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Modulus of elasticity

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1 ABSTRACT

The modulus of elasticity of a flat metal bar was determined by measuring its bending using a series of masses hung at the centre point of the bar. The experiment was carried out on two different flat steel bars, one with dimensions 10 mm x 2 mm x 500 mm and the other with dimensions 20 mm x 1.5 mm x 500 mm. The experimental data was analysed using graphical uncertainty analysis, and the Young's modulus was calculated from the slope of the line of best fit.

2 INTRODUCTION

2.1 Background

The Young modulus of elasticity is an important material property used in engineering and materials science to predict how materials will behave under different loads and stresses. It is used in designing structures such as buildings, bridges, and aircraft, as well as in manufacturing processes such as forming, bending, and stamping.

Different materials have different Young moduli of elasticity, and the value of the Young modulus of elasticity can also vary depending on factors such as temperature, strain rate, and the presence of defects or imperfections in the material. Therefore, accurate measurement of the Young modulus of elasticity is essential for understanding and predicting the behaviour of materials under different loading conditions. (Physics - Young’s Modulus, n.d.)

2.2 Purpose

The purpose of this experiment is to determine the modulus of elasticity of flat steel bars using a bending test. The experiment is carried out on two different bars to compare their mechanical properties.

2.3 Content of the work

Two different flat bars are supported at two points. The experiment involves measuring the bending using a dial gauge of those flat metal bars under a series of different loads, which applied at the centre point of the provided metal bar. The Young's modulus is then calculated from the slope of the line of best fit taken from the experiment geometric data.

3 Theory

3.1 Theory and principle related to the work

The elasticity of a material if determined by its modulus elasticity, which is a material's resistance to elastic (non-permanent) deformation. Materials first have elastic properties under stress; the stress then cause their shape to deform, but then the material will revert to its original state when stress is removed. After being deformed through the elastic region and yield point, materials are now in the plastic zone, where the deformation remains permanent even after the tensile stress is releases.

There are different way to calculate the elastic modulus. In this case, we are using the Young's Modulus of Elasticity.

3.2 Equation

The following equations are given in the instruction of the experiment.

When a FREELY supported horizontal flat bar is loaded at its CENTRE with a vertical force, the bending y at the CENTRE of a bar is given

$$y = \frac{l^3}{48 \times E \times I} \times F$$

where l is a distance between supporting points, E is Young's modulus of the bar material, I is square moment (axial surface moment) of a bar and F is the loading force. In case of a rectangular cross section in a bar

$$I = \frac{a \times b^3}{12}$$

where a is width of the cross section of the bar and b is its height.

Bending a bar is measured by using at least six loads (masses). Suitable load masses are e.g. 50 g … 300 g with intervals of 50 g. If load is expressed as masses the Eq. 1 gets a form

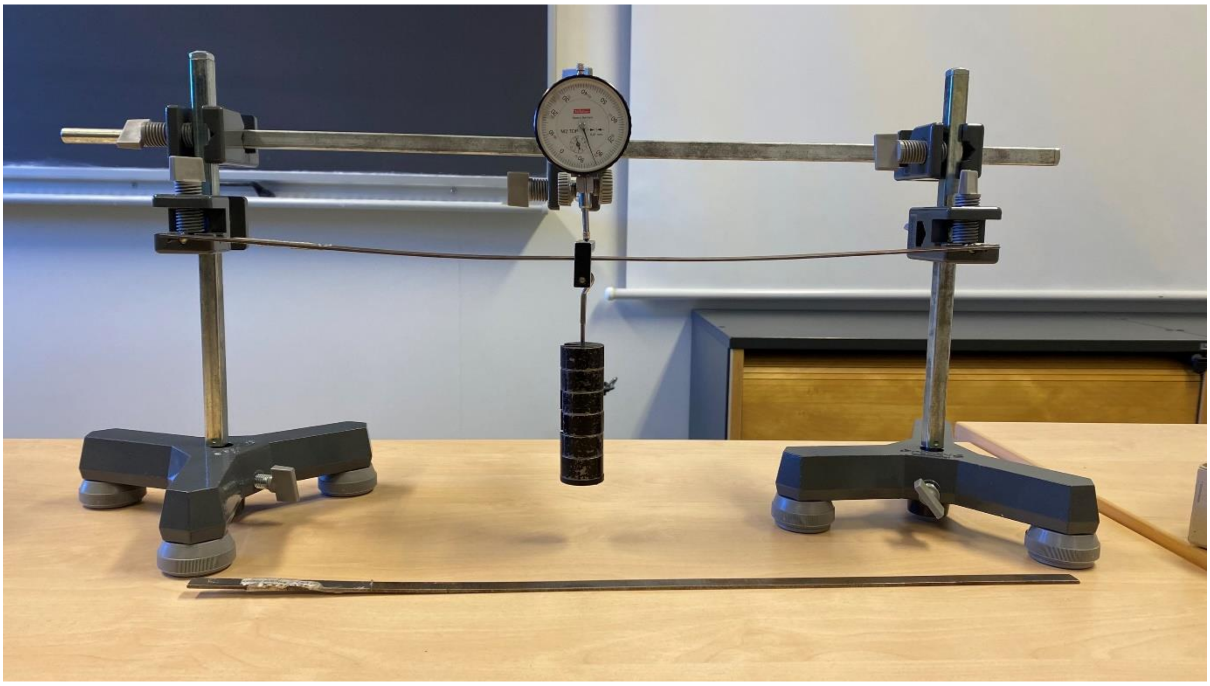
$$y = \frac{l^3 \times g}{48 \times E \times I} \times m$$

