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TWO-CHANNEL BALLISTIC TRANSFORMER GRAVIMETER

The two-channel ballistic transformer gravimeter for measuring the doubled value of the acceleration of gravity contains a gravimeter that uses a fixed glass tube made of a dielectric material, a magnetized test body in the form of a layer, a computer and an inductance winding, which is characterized by the fact that the fixed tube is made of a dielectric material, the inductance winding acts as a primary excitation winding connected to the power source, which additionally contains two identical sections of the secondary output winding, connected in series-opposite, to create two measurement channels, an electromagnet consisting of an armature made of magnetic material, an additional winding connected through a switch to an additional power source. To provide free vertical movement in two opposite directions along the OZ axis of the magnetized test body, it is proposed to use the proposed electromagnet consisting of an armature made of a soft magnetic material, an additional winding connected through a switch to an additional power source. The winding of the electromagnet is connected to the power source by a switch to create an electromagnetic flux of attraction to the test body, which, thanks to this, will rise to the uppermost position. At the next moment, the electromagnet switch is turned off, and the test body falls down under the action of the acceleration of gravity. The doubled output signal of the acceleration of gravity, which is removed from the secondary winding, is free from the effects of interference: external electromagnetic flows, inertial vertical acceleration, instrumental errors caused by changes in temperature, humidity, vibrations, pressure, the moment of dry friction forces, non-identity of the parameters of two identical sections of the secondary output winding and other factors - is submitted to the computer. The output of the computer is proportional to twice the acceleration of gravity value. Increased accuracy and reliability of measurements of the doubled value of the acceleration of gravity and increased efficiency of the search for minerals have been ensured.

Key words: two-channel gravimeter, gravitational acceleration, transformer gravimeter

БЕЗВЕСІЛЬНА ОЛЕНА, НЕЧАЙ СЕРГІЙ, ТОЛОЧКО ТЕТЯНА

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ДВОКАНАЛЬНИЙ БАЛІСТИЧНИЙ ТРАНСФОРМАТОРНИЙ ГРАВИМЕТР

Двоканальний балістичний трансформаторний гравіметр для вимірювань подвоєного значення прискорення сили тяжіння містить гравіметр, в якому використані нерухома скляна трубка із діелектричного матеріалу, намагнічене пробне тіло у вигляді шару, комп'ютер і обмотка індуктивності, який відрізняється тим, що нерухома трубка виконана із діелектричного матеріалу, обмотка індуктивності виконує роль первинної обмотки збудження, підключеної до джерела живлення, який додатково містить дві однакові секції вторинної вихідної обмотки, включені послідовно-зустрічно, для створення двох каналів вимірювання, електромагніт, що складається з якоря із магнітного матеріалу, додаткової обмотки, підключеної через перемикач до додаткового джерела живлення. Для надання вільного вертикального руху у двох протилежних напрямках уздовж осі OZ намагніченого пробного тіла запропоновано використання запропонованого електромагніту, що складається з якоря із магнітного матеріалу, додаткової обмотки, підключеної через перемикач до додаткового джерела живлення. Обмотка електромагніту підключається до джерела живлення перемикачем для створення електромагнітного потоку притягання пробного тіла, що завдяки цьому, підійметься у крайнє верхнє положення. У наступний момент перемикач електромагніту виключаємо, і пробне тіло падає вниз під дією прискорення сили тяжіння. Подвоєний вихідний сигнал прискорення сили тяжіння, що знімається з вторинної обмотки, вільний від впливів переходів: зовнішніх електромагнітних потоків, інерціального вертикального прискорення, інструментальних похибок, викликаних змінами температур, вологості, вібрацій, тиску, моменту сил сухого тертя, неідентичності параметрів двох однакових секцій вторинної вихідної обмотки та інших факторів, - подається на комп'ютер. Вихідний сигнал комп'ютера пропорційний подвоєному значенню прискорення сили тяжіння. Забезпечено підвищення точності та надійності вимірювань подвоєного значення прискорення сили тяжіння та збільшення ефективності пошуку корисних копалин.

Ключові слова: двоканальний гравіметр, прискорення сили тяжіння, трансформаторний гравіметр

Formulation of the problem

Today, gravimetric measurements on the Earth's surface are extremely relevant for many fields of science and technology: in geodesy and geophysics for finding mineral deposits; in cartography for studies of the shape of the Earth, in the aerospace industry for correction of inertial navigation systems of moving objects.

In [1], a ballistic transformer gravimeter is proposed, its description and principle of operation are given.

In works [2–7], a new sensitive element of the measuring system is proposed - a transformer gravimeter, which makes it possible to obtain greater accuracy of measurements of the acceleration of gravity compared to [1].

But in the known literature [1–11] there are no proposals to ensure the accuracy of the ballistic transformer gravimeter by using the principle of two channels and additional necessary design components.

