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THE CHARACTERIZATION OF THE CAPABILITY OF A BALANCE

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Abstract

A survey is given on important standardized definitions by which the capability of balances may be characterized. Some modifications are proposed with regard to the use of mass sensors for the continuous determination of mass variations. An important supplement is the 'relative resolution' introduced by Jenemann. Optimum values are presented.

Keywords: balance, resolution, sensitivity, standardization

Introduction

In scientific reports and in descriptions of instruments we are very often confronted with the incorrect use of parameters characterizing the features of a balance. In particular the notation 'sensitivity' seems to be unclear, though it is well defined by the Organisation Internationale de Métrologie Légale [1], by national [2] and international standards [3, 4] and in text books [5, 6].

Standardized definitions of parameters are destined to characterize the features of commercially manufactured instruments in its regulated use. Balances for commerce, laboratories etc., in general are used for single mass determinations of a sample in one particulate weighing procedure. Besides, thermo- balances, vacuum balances, layer thickness monitors [7] etc. are applied to record mass variations as a function of time [8], whereas the mass of the sample under investigation is determined separately using a laboratory balance. In case of a symmetric balance the counterweight than is used exclusively to counterbalance the sample mass, to set the zero position and to suppress buoyancy. Furthermore, mass and force sensors are used to monitor and to control production processes. For these purposes, some standardized definitions are not appropriate. Besides standardized definitions, therefore, some modified definitions and supplements are proposed.

Stability, drift

Stability (Meßbeständigkeit, constance) is the ability of a measuring instrument to maintain constant its metrological characteristics. It is usual to consider stability with respect to time [4].

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If mass variations should be observed as a function of time, the fluctuation of the readings and in particular the variation of the zero point should be limited. The spontaneous variation of the indication at constant sample weight and constant environmental conditions within a given period of time is an important characteristic of a balance. Often a slow drift (Meßgerätedrift, derive) is observed, caused by the irreversible change of the components of the instrument (fatigue of the material, wear). Furthermore, slow variations caused by environmental variations cannot be excluded completely. The sum of the variations may be quantified by the mean square deviation within an extended period of time.

Sensitivity, linearity

Sensitivity (Empfindlichkeit, sensibilité) is the change of the response of a measuring instrument divided by the corresponding change in the stimulus [4]. For balances this is the quotient of the observed variable l and the corresponding variation of the measured mass m at a given mass value [1–3]

$$S = \Delta l/\Delta m \tag{1}$$

For balances with digitized output instead of the analog variable l stands the digit.

The sensitivity may be appropriate to characterize usual balances. For mass sensors and research instruments, however, the output can be easily changed by means of levers or using an amplifier. In this case, the sensitivity is not a very useful information rather than the evidence of the linearity of the indication of the uncorrected sensor signal represented in a diagram l *vs.* m.

Maximum capacity

The maximum capacity (Höchstlast, portée maximale) is the upper limit of the specified measuring range not considering the additive tare mass [1–3].

For special research balances the tare (balance pan, crucible, suspension) can be varied so that approximately the whole capacity is disposible for the sample. If necessary the nominal load is exceeded and the maximum load is determined empirically. Therefore, in compliance with Czanderna [9] I propose

– The maximum capacity of a balance is the maximum sample mass which can be placed without injury to the balance or its operation.

Minimum capacity, measuring range

The minimum capacity is the lower limit of the measuring range. Below, measuring results are burdened with a too large relative error. The specified measuring range is the region between minimum and maximum capacity [1–3].

Discrimination

Discrimination (Ansprechvermögen, mobilité) is the ability of a measuring instrument to respond to small changes in the value of the stimulus. Discrimination threshold (Ansprechschwelle, seuil de mobilité) is the smallest change in the response of a measuring instrument. As a modified definition I propose:

– Discrimination is the minimum variation in mass that can be observed experimentally in a reproducible manner.

Relation of maximum capacity to discrimination threshold, relative resolution

For many applications the size of the sample may be chosen freely, because only the variation of the sample mass should be determined. In this case the relation of maximum capacity to discrimination threshold [9], maximum capacity to scale division (erroneous: sensitivity) [10] or the product load x sensitivity [8] are important criteria for the balance. Jenemann [11] uses the reciprocal relation discrimination threshold to maximum capacity=relative resolution (Auflösungsverhältnis, relative Auflösung). Hereby resolution is the quantitative expression of the ability of an indicating device to distinguish meaningfully between closely adjacent values of the quantity indicated [4].

About 2000 B.C. balances of the ancient Egyptians had a relative sensitivity of down to 10^{-4} [12]. The relative resolution gives no information about the accuracy [13] of weighings. Metrological kilogram balances for the comparison of mass standards achieve a relative sensitivity down to 10^{-9}, whereas in many weighings by standardization bureaus the mean uncertainty of measurement was 10^{-6}. A kilogram comparator balance exhibiting a relative resolution of about 2.5×10^{-9} built by Paul Bunge was in use from 1879 to 1951 at the Bureau International de Poids et Mesures at Sèvres [14]. Using a 5 cm long beam made of a quartz wire framework, Hans Petterson [15–17] reported on a balance for samples of 0.1 to 0.2 g and a sensitivity of 0.1 ng, corresponding to a relative resolution of 10^{-9}. The assertion, however, is not substantiated by published measuring results. Czanderna/Rodder produced an ultrahigh vacuum – ultramicrobalance equipped with a three-dimensional quartz wire framework beam. The deflection was detected by means of photocells and compensated for electrodynamically. The maximum load was 20 g and the discrimination threshold 30–100 ng, so the relative resolution was 10^{-8} [18]. The signal was constant to 1–2 μg within a period of 1/2 year. For typical commercial vacuum microbalances the relative resolution goes down to about 10^{-7}, and this is a realistic figure regarding the environmental influences as predetermined by the experimental conditions.

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