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Measurement of Young's Modulus of Wire by automatic Counting method of Interferometric Ring

Guijuan Yang, Xiulu Hao, Xiaotian Yu, Lina Wang* , Jialu Zhao and Lin Hong

Key Laboratory of Marine Biophysics of Liaoning Province, Dalian Ocean University, Dalian, China

*Corresponding author e-mail: l.n.w@163.com

Abstract. Young's modulus is an important physical quantity to describe the deformation resistance of solid materials, and it is one of the commonly used parameters in engineering technology. A device for measuring Young's modulus of wire by automatic counting of interference ring is mainly composed of an automatic counter of interference ring, a Michelson interferometer, a tension tester and a wire to be tested. The elongation of wire is recorded by recording the number of interference fringes and rotating coarse adjusting knob by using the automatic counter of interference ring, and at the same time measuring the tension applied on the wire to be measured by using the digital explicit tension measuring device, and substituting the calculation formula. The Young's modulus of the wire to be measured can be obtained directly.

1. Introduction

The Young's modulus of elasticity refers to the change of the shape of solid material after the longitudinal force, which is widely used in scientific research and engineering. Therefore, many college physics experiment courses have set up Young's modulus of elasticity experiment to measure solid material. Measurement of Young's modulus of wire by interference loop automatic counting method as an experimental device with simple structure and convenient operation, it can avoid all kinds of problems existing in traditional measuring methods of Young's modulus of wire, including tedious counting of eyes, complex exciter structure, time difference signal processing point and so on.

Historically, over 200 years ago, British physician and physicist Thomas Young (1773-1829) has carried out the Young's modulus measurement experiment of solid materials. With the continuous development of the industrial revolution, the demand and standard for the application of solid materials have been rising. It has become the goal of many new industries to look for solid materials with excellent properties and high deformability. In order to measure the Young's modulus of solid materials easily and quickly, people have been trying different measuring methods. In general, Young's modulus testing methods generally have dynamic method and static method.

The dynamic method includes pulse excitation method, sound velocity method and audio frequency resonance method. Static method is to apply a constant bending stress to the specimen, to measure its elastic bending deflection, or to apply a constant tensile (or compressive) stress to the specimen. The elastic deformation is measured. Or calculate the modulus of elasticity based on stress and strain. The principle of optical lever amplification is a widely used method to measure the Young's modulus of wire in colleges and universities.



Each of these methods has its advantages and disadvantages, but there is a common problem that the experiment takes a long time, the repeatable problem, so many data to be count, data processing is not easy, the experimental conditions are harsh, and the experimental method is not perfect enough. This is also one of the main reasons that affect the measurement of Young's modulus of wire, so how to improve the experimental method, simplify the experimental steps and reduce the influence of environmental factors is very important. The interference ring automatic counting device is shown in Fig.1.

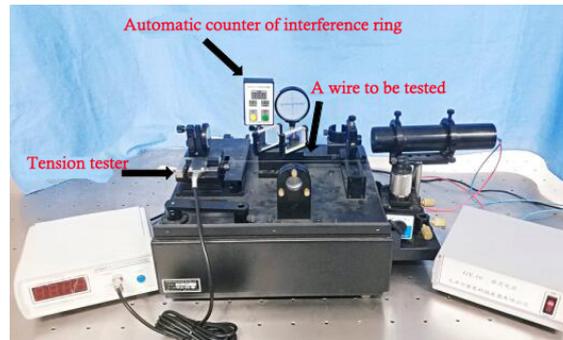


Fig.1. The interference ring automatic counting device

2. Experiment

2.1. Configuration and structure of automatic counter for Interferometric Ring

The device for measuring Young's modulus of wire by automatic counting of interference ring is mainly composed of an automatic counter of interference ring, a Michelson interferometer, a tension measuring instrument and a wire to be measured. The device is characterized in that the device includes a laser, a beam expander, etc. The digital display tension measuring device which is fixed with the moving mirror can read out the pull value in real time. The fine adjusting knob that adjusts the position of the moving mirror causes the wire to deform slightly, and a fixed frame is arranged near one end of the laser. One end of the wire to be tested is fixed on the fixed frame and the other end is fixed on the digital display tension measuring device. The interference ring automatic counter is used to calculate the number of interference ring fringes on the screen in real time. The experimental operation diagram is shown in Fig.2.

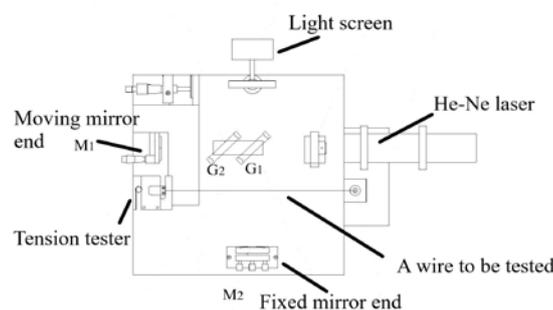


Fig.2. The experimental operation diagram

2.2. Application and Analysis of Michelson Interferometer

The laser beams pass through the Michelson interferometer and intersect. One end of the wire under test is attached to the tension meter fixed to the Michelson interferometer moving mirror and the other end to the stationary frame. The rotating mirror fine tuning knob gives the wire a continuous pull force, the moving mirror produces displacement, and the wire then produces a small deformation. At the

same time, the corresponding tensile force indicator is displayed on the tension measuring device. The number of stripes "gushing out" or "falling into" is found, and the Young's modulus of a specified segment of wire can be calculated according to the corresponding wavelength of fixed light wave on the laser.

