Automatic Weight Exchanger for Series Design Calibration

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Abstract

An automatic weight exchanger for series design calibration of a decade weights is described. The vertical pan with 6 loading positions is hanged down from a balance hook. Weights are loaded on and lifted off vertically. Every weight has its own vertical guide for lifting and loading. The vertical motion is realized by 6 synchronous stepping motors. The weight exchanger is installed with a commercial balance of 205 g capacity and 0.01 mg readability. The full operation is automated with a personal computer. The performance tests were carried out. The present status results indicate: Calibration time and labor could be reduced significantly. Uncertainty could be reduced by reducing operator's random error. Calibration series of 100-50-20-20'-10-10' g was tested successfully to give maximum Type A uncertainty of 0.014 mg. The apparatus will be incorporated with Internet web for remote calibration and education.

1. Introduction

Mass Laboratories of National Metrology Institutes have continuously improved the efficiency of measurement and calibration. The efficiency can be improved mainly by automation. Automation not only improves the measurement precision but also reduces the routine labor. The efficiency is improved due to reduced variance of the mass comparator and due to increased number of measurements. The variance is reduced because of more precise handling of weights and smaller influence of the operator performing the

weighing. Possible accidents such as dropping of weights could be also minimized by the automated weight exchanger.

However this automated weight exchangers are available for one to one weight comparison. The efficiency can be more improved by using calibration designs. Calibration design requires weighing of series weights in a decade. The commercially available automated comparators could not realize such design calibration without balance case opening. The balance case is usually necessary to open for exchange of compared combinations of weights. Opening of the comparator's case disturbs the temperature stability, consumes time and decreases the repeatability. Weight exchangers which do not require operator's interference during series weighing are only tested by a few laboratories such as Slovak Institute of Metrology (SMÚ). KRISS has developed the similar weight exchanger with the one by SMU.

The vertical pan with 6 loading positions is hanged down from a balance hook. Weights are loaded and lifted vertically. Every weight has its own vertical guide for lifting and loading. The tested exchanger is for 100-50-

20-20'-10-10' g series weights. The exchanger then automatically operates to perform orthogonal weighing designs

2. Weight Exchanger

The weight exchanger, instruments for air density measurement and a mass comparator are linked to a PC, which is also linked to the LAN of KRISS as shown in Figure 1. Therefore weighing design measurements could be performed on web, thus could be used for training purpose. Figure 2 shows the constructed weight exchanger on which a balance is mounted.
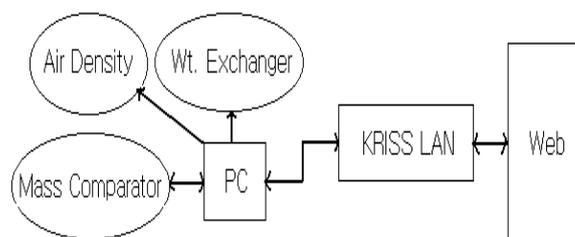

Figure 1. Weight exchanger linked with PC

Every weight in the weight exchanger has an individual vertical guide for lifting and loading. The vertical motion is realized by a synchronous stepping motor, shaft and cams by parallelogram type mechanism. The vertical

guide carries the loading plane for lifting and loading of the weighs.

Figure 3 shows the pan, which is partially assembled with a guide for 100 g weight.

The exchanger always heats its environment, which leads to temperature gradients in the weighing chamber. These gradients may prevent accurate estimation of air buoyancy. Therefore the stepping motors were mounted outside of the weight exchanger.

The control system consists of a personal computer and a controller for the motors. The PC also reads the mass comparator and the instruments, which measure air pressure, temperature and relative humidity. The instruments were located inside the exchanger chamber. The computer calculates mass values and their uncertainties. Also air buoyancy correction is made.

The weight exchanger is also operated via the PC. The code allows the transmission and the reception of data through serial ports or plug in cards in the computer. The mass comparator is connected to the PC-computer via the RS232 interface.

In front of the weight exchanger a digital

camera is installed for providing with view of the operation. The contents for training are to be built.

Figure 2. Photograph of constructed weight exchanger assembled with a balance


Figure 3. Vertical pan

3. Performance Tests

The performance test were carried with an AT201 by Mettler whose capacity and readibility are 205 g and 0.01 mg. The

centering of the weights is done by repeated lift and load on the pan . 2 or 3 lifts are sufficient for the centering.

(1) Repeatability by manual operation was compared with that by the automated weight exchanger. Repeatability of 10 weighings by the weight exchanger was about half of the repeatability by an experienced operator.

