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RESEARCH ON THE AUXILIARY VERIFICATION DEVICE OF LOAD MEASUREMENT APPARATUS FOR NON-AUTOMATIC WEIGHING INSTRUMENTS ACCORDING TO OIML R76

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Abstract: The "Auxiliary Verification Device" as one of the 3 test standards in OIML R76-1: 2006 (E) "Non-automatic Weighing Instruments" is described in detail. Since the Chinese regulation of "Electronic Truck Scale" for verification was issued, the new metrological method of verifying weighing instruments by using Load Measurement Apparatus (LMA) becomes legal in China. The maximum permissible error and the uncertainty of the LMA device are theoretically analyzed and experimentally verified. The results show that the LMA device is a kind of independent auxiliary verification device which meets the requirements of R76.

Keywords: international recommendation; weighing instrument; auxiliary verification devices; MPE; Load Measurement Apparatus;

1. INTRODUCTION

Weighing instruments are incorporated into the scope of legal management in most countries. A number of technical documents have been published by International Organization of Legal Metrology (OIML) in this field, including the OIML R76 "Non-automatic Weighing Instruments" [1]. R76-1: 2006 (E) was adopted at the 41st International Congress on Legal Metrology, held in South Africa in October 2006. Compared with the R76-1: 1992 (E), the new edition has been revised in terms of terminology, requirements for electronic weighing instruments, identification of scales and modules, metrological management, test procedures, metrology requirements etc.[2]. In China, the government has also established a number of verification regulations and product standards [3-4] according to R76.

In R76, the test standards include weights, auxiliary verification device and substitution of standard weights at verification [1]. Previously, only weights or substitution of standard weights are used as test standards by metrology institutes, so the verification of large non-automatic weighing instruments (such as truck scales) with full performance test is nearly impossible. Transporting a large number of weights is difficult and costly. Many institutes have investigated in the auxiliary verification devices since 1970s, but there is no one kind of device is used practically and legally [7-9]. At present, the Load Measurement Apparatus (LMA) which can be applied to verify the truck scales conveniently has been invented by Fujian Metrology Institute of China, and the national verification regulations have been issued and implemented in 2015[5-6]. In this paper, the maximum permissible error with relative expanded uncertainty of the LMA device are theoretically analyzed and experimentally verified. The results show that the LMA device is a kind of independent auxiliary verification device which is able to meet the requirements of R76.

2. AUXILIARY VERIFICATION DEVICE IN R76

For the verification of weighing instruments, 3 test standards are equivalent according to R76. In the meaning of using, the method of direct measurement using dead weights which meet the requirement of OIML R111 is the first choose. When there are not enough standard weights or auxiliary verification device, any other constant load may be used as standard, provided that standard weights of at least (1/2~1/5) MAX are used. Whichever method is chosen, full performance test over the whole range must be carried out. The auxiliary verification device is more convenient then weights and substitution in verifying large scales. According to R76, whether it is a part of the scale or not, as long as the maximum permissible errors of this device less than 1/3 of the maximum permissible errors for the applied load, it can be used as a certified test standard of auxiliary verification device.

However, there is no specific form and structure of the auxiliary verification device is stated in R76. There are many patents and papers from the United States, Germany, Japan and other countries show that a number of agencies used sensors, levers and other methods in research, but there is no successful application of the record.

LMA Method which is specified in Chinese national verification regular JJG1118-2015 “Electronic Truck Scale” is a successful metrological method using non-weights by now. The Load Measurement Apparatus device is separated with scale, and it is able to verify truck scales of Medium accuracy class with the range larger than 30t. The principle of LMA method is shown in Fig 1. A LMA device includes several standard load units, which can be loaded not only simultaneously for weighing error tests but also independently for the eccentric tests. Fig. 2 shows the calibration of a truck scale with 2 platforms and 6 load cells using LMA method. The reaction force beams and the basement which made by steel are removable after verification. The realistic scene of verification is shown in Fig 3.

