Experimental Study on Determining the Elastic Modulus of Metal Materials by Deflection Method

Liuchuang Wei\textsuperscript{1,}\textsuperscript{*}, Ping Wei\textsuperscript{2} and Yabiao Yang\textsuperscript{3}

\textsuperscript{1}Faculty of Mechanical and Electrical Engineering, Kunming University, Yunnan Kunming 650214, China

\textsuperscript{2}Faculty of Architectural Engineering, Kunming University, Yunnan Kunming 650214, China

\textsuperscript{3}Department of Assets and Laboratory Management, Kunming University, Yunnan Kunming 650214, China

\textsuperscript{*}Corresponding author. Email: weiliuchuang@126.com

Abstract. This paper studies the method of measuring the elastic modulus of metal materials by the deflection method. The relationship between the deflection and the load and the elastic modulus of the metal cantilever beam is established, so that the elastic modulus of the cantilever beam is indirectly measured. The experiment requires that the deformation of the material is within the elastic range. Furthermore, the deflection method is adopted. Not only the method is simple and does not require expensive equipment, but also the average value of multiple sets of experimental results is used as the modulus of elasticity of the material during measurement, which ensures a certain accuracy.

1. Introduction

Metal material is a commonly used engineering material, which occupies a very important position in engineering applications, and the elastic modulus is an important mechanical property of the material. From the present point of view, experimental research on the elastic modulus of materials Occupy a very important position.

The traditional method of measuring the elastic modulus of a metal material is to perform a tensile compression test by a universal testing machine, or an ultrasonic transmitter to measure the propagation speed of ultrasonic waves in the metal material, and establish a calculation relationship between the wave velocity and the elastic modulus. Indirectly measure the elastic modulus of metallic materials. There is also the vibration method, which estimates the elastic modulus by picking up the resonance frequency or natural frequency of the material, and indirectly measures the elastic modulus of the material.

The experimental results of the above method are accurate, but the equipment is expensive, and the selection of experimental materials is complicated, which is not conducive to practical operation. This paper focuses on the introduction of a simple method to measure the elastic modulus of the material. It is low, does not require expensive equipment, and can guarantee a certain measurement accuracy, so that it can be used under conditions that are not particularly sufficient.
2. Principle of measuring elastic modulus of metallic materials by deflection method

The deflection method is an experimental method for simply measuring the elastic modulus of a material. The measurement experiment method is to apply a concentrated load to the end of a metal cantilever beam and amplify the deflection of the beam with a laser pointer to establish the deflection and load between the elastic modulus of the metal beam To calculate the relationship of the elastic modulus of the metal beam indirectly.

![Figure 1. Measurement diagram](image)

The measurement schematic diagram is shown in Figure 1. During the experiment, the load was graded. Each load was 10N. A total of 4 different groups of l and a were taken for testing. The fitting relationship curve of load and deformation b was drawn. Substitute the formula (1) to calculate and analyze the results.

\[ E = F\left(l^2 a + \frac{2l^3}{3}\right)(2lb)^{-1} \]  

(1)

3. Experimental equipment and instruments

Experimental materials: several metal cantilever beams, laser pointer, steel ruler, spirit level, several 1 kg weights, several thin wires and tapes.

Experimental equipment: infrared rangefinder, fixed vise, vernier caliper.

4. Experiment procedure

A concentrated load is applied to the end of a metal cantilever beam, and the deflection occurring in the beam is amplified by a laser pointer, and a calculation relationship between the deflection and the load and the elastic modulus of the metal beam is established, thereby indirectly measuring the elastic modulus of the metal beam.

The specific steps in the experiment are as follows:

Step 1: Fix the vise firmly at a suitable height. In the experiment, the vertical height of the vise bayonet from the ground is 1.2 meters. A steel ruler is fixed at a suitable height on the opposite wall, and there is a certain horizontal distance from the vise. The horizontal distance in the experiment is 3.0 meters by using multiple measurements to find the average value.

Step 2: Replace the laser pointer with a new battery, remove the back cover, and firmly fix the laser pointer with a thin wire. It is fixed at one end of the metal beam to ensure that no shaking occurs during the experiment. The metal cantilever beam with the laser pointer is clamped straight on the vise. It is best to choose the center part of the cantilever beam to keep it level with the ground, the rules.

