COMPUTER SIMULATION OF BALANCE HANDLING

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Abstract

Several decades ago, when working in the field of magnetism, we had to use a balance the sensitivity of which was limited only by Brownian motion. This balance was a very slow one and to calculate the moment of force measured by it we used its equation of motion, \( T = J\ddot{\alpha} + k\dot{\alpha} + C\alpha \), where we measured the values of all the quantities present on the right-hand side of this equation. At the 21st Conference on Vacuum Microbalance Techniques in Dijon, we suggested that, with the help of a computer, this procedure could also be made applicable to the handling of fast balances. The present paper contributes to this topic by presenting a computer simulation of such a fast balance.

Keywords: balance, computer, mass determination, simulation

Some thirty years ago, we worked with a balance which had such a high sensitivity that its accuracy was limited only by the Brownian motion [1, 2]. This balance was very slow: the oscillation frequency \( \omega \) was very small and the relaxation time \( \tau \) was very large. To allow measuring times of a few seconds, we used Eq. (1) of Table 1. We measured the deflection angle \( \alpha \) as a function of time and calculated \( \dot{\alpha}(t) \) and \( \ddot{\alpha}(t) \). The values of the moment of rotational inertia \( J \), the damping constant \( k \) and the torsion constant \( C \) were known and so we could deduce the moment of force \( T(t) \) as a function of time from Eq. (1), where \( T(t) \) is the sum of the torque to be measured and the compensating torque.

In another paper in this volume [3], we discussed the possibility of applying this measurement procedure to beam microbalances in order to reduce the measuring time in that case to only a small fraction of the oscillating time. This procedure, however, involves uncertainties, as we discussed in that paper.

For our very slow balance mentioned above, we reduced such uncertainties by application of an iteration method. This iteration involved the reduction of the balance deviation from the equilibrium position. To minimize the time interval
necessary for this reduction, for the compensating torque we used two opposite pulses with a short interval between them. It may be expected that such an iteration method should also be applicable for faster beam balances.

We studied this by means of the computer simulation depicted in Table 1. The data used there are taken from a Gast vacuum microbalance with 2.5 g maximum capacity, which is used at present by one of the authors for measuring gas adsorption [4]. In Table 1, the equations and parameters on the left-hand side describe the working of the balance, and those on the right-hand side its automation. The motion of the balance is expressed by Eq. (2). Here, the amplitude $\alpha$ and phase angle $\varphi$ can be chosen arbitrarily, and the moment of torque $T$ is assumed to be independent of time. The relation between the parameters of Eq. (2) and those of Eq. (1) are expressed by Eqs (3) and (4), in which $\omega$ denotes the angular frequency and $\tau$ the relaxation time. Equations (5), (6), (7) and (9) give the values of the different parameters. It is the aim of the procedure to find the value of $T$ with the calculation on the right-hand side of the table. We choose the times for measuring the value of $\alpha$ by means of Eq. (8). We presume the measurements of $\alpha$ to be free from error.

The values of $\alpha$ at four times are given in Eq. (16). These values from the balance are the input of the automation facility on the right-hand side of Table 1. The automation facility uses Eqs (14) and (15) to give approximations of the values of $\dot{\alpha}(t)$ and $\ddot{\alpha}(t)$. Inserting Eqs (16) and (17) into Eq. (1) results in an approximation $T(t_2)$ of the moment of force to be determined: Eq. (18).

![Diagram](image-url)

**Fig. 1** Weighing procedure. For clearer demonstration, different scales are used on the vertical axis. The encircled numbers refer to the respective equations in Table 1.

![Diagram](image-url)

**Fig. 2** The two pulses of the compensating torque. See line 19 in Table 1.