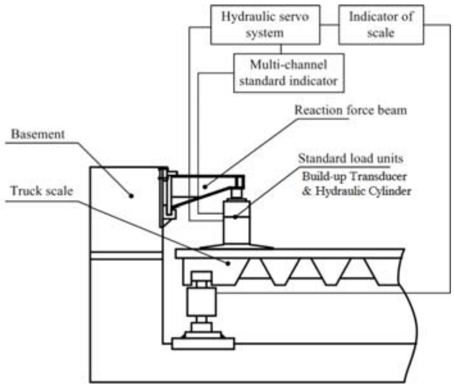

Fig. 1: Principle of LMA method (Sectional view)

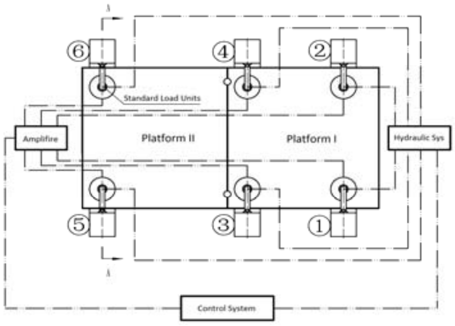

Fig. 2: Principle of LMA method (Top view)

Fig. 3: Scene of verification

The maximum permissible errors of the accuracy classifier under applied loads are specified in point 3.5.1, Table 6 of R76. According to OIML R111 and JJG 99-2006 "Weights", the test standard for Class III truck scales are weights of Class M_{12} or Class M_1. The maximum permissible errors of test standards are shown in Table 1. The column 5 shows the MPE of LMA which is specified in Chinese verification regular of JJG1119-2015 "Load Measurement Apparatus"[10].

Table 1 Maximum permissible error of test standards

Interval	Load	M_1 Weights MPE	M_{12} Weights MPE	LMA device MPE	Truck scale MPE
d =10kg	0≤*m*≤5 t	±(0~0.25)kg	±(0~0.5)kg	±1kg	±5kg
	5t<*m*≤20t	±(0.25~1)kg	±(0.5~2)kg	±2.4kg	±10kg
	20t<*m*≤30 t	±(1~1.5)kg	±(2~3)kg	±4kg	±15kg
d=20kg	0≤*m*≤10t	±(0~0.5)kg	±(0~1)kg	±2kg	±10kg
	10t<*m*≤40t	±(0.5~2)kg	±(1~4)kg	±5kg	±20kg
	40t<m≤60t	±(2~3)kg	±(4~6)kg	±8kg	±30kg
d=50kg	0≤*m*≤25t	±(0~1.25)kg	±(0~2.5)kg	±6kg	±25kg
	25t<*m*≤100t	±(1.25~5)kg	±(2.5~10)kg	±12kg	±50kg
	100t<m≤150t	±(5~7.5)kg	±(10~15)kg	±18kg	±75kg

As which can be seen from Table 1, the MPE of LMA device is less than the 1/3 MPE of truck scale. Therefore, if an LMA device meets the requirement of JJG 1119-2015, it is a legal auxiliary verification device line in R76.

3. ERROR TESTS OF LMA

A standard load unit consists of a hydraulic cylinder and a build-up transducer which is used as measurement standard. The build-up force transducer composed of 3 force transducers with ball-hinged secondary adjustment structure. Through a dynamic temperature compensation system, the transducer can be used in the temperature range of -10°C ~ 40°C. When the tilt is less than 0.5° and the eccentric less than 5mm, the transducer should keep the relative error of: repeatability ≤ 0.02%, reproducibility ≤ ±0.02%, long-term drift ≤ ±0.02%, indicate error ≤ ±0.02%.

Test results of a build-up transducer which is calibrated on a 300kN Dead-Weight Machine are shown in Fig.4 and Fig.5. High-precision build-up transducers are the basis for measurement, and the expanded uncertainty of applied calibration force is *U*=0.016% (95 % level of confidence).

