Young's Modulus Experiment

ENGR45 – Materials Science Laboratory

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Abstract

In this experiment the moduli of elasticity were measured for four different "off the shelf" materials: 20 gauge copper wire, 22 gauge copper wire, 30 pound fishing line and 20 gauge brass wire. The methods and techniques employed in determining these values required only a small testing apparatus, the tested materials in various wire gauges, a set of weights to apply force, and somewhat crude measurement tools—very little was needed in the way of precise equipment or specialized machinery. As such, these experimental results should only be considered to be general estimates of the true values of the modulus of elasticity constants for the tested materials and not necessarily representative of the true materials in their pure forms. In the cases where the accepted values were available, comparisons were made with the experimental values to assess the degree of success or failure of the experimental process and/or to draw attention to the discrepancies that exist in common items purchased through everyday hardware stores when compared to the pure materials. Table 1 summarizes the results of the experiment and shows an extremely large discrepancy between experimental and expected values.

Table 1. Experimental results and comparisons with accepted values

Material	Modulus of Elasticity (GPa)	Accepted Value (GPa)	Percent Difference (%)
20 Gauge Copper Wire	6.063	110	94.5
22 Gauge Copper Wire	7.904	110	92.8
30lb Monofilament Fishing Line	0.266	N/A	N/A
20 Gauge Brass Wire	10.567	97	89.1

Procedure

A device dubbed the "Young's Modulus Apparatus" was assembled for the purposes of this experiement and used for the testing of each material. The device is simple in that it allows a test wire to be anchored in two places within a metal chasis that sits approximately 1.5 meters off the ground. This arrangement allows weights to be applied to the bottom tip of the test wire by way of a weight bearing mechanism while the top portion is secured in place. At the point where the lower anchor point is located there exists a leveling device with an adjustment knob that can be used to make measurements with 1×10^{-5} m accuracy for the change of wire length which is obtained as additional weights are applied incrementally.

For each material a piece of wire was cut to an appropriate length and installed within the Young's Modulus Apparatus. Next, an initial length measurement was taken with a 1kg weight applied. While it is expected that the length of the wire changed with this applied stress, the weight allowed for a more complete straightening of the test wires, all of which had many small bends and kinks when a force was not being applied. By applying a weight in the beginning many of these inconsistencies were removed so that they would not contribute to the initial length value. Because it was expected that each tested material remained in the elastic range with only a 1kg mass applied, the true original length value was determined after the conclusion of the experiment using a linear regression technique on the data points that appeared within the observed elastic range.

The relevant properties for each material in this experiment were initial length of the wire (l_0), the diameter of the wire (d), the amount of applied force (N), and the change in length of the wire with each applied weight. The incrementing of the applied weights varied depending on the material: less weight was applied to those materials which registered greater length changes under lighter loads. For each newly applied weight the change in length was recorded along with the new total force. After approximately 10 readings were taken for each material the stress and strain values were calculated using the following formulas:

$$\sigma=\frac{F}{A}=\frac{mg}{\pi\left(\frac{d}{2}\right)^2} \qquad \varepsilon=\frac{l-l_0}{l_0}$$

Because each test wire had a load applied to it before an initial length measurement was taken, the experimental values of stress versus strain were graphed and the equation for the line of best fit was used to find the root value for the function (which indicated the unloading point as well as the original initial length of the wire). This produced the true initial length according to the relationship:

$$\frac{l_{intial\ measurement}}{(\varepsilon_{initial\ measurement}+1)}=l_0$$

Results

For 20 gauge copper wire the following experimental results produced a Young's Modulus constant of 6063 MPa, or 6.063 GPa. When compared to the accepted value this represents a percent difference of 94.5%. As the shown in Figure 1 the sample was never taken past the elastic region.

