Measurement of Bending Stress Using Strain Gauges

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Submitted: May 15th 2013

Abstract

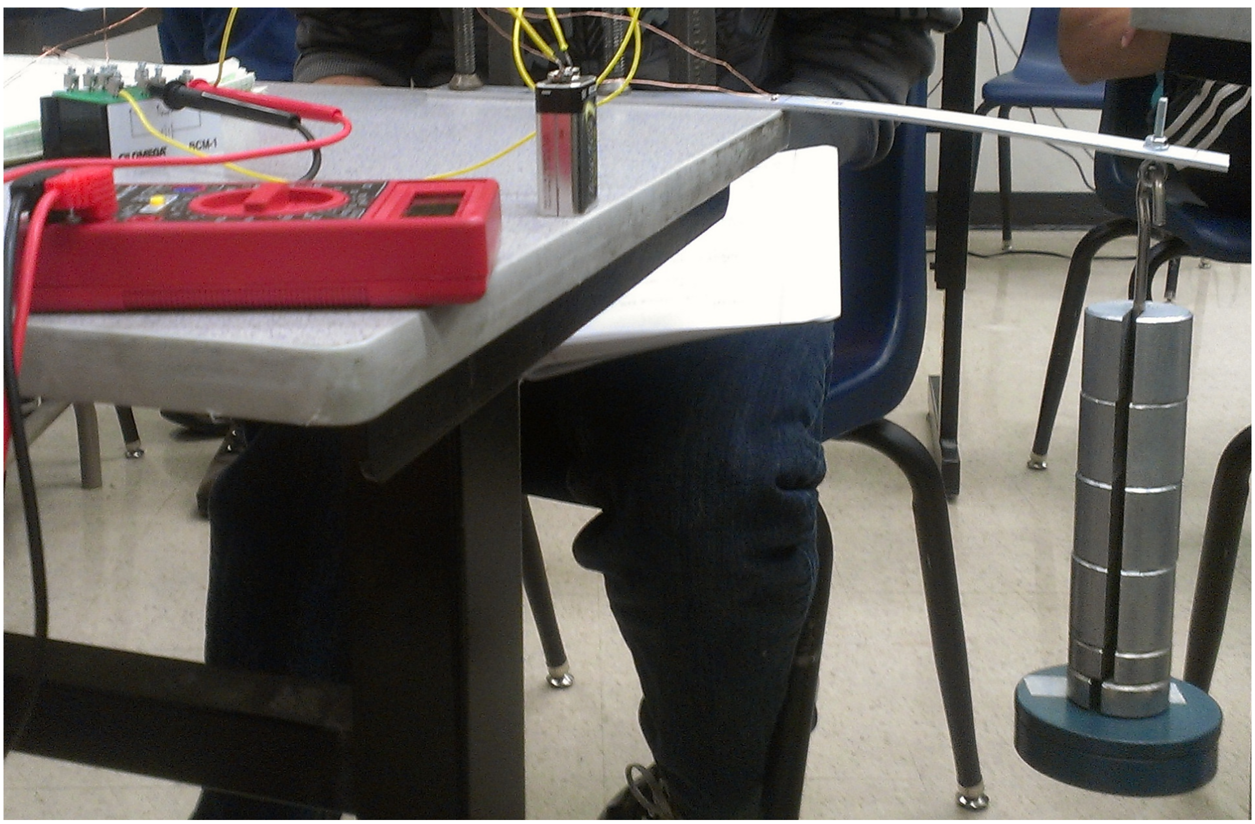
Various engineering methods, tools and devices can be used to determine the tensile properties of a material. It is beneficial to perform many different tests on a sample in order to better understand its characteristics and to corroborate experimental values obtained through previous procedures. One such test employs a small measurement device called a strain gauge which is capable of interpreting the bending stresses applied to a beam. The strain gauge is a small, individual element that participates in a simple measurement circuit which, along with the aid of a wheatstone bridge, translates the magnitude of an applied stress into a potential difference value. This potential difference value can then be used to calculate the amount of strain the sample is experiencing using a special equation. In this experiment the stress/strain properties of a 1/8″ by 1″ cross-sectional beam of Aluminum 6061 were investigated using this engineering method and an experimental value for the modulus of elasticity was found.