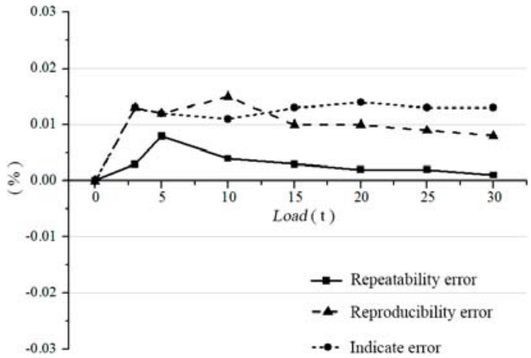

Fig. 4: Test result of errors of build-up tranducer

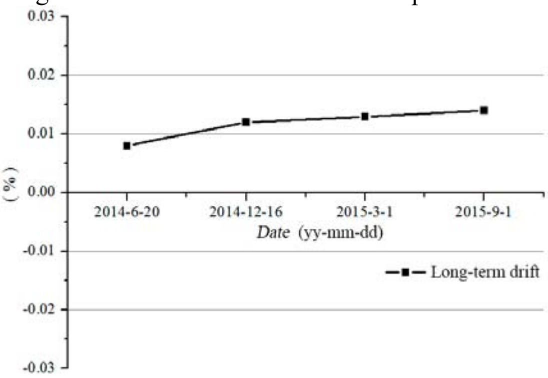

Fig. 5: Test result of long-term drift of build-up tranducer

A typical LMA device includes 8 standard load units. For the truck scales of different range and different number of load cells, the standard load units can be used as 4 groups. The Group I includes 4 units, while the Group II, III, IV include 6, 8, 10 units. The measurement range of Group III reaches 150 t. For the purpose of calibrating LMA device, an auto-calibration system has been built in Fujian China, which can be seen in Fig 6. The system makes up by 150t standard weights of Class F_2 which are made by stainless steel, a mass comparator, and an automatic loading system. The range of comparator is 200kg~150,000kg, and the resolution in 200kg~20,000kg is 0.1kg while in 20,000kg~150,000kg is 1kg. The zero-drift is less than ±0.001% FS / 30 min, and the repeatability is better than 0.002%. The "A-B-A" method is used in calibration. The A_1 test is to use dead weights to calibrate the mass comparator, and the B test is to calibrate the LMA device using mass comparator. The last process A_2 is to use deadweight to check the mass comparator.

Fig. 6 Auto-calibration system for LMA

A calibration was carried out for the LMA device of No.01 with standard units No.1-1~No.1-8. The results are shown in Fig 7 ~ Fig 9. The Group I includes the unit No.1-1, No.1-2, No.1-3 and No.1-4. The Group II includes units No.1-1 to No.1-6, and the Group III have No.1-7 and No.1-8 in addition. The errors shown below are the total errors of group.

The results show that the errors of all the 3 Groups in LMA device are all less than 1/3 of the maximum permissible errors for the applied load.

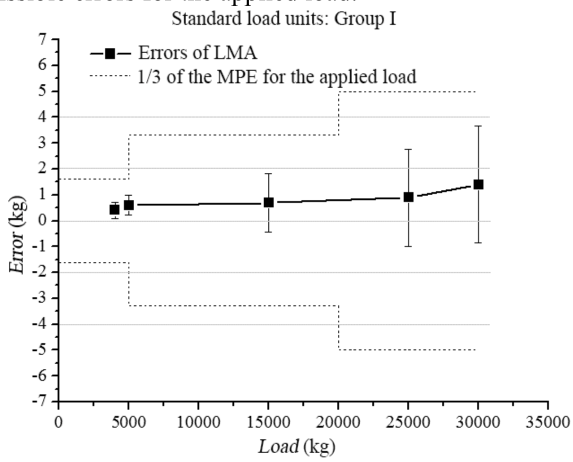

Fig.7: Calibration results of Group I

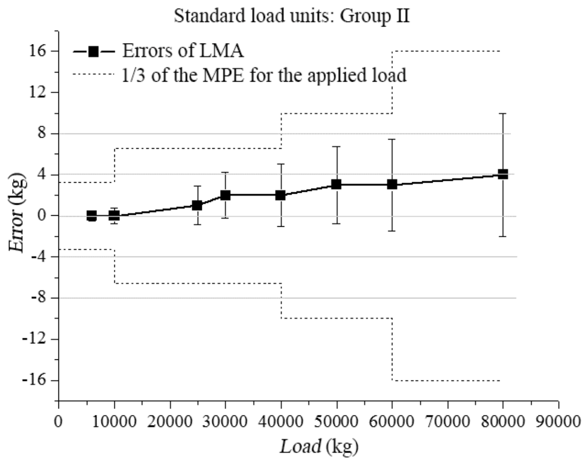

Fig.8: Calibration results of Group II

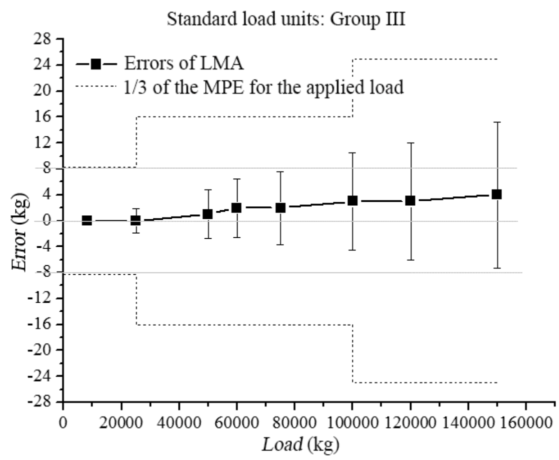

Fig.9: Calibration results of Group III

To reduce the fluctuation of hydraulic pressure, a close-loop dual-pump system using high speed self-adaption PID controller is used so that the pumps are able to work in their optimum areas in the whole measurement range. The curve of load fluctuation in 30min is shown in Fig. 10, and the relative stability is less than 0.003% / 30min.

