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RESEARCH ON INTELLIGENT AUTOMATIC MEASUREMENT SYSTEM OF LARGE MASS

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Abstract:
This paper describes a set of intelligent measurement system for large mass. The system realises the intelligent operation of the process of (100 kg ~ 1 000 kg) weights calibration, including loading and unloading reference weights, loading and unloading test weights, calculating data, and providing calibration records. These intelligent operations are realised by the design of the equal arm electromagnetic balance, loading and unloading weights, transmission mechanism, and the central intelligent control software. The system improves the accuracy and work efficiency of large weights calibration.

Keywords: metrology; weights; automatic measurement

1. INTRODUCTION

Large weights are not only an important reference in the mass quantity transfer system, but also the only reference for the verification/calibration of weighing instrument. Weighing instrument is the main measuring instrument in trade settlement, and its accuracy is an important technical basis in trade settlement. The stability and reliability mass of large weights are very important. It can affect the healthy development of the whole weighing instrument industry.

During the calibration of large weights, it is necessary to repeatedly load and unload reference weights and test weights. The loading and unloading of weights are cumbersome and slow, resulting in extremely low work efficiency. Moreover, most reference weights are formed by superposition of a large number of 20 kg weights. It takes a long time to complete a weight calibration, which will affect the measurement accuracy of the electronic weighing instrument or the machinery weighing instrument [1], [2]. Therefore, the realisation of automatic loading of weights and automatic operation is an urgent problem to be solved in large mass calibration.

The system realises the intelligent operation of the whole process of (100 kg ~ 1 000 kg) weights calibration, including loading and unloading reference weights, loading and unloading test weights, loading and unloading balance weights, calculating data, and providing calibration records. These intelligent operations are realised by the design of the equal arm electromagnetic balance, loading and unloading weights, transmission mechanism, and the central intelligent control software [3], [4], [5].

2. WORKING PRINCIPLE OF MASS TRANSFER

The system adopts the comparison transmission principle in mass quantity transmission. It compares the same mass of reference weight and test weight on the weighing pan and obtains the mass difference by comparison when the conventional mass of reference weight, material density, temperature, air density, and atmospheric pressure are known. Then with the help of a reasonable mathematical model, the conventional mass of the test weight is obtained [6], [7], [8]. The working principle block diagram is shown in Figure 1.

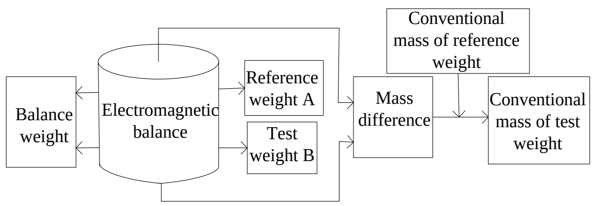

Figure 1: Working principle block diagram

3. INTELLIGENT AUTOMATIC MEASUREMENT SYSTEM COMPOSITION

The system is a set of intelligent automatic measurement system for 100 kg ~ 1 000 kg large weights, which is used for the calibration of 100 kg ~ 1 000 kg large weights of class F_2 and below. The hardware composition of the device includes: beam mechanism of electromagnetic balance, reference weight warehouse, weights carrying trolley, balance weights and their automatic loading and unloading mechanism. The reference weights are a number of

20 kg weights. A number of 20 kg reference weights are combined with the weight frame to form a reference weight group with different values. The structural diagram of the device is shown in Figure 2.