Material	Modulus of Elasticity (Experimental)	Modulus of Elasticity (Accepted)	Percent Difference
Aluminum 6061	57.4 GPa	68.9 GPa	16.7%

Procedure

Because use of the strain gauge required the construction of a circuit incorporating a wheatstone bridge, a terminal pad, and a 9-volt battery, special preparations were made to become better familiar with effective soldering techniques. A separate procedure was followed to learn how to apply solder to two separate leads so that a strong and conductive connection between them would be formed. In addition to this, cleaning and maintenance techniques for the soldering tool were practiced so that the buildup of residue on the tip would not occur and then impair the bridging of future circuit connections. The specific details of this procedure can be found in **Appendix 1**.

The material tested in this experiment was 6061 Aluminum. A sample of this material to measure bending stress and strain was made by cutting approximately 15″ of a length of beam with a 1/8″ by 1″ cross-sectional area. The sample was prepared to have weights strung from it by measuring a distance of 1″ in from one end and drilling a hole in the center of the broad side of the bar. This hole was then outfitted with an eyebolt using washers and a nut. The strain gauge was then carefully applied to the center of the same surface using superglue at a distance of 7″ from the same end. A terminal pad was used to bridge the strain gauge to two longer wires of equal length that would connect it to the rest of the circuit. Resistances were measured to confirm the completeness of the connections within the circuit and to ensure that they aligned with expected values for the strain gauge in the absence of an applied load. The aluminum beam sample was then clamped to a table so that 8″ in total protruded over the edge. The two wires were connected to a wheatstone bridge and a 9-volt battery and the resulting circuit was calibrated so that, without any bending occurring, a voltage reading of zero appeared on an attached voltmeter. Weights were finally applied to the beam, with voltage and force readings recorded at each incrementing step. This produced the apparatus shown in **Picture 1** and the set of experimental data points shown in **Figure 1**.



Picture 1. Measurement circuit and beam bending apparatus.

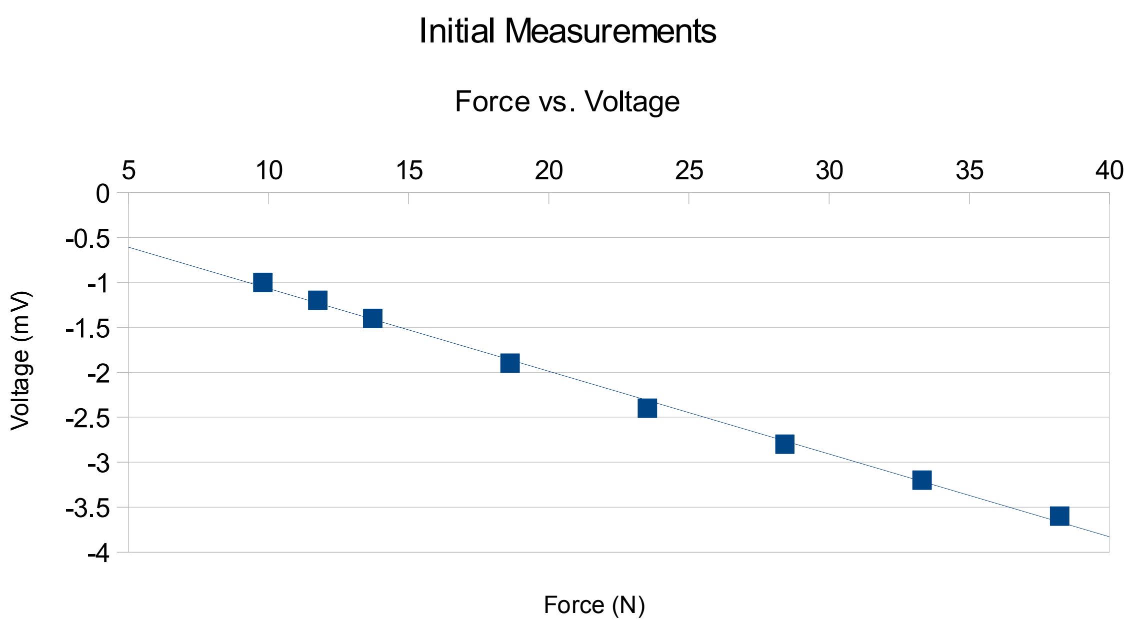


Figure 1. Initial measurements of applied force versus voltage.

