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CONSIDERATIONS ON THE PLANNED USE OF A SCIENTIFIC BALANCE ON MARS
Part II. Choice of the balance

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The balance is the most widely used complex measuring instrument in science and techniques. To install a balance on Mars is a challenge for numerous aspects of in situ measurements in the next decade. By means of a balance useful parameters could be determined and a variety of investigations could be carried out there. Possible applications of a balance on Mars are reviewed. Choice of type and demands on the balance with regard to the conditions on Mars are discussed. The first step is to test a load cell with strain gauge deflection sensor.

Keywords: *balance, gravimetry, Mars, surface, water*

Introduction

An important aim of the actual missions to Mars is the search for existing life or evidence of former life and of water as a precondition. In addition chemical processes within the interface soil surface/adsorbed gases should be investigated. We propose to determine the geometric structure of Martian soil and in particular its ability to store water. The conditions on Mars allow a very simple and proven gravimetric experiment [1, 2]. Requirements with regard to resolution, sensitivity and specified measuring range are modest. The effect is expected within the range of relative sensitivity of 10^{-3} of the sample mass.

A balance situated at the surface of Mars should be loaded with a sequence of soil samples, each for a day. The samples will adsorb carbon dioxide and water vapour of the Martian atmosphere. It is to be expected that because of the diurnal temperature cycle of about 100 K, variations of the adsorbed mass can be measured. From resulting curves specific surface area and pore size distribution should be calculated. In addition the results may help to analyse the Martian atmosphere.

In Part I we discussed the feasibility of gravimetric measurements on Mars. In this paper we discuss aspects on the choice of type of balance with regard to the conditions on Mars.

Applications of a balance on Mars

By means of a balance useful parameters could be determined and a variety of investigations could be carried out on Mars:

- Measurement of the acceleration and of gravitational fields during flight.
- Measurement of the gravitational field at the surface of Mars.
- Weighing of samples.
- Determination of effect of temperature and partial pressure on CO_2/H_2O-adsorptions of soil samples.
- Thermogravimetry of soil samples.
- Investigation of chemical reactions of soil samples with the atmosphere, e.g. corrosion.
- Measurement of atmospheric humidity using reference material.

Choice of the balance type

The choice of the type of a microbalance depends on whether it should be used exclusively to investigate the geometric surface structure of soil or as a universal mass sensor for additional purposes. Important aspects to consider are simple and rugged construction, easy handling, fault liability, influence of environmental

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conditions, size and mass, use of magnets, consumption of electric energy. Two general types of weighing methods can be distinguished [3]:

- The gravitational balance measures the force between the mass of the planet and the sample mass.
- The inertia or impulse balance measures the force required to accelerate the sample.

Gravitational balances

With gravitational balances the existence of the very homogeneous and constant gravitational field is used. The mean surface gravity on Mars is 3.74 m s^{-2} and though the gravitational field is weaker by the factor 0.38 than on Earth it is sufficient for the envisaged measurements. Gravitational lever balances require either a position sensor for the balance beam or they are compensated. In both cases signals can be transmitted to Earth.

- With an equal-armed balance a comparison with a dummy mass is made and therefore they exhibit a wide measuring range, sensitivity up to 10^{-9} and high resolution. Comparison measurements with standard reference materials are possible.
- Electromagnetic beam microbalances are compensated by Lorentz forces and the current required for balancing is measured [4]. Whereas in thermogravimetric instruments mainly rotating coil systems are applied [5], in precision lever balances mostly plunger coil systems are used. Both systems exhibit a large measuring range, high resolution and sensitivity. Figure 1 shows the scheme of a balance with rotating coil and Fig. 2 the interior of a laboratory balance with plunger coil.
- Also simple lever balances with deflection sensor, e.g. something like a letter scale, may meet the requirements.
- Spring balances (Fig. 3) and torsion balances are simple and rugged instruments. Though their relative sensitivity is poor in comparison with beam balances both types may be sufficient for our purposes. Spring balances are very simple in design. The extension of a helical spring may be measured by means of an optoelectronic sensor. The influence of temperature variations on the spring is a serious drawback. The measuring range of a spring balance depends on the design of the spring and can be chosen freely. The relative sensitivity is about 10^{-5}. No commercial instruments are on the market.
- Likewise simple in design, rugged and cheap are load cells equipped with strain gauges; their relative sensitivity is up to 10^{-5}. A large variety of such instruments is on the market. Usually the strain gauges are glued onto the spring element (Fig. 4). Resistance variations of the wires due to length changes are measured; consume of electric power is moderate. As this is a special type of a spring balance, load cells are strongly influenced by temperature variations.

