Lecture 08: Stress and Strain

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General information

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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

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.

Horizontal Segment $AB$:

$$\varepsilon_{AB} = \frac{AB' - AB}{AB}$$

Average normal strain:
Strain: example F

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Average shear strain:

$$\gamma_{xy} = \frac{\pi}{2} - \theta'$$
The two wires are connected together at $A$. If the force $P$ 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 ↔ Strain

Tensile test

Stress: \[ \sigma = \frac{P}{A} \]
(normal)

Strain: \[ \varepsilon = \frac{l - l_0}{l_0} \]
(normal)

**FIGURE 2-1**
A Tensile Test Specimen

ASTM standards
Stress ↔ Strain: tensile test

<table>
<thead>
<tr>
<th>All values in inches</th>
<th>Standard specimen at nominal diameter:</th>
<th>Small specimen at nominal diameter:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.500</td>
<td>0.350</td>
</tr>
<tr>
<td>Gauge length</td>
<td>2.00±0.005</td>
<td>1.400±0.005</td>
</tr>
<tr>
<td>Diameter tolerance</td>
<td>±0.010</td>
<td>±0.007</td>
</tr>
<tr>
<td>Fillet radius (min.)</td>
<td>3/8</td>
<td>0.25</td>
</tr>
<tr>
<td>Length of reduced section (min.)</td>
<td>2.5</td>
<td>1.75</td>
</tr>
</tbody>
</table>
Material properties

Microscale tensile test

Machine is about 1.5 mm in height!!
Material properties: Stress - Strain

Tensile test: ductile material

Necking

Failure of a ductile material

Fractured surface
Stress - Strain

Stress-strain diagrams: ductile materials

Ductile material

Engineering stress:

\[ \sigma = \frac{P}{A_{\text{initial}}} \]

True stress:

\[ \sigma = \frac{P}{A_{\text{true}}} \]
Stress ↔ Strain: Hook’s Law

\[ \sigma = E \cdot \varepsilon \]

\( E \) = proportionality constant

\( \varepsilon \) = strain

\( \sigma \) = stress

\( E \) (aka Young’s modulus)

Elastic range

Engineering stress

\( \sigma_k = 63 \) ksi

\( \sigma_f = 47 \) ksi

\( (\sigma_Y)_u = 38.4 \) ksi

\( (\sigma_Y)_l = 36 \) ksi

\( \sigma_{pl} = 35 \) ksi

\( \varepsilon_Y = 0.030 \)

\( \varepsilon_{pl} = 0.0012 \)

\( \varepsilon_f = 0.380 \)

\( \varepsilon \) (in./in.)

\( \sigma \) (ksi)

\( \sigma \)–\( \varepsilon \) diagram for mild steel
Stress ↔ Strain: elastic properties

For diagram shown: 
\( E = \frac{35 \times 10^3 \text{ psi}}{0.0012 \text{ in./in.}} \approx 30 \times 10^6 \text{ psi} \)

\( \sigma - \varepsilon \) diagram for mild steel

\( \sigma_u = 63 \)
\( \sigma_f = 47 \)
\( (\sigma_Y)_u = 38.40 \)
\( (\sigma_Y)_l = 36 \)
\( \sigma_{pl} = 35 \)

\( \sigma_Y = 0.030 \)
\( \varepsilon_{pl} = 0.0012 \)
\( \varepsilon_f = 0.380 \)

Remember \( E \) for steel!!
Stress ↔ Strain: Hook’s Law

\[ \sigma = E \cdot \varepsilon \]

\[ E = \text{Elastic modulus (aka)} \]

Remember: \( E \) is nearly the same for different classes of steels!!
Stress - Strain

Stress-strain diagrams: brittle materials

Brittle material

Offset method
Stress - Strain

Stress-strain diagrams: natural rubber

\[ \sigma (\text{ksi}) \]

\[ 2.0 \]

\[ 1.5 \]

\[ 1.0 \]

\[ 0.5 \]

\[ \sigma - \epsilon \text{ diagram for natural rubber} \]

\[ \epsilon \text{ (in./in.)} \]

Non-linear behavior !!

Stretching of rubber fibers
Stress - Strain

Stress-strain diagrams: gray cast iron

Why is gray cast iron tested in compression?

Non-linear behavior !!
Reading assignment

• Chapter 1 of textbook
• Review notes and text: ES2001, ES2501
Homework assignment

• As indicated on webpage of our course