Young's Modulus Using PASCO and Horizontal Testing Method

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Abstract

Young's Modulus is a coefficient involved with the stress/strain relation of a material. It is important in understanding how much stress a material can be under before deformation. The lower the coefficient the more elasticity a material will have. Youngs modulus is extremely important in building structures and understanding how a material behaves under stress. Using PASCO equipment and interfacing, different wires were stretched horizontally and resulting stresses and strains were obtained. The copper wire, tinned copper wire, and unknown wire produced moduli of 175 MPa, 171 MPa, and 4.26 MPa respectively. For future testing, the Young's modulus horizontal test can be optimized by correcting the experimental design that caused a slight dip in the force applied.

Introduction and Theory

This experiment is a simple experiment to measure Young's modulus by utilizing the PASCO interface. PASCO allows for extremely accurate measurements that can allow for low error experiment. Most experiments that involve elasticity often use hanging masses and vertical tests. This experiment is done horizontally by stretching a wire using a threaded turning device and measuring the values using PASCO. This experiment also provides a different approach to visualizing elasticity of materials as the wire is stretching and recording force measurements of that wire as it begins to stretch. Although deformation is inevitable in this experiment as one of the objectives is to stretch the wire until breakage, it can graph important data that shows elasticity and deformation of material when under stress and strain. The use of a horizontal test also can relate the experiment to a tensile force as well which is how much force is stretching the material rather than bending.

$$(3.1)\ Stress = \frac{F}{A}$$

Where F is the perpendicular force applied due to the hanging mass at the end of the rod (mass*gravity). A is the area of the cross-sectional region of the threaded bar. This is utilized in the graph of taking the force divided by the cross-sectional area.

$$(3.2)\ Strain = 1 - \frac{\Delta L}{L_0}$$

Where L_0 is the original length of the threaded rod and ΔL is the change in length of the threaded needle from the start position to where it is being measured. The reason for subtracting it from one is this is what is used in the graph to display the stress as strain increases. Plotting these formulas together and taking the slope gives the Youngs modulus and an equation:

$$(3.3)\ \frac{\frac{F}{A}}{\frac{\Delta L}{L_0}}$$

Where l_0 is the original length of the wire. l-l_0 is the elongation of the wire in mm. d is the original diameter of the wire in mm. m is the mass, g is gravity. E is the elastic modulus of the material that will be found with the given equation.

Procedure

PASCO was utilized for this experiment to generate the most accurate data and results. A mount was created as shown in figure 3.1 below. (need picture) On the left side there is a force gauge with an attached hook that the wire is to be tied too. In this experiment the wire was tied as tightly as possible using a knot to prevent slippage. The wire is then extended and wrapped around a rotary sensor once to measure the distance that the wire is stretched. The wire is then connected to a loop at the beginning of the threaded turning device. The loop is important as the wire must not twist as this would alter data significantly. The hook we used to prevent this from occurring is a fishing hook that turns as the threaded device is turned so that the wire remains stationary and does not twist, making sure that the only forces being applied is the pulling of the wire. This hook is then attached to a threaded bar with a stand that can be turned to stretch the wire out slowly. To position the experiment correctly the force sensor should be directly across from the fishing hook (see figure 3.2) attached to the threaded bar stand. The bar should be set so that the wire is tight while still having space to pull and stretch the wire. To record measurements - the position is plotted against the force on PASCO. Once the measurement is started the threaded bar can be turned using the handle that can be seen in figure 3.1 to tighten the wire. Continue to turn the wire until the wire either breaks or the threaded bar reaches the limit that it can stretch the wire. Note that starting the threaded bar out as close to the rotary sensor as possible will allow maximum distance to stretch the wire.

