RESEARCH ON DETECTING THE CENTER OF A WEIGHT

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Abstract– The centre of the weight need to be measured to correct the difference between centers of the test weight and the reference weight for high precise mass measurement, and a device is developed to locate the centre of the weight which includes a balance, a bridge and a supporting pole. A measuring method was proposed in [1]. A revised method is discussed in this paper and the effectiveness of the method is shown by measurements.

Keywords: center of a weight, balance, bridge, mass measurement

1. GENERAL INTRODUCTIONC

The test weight is compared with the reference weight on the mass comparator in high precise mass measurements. Due to vertical gradient of the earth's gravitational acceleration, if there is a difference between vertical centers of gravity of these weights, a correction for centers of gravity will be needed. In this case, the height of the vertical centre needs to be measured. If the weight is in regular shape, the centre of the weight can be determined easily with a ruler. However, most weights of high precision may be in OIML shape, in that case it can not be measured precisely only with a ruler. A device and corresponding device was proposed in [1] to measure the centre of the weight.
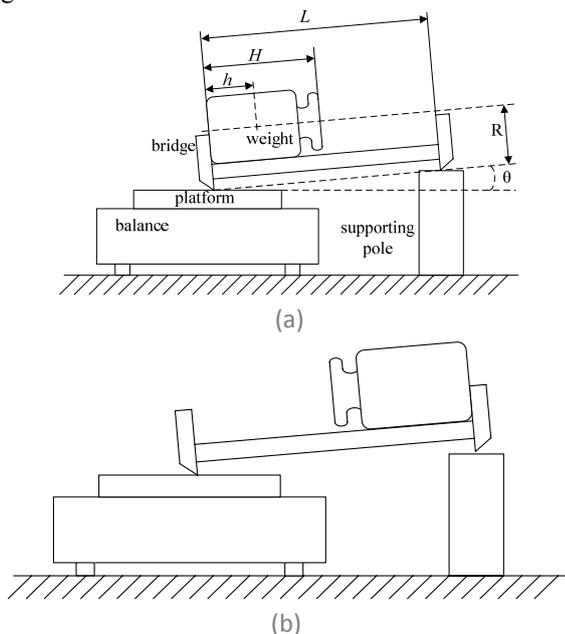

(a)

(b)

Fig1 configure of the device with the weight

The device and the method in [1] is introduced as figure 1 shows. The device contains a bridge, a balance, a supporting pole and a balance, and sometimes if the weighing pan of the balance is not flat enough, a platform is also needed.

During centre measurement, the bridge is supported by the balance and the supporting pole. The weight is put on the bridge, and is weighed by the balance. The weight needed to be measured twice as the weight need to be loaded on the bridge both as fig1 (a) and (b) shows.

Fig2 is the side, top, and end view of the bridge. In order to keep weights stable on the bridge, a V-groove is adopted in the bridge. The bridge has two knives, and they contact the platform and the surface of the supporting pole, thus knives should be smooth and parallel to each other.
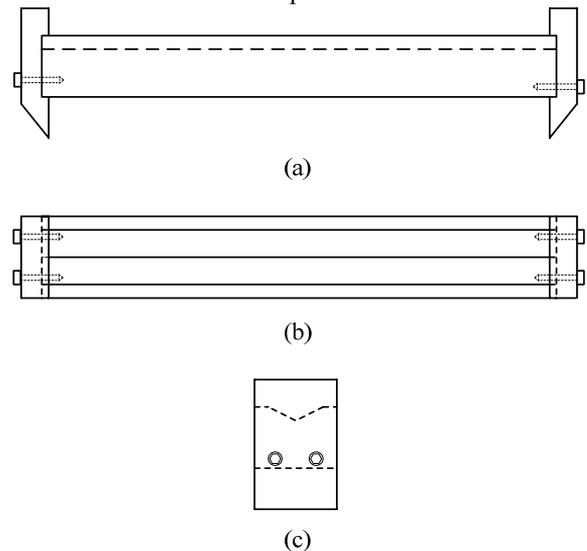

(a)

(b)

(c)

Fig 2 the side(a), top(b) and end(c) view of the bridge.