Analysis of recent research and publications

In [4], an analytical review of known gravimeters was carried out and a new transformer gravimeter was recommended for use. But in this publication there are no proposals for improving the accuracy of the transformer gravimeter by using the principle of two channels and additional components of the design.

In [5] a description of the measuring scheme of the experimental setup based on the transformer gravimeter for measuring the acceleration of gravity, as well as conducting a cycle of experimental studies with the aim of constructing the frequency characteristic of the output signal of the transformer gravimeter and the induction converter, is provided. However, there are no proposals for improving the accuracy of the transformer gravimeter by using the dual-channel principle and additional design components.

Article [6] is devoted to research on filtering the output signal of a measuring system with a transformer gravimeter. A filtering technique has been developed, which allows to separate the signal of the gravity acceleration anomaly of the transformer gravimeter from the largest obstacle of the vertical acceleration signal in order to increase the accuracy of the gravimeter by choosing the natural frequency of oscillations of the transformer gravimeter

0.1 s^{-1} at the point of intersection of the graphs of the spectral densities of the useful signal of the gravitational anomaly and the main disturbance of the vertical acceleration. But in this publication there are no proposals for improving the accuracy of the transformer gravimeter by using the principle of two channels and additional components of the design.

In [7], a transformer sensitive element that can be used as a gravimeter is described. However, there are no proposals for improving the accuracy of the transformer gravimeter by using the dual-channel principle and additional design components.

Comparative descriptions of various types of gravimeters (piezoelectric, string, MEMS capacitive, etc.) are given in [8–11]. However, in these publications, there are no proposals for improving the accuracy of the transformer gravimeter by using the two-channel principle and additional design components.

Thus, there are no proposals in the known literature [1–11] to ensure the accuracy and reliability of the transformer gravimeter by using the principle of two-channel and additional design components.

Therefore, the purpose of this article is to provide suggestions for improving the accuracy of the transformer gravimeter by using the dual-channel principle and additional design components.

To achieve the formulated goal, the following tasks were set:

- provide a description of the design of the proposed new transformer ballistic gravimeter;
- explain the principle of operation of the proposed ballistic transformer gravimeter;
- to provide an explanation of the operation of the new two-channel ballistic transformer gravimeter and to

justify that it provides an increase in the accuracy and speed of measurements of the doubled value of the acceleration of gravity.

Presentation of the main material of the article

The ballistic gravimeter given in [1] is known. It consists of two systems.

The first system for measuring the path and time of free movement, consisting of a test body in the form of a layer with magnetic properties, a transparent tube on a fixed base; inductor; device for holding the test body in the initial position; computer and the second system for measuring the path and time of free movement of the test body, which contains a source of pulsed light, a video camera and a unit for approximating the trajectory of the test body. The outputs of the coils are connected to the first input of the computer, the first output of which is connected to the input of the device for holding the test body in the initial position, the third output of the digital computer is connected to the input of the pulsed light source, the output of which is optically connected to the test body, which optically connected to the input of the video camera, the output of which is connected to the input of the unit of approximation of the trajectory of the test body, the output of which is connected to the second input of the computer, the fourth output of which is connected to the control input of the video camera, and the second output of the computer is the output of the ballistic gravimeter.

However, the ballistic gravimeter described in [1] has a number of significant disadvantages:

- well-known single-channel ballistic gravimeter of the inductive type. Under the action of an external electromagnetic flux-obstacle, significant errors occur in the known gravimeter, which act along the sensitivity axis OZ simultaneously with the useful signal of the acceleration of gravity g and significantly exceed it, which is unacceptable;
- vertical inertial acceleration, instrumental errors caused by changes in temperature, humidity, vibrations, pressure, moment of dry friction forces and other factors - act directly along the OZ sensitivity axis, distorting the correct operation of the known gravimeter, which is unacceptable;
- there is no explanation of the design and principle of operation of the device for holding the test body, the design of this device is not described;
- the first and second systems of the well-known gravimeter, designed to measure the path and time of vertical movement of the test body and consist of different devices, each of which has its own errors. Therefore, the

combination of two systems in order to increase the accuracy of the known gravimeter does not give such an effect of increasing the accuracy, because the errors of the devices of the two systems will add up;

- in [1] it is not described how the vertical movement of the test body up or down in two directions in the glass tube is ensured;
- the proposed measurement system of the well-known gravimeter consists of many components based on different operating principles, which reduces its reliability.