An automatic counter of the interference ring is placed behind the screen of the Michelson interferometer, and the tension meter that fastens one end of the wire to the moving mirror provides continuous tension to the wire by fine-tuning the knob, which causes the wire to stretch to produce small deformation. The number of interference rings varies on the counter. During the change period, the wire elongation is calculated by using the interference ring automatic counter to capture the optical signal.

2.2.1. Interference fringe analysis.

A beam of light emitted from the He-Ne laser S is decomposed into transmitted light and reflected light after the semi-permeable film of the spectrometer G_1 . After the transmission light is projected on the screen M_2 , it returns along the original path and then shines on the semi-permeable film of the splitter G_1 , which is reflected by the semi-permeable film. This beam of light is reflected in the direction of the viewing screen, and when the reflected light is incident to the mirror M_1 , it returns along the original path, and also in the direction of the viewing screen through the splitter G_1 . On the screen, the stripes produced by the interference of two beams of light can be seen. When two lights interfere, the formula is as follows:

$$2d\cos\theta = \begin{cases} \pm K\lambda & \text{.....Bright grain} \\ \pm (2K+1)\frac{\lambda}{2} & \text{..... Dark grain} \end{cases} \quad (\mathbf{K=1, 2, 3.....}) \quad (1)$$

[note: K is the interference order; d is the thickness of the air film]

At this point, the display screen will appear in the dark and light concentric ring. The interference ring diagram is shown in Fig.3.



Fig.3. The interference ring diagram

2.2.2. Young's modulus conversion.

Within the limits of elasticity, according to Hooke's law:

$$\frac{F}{A} = Y \frac{L}{\Delta L} \quad (2)$$

[note: F: tensile force of the wire; ΔL : the amount of elongation; L: the original length of the wire]

Y is Young's modulus, calculated as follows:

$$Y = \frac{FL}{A\Delta L} \quad (3)$$

[note: F: tensile force of the wire; A : cross sectional area of wire;]

Let the wire length L be measured and the average diameter be D. When the tensile force on the wire in the length direction is F, the elongation of the wire is ΔL . Then according to the definition, the Young's modulus of elasticity of the wire to be tested is obtained by combining with formula (3):

$$Y = \frac{4FL}{\pi D^2 \Delta L} \quad (4)$$

Δd is the distance from which the moving mirror moves, that is, $\Delta L = \Delta d$; Moving the moving mirror causes the stripes on the viewing screen to "gushing out" or "falling into" setting the number of stripes "gushing" or "sinking" to N (which can be obtained by an automatic interference ring counter), according to the Michelson interference principle. The relation between the moving distance Δd of the moving mirror and the number of stripe movement changes N can be concluded that:

$$\Delta L = \Delta d = \frac{N}{2} \lambda \quad (5)$$

λ is the wavelength of the incident light. So the Y can be calculate as:

$$Y = \frac{8FL}{N\pi D^2 \lambda} \quad (6)$$

3. Measurement

The method described follows the following steps:

First of all, take the wire to be tested with length L and diameter D, fix the two ends of the wire to the support column and the digital display tension measuring device respectively, turn the fine adjusting knob, and move the moving mirror end and the digital explicit tension measuring instrument. To ensure that the wire under test is in an elongated state

Then adjust the light path so that the ring center of the interference ring appears at the center of the glass observation screen. If the center of the ring of the interference ring is not at the center of the glazed glass viewing screen, adjust the mirror to ensure that the center of the interference ring is at the center of the viewing screen of the ground glass .

By rotating the fine adjusting knob, the fringe of the interference ring observed on the wool glass observation screen is sparse and the brightness is suitable, so that the number of the interference rings can be conveniently recorded,

Turn on the digital tension tester and set zero, then rotate the fine-tuning knob, and the digital tension tester will stretch the wire to be tested, When there is a reading on the digital display tension tester and the phenomenon of " gushing out " or " falling into " the interference ring appears on the observation screen of the ground glass, the automatic counter of the interference ring at the rear of the glass observation screen automatically records the number of stripes N, The digital display tension tester can record the tensile force F of the wire to be measured after changing N stripes.

The elongation of the wire under test is equal to the displacement of the moving mirror, which is equal to the change of the light path difference of two light rays in the optical path. Thus, the Young's modulus of the wire to be tested can be obtained.

After measuring the number of fringes N and tension F, the experimenter can calculate them by himself. He can also connect the digital explicit tension measuring instrument and the interference ring automatic counter to the computer through the data line, and the measured results can be transmitted directly to the computer. The calculation is carried out automatically by the computer according to the above formula.

4. Conclusion

In this paper, a simple and skillful device for measuring the Young's modulus of wire is presented. An automatic interferometer counting method is designed to eliminate the inaccurate measurement in

traditional measurement methods. The device and the corresponding measurement method have the following advantages.

The number of interference rings is recorded by the automatic counter of interference ring, and the metal wire is moved and straightened by adjusting the fine adjusting knob, which avoids the complicated human eye counting method and the process of drawing the metal wire with the fixed pulley to make the metal wire elongate. The tensile force applied on the wire under test can be measured by using a digital explicit tension measuring instrument, and the Young's modulus can be obtained directly after the calculation formula is substituted. The combination of optical knowledge and mechanical quantity is helpful to the knowledge of various disciplines.

In addition, it is not only limited to the measurement of Young's modulus of wire, but also can be used to measure the Young's modulus of other filaments. It is suitable for the comprehensive design experiment in college physics experiment and has good feasibility and practical value in the later Young's modulus measurement experiment.

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