Fig 3.1

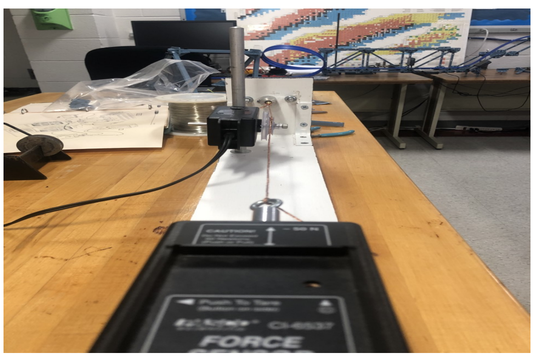

Fig 3.2

Data

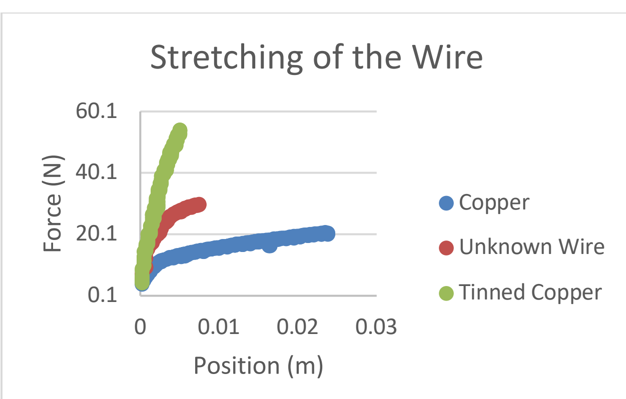

Fig 3.3 Force applied to wire vs stretching length of wire

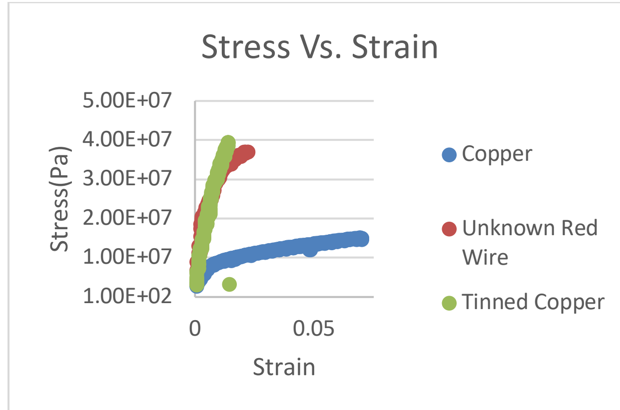

Fig 3.4 Stress versus strain of different wires based on equations 3.1 and 3.2.

Discussion

Looking at both graphs there is a clear correlation between how the wire stretches under a force and for what the actual stress vs. strain graph comes out to be. One issue when plotting these graphs is the PASCO system recorded position values too quickly for the force sensor to keep up. This caused there to be an excessive amount of null data points that are included in the graph preventing an accurate slope measurement. Due to this, a single slope point was calculated by hand, taking the third data point and the third to last data point for each wire. The reason for not taking the first data points is that it allowed for a more consistent measurement rather than the first or last point which could more likely have regularities in them. For the copper, a of Young's modulus of 175x10^6 pascals using the slope formula . $\frac{.07-.004907341}{36936773-68610}$ was generated. Comparing this to a theoretical value of copper being 117x10^6 Pascal, the magnitude of the generated value is close. The discrepancy can also be noted to have a large error value due to not being able to take the slope of the graph through excel. For the tinned copper wire, the generated value was 171x10^6 which is similar to the value for the bare copper wire. This shows that the tin coating played an insignificant role in the elasticity of the wire. This is most likely due to tin having a lower Young's modulus value which can result in its elasticity not being recorded. The last wire was an unknown wire. The unknown wire produced a Young's modulus of 4.26x10^6 Pascals.

The main error of the Young's modulus Horizontal test stems from having to turn the threaded device to pull the string. As the string is tightened, the knot that ties the string to the fishing hook can tighten. This might cause a slight dip in the force applied at some data points. This error caused minimal issues when calculating the Young's modulus due to the extreme amount of data points taken but it is still worth noting for future references.

REFERENCES

C "Using data logging to measure Youngs modulus" David Richardson, 2018 phys.educ. 53 023002. March 2018 iopscience.org/ped

"Development of Low Cost, Hands On Lab Experiments for an Online Mechanics of Materials Course" Dr. Jamie Douglas, Dr. Mark H Holdhusen. University of Wisconsin college. 120th ASE Annual Conference and Exposition June 2013.

"PASCO Scientific: Science Lab Equipment and Teacher Resources." *PASCO*, www.pasco.com/.