.

$$\gamma_{nt} = \frac{\pi}{2} - \lim_{\substack{B \to A \text{ along } n \\ C \to A \text{ along } t}} \theta'$$

Average shear strain:

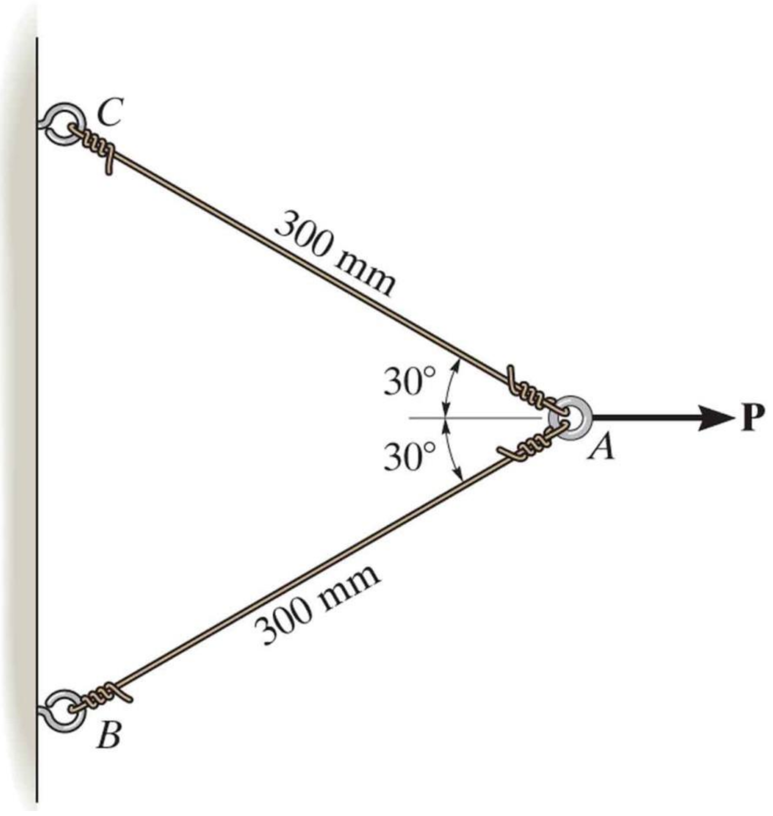
$$\gamma_{xy} = \frac{\pi}{2} - \theta'$$





Strain: example G

The two wires are connected together at A. If the force $\mathbf{P}$ causes point A to be displaced horizontally 2 mm, determine the normal strain developed in each wire.



Approach:

1) Define geometry
2) Determine change in geometry
3) Compute required strains

Stress $\leftrightarrow$ Strain

Tensile test

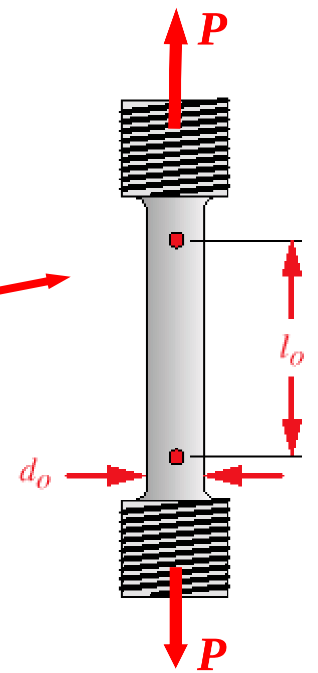


FIGURE 2-1
A Tensile Test Specimen

ASTM standards

Average Stress: (normal)

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

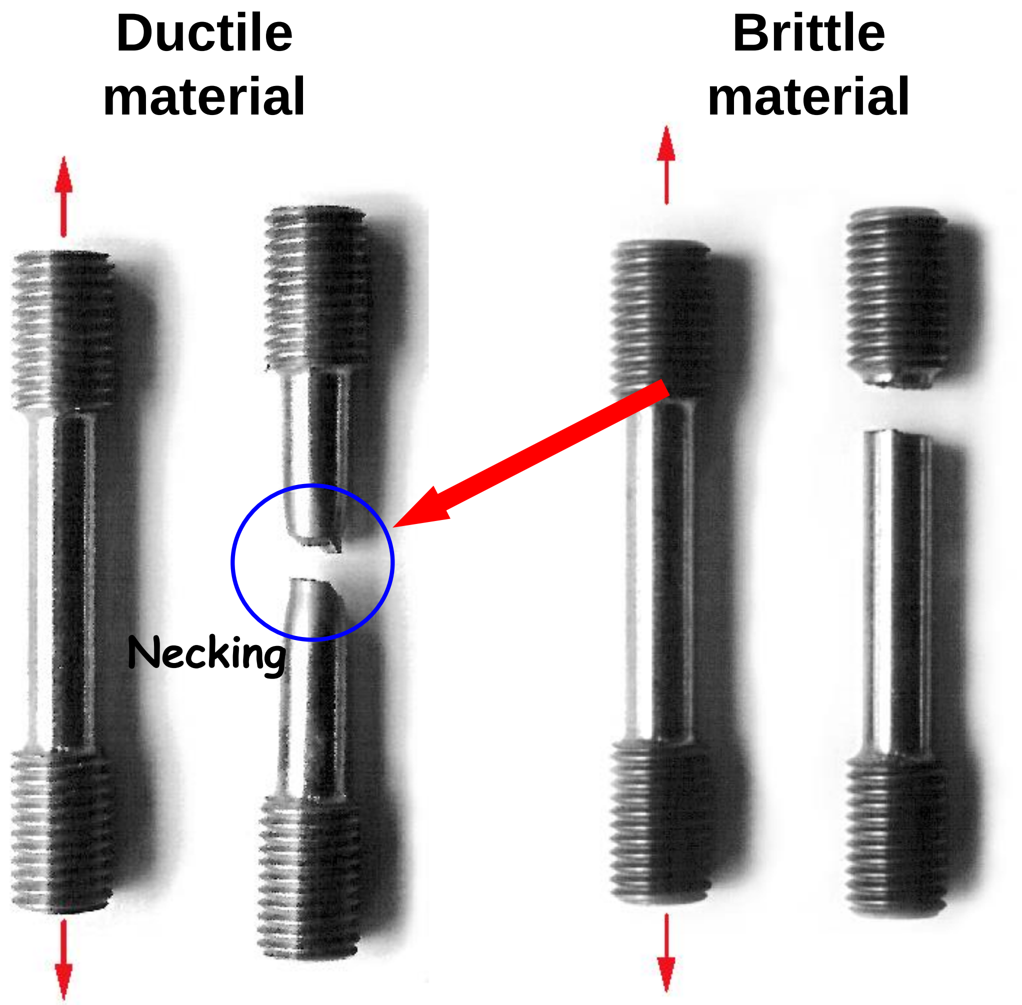
Average Strain: (normal)