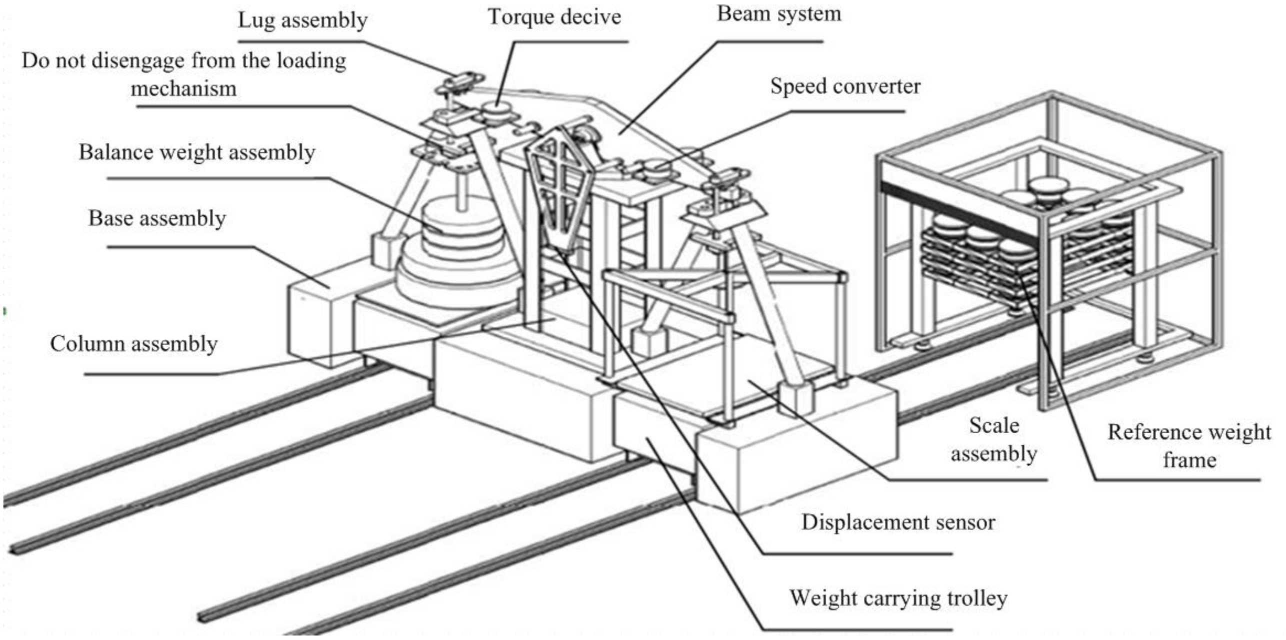

Figure 2: Schematic diagram of device structure

3.1. Electromagnetic Balance Body

The electromagnetic balance [9] adopts equal arm mechanical lever structure, the beam adopts diamond structure and is made of nodular cast iron. Its characteristic section is 工-shaped, uniform strength and small deformation, which reduces the measurement error of the balance caused by the influence of environmental temperature and humidity. This design is helpful to improve the stability and correctness of the balance. Electromagnetic dampers are symmetrically installed at both ends of the beam, and the damping force is set according to the weighing requirements, which can make the beam quickly reach the balance position.

The lifting lug adopts a cross lifting lug structure. The balance is equipped with a knife and knife bearing non disengaged device for loading and unloading weights. The disengaged device reduces the systematic error caused by the slight impact of loading and unloading weight and ensure the stability of the balance.

Table 1: Division values of electromagnetic balance in different ranges

Maximum capacity / kg	1 000	500	200	100
Actual division value / g	0.1	0.05	0.02	0.01

The automatic display of weighing data is completed by digital instrument. It realises the multi range display function of different weighing points and division values. The division values of different ranges are displayed in Table 1.

3.2. Automatic Loading and Unloading Balance Mechanism

The left weighing pan is the balance weight mechanism, which adopts the segmented balance method. Different balance weights are selected according to the mass of the test weight. There are six balance weights in total. The mass of the balance weights are 0 kg, 100 kg, 100 kg, 300 kg and 500 kg from top to bottom, and the “0 kg” section is the starting point of the balance weight when it is connected with the right empty weighing pan (shown in the balance weight assembly in Figure 2).

The balance weights with different mass values are automatically selected by the control system. The central shaft of the balance weight adopts the cone sleeve structure, and the weights can be lifted successively from the top. The lifting mass of the balance weights are 0 kg, 100 kg, 200 kg, 500 kg and 1 000 kg.

3.3. Reference Weights Frame

The reference weights frame is used to place multiple 20 kg reference weights (it is shown in the reference weight frame in Figure 2). Each layer has a weight bracket made of solid stainless steel with the same material as the reference weights. The weight bracket is used to hold multiple 20 kg reference weights. The weights bracket with this special structure is also used as the reference weights, and the mass is integrated into the nominal mass of the layer.

