IARJSET

ISSN (Online) 2393-8021
ISSN (Print) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

Vol. 6, Issue 12, December 2019

A Simple Instrument for Calculating the Young's Modulus of Metal Wires

Feroz A. Mir*

Department of Physics, BGSB University Rajouri, J&K, India

Abstract: This paper describes the design and construction of a simple laboratory instrument to obtain Young's modulus (Y) of metal wires. This designed setup can give values of Y correct to within 2%. The instrument was designed to be used in higher secondary schools and undergraduate practical classes. The current setup can be constructed quite economically using readily available cheap items. The current setup was used to calculate values of Y for copper wire.

Keywords: Instrument, Metal, Economically, Schools, Design

I. INTRODUCTION

Young's modulus is one of the vital essential material characteristics in engineering design since it is needed to know the deflection in a solid, when some force in terms of loaded is applied to it [1-4]. When vivid deeply into the matter, the Young's modulus (Y) of a solid tells us the nature of the binding forces between structural units of a solid in its different forms (single crystal, polycrystalline or in composite format) [2]. There are number of methods available to determine young's modulus of materials [3,4]. But each of these methods have own good and bad (in terms of design, efficiency and cost).

The instrument described in this communication was developed be used in higher secondary schools and undergraduate practical classes. Values of Y can be measured within the error of approximately 2%. The instrument is a simple and does not involve expensive laboratory equipment. It has been used to measure the modulus of a variety of metal wires, especially steel wires.

II. THEORY

Usually materials deform to some allowed extent when certain force (or stress =Force/Area) is applied to them in particular direction. Due to bonding in these materials, the internal forces (or elastic force) which restore the size and shape of the object when the stress is removed. If this reversible deformation, or strain (the ratio of the change in length to the initial length) change in these materials is directly proportional to the applied stress, then the material is said to be perfectly elastic. When these elastic materials are attached to a mass and are stretched, they start oscillations [1]. The basic law of elasticity is Hooke's law. If a force F is applied to an elastic object (such as a wire), the object will undergo a change in length ΔL which will be directly proportional to F.

Mathematically, this can be expressed as $F \,\alpha\, \Delta L$

$$F = - k \Delta L \qquad ---(1)$$

Where k is a proportionality constant called the stiffness constant of material.

Here it should be noted that the value of k for any shape (wire, bar, or spring etc) made of a given material is not constant at all, but depends on various geometrical factors like ; its length, cross-sectional area, shape etc of the spring. Two springs made of the same material but with different lengths will have different values of k. The stiffness constant, therefore, is a characteristic of the sample under study or consideration and cannot provide a measure of the elasticity of the material itself. In most applications, however, we are not interested in the properties of a particular sample, but rather in the fundamental properties of the material out of which a sample is made. Hooke's law may be written so that the proportionality constant depends only on the material of which the object is made and not on its dimensions. If we consider a copper wire as our "spring", experiment shows that the amount it stretches for a given force doubles if the cross-sectional area A of the wire is halved. But, if the same force per unit area is used, all copper wires do the same thing - they stretch a certain proportion of their length.

Mathematically,

$$\frac{\Delta L}{L} = \frac{1}{Y}\frac{F}{A} \qquad --- (2)$$

where L is the length of the wire, Y is a constant, $\Delta L/L$ is the proportional change in length of the wire and F/A is the force per unit area. F/A is called the stress and $\Delta L/L$ is called the strain.

ISSN (Online) 2393-8021
ISSN (Print) 2394-1588

IARJSET

International Advanced Research Journal in Science, Engineering and Technology

Vol. 6, Issue 12, December 2019

We can rewrite equation (2) as

$$\frac{F}{A} = Y\frac{\Delta L}{L} \quad \text{--- (3)}$$

which shows that the stress is directly proportional to the strain. According to equation (3), for elastic materials a plot of stress versus strain will be a straight line with a slope equal to Y.

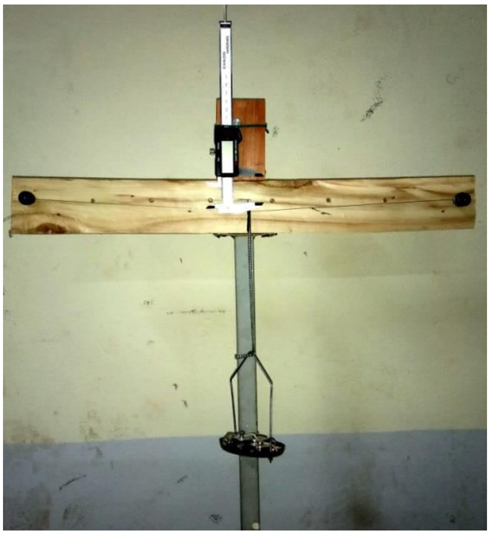

Fig.1 shows the designed setup.

