Calibration Method and Measurement Uncertainty Evaluation for the Levelness of the Level Rules

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Abstract. A calibration method for the level of the 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 level of the level rules was described.

Keywords: Metrology; The Levelness of Level Rules; Uncertainty in Measurement.

1. Introduction

The level rules are a measuring tool which uses the principle of liquid level to directly display the angular displacement with the level bubble and measure the deviation of the measured surface from the horizontal position, vertical position and inclined position [1]. According to the survey of many level rules manufacturers, the precision marked on the rule in the market at present refers to the metrological characteristics related to the levelness of the rule. However, the levelness of level rules is not found in industry standard JB/T 11272-2012 [4], and QB/T 4621-2013 [5]. The concept of levelness is mentioned in the standard T/ZZB 0494-2018[4], which is defined as the level ruler is placed in a horizontal (vertical or inclined) position, and one end of the level ruler is raised so that the bubble centerline of the level bubble coincides with the centerline of the two scribed lines. The levelness of the level rules includes both the identification threshold and sensitivity characteristics of the level bar, which is one of the important metrological characteristics of the level rules. Because the meaning of the definition of levelness of level ruler in reference [4] is not well understood, this paper attempts to propose a new definition of levelness of level ruler and its calibration method, and evaluate its measurement uncertainty.

2. Calibration Method

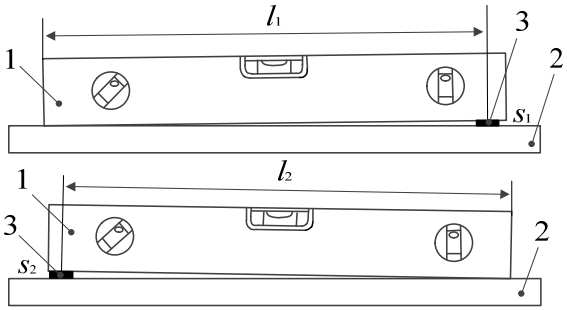
To facilitate understanding, the levelness of the level rules is defined as the maximum included angle between the working surface and the standard surface when the bubble of the level rules is centered. Calibration standard devices mainly includes grinding plate of level 1, feeler gauges of MPE are ± (0.005~0.016) mm, steel ruler of measuring range (0~1000) mm and MPE is ±0.20mm and special angle ruler [4]. The levelness calibration method for horizontal position is described below. Level the plate before calibration. Place the level ruler on the flat plate, and observe whether the bubble is centered after the level bubble in the horizontal position is stable. There are two situations:

When the bubble at the horizontal position is in the middle, select a feeler gauge with a suitable thickness of s_1 and insert it between the working face at one end of the level rule and the flat plate, so that the center of the bubble just moves past the symmetrical center of the left and right marking lines. Use a steel ruler to measure the distance l_1 from the contact point of the feeler gauge and the level rule to the other end of the rule. At the other end of the level rule, measure s_2 and l_2 again using the same method. The levelness b_i measured twice is calculated by equation (1), and the larger one is taken as the measurement result of levelness of horizontal position. The measurement diagram is shown in Figure 1.

$$b_i = 1000 \times \frac{s_i}{l_i} \tag{1}$$

Where b_i is the levelness measured for the i time, s_i is the thickness of feeler gauge selected, l_i is the distance from the contact point of the feeler gauge and the level gauge measured for the first time to the other end of the level rule.

When the bubble at the horizontal position is not centered, select a feeler gauge with appropriate thickness of s_1 and insert it between the working face at one end of the level ruler and the flat plate, so that the center of the bubble just moves past the symmetrical center of the left and right marking lines. Use a steel ruler to measure the distance l_1 from the contact point of the feeler gauge and the level ruler to the other end of the level ruler. Then the levelness bi of the horizontal position can be calculated by Formula (1).



1- level rule. 2- grinding plate. 3- feeler gauges

Fig 1. Schematic diagram for measurement of levelness in horizontal position

3. Evaluation of Measurement Uncertainty

3.1 Measurement Result

Under laboratory environmental conditions, measure the levelness of the horizontal position of a level ruler with a nominal levelness of 0.5mm/m and a length of 1000mm according to the above method. The measurement results are shown in Table 1.

Table 1. Measurement results of the level of the level rules

measured parameters	One end of level ruler	The other end of the level ruler
thickness of feeler gauge	0.30 mm	0.30 mm
distance from the contact point of feeler gauge and level rule to the other end of level gauge	988.3 mm	991.7 mm
levelness of horizontal position of level ruler	0.304 mm/m	0.303 mm/m

3.2 Measurement Model

The level measurement model is shown in Formula (1). Because each factor is independent of each other, the combined standard uncertainty is calculated by [5]

$$u_c^2(b_i) = c_1^2 u_1^2 + c_2^2 u_2^2 \tag{2}$$

Where coefficients of sensitivity are calculated by the following formulas

$$c_1 = \frac{\partial b_i}{\partial s_i} = \frac{1000}{l_i} \tag{3}$$

$$c_2 = \frac{\partial b_i}{\partial l_i} = -\frac{1000 \times s_i}{l_i^2} \tag{4}$$

3.3 The Source of Standard Uncertainty

See Table 2 for the source analysis of standard uncertainty components of measurement results.

