Thermal expansion coefficient measured by single slit diffraction

Guijuan Yang, Ziying Ren* and Jian Wang
School of Science, Dalian Ocean University, Dalian, China.

*Corresponding author E-mail: mir2014@foxmail.com

Abstract. The determination of thermal expansion coefficient of materials is a representative experiment in thermal experiments. With the application of modern computer methods to experiments, when measuring the material's thermal expansion coefficient, the thermal expansion coefficient of the material is calculated by measuring the distance between the diffraction stripes. However, there are significant errors in conventional methods, because of the limitation of the observation of diffraction stripes through human eyes. By improving the receiving device, the diffraction fringe is monitored in real time by using a CCD data acquisition system, which is not only easy to operate, but also reduces the coefficient of thermal expansion of the calculated material by computer programming, which is close to the real value.

1. Introduction
At present, there are only few reports on drying seafood products using ultrasound pretreatment. In this paper, scallop muscle, as a representative of seafood products, were treated in an ultrasound system, in different frequency, time and different temperature [1-4]. The hot air drying rate of treated scallop muscle was determined and, meanwhile, several quality parameters such as the shrinkage and rehydration rate of samples with pretreatment were determined to compare with those of untreated samples. Materials have the properties of thermal expansion and shrinkage, and the change in length due to temperature rise is called "thermal expansion". The thermal expansion coefficient of materials is an important index, which is widely used in industrial production and daily life, especially in the high-tech field, which requires high demand for materials. There are many ways to measure the thermal expansion coefficient [5-6], such as the traditional light lever method, the motion microscope method; more accurate measurements of the optical method, such as chopping interferometry, Michelson interferometry, [7-8] etc. The thermal expansion coefficient of optical measurement materials is relatively more accurate and at the same time more complicated. In this paper, a new method is adopted for measuring the coefficient of thermal expansion of materials with single joint diffraction, which is simple and easy to do, and the error is also small.
2. Experimental procedure

2.1. Experimental equipment
The laser beams, and the diffraction phenomenon occurs through the slit that is made up of two blades, with the lower end of the blade connected to the metal rods. After the loop heat pipe heating, metal bar is heated, then the expansion deformation occurs, pushing the lower blade up, making the single seam narrow, so the diffraction fringe changes. The thermal expansion coefficient of the metal is calculated by computing the spacing of fringes. Thermal expansion measurement system used in this study was also developed by the authors.

![Schematic of the thermal expansion measurement system](image1)

1. Optical maser 2. Single slit device 3. Observation device 4. Shell 5. Heating barrel 6. Resistance wire 7. Metal bar to be measured 8. Adiabatic connector 9. Blade 10. Temperature sensor 11. Temperature measuring and controlling instrument 12. Shading tube 13. Optical signal reception screen 14. CCD data processing module 15. Wire and computer

**Figure 1.** Schematic of the thermal expansion measurement system

![Schematic of the thermal expansion measurement system](image2)

5. Heating barrel 6. Resistance wire 7. Metal bar to be measured 9. Blade 16. Frame 17. Connection sleeve 18. Blade connection frame 19. Coamping bolt

**Figure 2.** Schematic of the thermal expansion measurement system
2.2. Experimental Principle and measurement

By the thermal expansion coefficient of metal, we can easily find the formula by experiment:

\[
\alpha = \frac{f (m - n) \lambda}{L_1 (T_2 - T_1)} \left( \frac{1}{\Delta X_{2mn}} - \frac{1}{\Delta X_{1mn}} \right)
\]  

(1)

Where \( f \) is the distance to the light screen; \( \Delta X_{mn} \) is the distance between the two stripes, \( m \) is \( m \)-class bright stripe, \( n \) is the \( n \)-class bright stripe on the side of the central bright grain, \( L_1 \) is the original length and \( \alpha \) is thermal expansion coefficient. \( \Delta X_{1mn} \) is the fringe spacing between the \( m \)-class bright stripe and the \( n \)-class bright stripe before heating; \( \Delta X_{2mn} \) is the fringe spacing between the \( m \)-class bright stripe and the \( n \)-class bright stripe after heating.

Use the formula above to measure the width of the diffraction fringes under different temperature, we can get the variation of slot width, namely deformation quantity of material under the change of temperature, and thus the coefficient of thermal expansion of the material can be calculated.

In this experiment, we used two methods to measure diffraction fringe spacing and compare them:

Traditional Method is using \( D_2 \) type reading microscope for reading to the naked eye, and then putting a diaphanous baffle plate on the reading microscope lens. And after diffraction fringes project on the block board, the reading microscope is moved up and down to read figures and thus fringe spacing comes out. Additional method is the Using of CCD Signals. By using a linear array transducer for optical signal capture, photocurrent are produced, and then use single-chip to complete analog-to-digital conversion, which converts into digital signal, and finally work out fringe spacing with software for analysis and computation.

2.3. Data Measurement and Analysis

After heating, the width of the seam becomes smaller, and the stripe light intensity decreases and becomes larger, which conforms to the theoretical derivation. In the experiment, due to the high sensitivity CCD data acquisition system, solar lighting and light intensity of central bright fringe can both make it into the state of saturation. So, the error is reduced by placing the lengthened box-shaped sunshade tube before the CCD data acquisition system to avoid the light and collecting the change of the position of the diffraction fringe which is on the same side of the central bright grain.

![Figure 3. Light intensity and pixel before heating.](image)

![Figure 4. Light intensity and pixel after heating.](image)

3. Conclusion

In this experiment, CCD image processing technology and computer technology are combined to measure the stripe spacing in real time, which can effectively reduce the influence of human factors in the measurement, and the error is smaller than the traditional method. Additionally, the fast and automatic measurement of line thermal expansion coefficient is achieved. More importantly, the test method is simple and practical to be popularized and used.
Acknowledgments
This work was supported by the Undergraduate Innovation and Entrepreneurship Training Program under contract No (L201610158004).

References
[1] K.S. Zhou, X.W. Zhao, Z.W. Hu, University physics experiment. Central South University Press. (2001) 127.
[2] K.H. Zhao, Y.H. Zhong, Optical. Beijing University Press. (1984) 211-215.
[3] A.H. Liu, S.Z. Wu, Improvement of the instrument for measuring the coefficient of solid linear expansion, College Physics. 24 (2005) 48-49.
[4] J. Wei, Principle of CCD. Technology of vertical and horizontal. 6 (2003) 70-72.
[5] Q. Y Wang, X.Z Sun, CCD application technology, Harbin Institute of Technology Press. (2008) 141-154.
[6] G.R. Cao, S.F. Jing, Y. Ren, CCD used for Moire fringe technology. Journal of measurement. 16 (1995) 33-34.
[7] H.Y. Zhang, X.K. Ma. Method of measurement for Linear CCD, Physical Experiment. 25 (2005) 10-13.
[8] Q.Q. Ruan, Digital image processing technology, China Railway Press. (1998) 23-28.