An Ocean Bottom Magnetometer for Marine Geomagnetic Field Survey: Developed dIdD and Fluxgate Sensor

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Abstract: A new type of ocean bottom magnetometer (OBM) for investigations of the basic magnetic field is developed.The data of marine geomagnetic field could not only improve the complete basic model of the geomagnetic field with high spatial and temporal resolution, but also satisfy the global geophysical field research needs. The developed OBM is according to the philosophy of design that it should be high sensitivity, low power consumption, light in weight, robust enough against mechanical shocks, reliability for long-term observations. So the developed prototype includes a compact spherical coil system and Overhauser effect sensor for measuring the total strength of the geomagnetic field and the vectors of strength, Delta inclination - Delta declination (this kind instrument called dIdD), meanwhile we also improve the performances of tri-axial fluxgate sensor for geomagnetic vector filed measurement (*H,Z* and *D* components). The advantages of this method are be calibrated by each other sensor and get the whole elements of basic geomagnetic field. Then we had carried out comparative measuring test in the Jinghai geomagnetic observatory. As a result, the developed OBM shows better performance in the accuracy of magnetic field and angle less than 0.2nT, 0.004° respectively.

1 INTRODUCTION

The marine magnetic field survey is very useful for reflecting the crust-mantle structure , and inferring global tectonic activity characteristics. The geomagnetic anomalies reveal much valuable information about the seafloor spreading and distribution of hydrothermal vents. With the progress of technology, in recent years the ocean magnetometer has been improved rapidly with accuracy, sensitivity and resolution (Auster et al., 2007;Antoni et al., 2012;Wang, 2015). At present, the method of marine magnetic field survey mainly uses the ship to carry the measurement instrument to carry on the survey, which include three methods: the first one is the geomagnetic measuring instruments installed in the non-magnetic, the second one is the geomagnetic measuring instruments in towed operation, the last one is free fall to the seabed for measurement (Guan, 2010;Kasaya et al., 2013).

The major ocean magnetic technology from total field strength measurement is first to total field gradient measurements, then to the vector(almost three components) measurement and full tensor multi-parameter measurement. Recently, the major instrument for ocean magnetic survey are still optically pumped magnetometer, The Overhauser magnetometer and proton procession magnetometer, which used in measuring the scalar parameter of total strength or the gradient value. Compared with the scalar magnetic survey method, vector magnetic survey is able to obtain the size and orientation information of the magnetic field simultaneously. So the measurement of ocean bottom geomagnetic vector has received more attention compared to geomagnetic scalar measurement by the ocean geophysicists, because of the geomagnetic vector measurement could effectively reduce multiple solutions in inversion using geomagnetic scalar data, help to qualitative and quantitative interpretation of magnetic field, to improve the detection resolution and positioning accuracy of underground orebody.

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So the new developed OBM with a compact spherical coil system and Overhauser effect sensor for measuring the total strength of the magnetic field and the vectors of strength, Delta inclination - Delta declination(this kind instrument called dIdD), meanwhile we also improve the tri-axial fluxgate performances of the traditional instrument for geomagnetic vector filed measurement. This paper is mainly focus on the key technology of the measurement sensor, and also the prototype development.

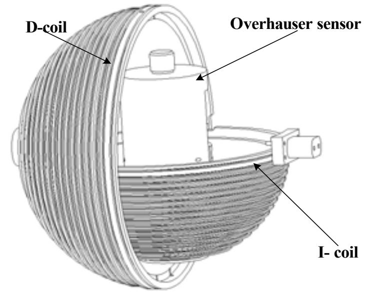
2 MAGNETOMETER

2.1 didD Sensor

The developed dIdD consists of an Overhauser effect sensor centered inside two orthogonal spherical coil systems (see Figure1). Coils are eventually aligned to be approximately perpendicular to the local geomagnetic field direction in the horizontal and geomagnetic meridian planes, respectively. One series of measurement consists of five consecutive measurements. There is no current measurement in the coils at first and later currents are applied to produce a deflection field. During these steps we have current in one coil in one direction then the same current to opposite direction. Later these steps are repeated with the other coil. At the end of the series we have five readings and using these five readings the absolute value of the vector and two angles can be calculated (Schott et al., 2001;Heilig, 2006;Hegymegi et al., 2004;Eugen, 2015).

