Calibration Method and Measurement Uncertainty Evaluation for the Zero Error of Level Rules

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Abstract. A calibration method for the zero error of level rules was proposed. According to the calibration method, the evaluation model of measurement uncertainty was established, and the sources of uncertainty were analyzed. Combined with the measurement example, the evaluation process of the measurement uncertainty for the zero error of level rules was described.

1. Introduction
The level ruler is a kind of measuring tool which uses the principle of liquid level to directly display the angular displacement with the level bubble and measure the deviation degree of the measured surface relative to the horizontal position, vertical position and inclined position. In order to ensure the reliability of the transfer of the measured value of the level ruler, JJF 1085-2002 "Calibration Specification for Level Rules" [1] gives the calibration methods of the flatness of the working face, the indication error, the zero error and other metrological characteristics. The zero error of the level rulers refers to the deviation error between the bubble center of the level bubble and the symmetry center of the left rear mark line of the level bubble when the level bar is placed in the standard horizontal state. In the industry standards related to the production and manufacture, such as JB / T 11272-2012 [2], and QB / T 4621-2013 [3], the zero error experiment method is given. However, the above standard only gives the calibration method of the zero error of level rulers, and lacks the evaluation of the measurement uncertainty of the relevant calibration. This paper aims at the calibration of the zero position error of the level, and evaluates its measurement uncertainty.

2. Calibration method for the zero error of level rulers
2.1. Zero error of horizontal position
In the laboratory environment, place the level ruler on the surface plate. After the bubble in the horizontal position is stable, use the reading microscope to measure the distance a1 between one end of the bubble and the mark line. Then, turn the level ruler 180° and put it in the original position of the surface plate, and measure the distance a2 between the other end of the bubble and the mark line again. Half of the difference between a1 and a2 is the zero error. The calibration process is shown in Figure 1.
2.2. Zero error of vertical position
Under the laboratory environment, the special plane parallel column is placed on surface plate, and then
the working face of the level ruler is close to the plane parallel column. After the bubble of the level
bubble in the vertical position is stable, the reading microscope is used to measure the distance $a_1$
between one end of the bubble and the mark line. Then turn the level ruler 180° and put it in the original
position of the special plane parallel column, and measure the distance $a_2$ between the other end of the
bubble and the mark line again. Half of the difference between $a_1$ and $a_2$ is the zero position error. The
calibration process is shown in Figure 2.

2.3. Zero error of 45° position
Under the laboratory environment, place the special 45° angle ruler on surface plate, and then close the
working face of the horizontal ruler against the 45° angle working surface. After the bubble of the level
bubble at 45° position is stable, measure the distance $a_1$ between the bubble end and the marking line
with the reading microscope. Then, turn the horizontal ruler and the special 45° angle ruler to 180° and
measure the distance $a_2$ between the other end of the bubble and the marking line again, and the
difference between $a_1$ and $a_2$ is zero error. The calibration process is shown in Figure 3.
3. Evaluation of measurement uncertainty

The indoor temperature of the measurement environment laboratory is (20 ± 5) °C, and the humidity is not more than 65%RH. The standard instrument was a 2-level plate, and the MPE was 0.01mm reading microscope. The measured object is a level ruler with nominal accuracy of 0.5mm/m.

3.1. Measurement model

According to the Calibration method, it can be seen that the measurement model is

\[ \delta = \frac{a_1 - a_2}{2} \]  

(1)

Where \( \delta \) is the zero error of the level ruler, \( a_1 \) is the distance between one end of the level rule and the marking line, \( a_2 \) is the distance between the other end of the level rule and the marking line. The unit is millimeter.

Because each component is independent of each other, the combined standard uncertainty is calculated by the following formula [4]

\[ u^2_c(\delta) = c_1^2u^2(a_1) + c_2^2u^2(a_2) \]  

(2)

Where coefficient of sensitivity \( c_1 \) is equal to 0.5, \( c_2 \) is equal to -0.5.

3.2. The source of standard uncertainty

The source of standard uncertainty components of measurement results is shown in Table 1.

| \( u(x_i) \) | The source of standard uncertainty | coefficient of sensitivity \( c_i \) | \( |c_i| \times u(x_i) \) |
|---|---|---|---|
| \( u(a_1) \) | The standard uncertainty introduced by the measurement of the distance between the bubble end of the level ruler and the mark line | 0.5 | 0.0031mm |
| \( u(a_2) \) | The standard uncertainty introduced by the measurement of the distance between the other bubble end of the level ruler and the mark line | -0.5 | 0.0031mm |

3.3. Calculation of standard uncertainty

3.3.1. Calculation of \( u(a_1) \). This standard uncertainty mainly includes the standard uncertainty caused by measurement repeatability and the standard uncertainty caused by reading microscope indication error.

Under the same conditions, the distance between one end of the same bubble and the mark line was measured for 10 times, and the standard deviation of single measurement experiment was 0.0055mm, then
\[ u(a_{1.1}) = 0.0055\text{mm} \]  

The MPE of the reading microscope is 0.01mm, assuming that the normal distribution is obeyed in the measurement range, then the standard uncertainty caused by reading microscope indication error is 

\[ u(a_{1.2}) = 0.01\text{mm} / (2\sqrt{3}) = 0.0029\text{mm} \]  

Since \( u(a_{1.1}) \) and \( u(a_{1.2}) \) are not related, then 

\[ u(a_i) = \sqrt{u^2(a_{1.1}) + u^2(a_{1.2})} = 0.0062\text{mm} \]  

3.3.2. Calculation of \( u(a_2) \). Since \( a_1 \) and \( a_2 \) are measured in the same way, there are 

\[ u(a_i) = u(a_2) = 0.0062\text{mm} \]  

3.4. Combined standard uncertainty 

According to the above analysis, according to formula (2), the combined standard uncertainty \( u_c(\delta) \) of the measurement results of the zero error of level ruler can be calculated as follows 

\[ u_c(\delta) = \sqrt{u^2(a_{1}) + u^2(a_2)} / 4 = 0.0044\text{mm} \]  

3.5. Expanded uncertainty 

Taking the inclusion factor \( k = 2 \), the expanded uncertainty of the zero error calibration of level rule is 

\[ U = k u_c(\delta) = 2 \times 0.0044 \approx 0.009\text{mm} \]  

4. Conclusion 

By using the proposed calibration method and the evaluation example of measurement uncertainty, the zero error calibration of level rules can be realized. Zero error is one of the important metrological characteristics of level rules. It is suggested to add an example of uncertainty evaluation of zero error calibration of level rules in the revision of relevant technical specifications, so as to guide the metrological calibration and improve the metrological characteristics. 

References 

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