Step 3: Use an infrared rangefinder to measure the height of the fixed end from the ground and the horizontal distance from the fixed end to the wall, and then adjust the vise bayonet to the level with a spirit level, and make the laser projection point on the wall. It is approximately on the same horizontal straight line as the fixed end.

Step 4: Observe the steel ruler to record the position of the center of the laser projection point at this time.

Step 5: Select a certain distance between the laser pointer and the fixed end as the experimental loading position. The four loading positions are \( l = 0.35, l = 0.37m, l = 0.38m, \) and \( l = 0.39m \). Stick the laser pointer switch with tape to keep it shining and project onto the steel ruler on the opposite wall.
Step 6: Take a 1kg weight for each load, tie it with a string and hang it at the specified loading position, load it in stages, load it four times, observe and record the data on the projection surface each time, and remove the weight after four times. Record the restored position of the center of the projection point.

Step 7: Remove the rod and use the other end of the rod to perform the loading experiment. Repeat the previous steps until the end of the four experiments.

5. Analysis of experimental results

According to the different values of l and a, four groups of experiments were carried out. The test results are shown in Table 1.

| F/N | b₁/m | b₂/m | b₃/m | b₄/m |
|-----|------|------|------|------|
| 0   | 0    | 0    | 0    | 0    |
| 10  | 0.085 | 0.083 | 0.09 | 0.095 |
| 20  | 0.165 | 0.172 | 0.18 | 0.19 |
| 30  | 0.245 | 0.258 | 0.274 | 0.283 |
| 40  | 0.325 | 0.343 | 0.372 | 0.378 |
| L, a/m | l=0.35 | l=0.37 | l=0.38 | l=0.39 |
|      | a=1.83 | a=1.81 | a=1.80 | a=1.79 |

Using the values of F and b in Table 1, a diagram showing the relationship between the fitted load and deflection is shown, as shown in Figure 2.

Figure 2. Relationship between F and b₁

Figure 3. Relationship between F and b₂

Figure 4. Relationship between F and b₃

Figure 5. Relationship between F and b₄

Use a vernier caliper to measure b = 0.03m and h = 0.0032m of the metal cantilever beam, that is, the moment of inertia of the cantilever beam is 8.129×10⁻¹¹mm⁴.

After calculation, the average value of the elastic modulus can be found to be 196.83Gpa.
6. Error Analysis
During the experiment, errors may occur due to several reasons, such as: the metal cantilever is not fixed enough, the quality of the laser pointer affects the force application end, the force application points are not in the same position, or the reading is not accurate enough.

7. Method improvement
The laser pointer used in the experiment has a certain quality, and you can find a product with a smaller mass and volume to replace it, such as a small super test machine, etc., which can be accurately fixed in a designated place with double-sided tape.

In order to prevent large shaking and the accuracy of the loading position during loading, a lightweight hook can be attached to the weight first, and directly loaded on a thin wire of an appropriate length during loading.

In order to make the vise bayonet as horizontal as possible in order to fix the rod firmly and uniformly, the bayonet needs to be polished or be covered with a layer of non-slip material.

If the material used has been used before, it also has an impact on the measurement of the elastic modulus, so in order to reduce the error, new materials can be used in the future measurement.

If the material used is slightly distorted or uneven, it will also cause a certain error in the measurement result. Therefore, in the future measurement, some straight materials can be selected for measurement.

8. Conclusion
This paper uses the deflection method to determine the elastic modulus of metal materials. When using the deflection method, some expensive equipment is not needed, and the experimental method is relatively simple. This method can be used as a simple method for measuring the elastic modulus of materials in the future.

In this experiment, the following main problems occurred:

- There is a big difference between the height of the fixed end from the ground and the height of the projection point from the ground when it is not loaded. At the beginning, we did three sets of experiments, but the error was particularly large when calculating the data. I repeated the calculation many times. After that, it was found to be an error in the equipment, so we measured it with a spirit level, and found that the large error caused by the vise bayonet was not level.

- When the stage is loaded, the projection of the projection point on the wall is not a vertical line, but a large deviation. Through our careful observation, it turned out to be a problem caused by the selection of the test piece, and the cross section of the test piece was not very standard. Each surface is not very horizontal and somewhat curved, so an error occurs.

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