INSTRUMENTATION

FORCE AND TORQUE

STRAIN GAUGES

- Several different types with bonded resistance strain gauge being the most common
- Made of a grid of very small wires bonded to a small plastic film
- Resistance of this network varies linearly with strain and is measured with a Wheatstone bridge
- Low cost, small size, high accuracy
- Needs to be recalibrated to keep accurate
MEASUREMENTS

BENDING, AXIAL, SHEAR, AND TORSION

STRAIN IS A FUNCTION OF THE FORCE APPLIED, GEOMETRY, AND MATERIALS PROPERTIES

<table>
<thead>
<tr>
<th>Stress</th>
<th>Equation</th>
<th>Stress</th>
<th>Equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bending Stress</td>
<td>[ \sigma_{\text{bending}} = \frac{M \times c}{I} ]</td>
<td>Bending strain</td>
<td>[ \varepsilon_{\text{bending}} = \frac{\sigma_{\text{bending}}}{E} ]</td>
</tr>
<tr>
<td>Axial Stress</td>
<td>[ \sigma_{\text{axial}} = \frac{F_{\text{axial}}}{A} ]</td>
<td>Axial strain</td>
<td>[ \varepsilon_{\text{axial}} = \frac{\sigma_{\text{axial}}}{E} ]</td>
</tr>
<tr>
<td>Transverse Shear Stress</td>
<td>[ \tau_{\text{transverse}} = \frac{F_{\text{transverse}}}{A_{\text{shear}}} ]</td>
<td>Shear strain</td>
<td>[ \gamma = \frac{\tau_{\text{shear}}}{G} ]</td>
</tr>
<tr>
<td>Torsional Shear Stress</td>
<td>[ \tau_{\text{torsion}} = \frac{T \times c}{I} ]</td>
<td>Torsional strain</td>
<td>[ \gamma = \frac{\tau_{\text{torsion}}}{G} ]</td>
</tr>
</tbody>
</table>

APPLICATIONS

- Mechanical: Measure deflection or deformations in parts.
- Civil: Monitor loadings in bridges, dams and other structures.
- Biological: Blood flow and tissue swelling.
LOAD CELLS

- Types of transducers that convert force into measurable output.
- Used in fields demanding high accuracy and precision.
- Typically measure mechanical force of objects.

TYPES

Different classes of load cells, based on type of signal generated
- Hydraulic
  - Accuracy within 0.25% or better.
  - Measure change in pressure of internal fluid.
  - Good for hazardous areas and can take high impacts (up to 5000 tons)
**TYPES**

- **Pneumatic**
  - Multiple chambers for higher accuracy than hydraulic cells.
  - Inherently explosion proof.
  - Safe for areas where cleanliness is needed.
- **Electric**
  - Typically measure fluctuations in electric field that are proportional to the load.
  - Many types: strain gauge load cell, piezoresistive load cell, inductive load cell, magnetostrictive load cell.

**SPRING GAUGE**

- Spring Scale
- Spring Balance
- Newton Meter
SPRING GAUGE: COMPOSITION

- Fixed Spring
- Hook/basket
- Visual System: Digital or Analog

SPRING GAUGE: OPERATION

- Hooke's Law: The force needed to extend a spring is proportional to the distance that spring is extended from its rest position.
- $F_s = kx$
SPRING GAUGE: VARIETY

- Weight
- Cheap Accelerometer
SPRING GAUGE: PROS AND CONS

- Pros: Cheap, simple, and robust
- Cons: Not as accurate as other measuring methods

QUESTIONS
REFERENCES

- causego.gov/alphabeta/cas/fdfarticles/ddfarticles/How-are-beam-and-bar-stresses-calculated-
  in-Autodesk-Nastran.html
- https://gab.wallawalla.edu/~curt.nelson/engr325/lecture/omega_dyneNH_SG.pdf
- https://www.britannica.com/science/Hooke's-law
- https://www.torque-force.eu/products/macro-spring-force-gauge/
- https://usa.banggood.com/8Pcs-Lab-Spring-Balance-Hook-Weight-Spring-Force-Meter-Spring-Dial-
  Scale-Spring-Dynamometer-1N-2_5N-5N-10N---1437171.html?cur_warehouse=CN
  Appliance-Mechanical-Spring-Scale.html
- https://en.wikipedia.org/wiki/Spring_scale
- https://www.shutterstock.com/image-photo/grocery-store-scale-fruit-veg-background-57985591