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ON MEASURING THE ACCELERATION OF GRAVITY WITH A GRAVIMETER ON A MOVING BASE

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The principal difficulties that arise in measuring the acceleration of gravity on a moving base are caused by the large effects of inertial accelerations and tilts of the gravimeter base on the readings of its sensitive system. These effects may reach hundreds and thousands of milligals, whereas the magnitude of the sought increment Δg of the acceleration of gravity rarely exceeds several tens of milligals.

To reduce the influence of alternating inertial accelerations on the readings of the gravimeter' s sensitive system, it is placed in a strongly damping medium. It is assumed a priori that over an observation interval of 10–20 min the mean value of the influence of such accelerations is zero. A drawback of the accepted procedure is the very low productivity and low level of detail of gravimetric surveying.

Below, one approach is proposed to carrying out detailed gravimetric surveys at sea, based on determining discrete values of the readings of the gravimeter' s sensitive system at moments when the influence of alternating inertial accelerations on the pendulum readings is close to zero.

The method is based on the fact that the motion of a strongly damped pendulum differs in phase from the inertial force caused by sea waves by approximately $\pi/2$.

Let vertical accelerations $\ddot{z} = \ddot{z}_0 \sin \omega t$ act on the pendulums. The differential equation of the pendulum motion can approximately be represented in the form

$$\ddot{\varphi} + 2\lambda\dot{\varphi} + n^2\varphi = \frac{\ddot{z}_0}{l} \sin \omega t. \tag{1}$$

For the case of a strongly damped pendulum, when $2\lambda \gg n^2$, in (1) one may neglect $\ddot{\varphi}$. The solution of equation (1) (without the term expressing the transient process, which we neglect) has the form

$$\varphi = \frac{\ddot{z}_0}{l\sqrt{n^4 + 4\lambda^2\omega^2}} \sin\left(\omega t - \operatorname{arc\,tg}\frac{2\lambda\omega}{n^2}\right). \quad (2)$$

Let us take the following pendulum parameters: damping coefficients $2\lambda_1 = 5000\ \mathrm{sec}^{-1}$, $2\lambda_2 = 10000\ \mathrm{sec}^{-1}$, square of the natural frequency $n_1^2 = n_2^2 = n^2 = 100\ \mathrm{sec}^{-2}$, reduced length $l_1 = l_2 = l = 2$ cm. The wave frequency (frequency of the heave of the surface vessel) is $\omega = 1\ \mathrm{sec}^{-1}$.

Substituting these values into (2), we find that the phase shift of one pendulum is 89°, and of the other 89°.5. Their amplitudes differ from one another by a factor of two. The points of intersection of the readings of these pendulums are locat-

are assumed to be close to the equilibrium position occupied by the pendulums when acted upon only by the acceleration of gravity and by systematic factors. The influence of alternating accelerations $\ddot{z}$ at the instants of intersection does not exceed several tens of milligals, which makes it possible, in 1-2 min, to eliminate these influences from the pendulum readings.

A laboratory check of the validity of the proposed method was carried out using a model of a two-pendulum marine gravimeter. The configuration of the pendulums and the damping properties of the medium were chosen in accordance with the conditions given above.

The model gravimeter, mounted on an examiner for determining the frequency characteristics of marine gravimeters, was placed on the platform of a test stand. By changing the speed and the magnitude of the angle of inclination of the gravimeter base, it was possible to imitate the variation of gravity anomalies according to a linear or sinusoidal law. Vertical accelerations were imposed with amplitudes up to 30 gal and with periods from 11 to 30 sec.

Under the action of disturbing accelerations, the amplitudes of the first pendulum differed substantially from the amplitudes of the second, but the points of intersection of the records were situated, with alternating signs, near the line characterizing the position of the pendulums that they occupied under the action of gravity. From the points of intersection of the pendulum readings, long-period anomalies produced by the examiner were confidently traced against a background of short-period disturbances whose amplitudes were considerably greater than theirs.

The development of a gravimeter with two identical sensitive systems differing only in the degree of damping presents certain difficulties. Meanwhile, there are two possibilities for using in practice the described property of strongly damped pendulums with the aid of only one pendulum.

The first of them is realized when there is a gravimeter whose readings are issued in the form of an electrical signal. In this case it can be "damped" in different ways by means of two electrical or electromechanical filters, for example galvanometers having the same static and different dynamic sensitivity and connected in parallel, and then the magnitudes of these signals can be found at the instants when they coincide with one another.

The second of the indicated possibilities is in principle realized when there is one real pendulum and a fictitious pendulum is introduced, whose parameters differ from those of the real pendulum only in the degree of damping.

Let us consider the system of differential equations of motion of these pendulums (as before, we replace the second-order equation by a first-order equation)

$$2\lambda_1\dot{\varphi}_1 + n^2 l\varphi_1 = f(t),$$

$$2\lambda_2\dot{\varphi}_2 + n^2 l\varphi_2 = f(t). \tag{3}$$

We shall assume that the first equation pertains to the fictitious pendulum and the second to the real one.

Denoting $\lambda_2 = \lambda_1 + \Delta\lambda$, $\varphi_1 - \varphi_2 = \varphi$, $\varphi_1 - \varphi_2 = \varphi$, and subtracting the second from the first equation of (3), we obtain

$$2\lambda_1\dot{\varphi} + n^2\varphi = 2\Delta\lambda\,\dot{\varphi}_2. \tag{4}$$

Its solution (without the term expressing the transient process) has the form

$$\varphi(\tau) = \frac{\Delta\lambda}{\lambda_1}\left[\varphi_2(\tau) - \frac{n^2}{2\lambda_1}e^{-\frac{n^2}{2\lambda_1}\tau}\int \varphi_2(t)e^{\frac{n^2}{2\lambda_1}t}\,dt\right]. \tag{5}$$

Let us consider the case in which the readings of both pendulums coincide, i.e. $\varphi = \varphi_1 - \varphi_2 = 0$.

This occurs when

$$\varphi_2(\tau) = \frac{n^2}{2\lambda_1}\,e^{-\frac{n^2}{2\lambda_1}\tau}\int \varphi_2(t)\,e^{\frac{n^2 t}{2\lambda_1}}\,dt. \tag{6}$$

Thus, when the instantaneous reading of the real pendulum $\varphi_2(\tau)$ is equal to its integral value

$$\frac{n^2}{2\lambda_1}\int \varphi_2(t)\,e^{\frac{n^2}{2\lambda_1}(t-\tau)}\,dt,$$

the real pendulum occupies a position in which the influence of inertial sign-changing accelerations on its readings is close to zero; and it assumes this position under the action only of the acceleration of gravity and of effects having a systematic character.

The approach described for extracting a signal against a background of large inertial accelerations can be used to determine the drift of the gyrovertical, i.e., to determine the true angle of inclination of the gravimeter base.

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Note: Figure translations are in progress. See original paper for figures.