Analysis of ways to increase accuracy of aviation gravimeters

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Abstract—The article considers all types of aviation gravimeters and presents conclusion on the potential of using gyroscopic gravimeters which have significant advantages over others, as they are able to provide higher accuracy and speed, have small dimensions and high sensitivity.

Index Terms—aviation gravimeter, accuracy, gravimeter.

1 INTRODUCTION

Knowledge of Earth’s gravitational field parameters is necessary for many branches of science and technology: for mineral exploration, especially in remote areas, mountains and oceans, in geology and geodesy, for correction of inertial navigation systems in aerospace industry [1], etc. Accuracy and speed of measurements of Earth’s gravitational field parameters (their anomalies \( \Delta g \)) depend, first of all, on the choice of gravimeter. Therefore gravimeter, as a major sensor of aviation gravimetric system (AGS) [2] should have high metrological characteristics: accuracy, sensitivity, speed and reliability [3]. Level of requirements to gravimeters is growing, inducing to create improved gravimeters of new types.

2. Emphasis of unsolved aspects of the general problem, to which the article is devoted. However, there is a lack of thorough analysis of aviation gravimeters in the literature [4-8 and others]. Some disembodied data relate to certain aviation gravimetric measurements or their certain aspects [4-8]. Generally, it should be noted that there are no overall systematic analysis of works in the field of aviation gravimetry. The National Technical University of Ukraine “KPI” and Industrial Research Institute for Automation and Measurements PIAP, conduct scientific and implementation works on research of accuracy characteristics of the most advanced aviation gravimeters of new types, i.e. single and double-ring dynamically configurable gravimeters (DCG) [9]. Solution of the scientific and practical problems makes it possible to greatly improve accuracy and speed of dynamically configurable aviation gravimeters.

3. Objective of the article is analytical review of available aviation gravimeters.

4. Analysis of recent researches. Great contribution to the theory and practice of land, sea and aviation gravimetric measurements was made by a number of prominent scientists-gravimetrists: V.O. Bagromyanets, Y.D. Bulanzhe, K.E. Veselov, A.M. Lozynska, A.A. Mykhaylov, S.A. Piddubnyy, Y.I. Popov, V.A. Tulin, V.V. Fedynskyy, M.Y. Heifetz and others.


Important role in the development of gravitation measurements has been given to the works of foreign scientists: L. La Costa, D. Harrison, A. Graf, J. Tomody, M. Holvani and others [10-12].

In recent decades, gravimetric and gradiometric researches have been mainly carried out at the bottom of the sea, on submarines and ships.

Marine facilities are most intensively studied in such research centers as CRI "Azimuth" (St. Petersburg) under supervision of L.P. Nesenyuk, G.B. Wolfson, B.A. Blazhnov; M.Y. Zhukovsky Air Force Academy (Moscow) under supervision of A.A. Krasovsky, A.I. Soroka; Higher Military Aviation Engineering School (Riga) under supervision of A.A. Veselov; Minsk Polytechnic Institute under supervision of I.Z. Dzhylavdari.

Since 1958 until now the most important works [4-8 and others] in the field of aviation gravimetric measurements in the CIS have considered to be those performed under supervision of Y.I. Popov at the Institute of Physics of the Earth of the Russian Academy of Sciences with the use of greatly damped gravimeters GAL-S and V.O. Bog-
Gravimeters with identical closed-circuit metal elastic systems are used abroad. Askania GSS-2 (Germany, 1956) is one of the most common gravimeters. Sensitive element is a weigh beam (aluminum rod), which is suspended on a horizontal twisted springs. La Costa Romberg gravimeter, to which the principle of Golitsyn’s vertical seismograph is applied, is also used. It includes a greatly damped sensitive element, i.e. a horizontal rod with a weight at one end and with the other end fastened. String gravimeters MIT and VSA (USA) are as well used. Accuracy (6-8 mGl) and speed of foreign aviation gravimeters are insufficient [10-14]. Measurement of gravitation anomalies on board in-flight is specific and more complex than measurements on ships:
- Instability of speed and direction shall be taken into account and, therefore, continuously recorded;
- In calculation of Eotvos correction the second term of correction formula shall not be ignored;
- Change of $\Delta g$ shall be taken into account along with a change of aircraft flight altitude;
- There are very difficult measurement conditions: gravimeter senses influence of aircraft vibration, rotation of aircraft along its longitudinal and transverse axes observed throughout the flight, in-flight bumps, etc.
- Long-period vertical accelerations shall be taken into account and eliminated.

Note: Accuracy of 1 mGl is achievable for marine gravimetric measurement, whereas such accuracy for aviation gravimetric measurement is yet problematic.
CIS used the following gravimeters for research in the field of aviation gravimetric measurements: marine gravimeter GAL-S developed under supervision of YI Popov at the Institute of Physics of the Earth RAS; string gravimeter GS developed at the All-Russian Research Institute of Geophysics under supervision of AM Lozinska (further effective researches and tests of GS were supervised by VA Bagromyanets); GAL-S developed at the Moscow Institute of Electromechanics and Automation (MIEiA) under supervision of LG Polyakov.
Studies have shown that accuracy [6-8 mGl] and speed of measurement of gravitation anomalies from aircraft are insufficient.

The results of GAL-S and GS measurements were handled after test flights for months.
Aviation gravimetric measurements conducted in the USA with vibration accelerometers Arma Lot D, Arma D4E; pendulum accelerometers VM-76 produced by Au-
It is shown that the most advanced aviation gravimeters are considered to be those on the basis of a dynamically configurable gyroscope, which have advantages in accuracy and dimensions as compared to other gravimeters. It has been proved that further development of aviation gravimeters is associated with creation of gyroscopic gravimeters, which, in turn, has a number of advantages in accuracy. In the future, it is advisable to study dynamic and static errors of a gyroscopic gravimeters, including on computers and experimentally. These studies will justify the feasibility of using gyroscopic gravimeters for aviation gravimetric measurements.

REFERENCES


Conclusions: