Discussion on the Delay Time of DGS AT1M Marine Gravimeter

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Abstract. The DGS AT1M marine gravimeter is lost by 0.13mGal in total, and the monthly drift value is less than 3mGal/month required by the investigation specification after static experiments in the constant temperature and humidity laboratory for 14 days. It is concluded that the consistency accuracy of gravimeter is 0.18mGal through calculation according to the marine measurement line of 6×6. The measured data is applied. The ship steering method is used for verifying that the set filtering time is the delay time of post-processing.

1. Introduction

High-precision marine gravity exploration has been paid more and more attention as the main means of non-seismic exploration technology with the development of marine science in China, the advancement of regional geological survey and the in-depth exploration of seabed oil and gas resources. High-precision gravity data have quite important applications: for example, abnormal masses can be interpreted as density differences and then as geological structures in geology; the abnormal mass is interpreted as the fluctuation of geoid and vertical line deviation in surveying so as to improve geodetic surveying and navigation positioning. Geological structures of various characteristic types can be analyzed by using gravity anomaly field [1-3]. Our institute introduced DGS AT1M marine gravimeter produced by DGS Company in the United States in July 2017 in order to meet the development requirements of current high-precision marine gravity measurement.

DGS AT1M marine gravimeter belongs to a precision instrument with high precision and high reliability capable of global dynamic measurement. The full feedback magnetic coupling gravity sensor is adopted, the pendulum rod is always locked in a horizontal position, namely pendulum rod drift angle β is locked at 0, CC (cross coupling) is equal to 0, the original error caused by pendulum rod movement is removed, and there is no cross coupling effect. It has the dynamic characteristic advantage of the linear spring gravimeter and the static characteristic advantage of the zero-length spring pendulum rod gravimeter, namely the linear spring gravimeter is not affected by cross coupling, and the zero-length spring pendulum rod gravimeter has high sensitivity and small zero drift.
2. Instrument experiment

2.1. Laboratory experiment
A static experiment [4-5] was conducted in the constant temperature and humidity laboratory of our institute from July 13 to July 27, 2017. The test lasted for 14 days. The total drop of the gravity value is 0.13mGal, the average daily drop is 0.01mGal, and the monthly drift is 0.29mGal as shown in figure 1, which meet the requirements of the measurement specification [6-7].

2.2. Sea trials
Beihai Survey Institute set up 6 main survey lines and 6 contact survey lines in a sea area of the Yellow Sea to conduct sea trials on the DGS AT1M marine gravimeter from August 7 to 8, 2017 as shown in figure 2.

The original data are corrected and processed through the following steps after the original marine gravity data are measured: sampling gravity data, damping delay correction, zero point drift correction, Etvs correction, calculation of normal field, spatial gravity anomaly correction and Bouguer gravity anomaly correction.

The measurement network adjustment of gravity data was conducted by the semi-system adjustment method after the above corrections are done, and the following results were obtained [8-11]:
(1) Total mileage: 137Km, number of main test lines: 6; number of contact test lines: 6; number of total stations: 2587;
(2) The consistency accuracy before adjustment of spatial anomaly is 0.79mGal; The consistency accuracy after adjustment of spatial anomaly is 0.18mGal.

![Figure 1. Static experiment of gravimeter](image1)

![Figure 2. Tack chart of sea trial](image2)

3. Delay time
Since the acceleration frequency of the vertical interference is very high, the strongly damped mode is usually adopted in the marine gravimeter to suppress the high-frequency interference. Namely, the gravity sensor is placed in the strong damp by physical means such as magnetic field, air, viscous liquid, etc. Therefore, the gravity change measured by the gravimeter suffers from a hysteresis process. Namely, the value measured by the gravimeter at the moment is actually the gravity value at the corresponding GPS position at a certain time previously, which is inconsistent with the real-time matching of gravity navigation, and an appropriate hysteresis time constant should be selected [12-13]. In addition, the vertical disturbing acceleration is further eliminated by the filter of the equipment aiming at marine measured data of DGS AT1M marine gravimeter. The filter belongs to a low pass FIR (finite impulse response) filter designed according to Exact Blackman window function. It has the greatest advantage of linear phase frequency characteristics, the data is not distorted after filtering, but there is a delay in time.