$$\varepsilon = \frac{l - l_o}{l_o}$$

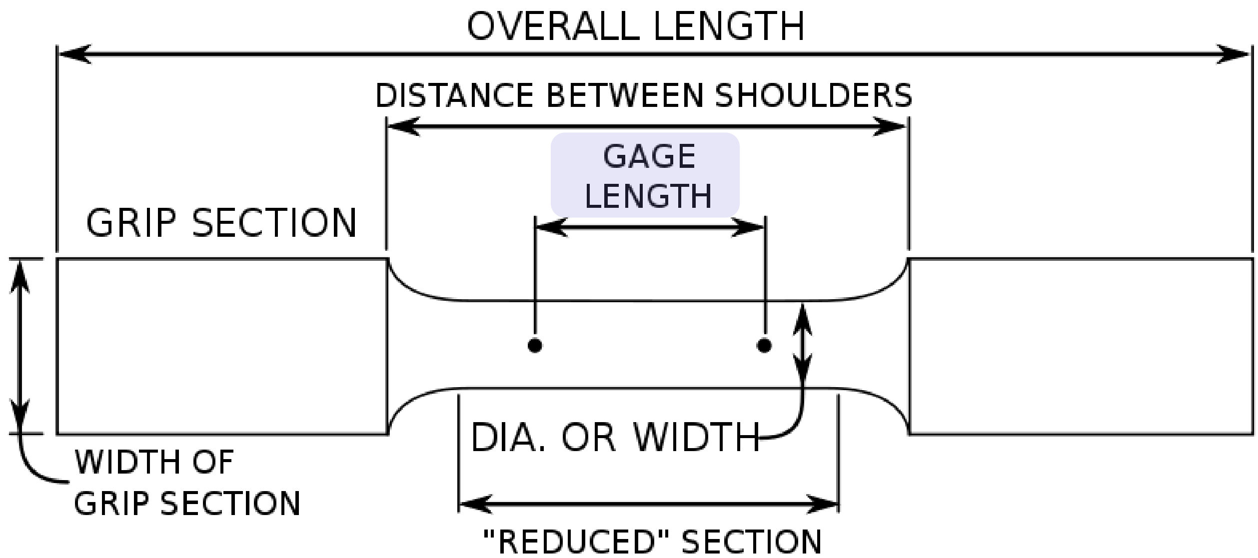
Stress ↔ Strain: tensile test

Tensile test

Typical results



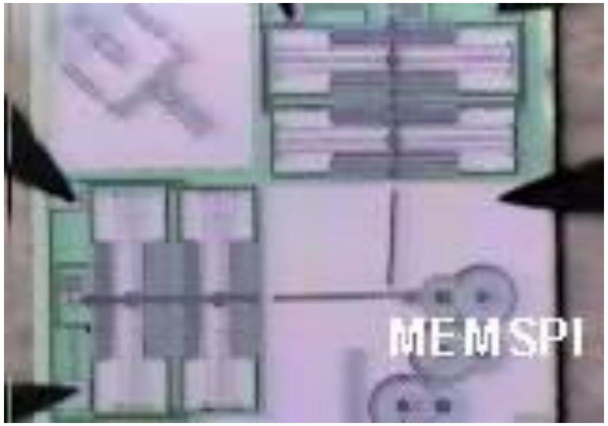
Stress ↔ Strain: tensile test



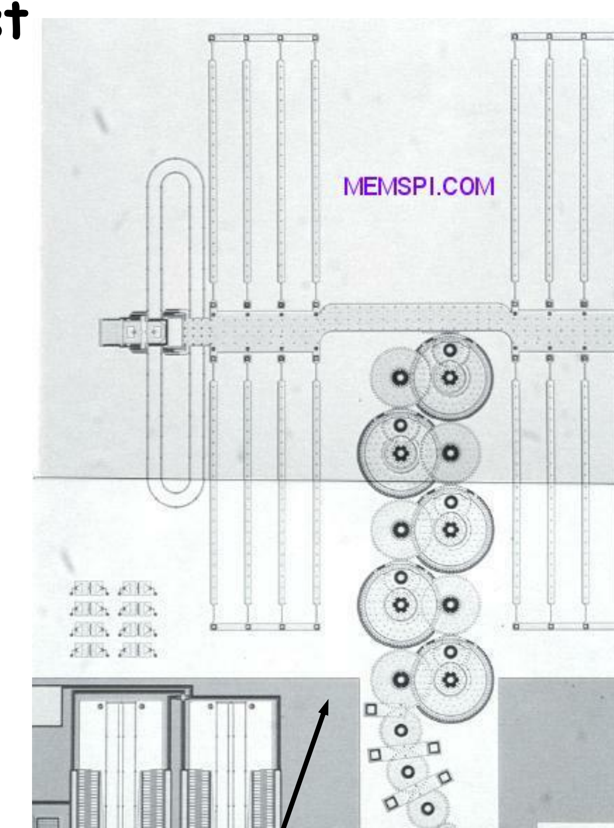
All values in inches	Standard specimen at nominal diameter:		Small specimen at nominal diameter:		
	0.500	**0.350**	**0.25**	**0.160**	**0.113**
Gauge length	2.00±0.005	1.400±0.005	1.000±0.005	0.640±0.005	0.450±0.005
