Experiment: Investigating the elastic and plastic extension of metallic wire

(Recording and evaluating with Data studio)

Objects of the Experiment

1. Recording the stress-strain diagram for different thicknesses of copper (Cu) wire & find its Young's modulus (for both wires) in proportional region.

Apparatus: Copper wires (0.25 mm and 0.3 mm) Force Sensor, Rotary Motion Sensor, Simple bench clamps(2), and Stand rods(2).

Principle

If a wire is strained by a tensile force it expands. If the strain is below the so-called elastic limit (EL) (Fig. 1) the wire returns to its original length after the strain has been removed. The expansion in the elastic range is given by the relative change of length:

$$\varepsilon = \Delta L / L \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad \text{(I)}$$

ε : extentional strain , ΔL : elongation, L : initial length

The stress σ is given by the force F which acts perpendicular on the cross sectional area A of the wire:

$$\sigma = F/A \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad \text{(II)}$$

F: normal force, A: cross-sectional area

If the deformations are small in comparison to the dimensions of the wire the expansion σ is proportional to the strain ε:

$$\sigma = E\cdot\varepsilon \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad \text{(III)}$$

The proportionality constant E depends on the material and is called the elastic modulus.

For most metallic materials Hooke's law (equation (III)) is valid throughout the elastic range (Fig.1). i.e. where the expansion is linearly proportional to its tensile stress. For some materials, e.g. aluminium, Hooke's law is only valid for a portion of the elastic range. For these materials a proportional limit *PL* (Fig. 1) is defined, i.e. the range in which the errors associated with the linear approximation are negligible.

If the strain exceeds this proportional limit *PL* the deformations are not proportional to the stress. However, the deformations still disappear between the proportional limit and the elastic limit after the stress has been relieved. Beyond the elastic limit *EL*, permanent deformation will occur. The elastic limit corresponds to the lowest stress at which permanent deformation can be measured.

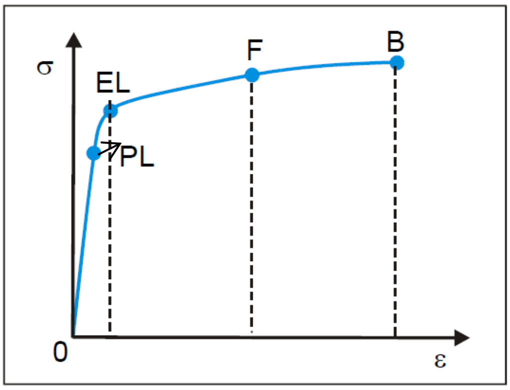

Figure 1. Representative graph of stress-strain-diagram for a metal

During further expansion the strain increases. When the flow point F has been reached a small increase in strain causes a large increase in expansion. Then follows a range where the cross-section decreases significantly until the sample breaks at point **B**. In this experiment an iron wire and a copper wire are elongated by turning a wheel. The elongation ΔL is measured by the Rotary Motion Sensor **S**. The tensile force F is measured by the Force Sensor S.

Setting up the experiment

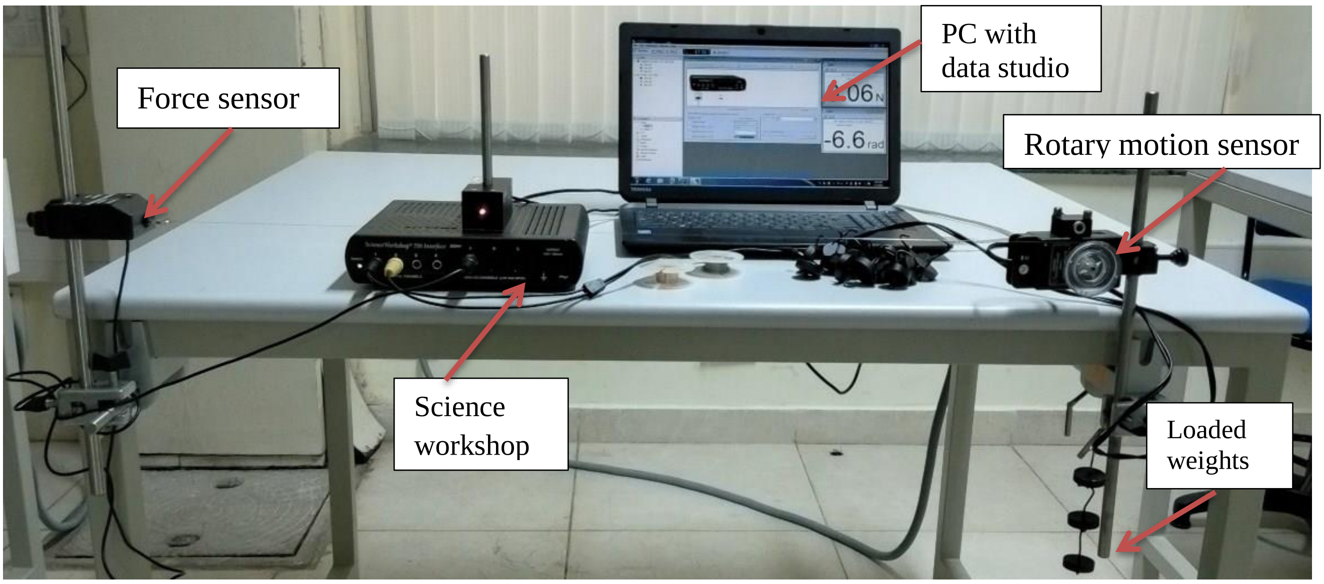

Figure 2. Experimental setup

The experimental setup is shown in Figure 2.