The reference weights frame is combined with a plurality of 20 kg reference weights to form a reference weights group with different mass, which is divided into four layers from bottom to top. The first and second layer reference weights frame is composed of four 20 kg reference weights and a stainless steel weight bracket with a mass of 20 kg to produce a mass of 100 kg. The third layer reference weights frame is composed of twelve 20 kg reference weights and a stainless steel weight bracket with a mass of 60 kg to produce a mass of 300 kg. The fourth layer standard weight frame is composed of twenty-two 20 kg reference weights and a stainless steel weight bracket with a mass of 60 kg to produce a mass of 500 kg. The automatic loading and unloading of reference weights starts from the lowest layer and is produced in this combination: 100 kg, 200 kg, 500 kg and 1 000 kg. The loading and unloading mass of the reference weights are automatically selected by the control system. The combination mode of reference weights frame is shown in Table 2.

Table 2: Combination mode of reference weights frame

Weight frame layer	**Reference weight frame / kg**	**Combination value / kg**
1	100	100
1+2	100+100	200
1+2+3	100+100+300	500
1+2+3+4	100+100+300+500	1 000

The reference weights outer frame is used to place the reference weights bracket, and the control system controls the weights carrying trolley to take out and put back the reference weights from bottom to top. There are pins with "wolf tooth stick" mechanism around the outer frame of the reference weights. Because the weights are loaded and unloaded from bottom to top, the length of the pins is lengthened from bottom to top.

3.4. Weights Carrying Trolley

The weights carrying trolley is a rail automatic control stepping trolley, which is used to carry the test weight or reference weight, and complete the rail movement in the tested area, weighing area and reference area. So as to complete the comparison of the reference weight and the test weight on the weighing pan.

The trolley has the functions of lifting and moving back and forth. It can give corresponding instructions by the control system according to the needs of calibration work. So as to realise the functions of reference weight and test weight in and out, loading and unloading.

4. INTELLIGENT CONTROL SYSTEM AND MAIN FUNCTIONS

4.1. Intelligent Control System

The intelligent control system is composed of central control cabinet and digital display control instrument. The central control cabinet includes central processing unit, environmental parameter acquisition module, weight parameter setting module, weight calibration program setting module, balance weight loading and unloading module, weight carriage control module, reference weight loading and unloading module, test weight loading and unloading module, measurement data acquisition and calculation module, etc. The digital display control instrument is a “touch screen”, which can display data and parameters, and can control various functions of the balance by touching the surface of the screen. The schematic diagram of the control system is shown in Figure 3.

The control system can set the inspection procedure according to the class of the test weight, and complete the automatic calibration. It includes the automatic loading and unloading of balance weights, the automatic loading and unloading of reference weights, loading and unloading of test weights, carrying out the automatic calibration operation, calculating data, and providing calibration records.

4.2. Main Functions

Initial Settings

The initial settings include setting the regulated power supply system of the electromagnetic measurement system, setting reading filtering system, setting the automatic temperature measurement function of the system, setting date and time, setting automatic backlight function and so on.

Emergency Protection Function

In order to protect the electromagnetic measurement system, the system provides overload protection function. When the balance mass exceeds the balance capacity for a certain time, the balance will be automatically turn to the non-disengaged state, so that the loaded excessive mass can be unloaded from the electromagnetic measurement system.