Let m_0 denotes the mass of the weight, m_1 is the change in mass indicated when the weight is loaded on the bridge. For equilibrium, a equation can be got below,

$$h = \left(\frac{m_0 - m_1}{m_0} \right) L + R \tan \theta \qquad (1)$$

From figure 1 (b), the following relation should hold,

$$h = \frac{m_2}{m_0} L - R \tan \theta \qquad (2)$$

Here m_2 is the indication when the weight is loaded as figure 1 (b) shows.

From (1) and (2), the centre of the weight can be calculated as below,

$$h = \left(\frac{m_0 - m_1 + m_2}{m_0} \right) \frac{L}{2} \qquad (3)$$

This method is effective, but usually the indication of the balance is not very stable during measurement, thus a revised method is researched in this paper to increase the stability.

2. REVISED METHOD

In order to reduce error, an ABA process is involved to get m_1-m_2, here "A" means weight is loaded at the position near the weighing pan (as figure 1 (a)), "B" means weight is loaded far from the weighing pan (as figure 1 (b)). In order to simplify the weighing process, the balance is tared when the weight is put on the bridge as figure 1 (a) shows and get initial zero indication I_0, then put the weight on the bridge as figure 1 (b) shows, and get indication I_1, and finally put the weight as figure 1 (a) shows again to get indication I_2, then calculate as below:

$$\Delta m = m_2 - m_1 = I_1 - \frac{I_0 + I_2}{2} \qquad (4)$$

Thus (3) can be revised as

$$h = \left(\frac{m_0 + \Delta m}{m_0} \right) \frac{L}{2} \qquad (5)$$

As fig3 shows, at ideal situation, below equations will hold:

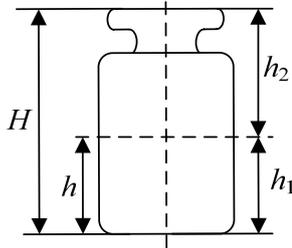$$h = h_1 \qquad (6)$$
$$H = h_1 + h_2 \qquad (7)$$

Fig3 relative parameters of the weight

Here h_1 and h_2 represent the distance of the center position to below or up surface of the weigh. However, during real measurements, normally equation (6) and (7) may not hold, there may be a different between h and h_1. This may be a systematic error. So a new measuring step and new formulas are suggested.
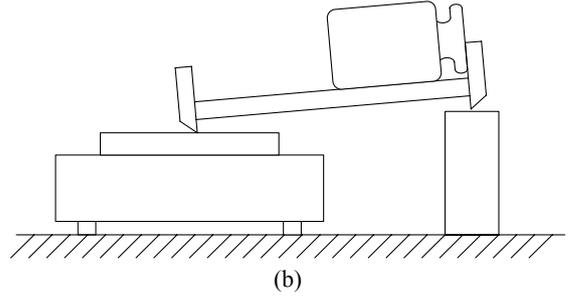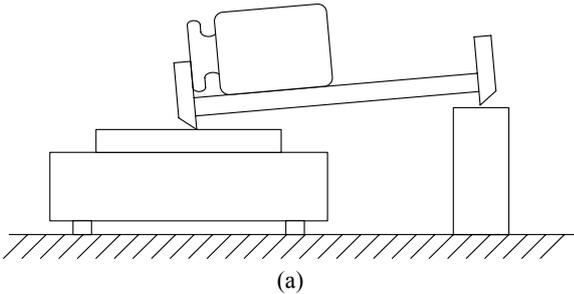

(a)

(b)

Fig4 reverse measurement configuration

As figure 4 shows, the weight can also be measured in reverse direction compared to figure 1.

