LEVER CONSTANTS AND GRAVITY METER SENSITIVITY

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Summary: For the Worden, Sharpe and Scintrex gravity meters, the lever constants were derived from the amplitude response to the vertical motion and their relation to the sensitivity of the gravity meter was verified. It is then possible to calculate the lever constants for the actual sensitivity of the gravity meter without further measurements and to apply them to estimating the dynamic behaviour of the reading beam.

1. INTRODUCTION

In studying the influence of vibrations on the Sharpe and Worden gravity meters, the basic lever parameters, i.e. the free period $T_g$ and the damping constant $D_g$, were derived from the amplitude response of the gravity meter reading beam to vertical harmonic motion [1]. Though the calculated parameters were determined very accurately (standard deviations being 1—2 per cent), substantially greater differences of both lever constants have been observed after a long-lasting operation in the field. These changes of lever constants were probably due to unintentional tilting of the measuring system during level adjustment. The lever constants should be in unique relations with the gravity meter sensitivity and, therefore, before each further test also the sensitivity was checked.

The results of the lever constant measurements carried out with the Worden, Sharpe and Scintrex gravity meters are presented in this paper. In order to detect the changes of dynamic properties of the gravity meters and to verify the validity of the relations between the lever constants and the sensitivity, the sensitivities of the gravity meters were changed. The purpose was to derive the lever constants for the whole range of sensitivities recommended by the manufacturer from a single test of the gravity meter on a vibrating platform. The actual lever constants may then be applied to determining the duration of the transient motion of the reading beam in adjusting to the reading line and estimating the sensitivity of the gravity meter to the vertical component of low-frequency seismic waves.

2. THEORETICAL BACKGROUND

We have used a simplified model of the gravity meter measuring system in deriving the basic relations between the lever constants and the sensitivity. The complicated mechanical part is substituted by a single physical pendulum with a vertical oscillation plane. The equilibrium position of its centre of mass is near the horizontal plane passing through the solid axis of rotation of the lever. In this way the rigid system

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with one degree of freedom substitutes the actual system with elastic axes and several springs. With the optical indication of the lever position, the sensitivity $s$ of the gravity meter is defined as the deviation $a$ of the reading beam in the eye-piece caused by a unit change of the gravity acceleration $\bar{g}$. The following relation then holds for the sensitivity $[2]$,

\begin{equation}
(1) \quad s = \frac{a}{\bar{g}} = \frac{p o T_o^2}{4 \pi^2 l},
\end{equation}

where $p$ is the distance of the lever beam from the lever axis of rotation, $l$ is the reduced lever length and $o$ is the optical magnification of the beam deflection displayed in the eye-piece. For the deviation $a$ in micrometres and the acceleration in $\mu m \ s^{-2}$ the sensitivity defined in this way has the dimension of $s^2$. It is determined by the stable constructional parameters $p$, $o$, $l$ and by the lever period $T_o$ which is adjustable within a certain range. These quantities are not given by manufacturers.

The deviation of the reading beam in the eye-piece can be measured only in terms of the optical scale units. For example, with the Sharpe and Scintrex gravity meters there is a linear scale of 10 numbered lines in the eye-piece, with the Worden gravity meters there are 2 scale lines symmetrically on either side of the nulling line. We can write $a(\mu m) = k_a a(SD)$, where $k_a$ is the length of one scale division in micrometres and $a(SD)$ is the deviation measured in scale divisions. The sensitivity $s_{SD}$ in scale divisions reads

\begin{equation}
(2) \quad s_{SD} = \frac{a(SD)}{\bar{g}(\mu m \ s^{-2})} \sim s.
\end{equation}

Instead of the sensitivity $s_{SD}$ the reciprocal constant $c$, corresponding to the gravity acceleration difference per one division deviation of the reading beam, is usually applied. Using constant $c$ relations (1) and (2) yield

\begin{equation}
(3) \quad T_o = k_T c^{-1/2},
\end{equation}

where $k_T$ depends on the unknown constructional parameters of the gravity meter.

The moment of damping forces acting on the lever is constant and, therefore, the damping constant is, as in a linear oscillator, directly proportional to the magnitude of the lever period. If we denote the coefficient of proportionality as $k_D$, the damping constant is

\begin{equation}
(4) \quad D_o = k_D T_o.
\end{equation}

Both coefficients $k_T$ and $k_D$ should be constant for a particular gravity meter, with the exception of gravity meters with variable damping, where $k_D$ is changed after each new damping adjustment. With a change of the gravity meter sensitivity a change of both lever constants takes place. To be able to determine the dynamic properties of the lever uniquely, it is, therefore, necessary to eliminate the influence of the spontaneous changes of sensitivity and also to give the actual sensitivity at the time of measurement. Having complete values of $T_o$, $D_o$ and $c$ and using relations (3) and (4), it is possible to calculate the constants for any sensitivity. The validity of the above-mentioned relations was verified with several gravity meters.