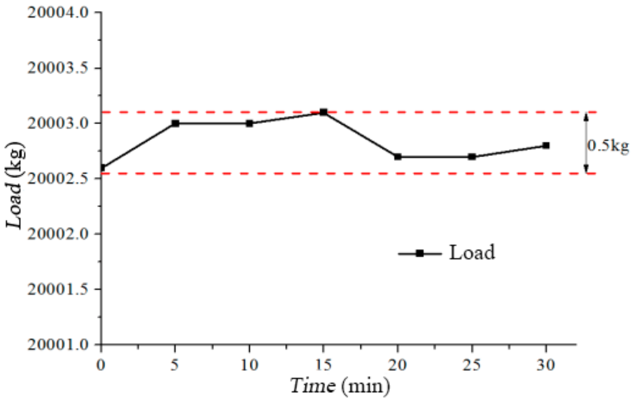

Fig.10: Fluctuation of load

According to the measuring principle and the calibration of LMA, the relative expanded uncertainty can be calculated as shown in equation (1).

$$U = \frac{k}{m}\sqrt{u^2(m_A) + u_1^2(\Delta m) + u_2^2(\Delta m) + u_3^2(\Delta m) + u_4^2(\Delta m)} \qquad (1)$$

with the following quantities:
m is the applied load;
$u(m_A)$ is the standard uncertainty associated with standard weights;
$u_1(\Delta m)$ is the standard uncertainty associated with mass comparator;
$u_2(\Delta m)$ is the standard uncertainty associated with repeatability of calibration results;
$u_3(\Delta m)$ is the standard uncertainty associated with temperature of the instrument;
$u_4(\Delta m)$ is the standard uncertainty associated with drift in the zero output.
To take all the factors above into account, the LMA device has a relative expanded uncertainty of U = 0.03% for k=2 over the whole measurement range.

Test results and uncertainty budget show that the LMA device (No.01) meets the requirements of JJG 1119-2015 and the OIML R76, and it can be used for verifying truck scales of Class III. A comparison was carried out between LMA method and deadweight method in calibration of truck scale up to 150t, and the E_n values are all less than 1 in all items and all applied calibration points.

4. CONCLUTION

LMA device is one kind of auxiliary verification device in line with the OIML R76: 2006 (E), and the verification of truck scale without dead weights is realized by LMA method. The results come from both theoretical analysis and experimental verify show that the maximum error of standard load unit groups of LMA is lower than 1/3 of the maximum permissible errors of Class III truck scales for the applied load. The precision is in line with the provisions in point 3.7.2 of R76, and LMA device can be used as a legal test standard of truck scales that makes calibration more convenient and safer.

5. REFERENCES

[1] Non-automatic Weighing Instruments. OIML R 76 2006(E).

[2] Michael Denzel. Modification of Non-automatic weighing instruments OIML R 76 recommendation [J]. Wagen, Dosieren + Mischen, vol. 6, 2005.

[3] Standardization Administration of the People’s Republic of China. GB/T 7723-2008 Fixed Location Electronic Instrument[S]. China Standard Press, 2009.

[4] General Administration of Quality Supervision, Inspection and Quarantine of the People’s Republic of China. JJG539-1997 Verification Regulation of Digital indicating Weighing Instrument[S]. China Metrology Press, 1997.

[5] General Administration of Quality Supervision, Inspection and Quarantine of the People’s Republic of China. JJG1118-2015 Verification Regulation of Electronic Truck Scale (Method of Load Measurement Apparatus of Electric Weighing Instrument) [S]. China Metrology Press, 2015.

[6] General Administration of Quality Supervision, Inspection and Quarantine of the People’s Republic of China. JJG1119-2015 Verification Regulation of Load Measurement Apparatus of Electric Weighing Instrument[S]. China Metrology Press, 2015.

[7] LiRen Shen. Detection Method Discussion of Large-scale Weighing Instrument [J].Weighing Instrument, vol. 35, pp. 30-35, 2016.

[8] GuangLan Zhang. Research on the Verification Method of Large-scale Weighing Instrument[J]. Modern Measurement and Laboratory Management, vol. 5, pp. 28-30, 1978.

[9] JunGuo Wang. Introduction of Calibration and Calibration Method for Field Scale of Large Weighing Instrument[C]. The 7th Weighing Technology Seminar,2009.

[10] Hui Chi. JJG 1118-2015 Interpretation of Verification Regulation of Electronic Truck Scale (Method of Load Measurement Apparatus of Electric Weighing Instrument) [J]. China Metrology, vol. 2, pp. 124-126, 2016.