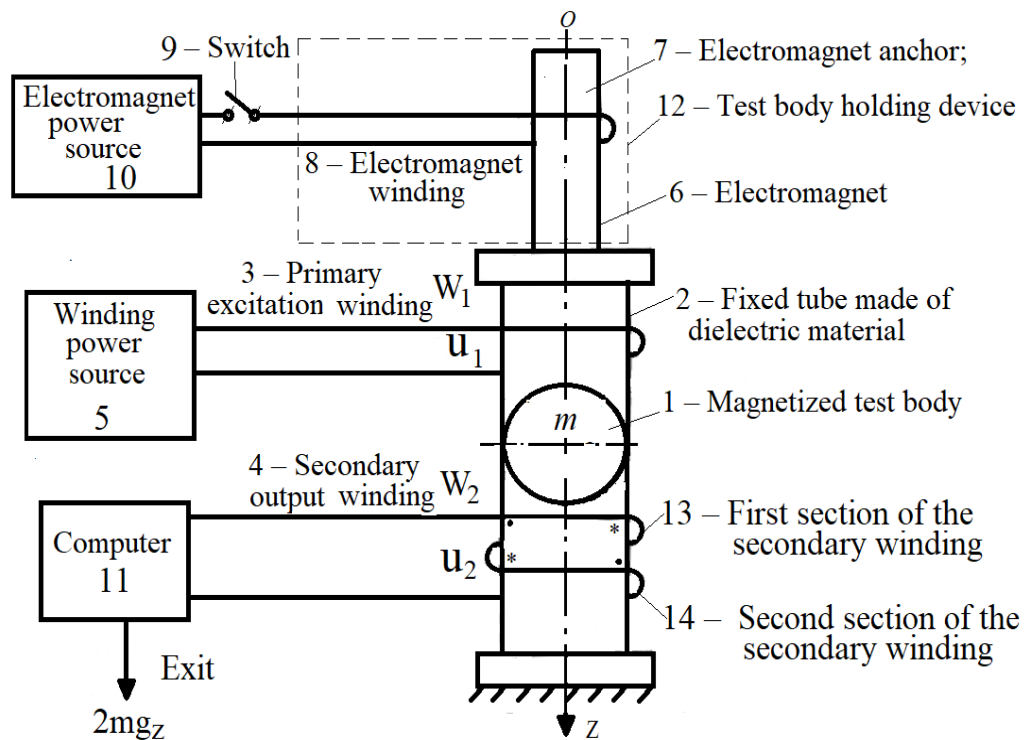


Fig.1. Schematic diagram of a two-channel ballistic gravimeter: 1 – magnetized test body; 2 – fixed tube made of dielectric material; 3 – primary excitation winding; 4 – secondary output winding; 5 – winding power source; 6 – electromagnet; 7 – electromagnet anchor; 8 – electromagnet winding; 9 – switch; 10 – electromagnet power source; 11 – computer; 12 – test body holding device; 13 – the first section of the secondary winding; 14 – the second section of the secondary winding

Without eliminating the indicated significant shortcomings, the accuracy of calculating the acceleration of gravity by the ballistic gravimeter will be low.

Thus, the significant disadvantages of the well-known ballistic gravimeter [1] are the low accuracy and reliability of gravity acceleration measurements due to the fact that it is not dual-channel and is subject to significant influence of external electromagnetic flows - interference; it is affected by significant vertical inertial acceleration and instrumental errors caused by changes in temperature, humidity, vibrations, pressure, the moment of dry friction forces, errors due to the non-identity of the first and second systems for measuring the time and path of movement of the test body, consisting of different devices, and other factors acting along the axis of sensitivity OZ, distorting the operation of the well-known ballistic gravimeter, the design of which lacks a power source for the windings and a switch for changing the direction of the fall of the test body, as well as - an explanation of the design and principle of operation of the device for holding the test body.

The purpose of this article is to significantly increase the accuracy and reliability of ballistic two-channel transformer gravimeter measurements.

We solve the problem by creating a two-channel ballistic transformer gravimeter for measuring the doubled value of the acceleration of gravity, which uses the following elements: a fixed tube, a magnetized test body in the form of a layer, an inductance winding, a device for holding a test body, a computer.

What is new in the ballistic transformer two-channel gravimeter is that the stationary tube is made of dielectric material, the inductance winding acts as the primary excitation winding, connected to the power source, which additionally contains two identical sections of the secondary output winding, connected in series-opposite to create two measurement channels, and the device for holding the test body in the initial position contains an electromagnet consisting of an armature made of a magnetic material and an additional winding connected to an additional power source through a switch.

Figure 1 shows the structural diagram of a two-channel ballistic transformer gravimeter for measuring the doubled value of the acceleration of gravity.

In this figure, you can see a stationary tube 2 made of dielectric material, in which there is a magnetized test body 1 in the form of a layer that can move down and up along the tube parallel to the OZ axis. In the upper part of the tube 2, there is a device 12 for holding the test body in the initial position, which includes an electromagnet 6, consisting of an armature 7 made of a soft magnetic material and an additional winding 8. This additional winding 8 is connected to an additional power source 10 through a switch 9. On the outer part of the tube 2, there are the

inductance winding 3, which acts as the primary excitation winding and is connected to the power source 5, and two identical sections 13, 14 of the secondary output winding 4, made in series-opposite to create two measurement channels. The outputs of the secondary output winding 4 are connected to the computer 11, the outputs of which are, in fact, the outputs of the entire two-channel ballistic transformer gravimeter.