The bending stress values for each applied force were then determined from the experimental data by using the equation:

$$\varepsilon_{bending} = \frac{-4\left[\frac{v_{out}}{v_{excitation}}\right]}{(GF)\left(1+2\left[\frac{v_{out}}{v_{excitation}}\right]\right)}$$

where *GF* is the gauge factor constant value associated with the strain gauge (*GF* = 2.13), v_{out} is the measured voltage across the wheatstone bridge, and $v_{excitation}$ is the source voltage. The bending stress was calculated using the equations:

$$\sigma_{bending} = \frac{My}{I} \quad , \quad I = \frac{bh^3}{3} \quad \text{and} \quad M = Fd$$

where *M* is the moment, *y* is the distance from the neutral axis (or half the thickness of the beam), and *I* is the moment of inertia. The modulus of elasticity *E* for bending stress and strain is taken to be the same value as for linear stress and strain and is represented by the relationship:

$$\sigma_{bending} = E\,\varepsilon_{bending}$$

Using these equations, bending stress and bending strain values were calculated and then graphed. This experimental data is shown in **Figure 2** below.

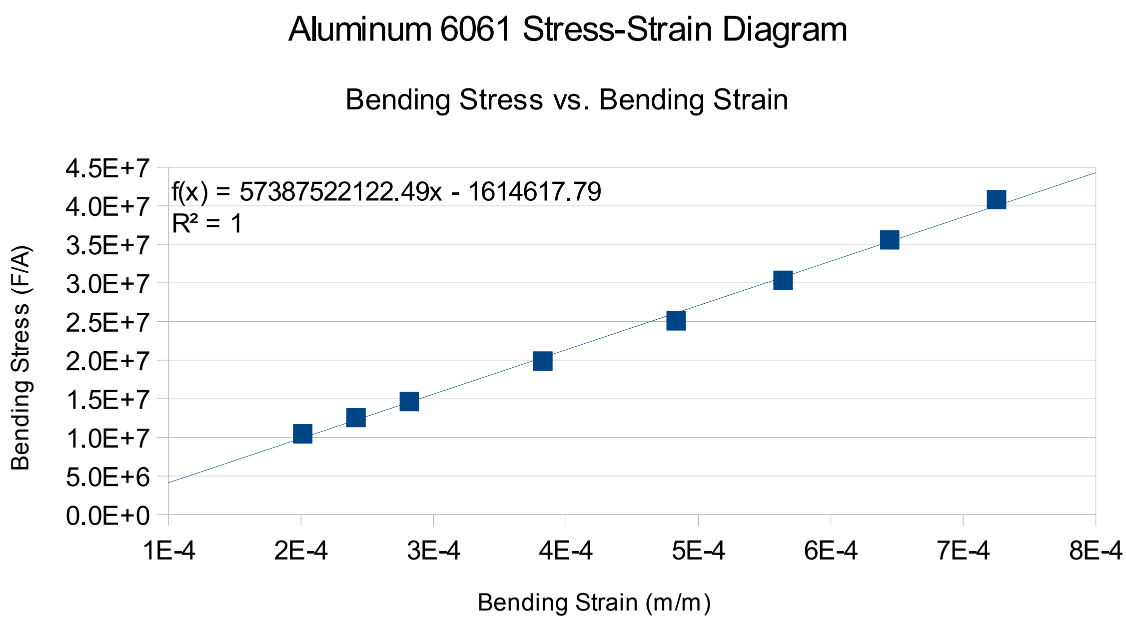


Figure 2. Stress-Strain diagram for Aluminum 6061 experimental data.

Results

The slope for the line of best fit found in the graph of experimental bending stress versus bending strain represents the experimental value for the modulus of elasticity for the Aluminum 6061 sample:

$$E = 57.4\, GNm^{-2} = 57.4\, GPa$$

The experimental value compared to the accepted value of 68.9 GPa produces a total percent difference of 16.7%. Although this represents a substantial amount of error, the value is close enough to confirm the success of the procedure. It is expected that the majority of this error can be attributed to the location of the strain gauge being about an inch from the center of rotation, if the beam is viewed as a lever arm. An increase in accuracy is expected when the strain gauge is placed in the position where the greatest amount of bending occurs in the beam: where the beam joins the table. Some of the error is also due to a general impreciseness of measurements: using equipment with increased precision, along with a greater diligence in obtaining true experimental values, will work to improve experimental data.

Conclusion

Overall the experiment proved to be successful and an acceptable experimental value for the modulus of elasticity for 6061 Aluminum was obtained. It is recommended that the procedure be repeated to find and eliminate the major sources of error, which will involve finding the optimal placement of the strain gauge along the beam. In addition to this, using measurement tools with increased precision will aid in determining a more precise value for the modulus of elasticity. Future considerations must be made for the purchase of a higher quality strain gauge that is capable of reporting more precise voltage values to the measurement circuit. However, due to its somewhat prohibitive cost compared to other components in the experimental apparatus, all major sources of error must first be removed in order to justify this expense.