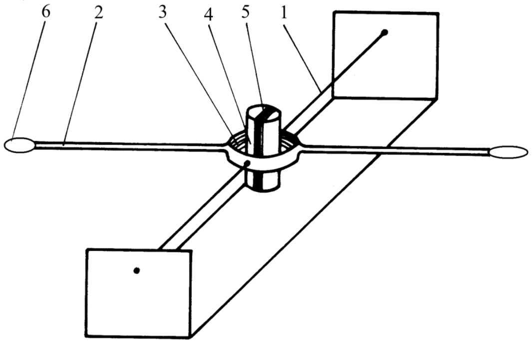

Fig. 1 Scheme of an electromagnetic Gast type microbalance; 1 – torsion wire, 2 – balance beam, 3 – rotating coil, 4 – permanent magnet, 5 – stator coil, 6 – balance pan

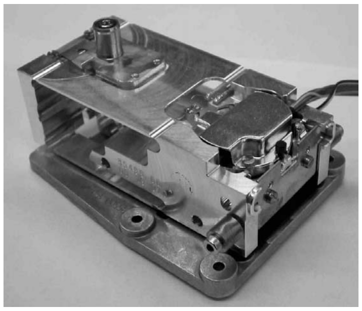

Fig. 2 Monolith-system of an electromagnetic balance with solenoid plunger. Sartorius AG, Göttingen, Germany

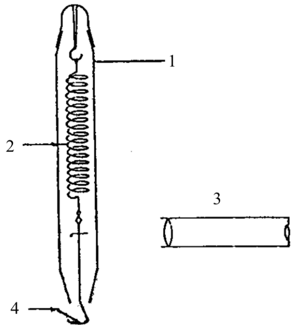

Fig. 3 Helical spring balance; 1 – protection tube with spring suspension, 2 – helical spring, 3 – deflection sensor, 4 – balance pan

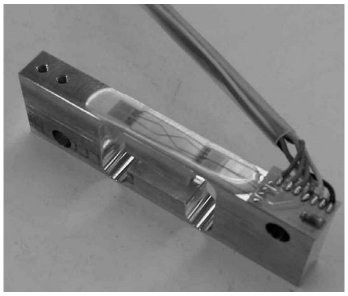

Fig. 4 Load cell with strain gauge; Sartorius AG, Göttingen, Germany

Impulse balances

Impulse balances do not need a gravitational field [6–9]. They are independent on location and situation and can be operated also at zero gravity in satellites and spacecrafts (Fig. 5). Indeed quartz oscillators are used to measure contamination in space.

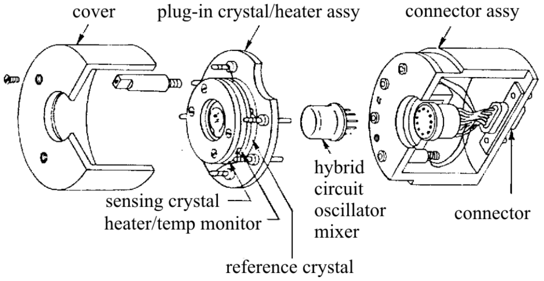

Fig. 5 Quartz crystal balance for contamination measurements in space

For our purpose oscillating systems may be used. The oscillations produce the required force which is necessary to accelerate the sample mass periodically. Variations in mass are detected by a shift in the resonance frequency and this signal can be transmitted easily and error-free to Earth. An additional sensor is not necessary.

Crystal oscillators (quartz, $GaPO_4$ [10]) are operated with high frequency. Unfavourably, the sample material must be coupled strongly to the surface of the sensor. Otherwise the impedance of loose samples, and not the mass, is measured. That problem may be overcome by means of lever connections between sensor and sample pan. Using low frequencies (oscillating string, band, tapered element) this problem can be of minor importance.

An electronic balance based on a loud speaker or ear phone design should be simple, rugged and cheap. Such a system could be operated in two modes: as an electromagnetic plunger coil system in the gravitational field and as an oscillating impulse system (Fig. 6) [11, 12]. By constructional means the maximum sensitivities of both modes could be separated to different ranges. It is hoped that in this way two tasks may be solved better: determination of the sample mass and measurement of small mass variations due to surface reactions.

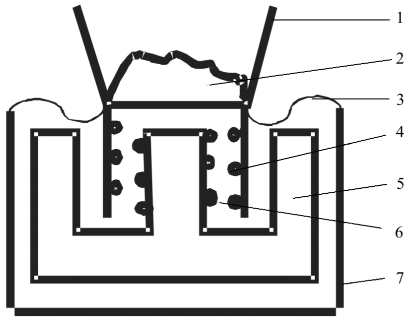

Fig. 6 Draft of an electromagnetic plunger coil/oscillating balance; 1 – balance pan, 2 – sample, 3 – corrugated membrane, 4 – plunger coil, 5 – pot magnet, 6 – stationary coil, 7 – case

Conclusions

We propose a gravimetric experiment on Mars to determine the geometric surface structure of the soil. We are going to test a load cell with strain gauges. Further applications of a balance on Mars are discussed.

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