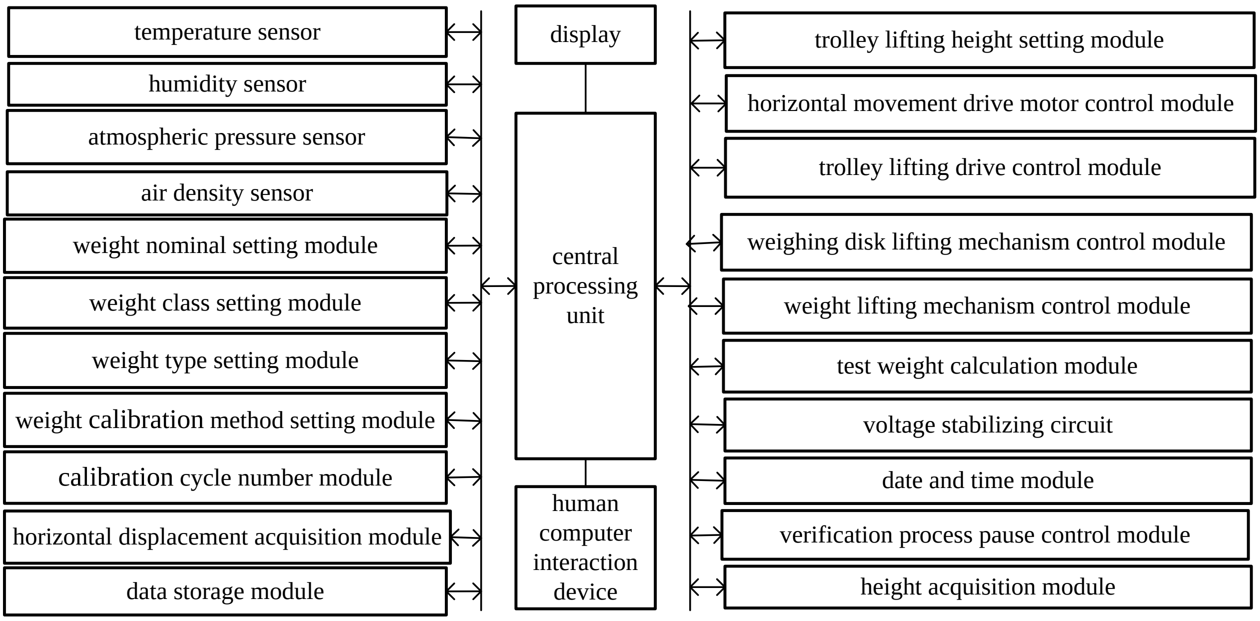

Figure 3: Schematic diagram of control system

The system has the balance protection function of reference weight and balance weight. When the loading state of reference weight is non-zero, the system will automatically detect and compare the loading mass of reference weight and balance weight. It is allowed to start the balance only when the masses of the two weights are equal.

The system has the reference weights warehousing protection function. There is an ultrasonic height sensor in the front and upper part of the reference weights warehouse, which can be used to measure the height of the weights to enter the weights warehouse. When the measured height is higher than the corresponding set value, the system considers that there are other objects on the weighing pan that cannot put the reference weights into warehousing. The system can automatically stop the movement of the weights carrying trolley for protection.

Automatic Calibration Program of Weights

The system has an automatic weight calibration/verification application program, which can carry out the full-automatic calibration/verification of ABA method, ABBA method and AB1B2B3…A method (one reference weight is compared with five test weights at most).

Information input setting is required before calibration. After the setting is completed, click the “start” button to start the weight automatic calibration/verification program, or restore the program from the suspended state to the activated state. The flow chart of weight automatic calibration is shown in Figure 4.

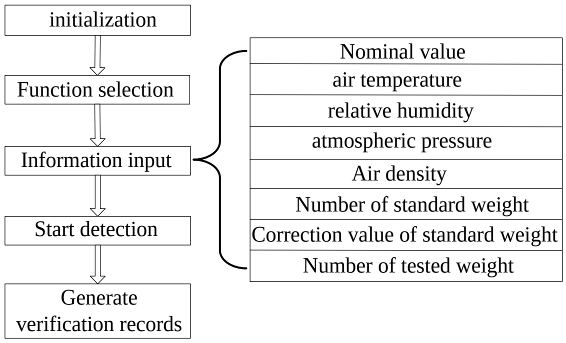

Figure 4: Flow chart of weight automatic calibration program

Balance Calibration/Verification Program

The program is designed to calibration/verification the performance of the balance. Since the repeatability is the main technical index in the mass quantity transmission, the calibration balance is mainly to calibrate the repeatability of the balance [10], [11]. Before calibration, information input settings are required, including test load, measurement times, equipment number, reference weight information, temperature, humidity and other information. After setting, click the “start” button to start the automatic calibration/verification program of the balance, or restore the program from the suspended state to the activated state.

5. WEIGHT AUTOMATIC MEASUREMENT DATA AND RESULT COMPARISON

In order to verify the good effect of the system, two methods of automatic measurement and manual measurement are used to measure and compare the conventional mass of the same class M_1 large weight [12]. The comparison was carried out under the same environmental conditions of 20.5 ℃ temperature and 53 %RH humidity.