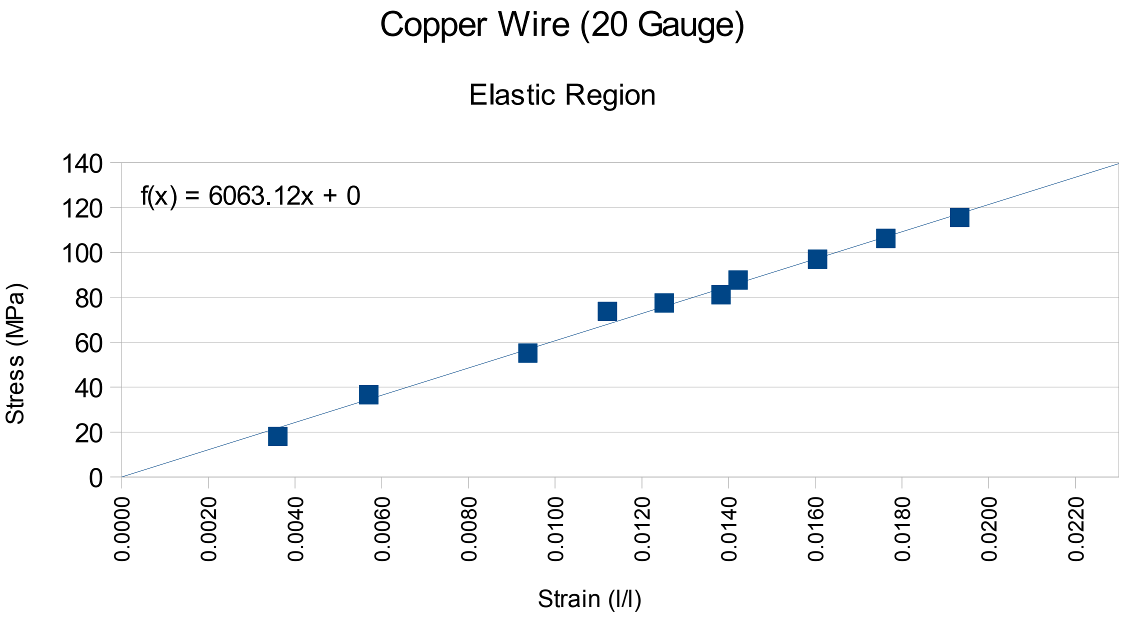

Figure 1. Elastic Region for 20 Gauge Copper Wire.

For 22 gauge copper wire a slightly different experimental value was found: 7904 MPa or 7.904 GPa. This represents a percent difference of 92.8%. This sample was taken past its elastic region into the plastic region, as shown by Figure 2 on the following page. The first five data points were used to determine the value for the modulus of elasticity since the graph became non-linear starting approximately with the fifth data point (see Figure 3, next page).

The 30lb monofilament fishing line proved to be the most ductile by showing greater increases in strain for smaller applied stresses (see Figure 4, page 6). The Young's modulus constant was found to be 266 MPa (or 0.266 GPa), a value which could not be compared to a known value. Like the first copper sample this material was not taken into the plastic region and maintained a consistent linear relationship when all of its data points were plotted. This result is expected since fishing line is designed to handle large variations in load without breaking.