- Mount the bench clamps to the table. The distance between the simple bench clamps about 100 cm.
- Fix a stand rod (25 cm) to each simple bench clamp & the force sensor (left end) and Rotary
  Motion Sensor (right end) as shown in Figure 2.
- Connect the force sensor and rotary motion sensor to science workshop. Then PC is interfaced to the science workshop as shown in the figure 3.

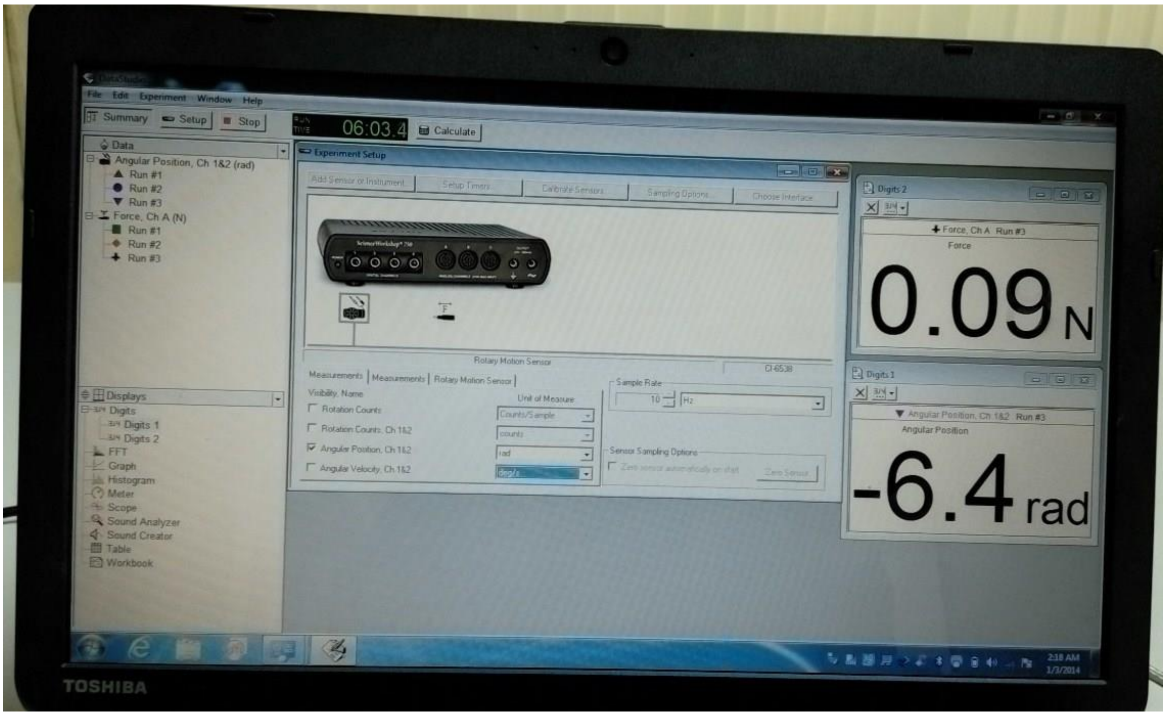

Figure 3: snap shot of the interface software

Open the data studio software in PC and select the force sensor and rotary motion sensor as they connected to respective knobs. Then assign the appropriate units to the physical quantities.

Data studio plotting the stress σ as function of the expansion ε

Plotting "stress-strain-diagram" by taking "ε" on the X-axis and "σ" on the Y-axis Length of the wire L, and angle $\Delta\theta$ can be measured by using rotary motion sensor then elongated length $\Delta L = r \,.\, \Delta\theta$. Stress can be found by using

$$\frac{\Delta L}{L} = \frac{r\Delta\theta}{L}$$

Cross-sectional area of the metallic wire, A Force 'F' can be measured with the help of a force sensor and hence stress ($\sigma = F/A$) Nm^{-2} can be found.

Slope i.e. Stress/strain will give elastic modulus of given metallic wire. The fit of a straight line through the origin in the proportionality region gives the elastic modulus:

Repeat the experiment for other wire as well.

References: (**LD Physics Leaflets P7.1.4.2 ----**
http://www.ld-didactic.de/documents/de-DE/EXP/P/P7/P7142_e.pdf)

Task 1: make the connections as shown in write up. Note down the force and angular displacement value after adding each weight.

Task 2: Trace the diffraction pattern for the above task (for all weights)

Task 3: calculation of bulk modulus, plot stress (ε) Vs strain (σ)

Weight	Angular displacement	force	strain	Δl	stress

Task 4: Repeat the experiment for the other copper wire of thickness (0.3 mm).