Table 2. Source and explanation for standard uncertainty of measurement results

$u(x_i)$	the source of standard uncertainty	evaluation method
u_{11}	standard uncertainty component introduced by thickness deviation of feeler gauge	class B method
u_{12}	standard uncertainty component introduced by flatness of flat plate	class B method
u_{21}	standard uncertainty component introduced by measurement repeatability	class A method
u_{22}	standard uncertainty component introduced by indication error of steel ruler	class B method

3.4 Calculation of Standard Uncertainty

3.4.1 Calculation of u_1

Standard uncertainty component introduced by thickness deviation of feeler gauge is u_{11}. The limit deviation of the feeler gauge with a thickness of 0.30mm is ± 0.008mm. If it is uniformly distributed, the standard uncertainty component u_{11} introduced by the thickness deviation of the feeler gauge is

$$u_{11} = 0.008\text{mm} / (\sqrt{3}) = 0.005\text{mm} \tag{5}$$

Standard uncertainty component introduced by flatness of flat plate is u_{12}. The allowable limit of level 1 plate flatness is 0.019mm. If it is uniformly distributed, the standard uncertainty component u13 introduced by the plate flatness is

$$u_{12} = 0.019\text{mm} / (2\sqrt{3}) = 0.005\text{mm} \tag{6}$$

Then the standard uncertainty component u_1 introduced by the feeler gauge thickness is

$$u_1 = \sqrt{u_{11}^2 + u_{12}^2} = 0.007\text{mm} \tag{7}$$

3.4.2 Calculation of u_2

Standard uncertainty component introduced by measurement repeatability is u_{21}. Under the same conditions, select a feeler gauge of the same thickness so that the center of the bubble just moves past the symmetrical center of the left and right marking lines. Use a steel ruler to measure the distance between the contact point of the feeler gauge and the level gauge and the other end of the level gauge. Carry out 10 repeated measurements according to the above operations, and the calculated standard deviation of single measurement experiment is 0.532mm. Then the standard uncertainty component $u2_1$ introduced by measurement repeatability is

$$u_{21} = 0.532\text{mm} \tag{8}$$

Standard uncertainty component introduced by indication error of steel ruler is u_{22}. The MPE of the steel ruler with the measurement range of (0~1000) mm is ± 0.20mm. If it is uniformly distributed, the standard uncertainty component u22 introduced by the indication error of the steel ruler is

$$u_{22} = 0.20\text{mm} / \sqrt{3} = 0.115\text{mm} \tag{9}$$

Then the distance between the contact point of the feeler gauge and the level ruler and the other end of the level ruler is measured to measure the introduced standard uncertainty component u_2 is

$$u_2 = \sqrt{u_{21}^2 + u_{22}^2} = 0.544\text{mm} \tag{10}$$

3.5 Combined Standard Uncertainty

According to the above analysis, according to formula (2), the combined standard uncertainty $u_c(b_i)$ of the measurement results of the levelness of horizontal position of level ruler can be calculated as follows

$$u_c(b_i) = \sqrt{c_1^2 u_1^2 + c_2^2 u_2^2} = 0.007\text{mm/m} \tag{11}$$

3.6 Expanded Uncertainty

Taking the inclusion factor $k = 2$, the expanded uncertainty of the levelness of horizontal position of level ruler is

$$U = \sqrt{2}ku_c(b_i) = \sqrt{2} \times 2 \times 0.007 = 0.02\text{mm/m} \tag{12}$$

4. Conclusion

The proposed calibration method and its evaluation example of measurement uncertainty can be used to calibrate the levelness of the horizontal position of the level ruler. For the bubbles at vertical and inclined angles, the levelness of leveling rod at corresponding positions can be calibrated with special angle ruler. The levelness of the level rules reflects the identification threshold and sensitivity of the level bar. It is suggested that this metrological characteristic be added when the relevant technical specifications are revised.

References

[1] JJF1085-2002 Calibration Specification for spirit levels. China Metrology press, 2002.
[2] JB/T 11272-2012 Spirit level. China Machine Press, 2012.
[3] QB/T 4621-2013 General requirement for spirit levels. China Light Industry Press, 2013.
[4] T/ZZB 0494-2018 Spirit level. Zhejiang Federation of Brand Building, 2018.
[5] JJF1059.1-2012 Evaluation and Expression of Uncertainty in Measurement. China Metrology Press, 2012.