(2) From top to down, weight of 10 g, 10 g, 20 g, 20 g, 50 g, 100 g were designed to be positioned. The stability of positioning was tested by repeatability of the 100 g weight on every position. Figure 4 shows the results. At lower positions the standard deviations were reduced. The first pan was unstable with the 100 g weight mainly due to the small sitting area of the first pan. This result indicates that the bottom surface of a weight should flat as possible as. Therefore OIML recommendations should consider this effect because in future most weighings are to be carried out on a weight exchanger. (3) Standard deviation of each pan with its designated weight was about the level of 0.01 mg.
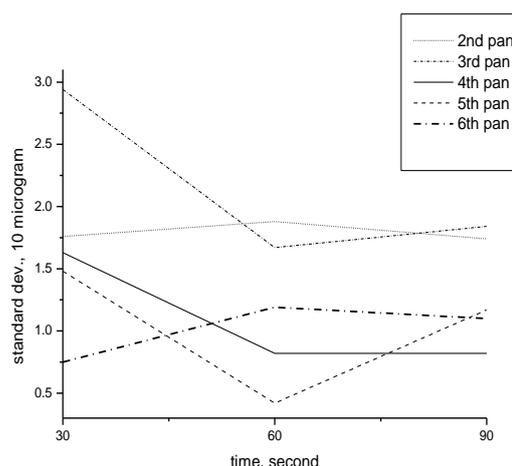
Figure 4. Position stability

Initially right after construction 100 g pan produced a little bigger standard deviation.
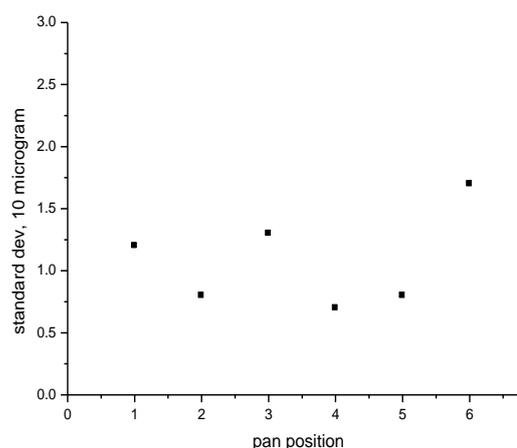

Figure 5. Standard deviation of each pan with its designated weight

The pan was refined to give present results.

(4) Stabilization time for loading was tested with measurements of series weighing. Weights of series were loaded and readings were made to give standard deviation with

progressing time. The results are shown in Figure 6. Each series reaches to stabilization after about 60 seconds. Series of 10+20+20+50 might have experienced drift.
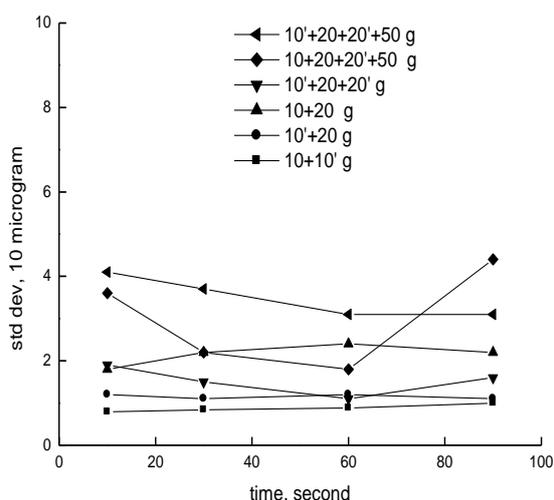
Figure 6. Stabilization time in series weighing

(5) Complete series weighing was tested with the orthogonal calibration design of 12 observations. The orthogonal design for test is shown as Table 1. The type A uncertainty of 95.5 % confidence level for weight of 50, 20, 20', 10, 10' weights was found to be 0.014, 0.009, 0.009, 0.009 and 0.009 mg respectively. These results were obtained in a room where environmental conditions were maintained under such conditions as temperature drift of 0.2 degree Celsius, humidity drift of 1 %, atmospheric pressure drift of 0.2 mmHg during the whole weighing.

Table 1. Calibration design used for test

	10	5	2	2'	1	1'
1	+	-	-	-	-	
2	+	-	-	-		-
3		+	-	-	-	
4		+	-	-		-
5			+	-	+	-
6			+	-	+	-
7			+	-	-	+
8			+	-	-	+
9			+		-	-
10			+		-	-
11				+	-	-
12				+	-	-

The type A uncertainty was calculated from the following variance. It was shown that the Matrix C introduced by Cameron et al. which is conceptually close to $(X^{*'}X^{*})^{-1}$ plays an important role because the variances of the estimates $\hat{\beta}$ can be expressed as follows:

$$\text{variance } (\hat{\beta}_i) = C_{ii}\sigma^2$$

The standard deviation "within the group", σ was calculated from the residuals between the observation and the estimated . The estimated observation could be determined by multiplication of design matrix and solution vector of the normal equation, $X\hat{\beta}$.

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4. Conclusions

A weight exchanger for series calibration has been constructed and several test measurements have been made. The test results show that the standard deviation of weighings with the exchanger is improved compared with that by manual weighing. The tests were performed with a commercial balance of 205 g capacity and 0.01 mg readability. Stability of weight on arbitrary position was tested to give the results that sequence of 10-10-20-20-50-100 g is stable. Every weight on its own position has standard deviation of about 0.01 mg. Stabilization time of 60 seconds were found to be optimum. Maximum Type A uncertainty for the series weighing test was found to be 0.014 mg. The series weighing was performed successfully even in the unconditioned room environment.

5. References

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