From equation (1), h_1 and h_2 can be calculated,

$$h_1 = \left(\frac{m_0 + \Delta m_1}{m_0} \right) \frac{L}{2} \qquad (8)$$

$$h_2 = \left(\frac{m_0 + \Delta m_2}{m_0} \right) \frac{L}{2} \qquad (9)$$

Use (8) and (9) in (5), then

$$L = \frac{2m_0}{2m_0 + \Delta m_1 + \Delta m_2} \cdot H \qquad (10)$$

Use (10) in (8), and from (6), a equation can be get as below:

$$h = \frac{m_0 + \Delta m_1}{2m_0 + \Delta m_1 + \Delta m_2} \cdot H \qquad (11)$$

Compared (11) with (5), the difference is that instead of measuring L, the height of the weight need to be measured. Another difference is that at this time Δm_2 also need to be measured, that means method 2 need more measurements. But results showed that this procedure may increase the accuracy of the final result.

Procedure for this method is as below:

Step1: put the weight as figure 1 shows, tare the balance, and record the indication of the balance as I_0. In normal case, the indication is zero.

Step2: put the weight as figure 2 shows, record the indication of the balance as I_1.

Step3: put the weight back as figure 1 shows, record the indication as I_2.

Step4: calculate Δm_1 following equation (4).

Step5: put the weight as figure 4 shows, tare the balance, record the indication of the balance as I_3.

Step6: put the weight as figure 5 shows, record the indication as I_4.

Step7: put the weigh back as figure 4 shows, record the indication as I_5.

Step8: calculate Δm_2 following equation (4).

Step9: calculate the center of the weight use the equation(11)

For the initial method, only Step1 ~ Step4 are needed, and the center h can be calculate using equation (5).

3. MEASURING RESULTS

3.1 setup of the system

Fig5 shows the setup of the device. The device involved in the measurement includes:

Fig5 real system

1) a balance, the maximum capacity is 5.1 kg, the resolution is 1 mg.

2) a bridge, which shape is showed in figure 2. The weight can be put on the bridge to measure its center.

3) a small platform, which can be put on the weighting pan of the balance, is used to support one side of the bridge.

4) a cylinder, which supports another side of the bridge.

Since the bridge has two knives, in order to support the bridge firmly, one gap is designed on one side of the platform and the cylinder each. In this report, the center of the weight is measured on both side that with/without gap.

In order to keep the indication of the balance stable, the balance is installed inside a large wind shield.

3.2 Results

The Center of a cylinder weight is measured. The height of the cylinder is 69.07 mm, so the center of the weight is 34.535 mm. The length of the device L is 150.20 mm. One surface of the weight is marked with "310". Let this surface be the base surface, it means h is the distance between the center and this surface.

During each measurement, 10 ABA weighing cycles was adopted to measure Δm_1 and Δm_2.

In order to make a contrast, let method 1 denotes the initial method in [1], method 2 denotes the method in this paper.

Two groups of measurements were performed. In first group, a gap was designed on the small platform, and one knife of the bridge was put inside the gap. The result is shown as below.

Table1 Measuring results of Δm_1 and h_1

No.	I_0 (g)	I_1 (g)	I_2 (g)	Δm_1 (g)	h_1 (mm)
1	0.000	-525.357	0.121	-525.418	35.2149
2	0.000	-526.458	-1.581	-525.668	35.1959
3	0.000	-525.958	-0.707	-525.605	35.2007
4	0.000	-525.161	0.018	-525.170	35.2337
5	0.000	-526.733	-1.48	-525.993	35.1712
6	0.000	-524.83	0.536	-525.098	35.2391
7	0.000	-525.609	-0.114	-525.552	35.2047
8	0.000	-525.966	0.502	-526.217	35.1542
9	0.000	-526.95	-0.981	-526.460	35.1358
10	0.000	-527.02	-0.323	-526.859	35.1055
average				-525.804	35.1856

