Mechanics of Materials

Week 3

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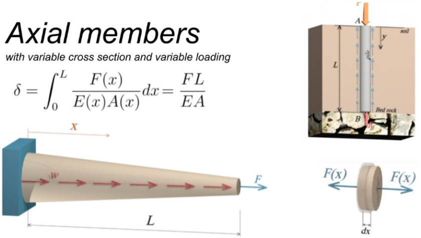
Academic Year: 2024
Semester: Second

Overview

Deformation of Axially Loaded Members

- Axially loaded members deform under applied axial forces.
- **Normal stress (σ):** $\sigma = \frac{P}{A}$, where P is the axial force and A is the cross-sectional area.
- **Axial deformation (δ):** $\delta = \frac{PL}{AE}$, where L is the length of the member, E is the modulus of elasticity.
- Assumptions include small deformations and linear elastic



Thermal Stress

Definition: Stress induced in a material due to temperature changes when expansion or contraction is restrained.

Key Formula:

$$\sigma = E\alpha\Delta T$$

Where:

- E: Modulus of elasticity
- α: Coefficient of thermal expansion
- ΔT: Change in temperature

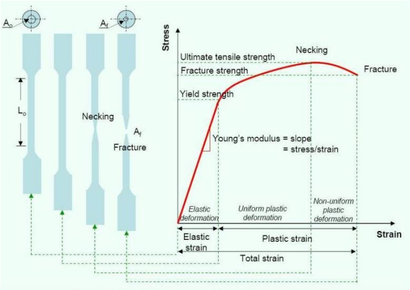
Tension Test

Tension Test:

- Evaluates material strength and behavior under axial tension.
- Generates a plot of normal stress (σ) versus normal strain (ε).

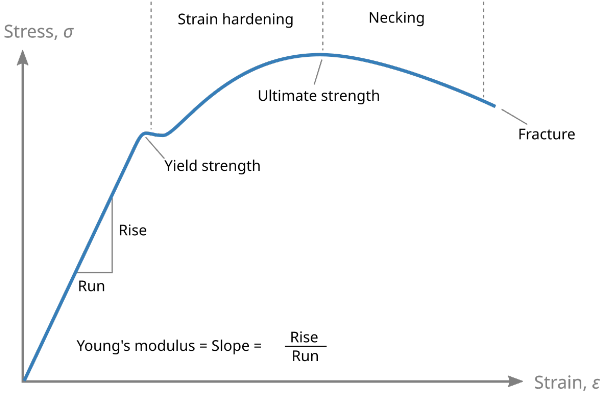
Key Regions of the Stress-Strain Curve:

- **Elastic Region:** Linear relationship where $\sigma = E\varepsilon$.
- **Yield Point:** Transition from elastic to plastic deformation.
- **Strain Hardening:** Stress increases with strain post-yield.
- **Necking and Fracture:** Material begins to neck, leading to failure.



Shape of Ductile Specimen at Various Stages of Testing

Stress-Strain Diagram

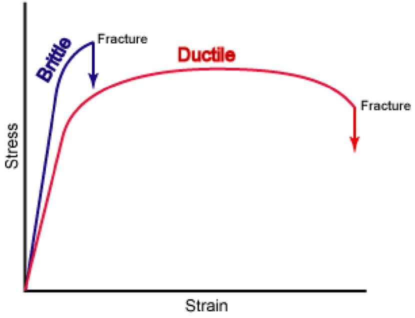


- **Modulus of Elasticity (E):** Slope in the elastic region.
- **Modulus of Resilience:** Area under the curve up to the yield point, indicating energy absorption before permanent deformation.
- **Modulus of Toughness:** Total area under the curve, representing energy absorption capacity until fracture.

Ductility and Brittleness

Ductile Materials:

- Undergo significant plastic deformation before failure.
- Examples include most metals and some polymers.
- Ductility measured by percent elongation or reduction in area.



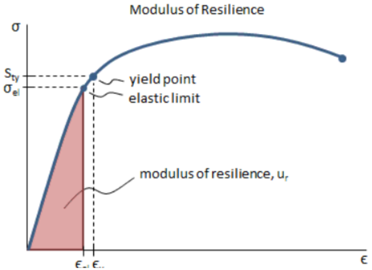
Brittle Materials:

- Exhibit little to no plastic deformation before fracture.
- Examples include cast iron, glass, and some

Strain Energy and Creep

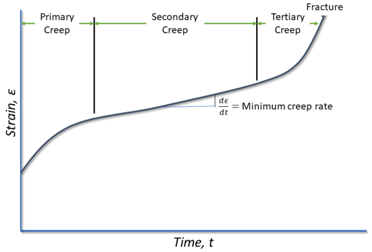
Strain Energy:

- Energy stored in a material due to deformation.
- **Modulus of Resilience:** Energy per unit volume up to yield.
- **Modulus of Toughness:** Total energy per unit volume until failure.



Creep:

- Gradual deformation under constant stress over time.
- Important in high-temperature applications.



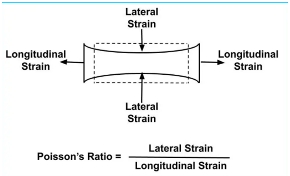
Shear Stress and Poisson's Ratio

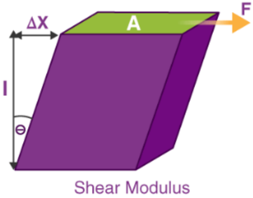
Poisson's Ratio (ν):

- Ratio of lateral strain to longitudinal strain.
- Ranges typically from 0 to 0.5 for most materials.
- Formula: $\nu = -\frac{\epsilon_{\text{lat}}}{\epsilon_{\text{long}}}$

Shear Stress (τ) vs. Shear Strain (γ):

- Shear modulus (G): $G = \frac{\tau}{\gamma}$
- Relationship with Young's modulus: $G = \frac{E}{2(1+\nu)}$





Shear_Stress.png

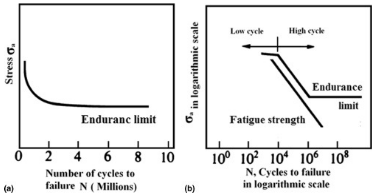
Fatigue and Long-term Behavior

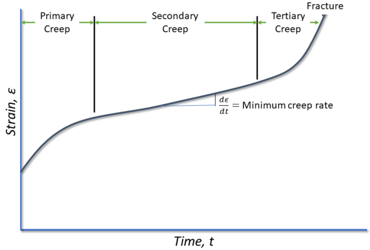
Creep:

- Time-dependent deformation under constant load.
- Accelerated by high stress and/or temperature.
- Design must ensure materials do not exceed creep limits.

Fatigue:

- Failure under repeated loading cycles.
- Critical in design to avoid below endurance limit or fatigue strength.





Summary

- Axial loading leads to deformation, crucial for structural integrity.
- Thermal stresses must be managed due to temperature changes.
- Stress-strain diagrams are key to understanding material behavior.
- Strain energy concepts explain material resilience and toughness.
- Shear stress and Poisson's ratio affect material response under various loads.
- Creep and fatigue are significant for long-term material performance.