Diameter tolerance	±0.010	±0.007	±0.005	±0.003	±0.002
Fillet radius (min.)	3⁄8	0.25	5⁄16	5⁄32	3⁄32
Length of reduced section (min.)	2.5	1.75	1.25	0.75	5⁄8

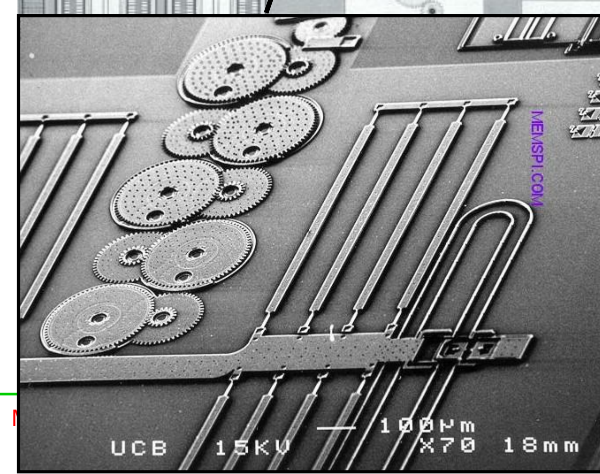
Material properties

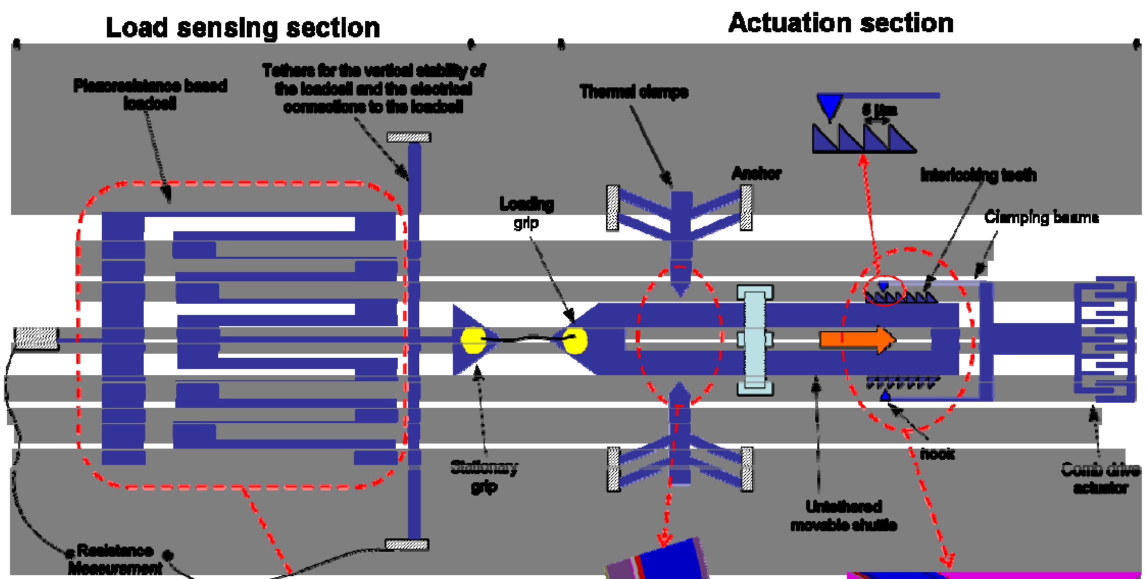
Microscale tensile test

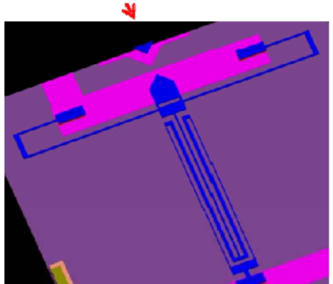


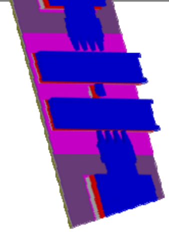
Machine is about 1.5 mm in height !!