III. DESIGN & CONSTRUCTION

Fig.1 shows the designed set up. Here sample under study (wire) is fixed at the both ends by screws. The force (weight) is fixed at the middle of the wire by hanging a pan. The deflection in the length is measured by digital Vernier clipper fixed at the same point where the load is applied. This digital Vernier clipper can measure deflection up to 50 micrometer in an easy and accurate way. Finally a graph between stress (F/A) versus strain (ΔL/L) is plotted, and the slope gives the Y. In the current experiment we used steel wire of 1mm diameter & 0.552 m of length.

IV. RESULTS AND DISCUSSIONS

Fig.2 shows the deflection in length of copper wire when different load (force or weight) is applied to it. Looking at the graph closely shows all the feature which a metal wire should show. Here up to point **'A'** the variation in length is linear (stress is proportional to the strain), beyond that point the flat behavior comes in the play. This is the region of supper elasticity. Due to safety purposes we did not apply much load beyond this point.

Table I. shows the various parameters of the sample.

Sample	**Length (m)**	**Diameter (mm)**	**Y x 10^9Nm^{-2} (by our instrument)**	**Y x10^9Nm^{-2} (Standard)**
Steel	0.552	1	196	200

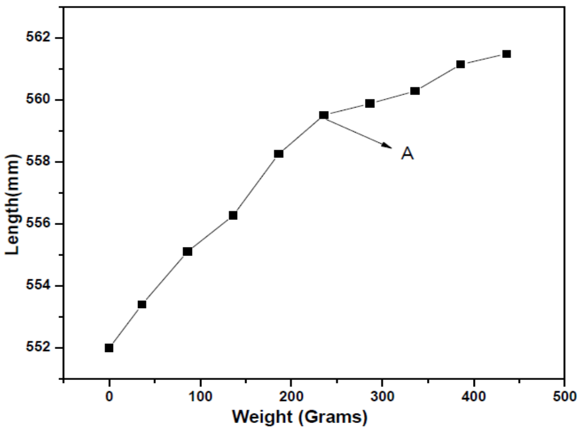

Fig.2 Shows the deflection length with applied load.

IARJSET

ISSN (Online) 2393-8021
ISSN (Print) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

Vol. 6, Issue 12, December 2019

Fig. 3 shows the stress versus strain plot. A linear fit of this plot and its slope gives us Young's Modulus of the wire. The results obtained are given in the table I. The current instrument show results within 2% error in comparison to the standard value (measured by Universal Testing machine). The current instrument can be designed with very low cost, and can be used to demonstrate stress versus strain, and hence calculation of Y in a easy and accurate manner.

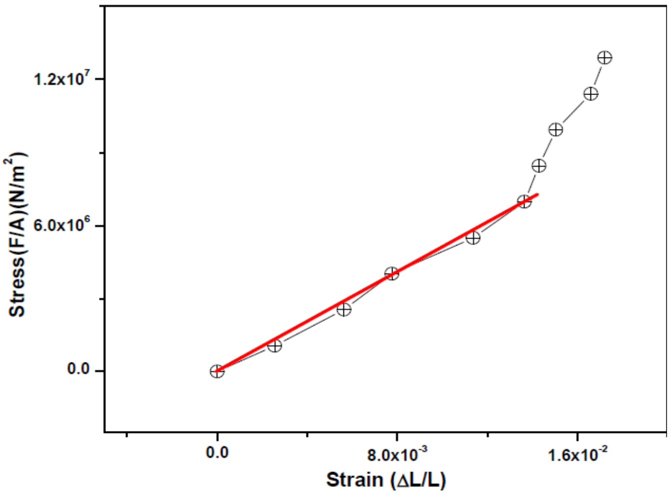

Fig.3 shows the stress versus strain graph.

V. CONCLUSION

We designed a simple laboratory setup to calculate Young's modulus (Y) of metal wires. This homemade instrument can be designed with low cost, and give values of Y correct up to 2% of standard value. The current instrument can find application in higher secondary schools and undergraduate practical classes. This setup was used to demonstrate and calculate the values of Y for copper wire.

ACKNOWLEDGMENT

The author would like to thank UGC India for providing him Start-Up Project to carry out this work.

REFERENCES

[1]. Halliday, Resnick, Walker, 1997. Fundamentals of Physics. 5th ed. John Wiley & Sons, Inc. In Czech: Fyzika, Brno, VUTIUM 2000, 2002.
[2]. J.D. Lord, M. Rides, M.S. Loveday, Modulus measurement methods, TENSTAND WP3 Report, National Physical Laboratory, Jan 2005.
[3]. B.F. Dyson, M.S. Loveday, M.G.Gee, (Eds), Aspects of materials metrology and standards for structural performance, Chapter 8: Aspects of modulus measurements, Elsevier Applied Science, London, 1994.
[4]. A.Wolfenden, et al., "Dynamic Young's modulus measurements in metallic materials: results of an interlaboratory testing program", Journal of Testing and Evaluation, Jan 1989, pp2-13.