Design and Application of Automatic Calibration Device for Multi-Channel Resistance Strain Gauge Indicator

Xiaoyin Hu*, Ye Li, Haoyu Zhang, Yueling Yu, Zhangyi Kang

Shanghai Institute of Measurement And Testing Technology, Shanghai 201203, China

*Corresponding author’s e-mail: huxy@simt.com.cn

Abstract. In this paper, an automatic calibration device for multi-channel resistance strain gauge indicator is designed and its applicability and measurement accuracy are verified at laboratory. The calibration done by original resistance bridge calibrator is time-consuming for its manual operation and complex calibration process. With the intent to increase calibration efficiency, an automatic channel switch device was developed, and the resistance bridge calibrator was automated. The designed calibration device is completely computer controlled enabling a sequence of unmanned measurements. The calibration device was verified at laboratory that the maximum of error is 0.072%. It was applied to calibrate a 60-channel resistance strain gage indicator to approve its practical applicability. The result shows that the designed calibration device can realize automatic calibration and the efficiency is increased by 40%.

1. Introduction

Strain gage is one of the most reliable strain measurement devices in laboratory and industrial field [1-3]. Dozens of and sometimes thousands of strain gages are used in material and structural stress analysis [4-5]. The strain gage indicator is the measuring device of the strain gage by means of Wheatstone bridge (shown in Figure 1). Calibration of multi-channel strain gage indicator done with the resistance bridge calibrator (shown in Figure 2) is time consuming, because an operator is needed to manually manipulate the switches on the calibrator and switch channel [6]. The traditional calibrator is designed for strain gage indicator with just several channels. It’s a tedious work to do the calibration of an indicator with dozens of channels by the traditional calibrator. Kreuzer designed a new circuit to realize automatic calibration. However, the problem of channel switch is not taken into consideration and the calibrator is not applicable for half bridge and full bridge [7]. Xu designed an automatic calibration. The device is developed for a specific strain gage indicator and not suitable for others [8]. For this reason, an automatic calibration device for the multi-channel strain gage indicator is designed, and its applicability and performance are validated at laboratory.

Figure 1. Wheatstone bridge
Figure 2. Traditional resistance bridge calibrator
2. Design of the calibration device

The designed calibration device presented in Figure 3 is made up of three parts: calibrator automation system, channel switch system and computer software.

The calibrator automation system automates the traditional resistance bridge calibrator. Six motors are installed on the calibrator through mechanical connection. Instructions from the computer software actuate the motors to rotate. Each rotary switch on the calibrator can generate ten fixed-strain loading values by fixed-angle rotation. The angles corresponding to strain loading values are measured to ensure motors can reach correct position. The calibration process is controlled by the computer software. The strain loading values of six motors in software is defined. The motors rotate according to the edited calibration documents to generate strain loading. The designed calibrator automation system can be applied to any resistance bridge calibrator that has similar mechanical structure. The main differences are the number of motors and setup of angels.

![Figure 3. Designed calibration device](image)

The channel switch system has 60 channels and is applicable for the majority of the strain gage indicator. The circuit is shown in Figure 4. The open and close of the channel is controlled by a relay. The relay will close when receiving the current from the photoelectric coupler. The power supply is controlled by computer program to determine the channel number to switch.
3. Verification and application of the calibration device

The error of the designed calibration device is greater than the original calibrator for the electron component applied in the channel switch system. To verify the performance of the designed calibration device, especially the error introduced by channel switch system, a high-class resistance strain gage indicator the relative uncertainty of which was 0.005% \((k=2)\) was employed. The parameters of the resistance strain gage indicator are listed in Table 1. Measurement results are shown in Table 2 and the max error is 0.072%.

To prove the applicability of the designed calibration device, a 60-channel resistance strain gage indicator (model: EDX-5000A-60) was calibrated by the device shown in Figure 5. All channels were connected to the channel switch system before the calibration and a calibration file is edited according to requirements. The setup parameters include channel number, strain loading value and silent period time. In this calibration, strain loading values of each channel were 200\(\mu\varepsilon\), 500\(\mu\varepsilon\), 1000\(\mu\varepsilon\), 2000\(\mu\varepsilon\) and 5000\(\mu\varepsilon\), and motors kept still for 20 seconds after reaching the position. Then, the calibration started. The designed calibration device completed the calibration process according to the excel file in 105 minutes with no manipulation from the operator and data was saved in computer. The source record was produced according to the calibration excel file and data file. It is known from practice that 3 hour is the minimum time to do the calibration of an indicator with 60 channels by traditional bridge calibrator.

![Figure 4. Channel switch circuit](image)

| Model   | Measurement Range | Relative Uncertainty \((k=2)\) |
|---------|-------------------|-------------------------------|
| DMP40   | \((0.01\sim10^4)\mu\varepsilon\) | 0.005%                        |
Table 2. Measurement Results

|     | Actual value/$\mu\varepsilon$ |     |     |     |     |
|-----|-------------------------------|-----|-----|-----|-----|
|     | $\times 10^3\mu\varepsilon$  | $\times 10^2\mu\varepsilon$ | $\times 10^1\mu\varepsilon$ | $\times 10^0\mu\varepsilon$ | $\times 10^{-1}\mu\varepsilon$ |
| 1   | 999.8                         | 100.0                      | 10.0                        | 1.0                         | 0.1                         |
| 2   | 1999.5                        | 199.9                      | 20.0                        | 2.0                         | 0.2                         |
| 3   | 2998.2                        | 299.9                      | 30.0                        | 3.0                         | 0.3                         |
| 4   | 3997.8                        | 399.8                      | 40.0                        | 4.0                         | 0.4                         |
| 5   | 4996.4                        | 499.7                      | 50.0                        | 5.0                         | 0.5                         |
| 6   | 5996.2                        | 599.7                      | 60.0                        | 6.0                         | 0.6                         |
| 7   | 6995.7                        | 699.6                      | 70.0                        | 7.0                         | 0.7                         |
| 8   | 7995.2                        | 799.6                      | 80.0                        | 8.0                         | 0.8                         |
| 9   | 8995.2                        | 899.5                      | 90.0                        | 9.0                         | 0.9                         |
| 10  | 9995.5                        | 999.5                      | 100.0                       | 10.0                        | 1.0                         |

Figure 5. 60-channel strain gage indicator

4. Conclusions
In this paper, an automatic calibration device for multi-channel resistance strain gauge indicator is designed and verified. The traditional manual-operation resistance bridge calibrator was automated, and an automatic channel switch device was developed. The result of verification implemented at laboratory shows that the maximum error of calibration device is 0.072% and the calibration efficiency can increase by 40%.
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