The test weight was a Class M_1 1 000 kg reference with a conventional mass m_{ct}, given by the National Institute of Metrology, of 1 000.021 kg. The reference weight, with conventional mass m_{cr}, varied between the two measurement methods:

1. Automatic measurement:
   Class F_1, 20 kg (the method described in section 3.3) m_{cr1} = 1 000.000 6 kg
2. Manual measurement:
   Class F_1, fifty 20 kg weight combinations m_{cr2} = 1 000.000 9 kg

The measuring instruments for the two measurement methods were as follows:

1. Automatic measurement:
   Intelligent measurement system
2. Manual measurement:
   Comparator CCS1000K (Max = 1 510 kg, d = 1 g)

The weighing cycle was ABA (r1 - t - r2) with three measurement series. The indication difference ΔI_i from measurement sequence i is calculated as $\Delta I_i = I_{\text{t}i} - (I_{\text{r1}i} + I_{\text{r2}i})/2 \quad i = 1,..,n$.

In cycles ABA, n is the number of sequences. The i values are given in the order in which the weights should be placed on the weighing pan. The subscripts "r" and "t" denote the reference weight and test weight respectively. The measurement data is shown in Table 3, with a comparison of the two methods given in Table 4.

Table 3: Measurement data

Sequence number	Weighing cycle	Automatic measurement: Indication I / g		Automatic measurement: Indication difference ΔI_i / g	Automatic measurement: Average difference ΔI_i / g	Manual measurement: Indication I / g		Manual measurement: Indication difference ΔI_i / g	Manual measurement: Average difference ΔI_i / g
1	A	I_{r1}	-12.3	21.90	21.02	I_{r1}	0	21.0	18.17
	B	I_{t}	9.7			I_{t}	22		
	A	I_{r2}	-12.1			I_{r2}	2		
2	A	I_{r1}	-11.9	20.95		I_{r1}	2	18.5	
	B	I_{t}	9.1			I_{t}	20		
	A	I_{r2}	-11.8			I_{r2}	1		
3	A	I_{r1}	-11.7	20.20		I_{r1}	1	15.0	
	B	I_{t}	8.5			I_{t}	17		
	A	I_{r2}	-11.7			I_{r2}	3		

Table 4: Comparison of two methods

Comparison items	Automatic measurement	Manual measurement
$\Delta m_{\text{c}j}$ / g	21.02	18.17
$m_{\text{ct}j}$ / kg	1 000.021 92	1 000.019 07
$s(\Delta m_{\text{c}})_j$ / g	0.50	1.74
$\lvert m_{\text{ct}j} - m_{\text{ct}} \rvert$ / g	0.92	1.93
Working time / h	0.5	1

In Table 4, the comparison items are defined as follows:

- $\Delta m_{\text{c}j}$ = conventional mass difference = average indication difference from measurement sequence i for n cycles = $\frac{1}{n}\sum_{i=1}^{n} \Delta I_i$
- $m_{\text{ct}j}$ = conventional mass of the test weight = $\Delta m_{\text{c}j} + m_{\text{cr}j}$
- $s(\Delta m_{\text{c}})_j$ = estimate of standard deviation of the mass difference = $\frac{\text{MAX}(\Delta m_{\text{c}i}) - \text{MIN}(\Delta m_{\text{c}i})}{2 \times \sqrt{3}}$
- $\lvert m_{\text{ct}j} - m_{\text{ct}} \rvert$ = difference between the measured conventional mass of the test weight and its reference conventional mass

The value of j represents the serial number of the measurement method (automatic measurement method j = 1, manual measurement method j = 2)

From Table 4 it can be seen that the conventional mass of the test weight measured by automatic measurement method and the standard deviation of the mass difference are better than the manual measurement method, and that the working time used by automatic measurement method is much lower than the manual measurement method. The test results show that the method of using intelligent automatic measurement system to automatically measure large weight is effective and feasible, which helps to improve the calibration efficiency of large weight.

6. SUMMARY

The system realises the intelligent automatic measurement of large weights, solves the error problems caused by personnel operation proficiency, calibration time, reading accuracy, recording correctness and other factors, and improves the accuracy and reliability of calibration data. The application of this device will improve the work efficiency of large weights calibration, improve the working environment and working state of calibration personnel, and improve the measurement ability or technical level of large weights.

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