Table2 Measuring results of $\Delta m2$ and h2

No.	I_0 (g)	I_1 (g)	I_2 (g)	Δm_2 (g)	h_2 (mm)
1	0.000	-526.172	-0.28	-526.032	35.1682
2	0.000	-526.224	-0.098	-526.175	35.1574
3	0.000	-526.742	-0.234	-526.625	35.1232
4	0.000	-526.154	-0.096	-526.106	35.1626
5	0.000	-526.507	-0.458	-526.278	35.1496
6	0.000	-526.158	0.172	-526.244	35.1522
7	0.000	-527.134	-0.635	-526.817	35.1087
8	0.000	-526.902	0.351	-527.078	35.0889
9	0.000	-526.171	-0.091	-526.126	35.1611
10	0.000	-526.494	-0.490	-526.249	35.1518
average				-526.373	35.1424

From table1, it is obvious that h_1 is larger than theoretical value of center, the difference is 0.6506 mm.

From table2, h_2 is also larger than theoretical value of center, the difference is 0.6070 mm. Also h_1+h_2 is 70.3279 mm, the sum is larger than the actual height, and the difference is 1.2579 mm.

Use (11) to calculate the center of the weight, the result is: h = 34.5562 mm, is very close to the theoretical value, the difference is 0.0212 mm.

In the second group, knives of the bridge were put on smooth surfaces. The result is as below.

Table3 Measuring results of Δm_1 and h_1

No.	I_0 (g)	I_1 (g)	I_2 (g)	Δm_1 (g)	h_1 (mm)
1	0.000	-532.587	1.898	-533.536	34.5986
2	0.000	-533.412	-0.98	-532.922	34.6452
3	0.000	-532.603	-1.154	-532.026	34.7132
4	0.000	-531.473	-0.192	-531.377	34.7625
5	0.000	-533.265	0.684	-533.607	34.5932
6	0.000	-532.931	-0.635	-532.614	34.6686
7	0.000	-532.161	0.93	-532.626	34.6677
8	0.000	-533.085	0.253	-533.212	34.6232
9	0.000	-533.62	-0.225	-533.508	34.6008
10	0.000	-533.785	-0.407	-533.582	34.5952
average				-532.901	34.6468

Table4 Measuring results of Δm_2 and h_2

No.	I_0 (g)	I_1 (g)	I_2 (g)	Δm_2 (g)	h_2 (mm)
1	0.000	-534.577	-0.312	-534.421	34.5314

2	0.000	-533.675	-0.63	-533.360	34.6120
3	0.000	-533.479	0.795	-533.877	34.5728
4	0.000	-534.663	0.548	-534.937	34.4923
5	0.000	-533.424	0.361	-533.605	34.5934
6	0.000	-535.017	-0.698	-534.668	34.5127
7	0.000	-531.305	1.137	-531.874	34.7248
8	0.000	-534.451	-1.124	-533.889	34.5718
9	0.000	-531.731	1.204	-532.333	34.6899
10	0.000	-533.098	-0.478	-532.859	34.6500
average				-533.582	34.5951

From table 4, the center of the weight is 34.6468 mm if method 1 adopted, the difference is 0.1118 mm to the theoretical value, compared with results using method 1 on surfaces with gaps, it showed the difference was reduced from almost 0.6 mm to 0.1 mm.

Following Method 2, the final result is 34.5608 mm, the difference from the theoretical value is about 0. 0258 mm.

4. CONCLUSIONS

From above results, the revised method in this paper shows better stability and high accuracy. Different method may need different information. For Method 1, the length of the bridge needs to be measured, and the weight needs to be measured in two positions. For Method 2, the height of the weight needs to be measured, and the weight needs to be measured in four positions.

Compared all results from these two methods, if the support surface has no gap, the results are all acceptable. However, Method 2 shows a strong robust in these two kinds of conditions.

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