Figure 2 presents a generalized diagram of the construction of a ballistic two-channel transformer sensitive element, where 13 and 14 are the first and second sections of the secondary winding of a ballistic two-channel transformer sensitive element, M is the mass of the test body.

The two-channel ballistic transformer gravimeter works as follows.

According to the law of electromagnetic induction, the excitation flux created by the primary excitation winding induces two oppositely directed electromotive forces in the two sections of the secondary output winding, thanks to which, under the influence of interference from harmful external electromagnetic fluxes, inertial vertical acceleration, instrumental errors caused by temperature changes, humidity, vibration, pressure, moment of dry friction forces, residual non-identity of the parameters of two identical sections of the secondary output winding, and other factors, their influence on the resulting accuracy of gravity acceleration measurements is canceled and to provide vertical movement in two opposite directions along the OZ axis of the test body in the form of a magnetized layer, the winding of the electromagnet is connected to the power source by a switch to create an electromagnetic flow of attraction of the test body, which, thanks to this, will rise to the uppermost position, at the next moment, the electromagnet switch is turned off, and the test body falls down under the action of the acceleration of gravity, the output acceleration signal is doubled gravitational force removed from the secondary winding, free from the effects of interference: external electromagnetic fluxes, inertial vertical acceleration, instrumental errors caused by changes in temperature, humidity, vibrations, pressure, moment of dry friction forces, non-identity of structures of two identical sections of the secondary output winding and others factors, is fed to the computer, from which the output signal of the gravimeter is taken, proportional to the doubled value of the acceleration of gravity.

We will explain the operation of the two-channel ballistic transformer gravimeter.

The output electric signal of the ballistic two-channel transformer sensitive element u_2 , proportional to the total emf of the two sections of the output secondary winding, will have the form:

$$u_2 \equiv E_z = E_1 + E_2 \equiv mg + m\Delta\ddot{h} + \Delta i + \Delta n + mg - m\Delta\ddot{h} - \Delta i - \Delta n = 2mg, \quad (1)$$

where E_1 – the output signal from the first section of the secondary winding; E_2 – output signal from the second section of the secondary winding; $u_2 \equiv E_z$ – output signal of ballistic two-channel transformer sensitive element; m – mass of the test body; $\Delta\ddot{h}$ – errors from vertical acceleration; Δi – instrumental errors, Δn – errors of non-identity of the parameters of two identical sections of the secondary winding.

The generalized scheme of the ballistic two-channel transformer sensitive element is shown in Figure 2.

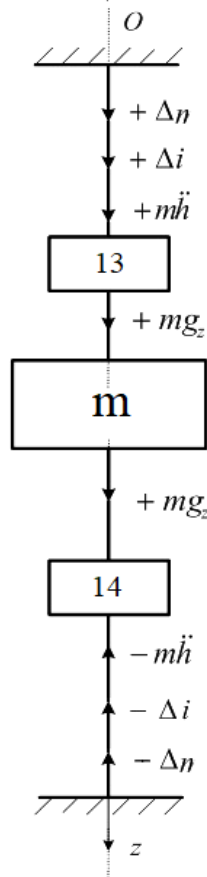


Fig.2. Generalized diagram of the construction of a ballistic two-channel transformer sensitive element:

13, 14 – the first and second sections of the secondary winding of a ballistic two-channel transformer sensitive element, m is the mass of the test body

It can be seen from equation (1) that the output signal of the ballistic two-channel transformer gravimeter u_2 contains a double value of the useful signal of the acceleration of gravity and does not contain inertial vertical acceleration, total instrumental errors and errors due to the non-identity of the parameters of the two sections of the secondary output winding. The signal u_2 is fed to the input of the computer 11, from the output of which a signal proportional to the doubled value of the acceleration of gravity is removed.

Thus, the proposed two-channel ballistic transformer gravimeter provides a significant increase in the accuracy and reliability of measurements of the doubled value of the acceleration of gravity. This allows, for example, to adjust the flight trajectories of aircraft and space vehicles with high accuracy and speed in real time and more efficiently search for mineral deposits and mobile military objects.

Conclusions

It is substantiated that due to its design features, the proposed two-channel ballistic transformer gravimeter provides a significant increase in the accuracy and reliability of measurements of the doubled value of the acceleration of gravity.

This allows, for example, to adjust the flight trajectories of aircraft and space vehicles with high accuracy and speed in real time and more efficiently search for mineral deposits and mobile military objects.

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