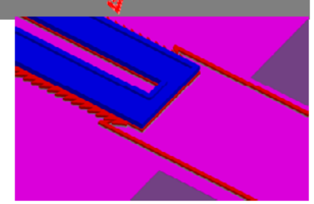








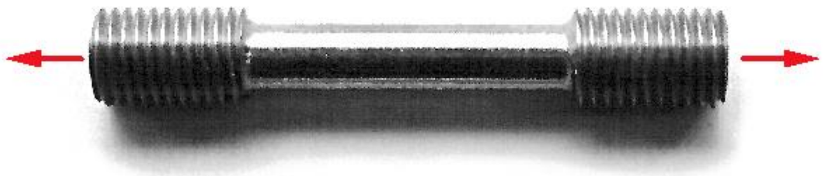


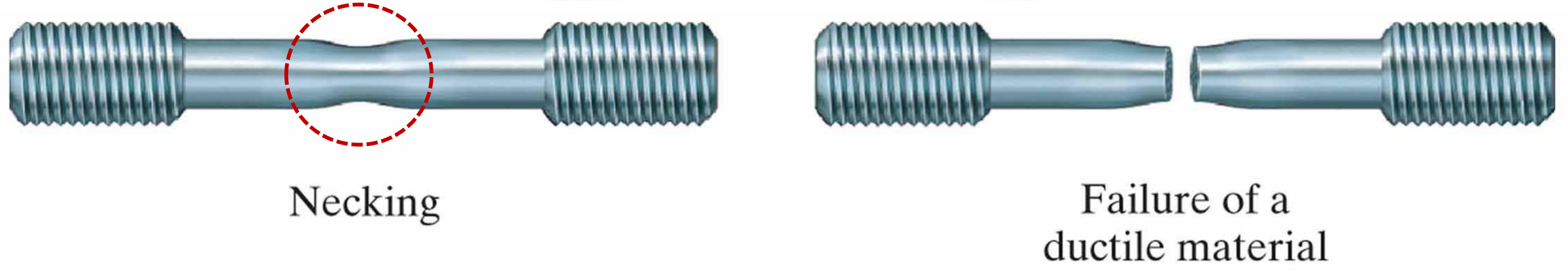


UIUC/Sandia Labs

Material properties: Stress - Strain

Tensile test: ductile material



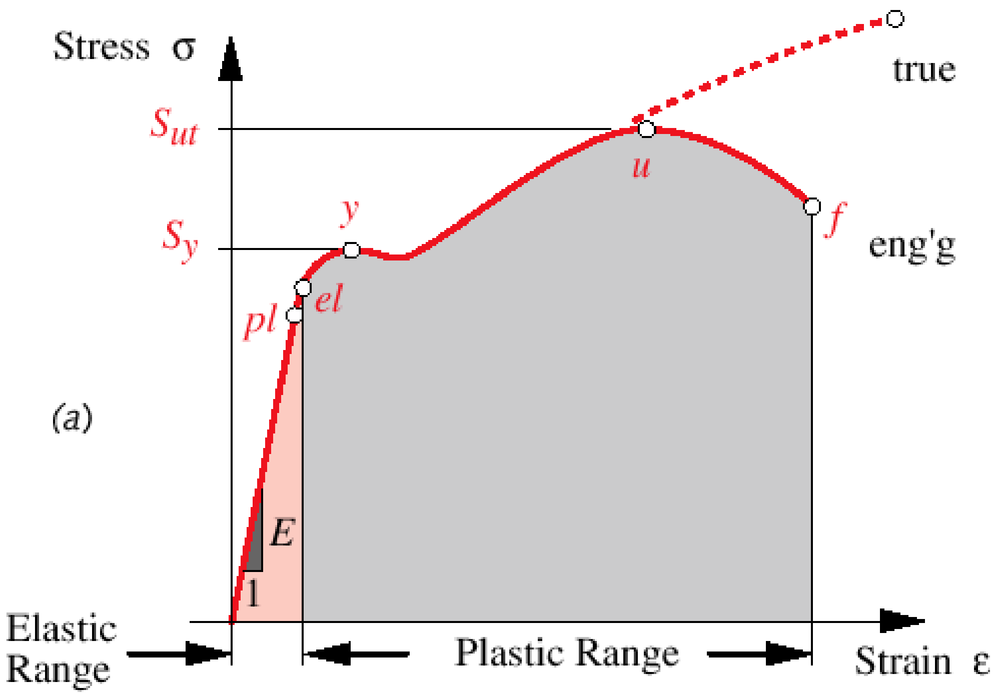


Fractured surface

Stress - Strain

Stress-strain diagrams: ductile materials

Ductile material



Engineering stress: $$\sigma = \frac{P}{A_{initial}}$$

True stress: $$\sigma = \frac{P}{A_{true}}$$

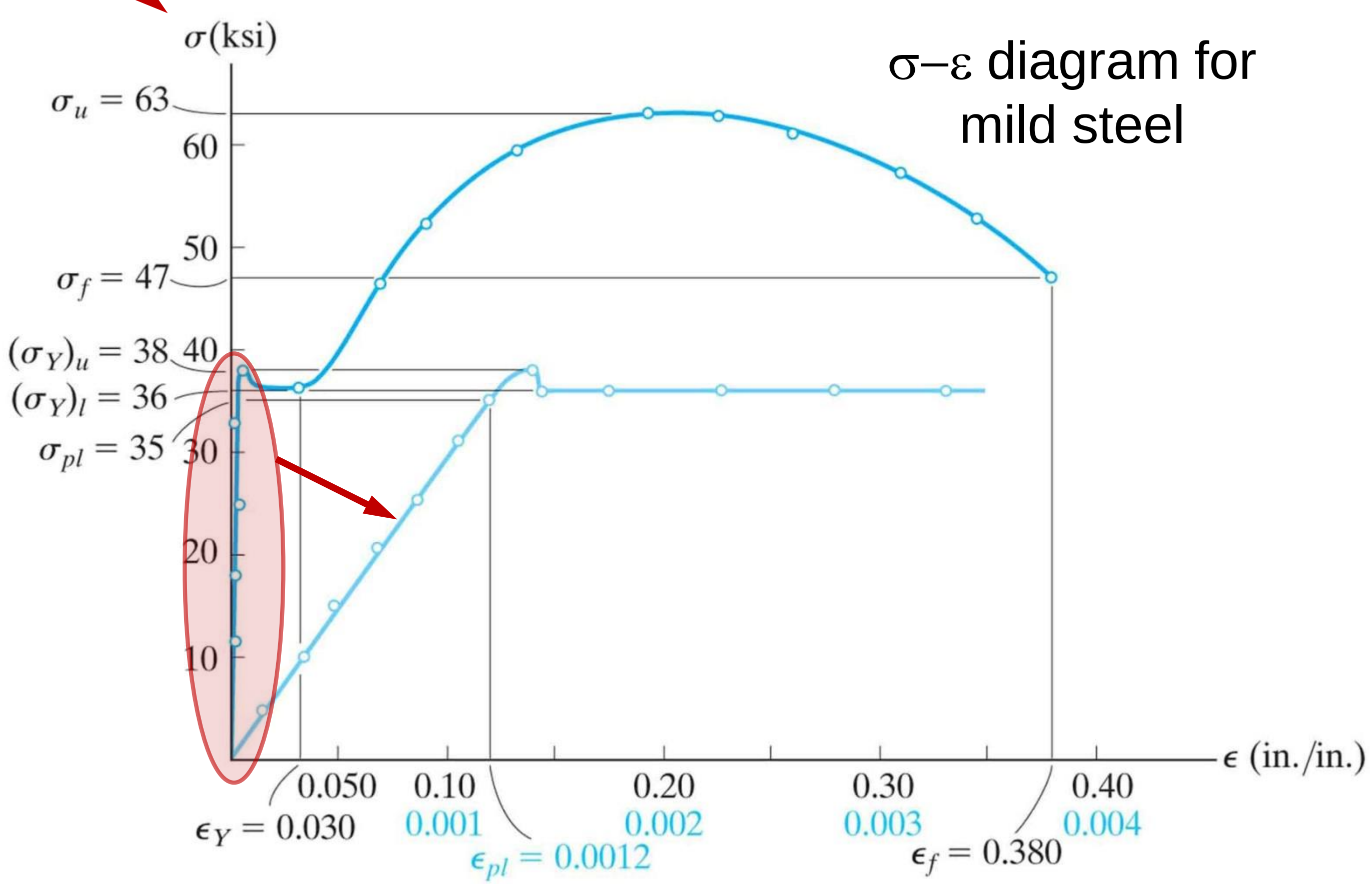
Stress ↔ Strain: Hook's Law

$$\sigma = E \cdot \varepsilon$$ ← Elastic range

E = proportionality constant ← E (aka Young's modulus)