Write measuring points (m, y) in a table. Set measuring points into (m,y)-coordinate system and fit a line into the measuring points in a coordinate system. Determine the slope of the line k from that experimental data. Calculate the Young's modulus E from the slope of the line k, which is given

$$k = \frac{l^3 \times g}{48 \times E \times I}$$

4 Equipment and measurements

4.1 Measuring equipment



- Dial gauge 10/0.01mm
- Holder for dial gauge
- 2 flat bars made of steel: 10mm x 2mm x 500mm and 20mm x 1,5mm x 500mm
- Different loads

4.2 Measurements

First, we get ourselves familiar with the dial gauge and its working principle to be able to set up the experiment. The first bar is then set up, supported at both ends. Different masses are now be loaded at the centre of the bar, which make the metal bar bends; then the dial gauge is used to calculate the bending of the bar at the centre when put on those different masses.

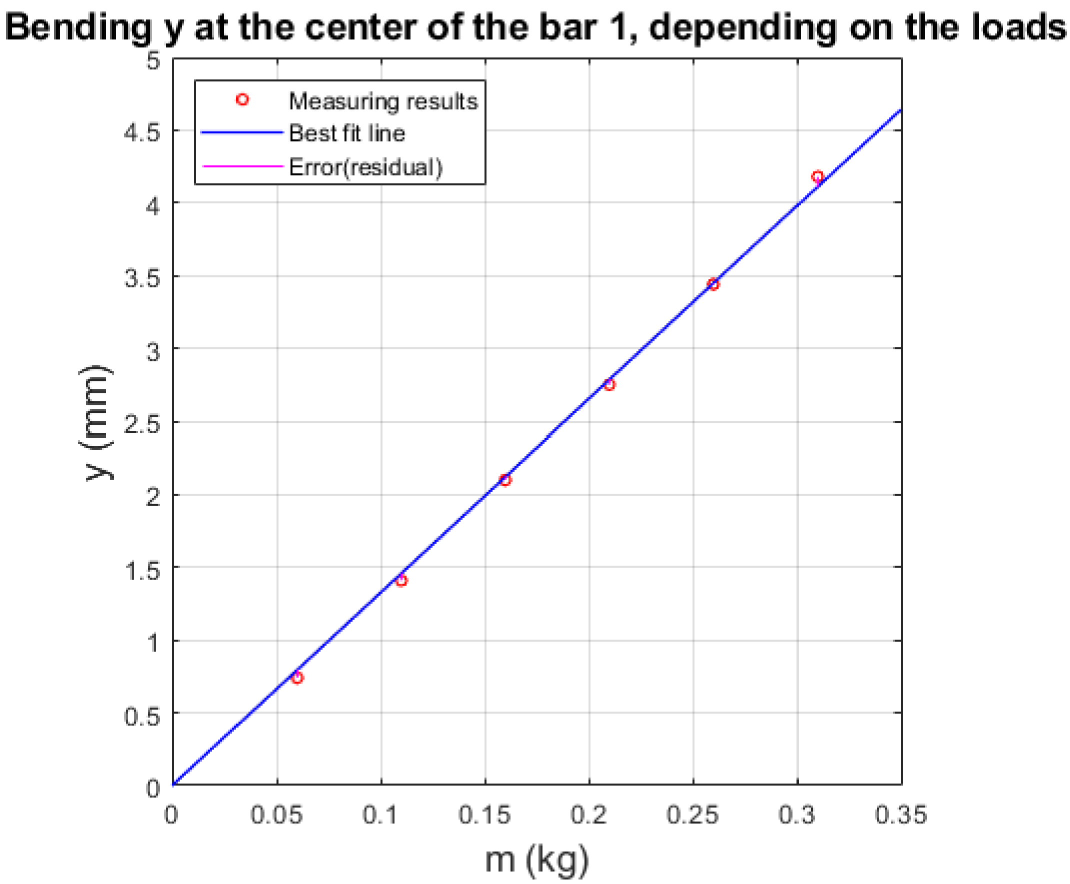
The measurements points are then put into the table (mass m and bending y), and into a (m, y) coordinate system. The best fit line and the slope k of it are calculated from the coordinate system, then the young's modulus E is calculated from the slope k.

5 Result

Result for measuring the first metal bar, which has a dimension of 10mm x 2mm x 500mm, are recorded into a table.

m(kg)	y (mm)
0,6	0,74
0,11	1,41
0,16	2,1
0,21	2,75
0,26	3,44
0,31	4,18

Data from the table is then converted into a (m, y) – coordinate system and a line of best fit is drawn, as well as error lines, or residuals.



