VIENNA UNIVERSITY OF TECHNOLOGY

FACULTY OF PHYSICS

LABORATORY III

Laboratory Report

Elasticity Modulus

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1 Elasticity Modulus of Tension Rods

1.1 Fundamentals

The elasticity modulus (Young's modulus) E describes the relationship between stress and strain in the elastic deformation region. For a tension rod under axial load:

$$E = \frac{\sigma}{\varepsilon} = \frac{\frac{F}{A}}{\Delta \frac{L}{L_0}} \tag{1}$$

where F is the applied force, A is the cross-sectional area, ΔL is the elongation, and L_0 is the original length. The measurement uses strain gauges with a bridge circuit configuration.

1.2 Setup

Equipment:

- Bridge extension device
- Tension rods (Aluminum, Steel, Brass, Plexiglas)
- Strain gauge measurement system
- Calibrated weights or voltage source
- Digital multimeter

Material Specifications:

- Aluminum: $D = 14.85$ mm, $d = 3.7$ mm
- Steel: $D = 15$ mm, $d = 2.2$ mm
- Brass: $D = 15.8$ mm, $d = 3$ mm
- Plexiglas: $D = 15.2$ mm, $d = 7.7$ mm

K-factor: $k = 2.03 \pm 1\%$ (pre-calibrated)

1.3 Procedure

1. Switch the bridge extension device to 1/2 position
2. Connect the first tension rod to the bridge extension
3. Wait 5 minutes for thermal equilibration
4. For each material, perform 4 measurement series:
   - Series with 5V and 2.5V excitation voltage, OR
   - Series with 2 kg and 5 kg loading
5. Take at least 6 measurements per series
6. Record all voltage readings and corresponding loads
7. Repeat for all four materials

1.4 Measurement Values

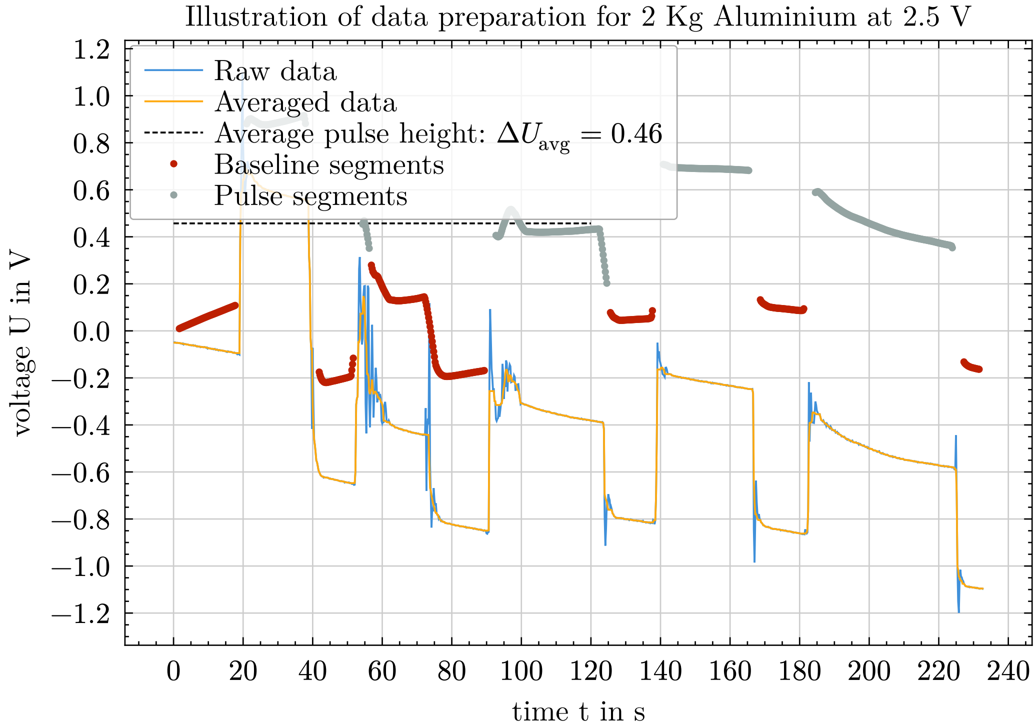

Figure 1: After applying a rolling average onto the raw data, it is segmented into baseline, pulses, rising and falling slopes. Afterwards a quadratic function is fitted onto the baseline dataset and subtracted from the segmented dataset. This results in clear baseline and pulse datasets which can be averaged over.