Engineering stress

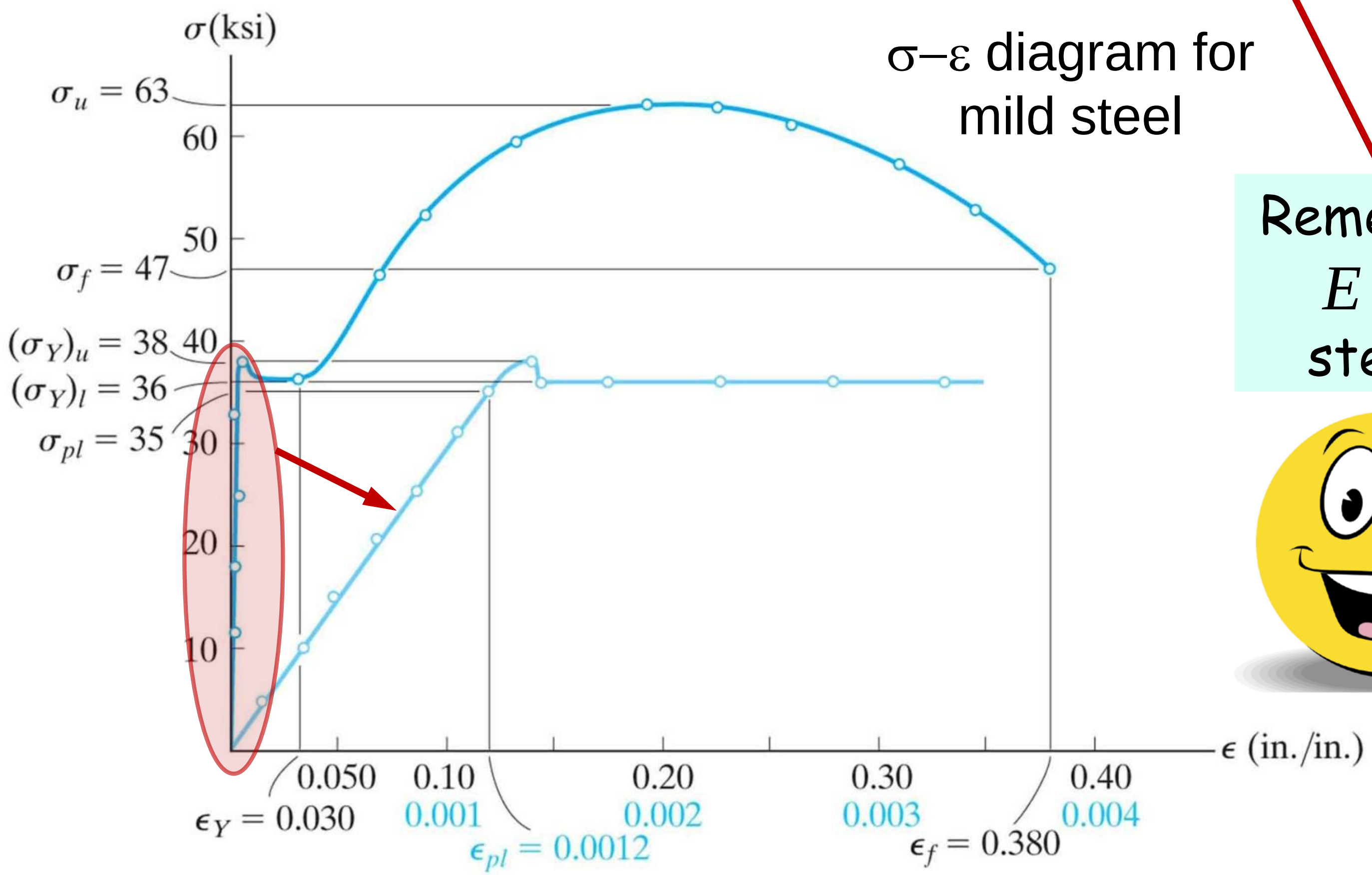
σ–ε diagram for mild steel



Stress ↔ Strain: elastic properties

For diagram shown:
(E for steel)

$$E = \frac{35 \times 10^3 \ psi}{0.0012 \ in/in} \approx 30 \times 10^6 \ psi$$



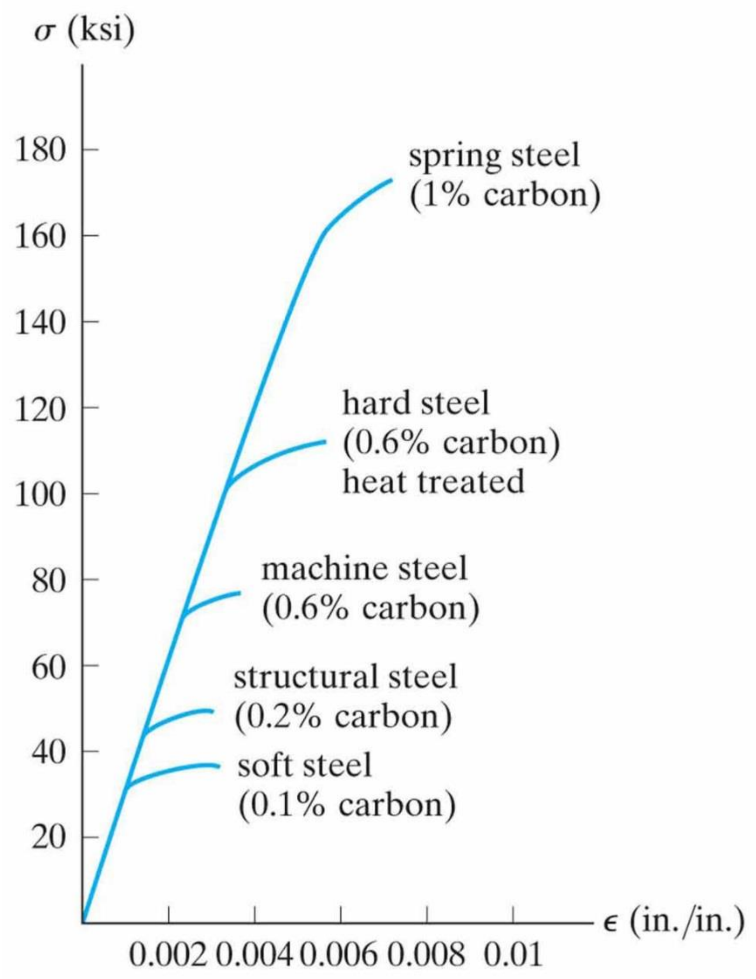
σ–ε diagram for
mild steel

Remember
E for
steel !!