The linear coefficient, or slope k of the figure is 13,2605.

This is then used to calculate the Young's modulus E of this metal bar:

$$I = \frac{a \times b^3}{12} = 500$$

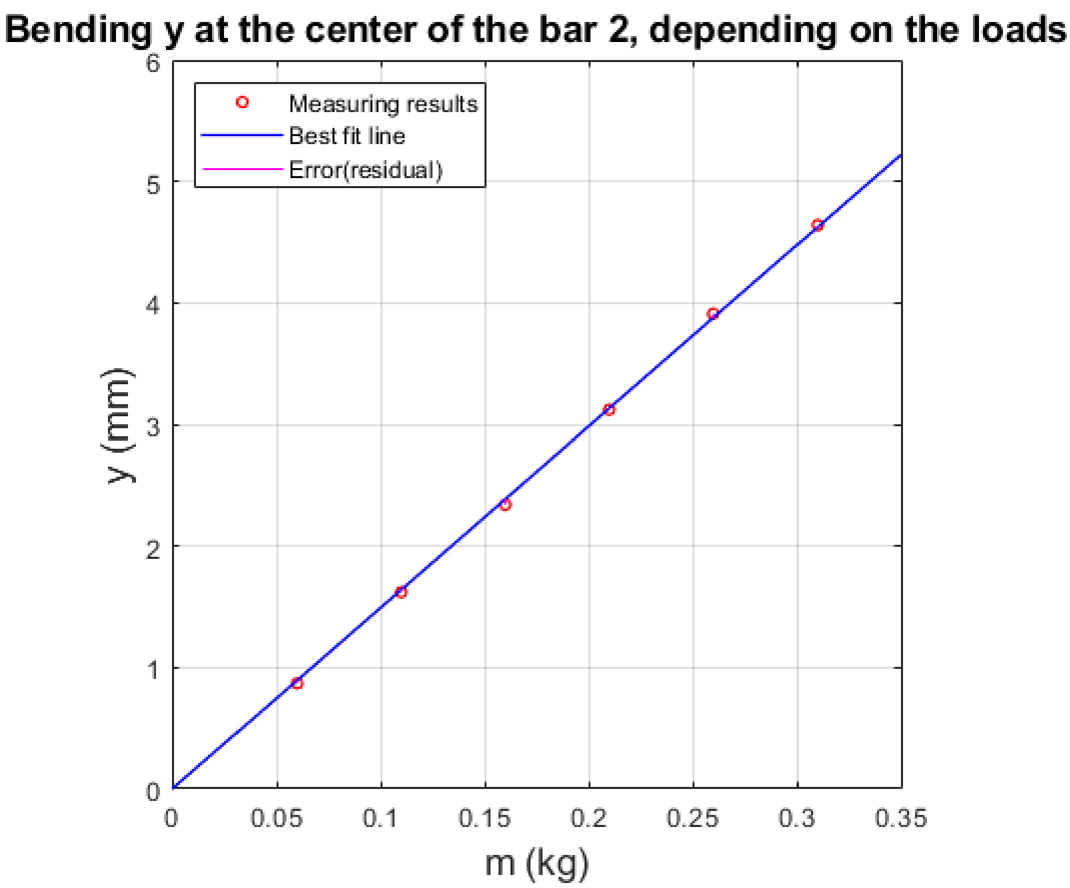
$$k = \frac{l^3 \times g}{48 \times E \times I}$$

$$\rightarrow E = \frac{l^3 \times g}{48 \times k \times I} = \frac{500^3 \times 9.81}{48 \times 13.2605 \times 500} \approx 28991.8\ (MPa) \approx 289.9 (GPa)$$

Result for measuring the second metal bar, which has a dimension of 10mm x 2mm x 500mm, are recorded into a table

m(kg)	y (mm)
0,6	0,87
0,11	1,62
0,16	2,34
0,21	3,12
0,26	3,91
0,31	4,64

Data from the table is then converted into a (m, y) – coordinate system and a line of best fit is drawn, as well as error lines, or residuals.



The linear coefficient, or slope k of the figure is 14,9137.

This is then used to calculate the Young's modulus E of this metal bar:

$$I = \frac{a \times b^3}{12} = 500$$

$$k = \frac{l^3 \times g}{48 \times E \times I}$$

$$\rightarrow E = \frac{l^3 \times g}{48 \times k \times I} = \frac{500^3 \times 9.81}{48 \times 14{,}9137 \times 500} \approx 256947\ (MPa) \approx 256.9(GPa)$$

6 Conclusions (Reflection)

The literature value of steel elastic modulus is usually around 190-210 GPa.

In our experiment, the results are 289,9 and 256,9 respectively (2 steel bars), so there are some errors occurred. We suspect that there are some error sources:

Human errors. This may have occurred during the measurements, such as reading accuracy, etc.

Hardware/ equipment errors. The bars seem to have been used several times, thus the condition of them have somewhat deteriorated.

7 References (Literature references / Sources)

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