To have enough volume of homogeneous magnetic field in limited space of glass sphere and the size of the Overhauser sensor which has to be placed into the I-coil we use spherical coil systems based on the Braunbek coil by increasing the coil to 34 sets coils and non-homogeneous field better than 5‰ in the volume of 70 mm in diameter and 140 mm in long, which could ensure the OVERHAUSER sensor normal operation developed by China University of Geosciences (CUG).

The orthogonal spherical coil systems is built for a conventional PPM material and the diameter of D-coil and I-coil was 35cm and 30cm respectively. High level of orthogonality of the two bias coils can be achieved experimentally by the method of Heilig B (Heilig, 2012) introduced and tested in Jinghai geomagnetic observatory. To repeat adjusting angle and testing, we have got good orthogonality of the two bias coils about 90.04°and the coils constant of 1057nT/mA, 1265nT/mA respectively.



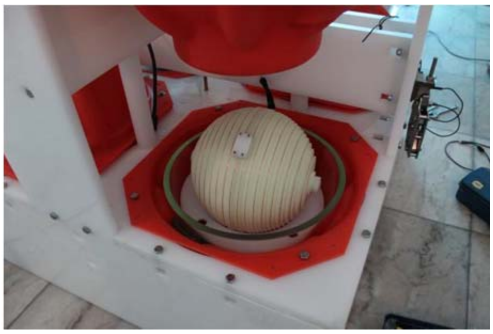
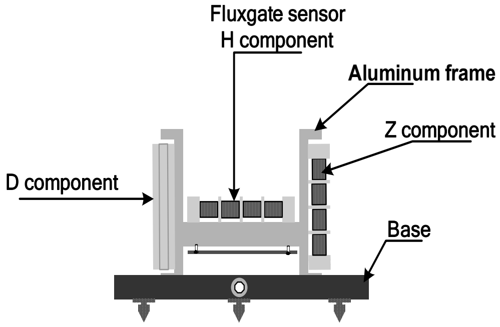


Figure 1: The developed dIdD sensor (left is structure schematic, right is physical photo)

2.2 Fluxgate Sensor

The developed fluxgate sensor is based on second harmonic Fourier component with the requirements of high resolution, low noise and long-term stability characteristics for geomagnetic relative observation instrument, suppressing the influence of outside temperature on the sensor output and obtaining low temperature coefficient (Mitra, 2011;Owais and Atiq, 2011). So the core as magnetic sensitive element is formed by alloy frame of high plasticity, endurance strength wrapped by high permeability permalloy material strip and at least two coils, a drive-coil and a pick-up coil. In order to better suppress the fundamental wave signal, the magnetic core adopts the ring frame and is driven periodically into saturation by a square current that flows through the drive-coil. It can be shown that the amplitude of the second harmonic frequency component will be measured by external magnetic field. Due to alternating amplification and deep feed-back loop, the stability and linearity of the magnetometer are promoted. Figure 2 shows the developed fluxgate sensor, and which performances of sensitivity 40uV/nT, noise 0.2nT(p-p).



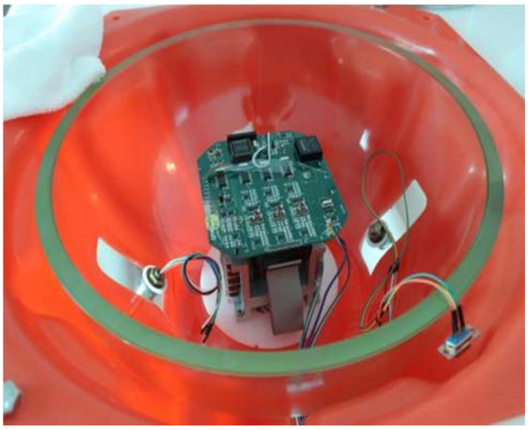


Figure 2: The developed fluxgate sensor (left is structure schematic, right is physical photo)

3 THE MECHANICAL DESIGN OF THE OBM

In our design, the developed OBM fall free to the seabed for measurement without communication cable, so the prototype could not communicate with the main control device on the boat or ground observatory when it measuring in the ocean bottom. Because of the longer deployment duration, the timing requirements is necessitate a more accurate internal clock and timer is required to product signal to the main control unit to fuse wire releasing the OBM structure from the counter weight so that it rises due to its ascending buoyancy. Using the release acoustic sends the signal to communicate with the main control device for the OBM recovered. The counter weight made by the Non-magnetic white cement material provide enough sinking buoyancy to let the OBM down to the seabed.