1.5 Data Analysis

1. Calculate cross-sectional area: $A = \frac{\pi}{4}(D^2 - d^2)$
2. Calculate stress: $\sigma = \frac{F}{A}$
3. Calculate strain from voltage readings: $\varepsilon = \frac{U}{k \cdot U_{\text{bridge}}}$
4. Plot stress vs. strain for each material
5. Determine E from the slope of the linear region
6. Perform error propagation analysis considering individual measurement uncertainties
7. Compare experimental values with literature values

Weight (kg)	Voltage (V)	Material	Pulse Height (V)	Strain	Stress (MPa)	E-Modulus (GPa)
2	2.5	Alu	0.5093	200726.7	0.12	0
2	5	Alu	1.0128	199566.7	0.12	0
5	2.5	Alu	1.2686	499937.3	0.3	0
5	5	Alu	2.5238	497300.1	0.3	0
2	2.5	Glas	4.3655	1720377	0.15	0
2	5	Glas	2.1122	416194.9	0.15	0
5	2.5	Glas	4.9465	1949341.9	0.36	0
5	5	Glas	5.7489	1132793.5	0.36	0
2	2.5	Messing	0.1331	52459.3	0.1	0
2	5	Messing	0.2313	45576.4	0.1	0

5	2.5	Messing	0.5061	199444.2	0.26	0
5	5	Messing	0.5871	115677.9	0.26	0
2	2.5	Stahl	0.2946	116117.6	0.11	0
2	5	Stahl	0.4572	90081.1	0.11	0
5	2.5	Stahl	0.4539	178882.8	0.28	0
5	5	Stahl	0.6541	128882.6	0.28	0

2 Bending Beam Analysis

2.1 Fundamentals

For a cantilever beam under point load, the deflection w is related to the applied force F by:

$$w = \frac{FL^3}{3EI} \tag{2}$$

where L is the beam length, E is the elasticity modulus, and I is the second moment of area. The relationship between bending moment and curvature is:

$$M = EI\kappa \tag{3}$$

2.2 Setup

Equipment:

- Cantilever beam setup
- Displacement measurement system (dial gauge or LVDT)
- Calibrated weights
- Ruler for length measurements
- Caliper for cross-section measurements

Beam Configuration:

- Length L to be measured
- Cross-section dimensions to be determined
- Support conditions: fixed-free (cantilever)

2.3 Procedure

1. Set up the cantilever beam with proper clamping
2. Ensure the beam is horizontal using a level
3. Position the displacement measurement device at the free end
4. Apply loads incrementally (suggested: 0.5, 1.0, 1.5, 2.0 kg)
5. Wait for stabilization between each load increment
6. Record deflection for each load
7. Repeat measurements 3 times for statistical analysis
8. Unload and check for permanent deformation

2.4 Measurement Values

Data Collection:

Load F (N)	Deflection w (mm)	Trial 1	Trial 2	Trial 3
0	0			
4.9				

9.8				
14.7				
19.6				

Beam Geometry:

- Length $L =$ mm
- Width $b =$ mm
- Height $h =$ mm
- Second moment of area $I = \frac{bh^3}{12} =$ mm⁴

2.5 Data Analysis

1. Plot load F vs. deflection w
2. Determine the slope $k = \frac{\Delta F}{\Delta w}$
3. Calculate theoretical deflection: $w_{\text{theory}} = \frac{FL^3}{3EI}$
4. Compare experimental slope with theoretical prediction
5. Calculate experimental elasticity modulus: $E_{\text{exp}} = \frac{FL^3}{3Iw}$
6. Analyze linearity and determine measurement uncertainty
7. Calculate percentage error compared to known material properties
8. Discuss sources of experimental error (beam self-weight, clamping effects, measurement precision)

Error Analysis:

- Systematic errors: calibration, geometric measurements
- Random errors: measurement repeatability, environmental factors
- Propagation of uncertainties through calculations

Expected Results: Compare experimental values with typical elasticity moduli for common materials (Steel: 200 GPa, Aluminum: 70 GPa).

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