Stress ↔ Strain: Hook's Law

$$\sigma = E \cdot \varepsilon$$

E = Elastic modulus (aka)

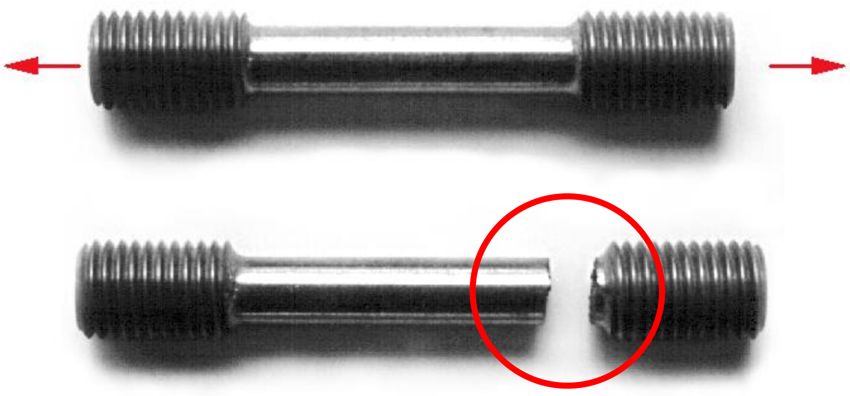


Remember: E is nearly the same for different classes of steels !!