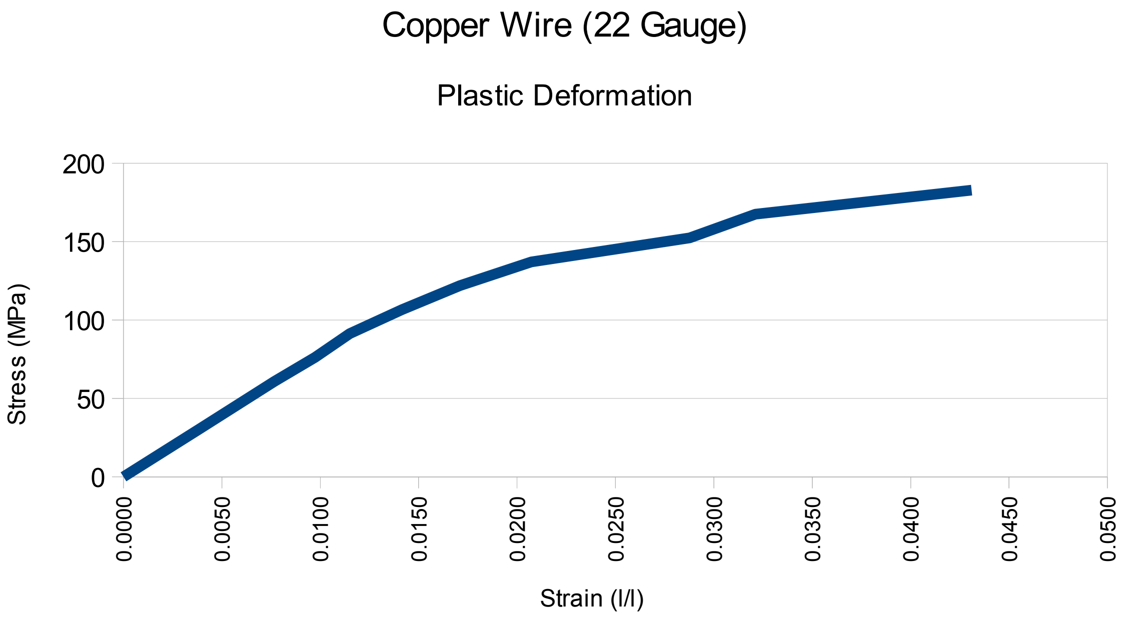

Figure 2. Entering the plastic deformation region for 22 gauge copper wire.

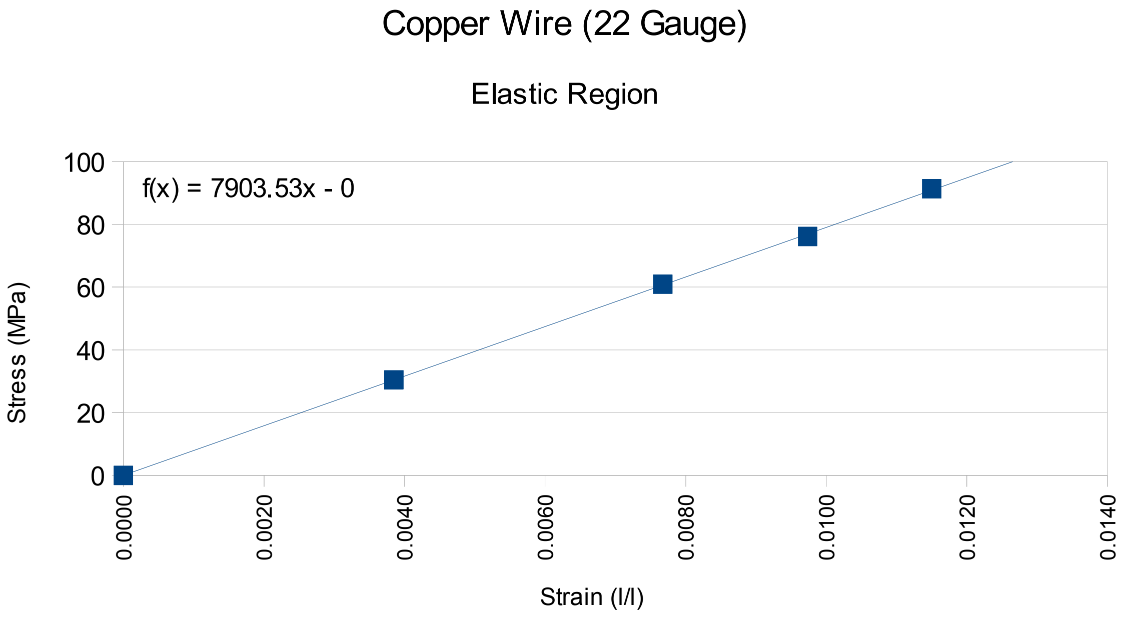

Figure 3. The elastic region for 22 gauge copper wire represented by the first five data points.