Figure 3 shows the developed OBM structure, which includes six thick glass spheres which contained the developed magnetic sensors, release acoustic electronics, main processing unit and the batteries for the electronic system , thus providing both ascending buoyancy and the pressures housing. To cushion the glass, the spheres then go inside yellow plastic "hardhats". The overall support platform is made of non-magnetic material PVC board, considering the corrosion resistance, hardness and nonmagnetic.

Figure 3: The construction of developed OBM (left is mechanical assembly drawing , right is physical photo)

4 MEASURING TEST AT JINGHAI GEOMAGNETIC OBSERVATORY

The developed prototype has been set up in geomagnetic Laboratory of Jinghai observatory. Because the bias current of dIdD is disturb to the fluxgate sensor output, so the distance between the two sensors was far enough in this comparative measuring test. During the trial operation (from 28th September to 31th October, 2017), we collected the raw observation data of prototype with 1Hz sampling. Figure 4 shows the geomagnetic diurnal variation curve and noise of two developed sensors on 8th October 2017, and we calculate the noise to evaluate performance of developed prototype using the time series from16:00 to 20:00(UTD) of 8th October because artificial noise and natural geomagnetic variance are small. The corresponding results are shown in Table 1. We could see from the results that the two developed magnetic sensors could record the geomagnetic diurnal variation precisely, the accuracy of magnetic field and angle less than 0.2nT, 0.004° respectively.

Table 1: The results of noise between developed dIdD and fluxgate sensor.

Instrument type	dIdD			Fluxgate sensor		
Magnetic component	*F* (nT)	*dI* (°)	*dD* (°)	*H* (nT)	*Z* (nT)	*D* (nT)
Noise (P-P value)	0.19	0.0029	0.0033	0.09	0.16	0.09

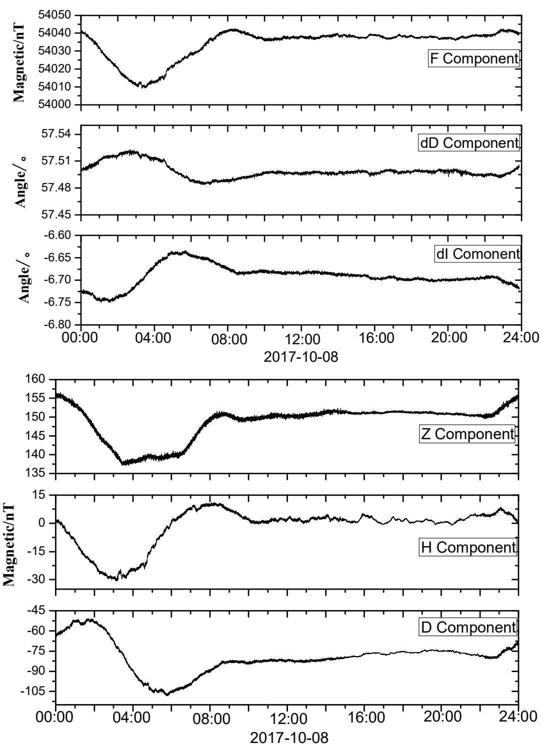


Figure 4: The geomagnetic diurnal variation curve of two developed sensor on Jinghai observatory(upper is dIdD, down is fluxgate sensor).

5 CONCLUSIONS AND FUTURE WORK

In this paper we developed two prototype magnetic sensors for marine geomagnetic field survey, and carried out parallel observation to evaluate the performance of each developed sensor. Then present the design and construction of developed OBM. This sensor combination observation method could be mutual calibrated by each other and get the whole elements of basic geomagnetic field. But during parallel observation, we didn’t consider the distance and volume of developed OBM, so the next work we would focus on the final prototype to eliminate the bias current interference to fluxgate sensor output.

Follow-up work would also focus on the optimization of the dIdD sensor circuit to improve the bias magnetic stability and reduce the noise which can improve the effective resolution, the fluxgate sensor mechanical structure by using suspension device to improve stability. Because of the developed OBM is free fall to the seabed for measurement, we could know the initial attitude information by using attitude device to measure the measurement coordinate system, then analyze the mathematical logic relationship between the geographic coordinate and measuring coordinates by using coordinate rotation algorithm, so we need take a series of experiments and tests which the developed OBM tiling arbitrary angle, it still could get high quality geomagnetic observation data.

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