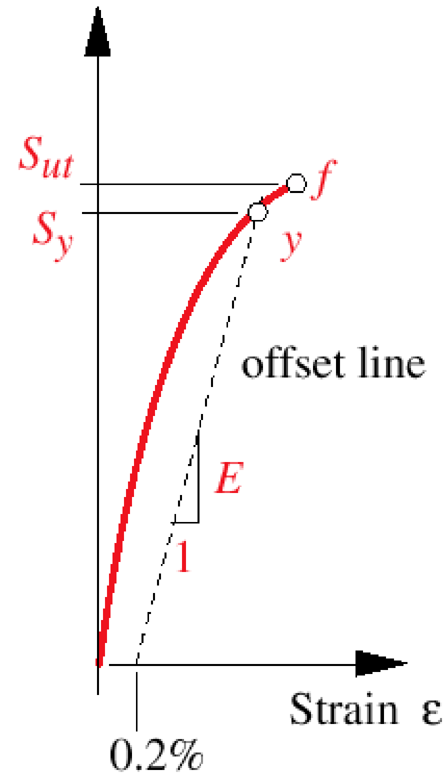
Stress - Strain

Stress-strain diagrams: brittle materials

Brittle material



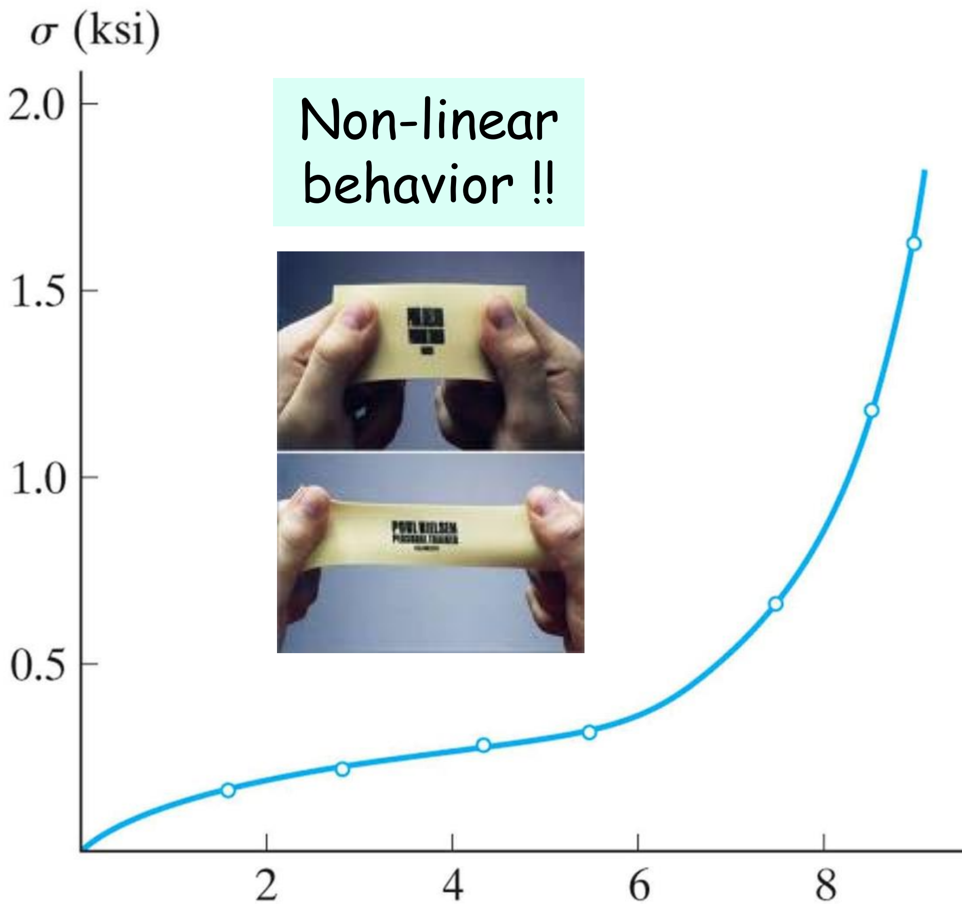
minimum
necking



Offset
method

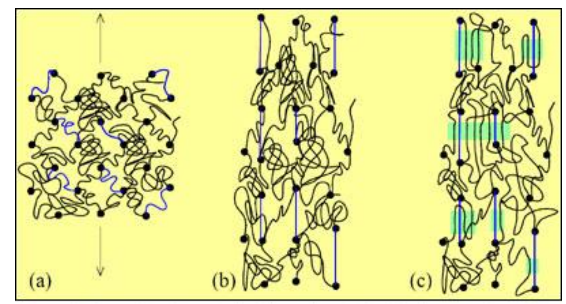
Stress - Strain

Stress-strain diagrams: natural rubber



$\sigma\!-\!\epsilon$ diagram for natural rubber

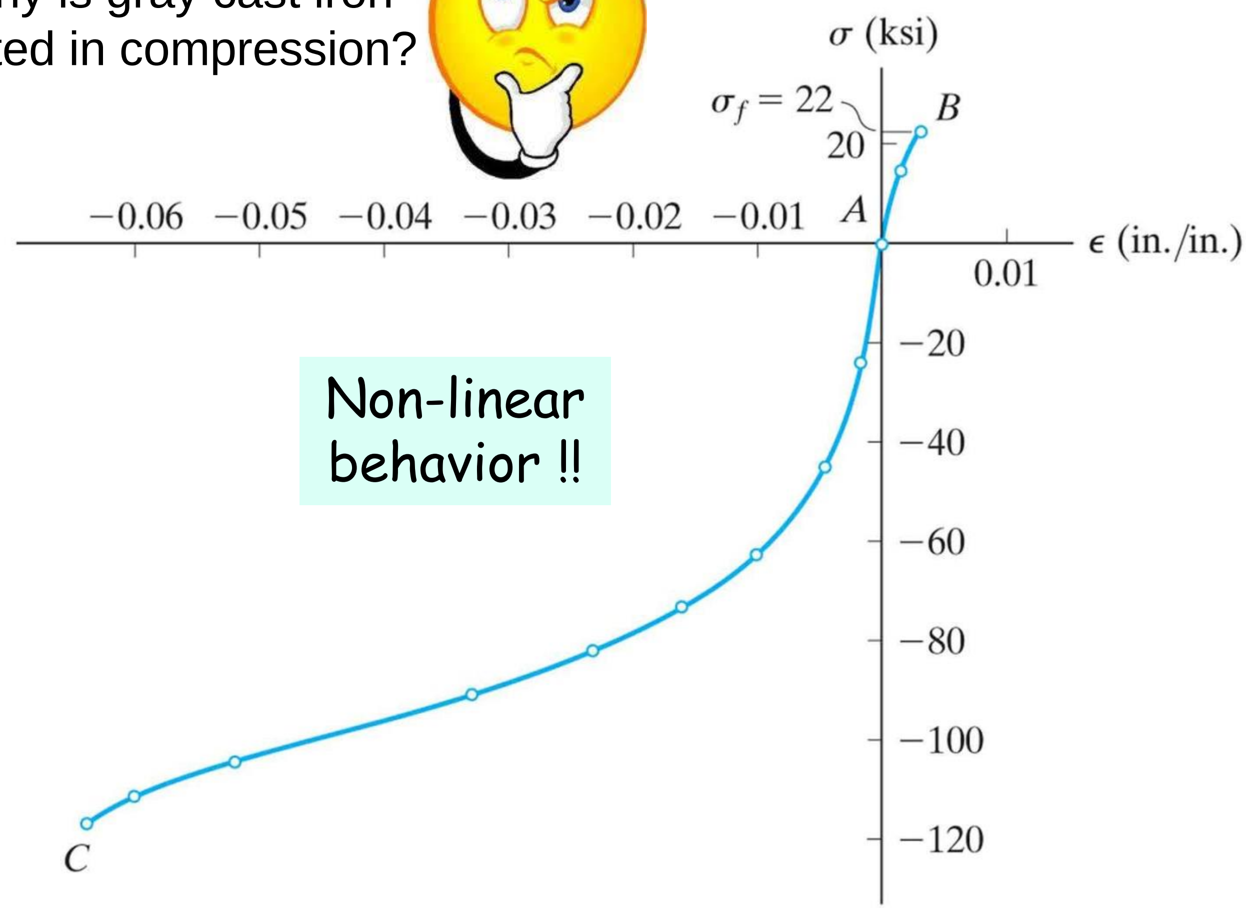
Stretching of rubber fibers



Stress - Strain

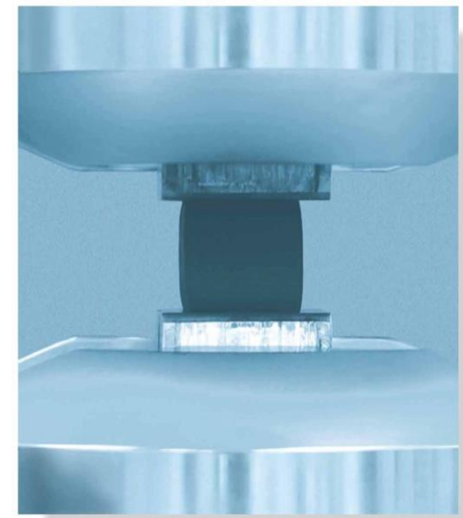
Stress-strain diagrams: gray cast iron

Why is gray cast iron tested in compression?



Non-linear behavior !!

σ–ϵ diagram for gray cast iron



Reading assignment

- Chapter 1 of textbook
- Review notes and text: ES2001, ES2501

Homework assignment

- As indicated on webpage of our course