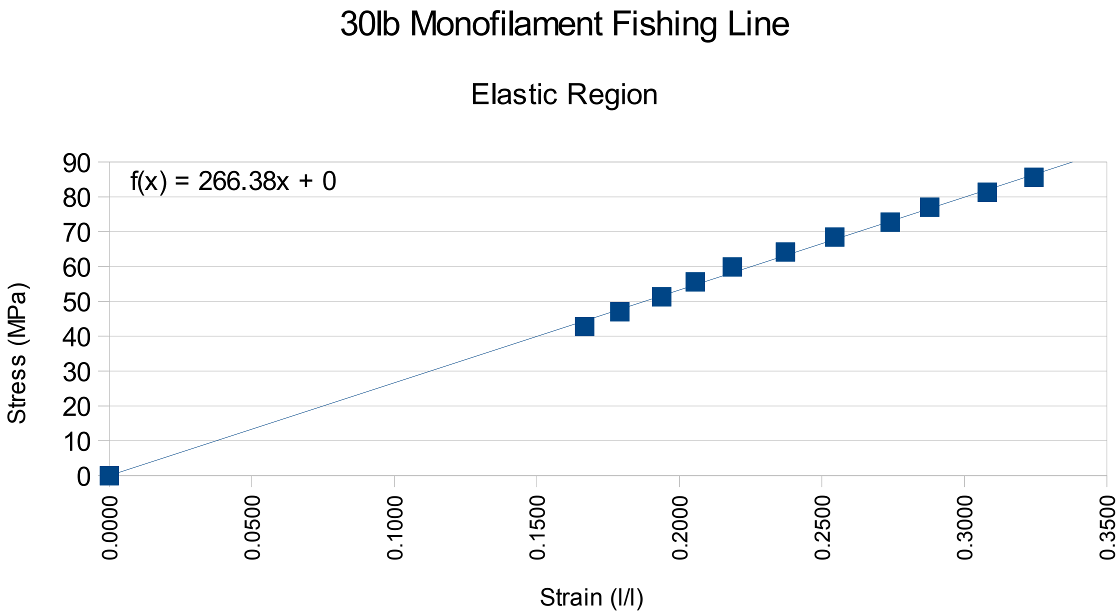

Figure 4. The elastic region for 30lb monofilament fishing line.

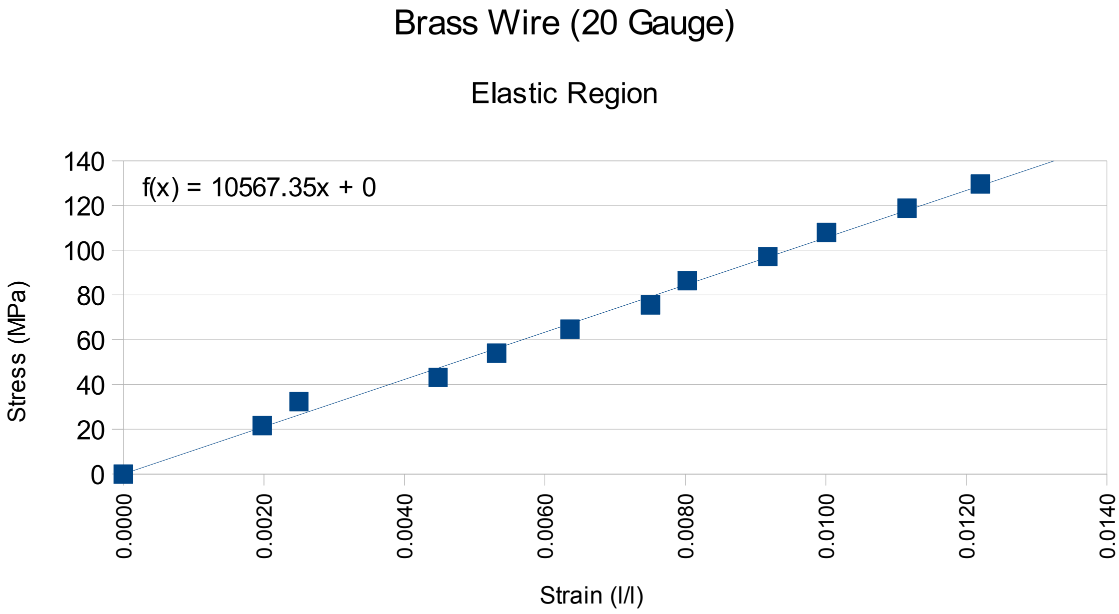

Figure 5. The elastic region for 20 gauge brass wire.

Finally, the 20 gauge brass had a modulus of elasticity value of 10567 MPa or 10.567 GPa. This also differed greatly from the accepted value and produced a percent difference of 89.1%. Like the 20 gauge copper sample, the 20 gauge brass sample was never taken past its elastic region. The relationship of stress versus strain for this sample can be seen in Figure 5 (previous page).

Conclusion

As the experiment results clearly show, the samples of copper and brass obtained at the local hardware store differ enormously from the known and accepted values for pure samples. The values are so different that a verification of the mathematical techniques used in this experiment to obtain them is required. However, provided no errors exist in these calculations then this experiment proves that wildly varying properties exist in "off the shelf" materials: when a person buys copper or brass from an inexpensive and convenient source he or she is oftentimes receiving something that is quite different and, as far as tensile strength is concerned, completely unrecognizable.