If the marine gravity measurement is implemented at the speed of ten knots, the ship moves for about 5 meters per second, the selection of delay time is inaccurate, which may lead to errors for hundreds or even thousands of meters between the measured value and the actual position, thereby affecting the measurement accuracy of the gravity value. Therefore, we need to make a specific discussion about the time of delay correction.
Song Wenyao et al. measured the damping delay time of the gravimeter under static conditions according to the following steps: firstly, the instrument was set in a static equilibrium state under the condition of making preparations for field work, and the balance condition was destroyed manually, and the time was recorded in time at an interval of 0.1 seconds. Then, the time of restoring to original equilibrium condition was observed and recorded. The former was set as \( t_1 \), the latter was set as \( t_2 \), its time difference was \( \Delta t = t_2 - t_1 \), the above procedures are repeated, the damping delay time of the instrument can be obtained.

Fu Yongtao proposed to use the ship maneuver steering method to obtain the fast change of the heading and speed in the actual damping delay time during the measurement process of the gravimeter according to marine operation experience for many years, which would produce relatively large Etvs effect and then cause the rapid change of the gravimeter reading. The time corresponding to the significant change in the gravimeter reading is subtracted from the time corresponding to the significant change in the edworth correction value, namely the actual delay time in the measurement process of the gravimeter.

The above two methods are comprehensively considered, the author thinks that the ship maneuver steering method is more in line with the actual situation of marine gravity measurement. Therefore, the ship maneuver steering method is used below to study the delay time of DGS AT1M marine gravimeter.

Four gravimetric profiles (two east-west survey lines and two north-south survey lines) in a work area with filtering time of 180s were selected for analysis. It is shown in figure 3 and figure 4 that A1, A2, A3 and A4 points belong to time corresponding to Etvs correction values (calculated by the measured heading, speed and latitude) during obvious changes. B1, B2, B3 and B4 points belong to time corresponding to gravimeter reading during obvious. The difference thereof is the delay time of gravimeter.
Table 1 shows that the total delay time of DGS AT1M marine gravimeter is about 178.25s when the filtering time is 180s. Because there is a certain human error in selection of Etvs and the change time of gravity value, and it can be considered that the delay time is 180s.

**Table 1. Calculation table of 180s filtering time delay time**

| No. | A(s) | B(s) | Difference value (s) | Mean value (s) |
|-----|------|------|----------------------|----------------|
| 1   | 2442 | 2618 | -175                 |                |
| 2   | 2024 | 2213 | -181                 |                |
| 3   | 2870 | 3028 | -176                 | -178.25        |
| 4   | 1757 | 1942 | -199                 |                |

The filter parameter is changed to 300s, and four other survey lines are selected to calculate the delay time by using the same method (figure 5).

![Figure 5](image-url)

**Figure 5.** Gravity profile (B line and black line) and Etvs correction value profile (B line and red line) of the survey line (300s)

**Table 2. Calculation table of delay time during 300s filtration**

| No. | A(s) | B(s) | Difference value (s) | Mean value (s) |
|-----|------|------|----------------------|----------------|
| 1   | 195  | 502  | -307                 |                |
| 2   | 616  | 904  | -288                 |                |
| 3   | 1290 | 1594 | -304                 |                |
| 4   | 3701 | 4012 | -311                 | -299.5         |
| 5   | 710  | 1005 | -295                 |                |
| 6   | 3786 | 4073 | -287                 |                |
| 7   | 3493 | 3792 | -299                 |                |
| 8   | 3796 | 4101 | -305                 |                |

Table 2 shows that the total delay time of DGS AT1M marine gravimeter is about 299.5s when the filtering time is 300s. Since there is a certain human error in selection of Etvs and the change time of gravity value, it can be considered that the delay time is 300s.
gravity value, and it can be considered that the delay time is 300s. The two points are integrated, it can be considered that the delay time is the filtering time of field collection during post-processing of DGS AT1M marine gravimeter.

4. Conclusion
The following conclusions can be drawn by analyzing the static, dynamic and measured data of the DGS AT1M marine gravimeter:

(1) The monthly drift of DGS AT1M marine gravimeter is about 0.27 mGal, which is less than 3 mGal per month, which meets the requirements of marine geological and geophysical survey specifications.

(2) The consistency accuracy in the space gravity anomaly is calculated to be 0.18mGal through the 6×6 # shaped marine survey line, which meets the requirements of the national specification.

(3) The ship steering method is applied, and it is concluded that the delay time for post-processing is the filtering time set by the user through verification of 180s and 300s filtering time.

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