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Research on Magnetic Characteristics of Small UAV for Aeromagnetic Measurement

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Abstract. UAV has the characteristics of small size, light weight, low cost, convenient assembly and maintenance, etc. It is suitable for aeromagnetic exploration, mapping, agriculture and forestry plant protection and other fields. Commercial drones, combined with aerospace magnetic measurement with its excellent platform value, can play an important role in small-scale geomagnetic surveying and magnetic anomaly detection in key areas. In the aeromagnetic measurement process of the drone, the small-scale and high-integrated hardware configuration results in a high level of near-field magnetic interference of the drone, which affects the magnetic detection effect. This paper selects a small commercial unmanned aerial vehicle for magnetic characteristics research. The static and dynamic flight magnetic tests of the UAV were carried out in the zero-magnetic laboratory, and the magnetic moment and magnetic field characteristics were analyzed. The experimental results will be used as the data basis for magnetic interference noise reduction in UAV aeromagnetic survey applications.

1. INTRODUCTION

The Unmanned Aerial Vehicle (UAV or Drone) is a non-manned aircraft operated by wireless remote control equipment and its own program control device. It involves sensor technology, communication technology, information processing technology, intelligent control technology and power propulsion technology. The advantage of the drone is that it could provide a movable and stable platform, thus expanding the application in combination with other payloads. With the entry of a large amount of private capital, the development technology of drones has matured, the manufacturing costs have been greatly reduced, the expansion has been continuously updated, and the application fields have been continuously expanded. In addition to the basic functions, commercial drones have gradually played a role in agricultural plant protection, power inspection, geological exploration, environmental monitoring, forest fire prevention, military and other fields. Combining the traditional aeromagnetic measurement with the UAV technology, the commercial drone is characterized by small size, light weight, low cost and convenient assembly and maintenance, which makes the aeromagnetic measurement expand into a new direction.

2. Development of commercial drones

With the wide application of light composite materials, the continuous improvement of satellite positioning accuracy, the development of electronic and radio control technology, especially the emergence of multi-rotor UAV architecture, the entire UAV industry has entered a stage of rapid development.



In the next few years, the trend of lower hardware costs, improved endurance, lower product prices, and increased product features will be expected to further enhance the technical level of consumer-grade UAVs. Artificial intelligence and machine learning technologies are applied in the field of drones. More and more in-depth will also promote the development of drones.

NASA has newly established the UAV Application Center, which specializes in various civil research on drones. It cooperates with the US Ocean and Atmospheric Administration (NOAA) to use drones for scientific research such as weather forecasting, global warming and glacial ablation. In the 2007 forest fire, NASA used the drone to assess the severity of the fire and the estimated damage. Scientists from the US Federal Geological Survey launched the UAV on the Red Rock Lake in Montana. The thermal imaging camera on board will help scientists search for the location of the hot springs on the lake and help the fish spend the cold winter in. The Shenyang Institute of Automation of the Chinese Academy of Sciences has developed a civilian unmanned helicopter, which can be used for earthquakes, floods, fires, transmissions, and oil observations. A type of UAV developed by BUAA can realize full autonomous take-off, landing, hovering and route planning flights, and it can be matched with many payloads.

The use of geomagnetic field for navigation has become a hotspot in the field of navigation because of its passive and concealed advantages. In the geomagnetic navigation technology, obtaining the accurate measurement value of the geomagnetic field in the navigation area is the premise of geomagnetic matching and the key factor for determining the navigation accuracy. Due to the special characteristic of the magnetic field detection payload, the magnetic interference of the UAV platform will affect the magnetic field detecting equipment during the aeromagnetic measurement process. Therefore, it is necessary to measure and analyze the magnetic characteristics of the UAV body before the flight mission. Noise is processed to obtain high quality magnetic field data.

3. UAV platform impact on aeromagnetic survey

Airborne geomagnetic measurements are also subject to a variety of factors such as small space, power supply interference, and space radiation. These disturbances will result in data errors in the on-board geomagnetic measurements and a decrease in the operational stability of the measuring device.

During the geomagnetic measurement process of the UAV, the detection magnetic field is affected by various interferences, mainly including the inherent error of the sensor, ferromagnetic interference, and dynamic interference. Among them, ferromagnetic interference is mainly composed of hard iron interference and soft iron interference. The project is selected in the zero-magnetic test facility. The UAV is not powered. By applying the zero field of the environment, the influence of soft magnetic interference is reduced, the magnetic moment is measured, and the magnetic level of the drone is evaluated.

The dynamic interference of drones is mainly motor dynamic interference, random noise interference, electromagnetic radiation interference of airborne electronic equipment, and electromagnetic radiation interference outside the machine. Among them, we mainly study the dynamic interference of motors. Due to the light weight requirements of drones, the body materials are mostly made of non-magnetic materials such as composite materials and carbon fibers. The motor is the main source of strong magnetic field interference. The dynamic interference mentioned mainly refers to geomagnetic measurement. The high frequency alternating magnetic interference generated by the motor during the process changes its amplitude and frequency as the operating state of the motor changes. The magnetic interference of the motor consists of two aspects, one is the high-frequency alternating magnetic field generated during the operation of the motor; the other is the magnetic field generated by the equivalent current in the motor equipment. During the operation of the motor, the current flowing through the motor becomes stronger as the speed increases. The steady current in the motor can be simplified to a DC current source, and the magnetic field interference generated is proportional to the current intensity of the equivalent current source.

The dynamic interference in this paper is mainly for DC motors. The magnetic noise signal of a DC motor from low speed to high speed is approximately linear, that is, the magnetic field changes approximately linearly. When the motor speed is at a constant value, the magnetic field disturbance generated is also a fixed value. Because there is a one-to-one correspondence between the current

intensity flowing through the motor and the motor speed, there is a one-to-one correspondence between the current intensity and the generated magnetic field interference. That is, the magnetic field noise is proportional to the equivalent current strength of the motor.

During the process of DC motor running from standstill to full speed, the magnetic interference generated by the equivalent current is more obvious than the ferromagnetic interference and the high frequency interference of the motor. The high frequency alternating magnetic field noise can be filtered using Kalman filtering.

Therefore, measuring the magnetic characteristics of the platform of the UAV itself is the premise basis for the future aeromagnetic measurement and magnetic interference noise reduction.

4. UAV zero magnetic characteristics test

4.1. Test Conditions

4.1.1 Commercial drone

This project selects a small four-rotor UAV of a certain brand, as shown in Figure 1. The drone is a widely used commercial drone. The weight of the whole machine is 1388g and the maximum flight time is 30min. It has the characteristics of small size, light weight, convenient retraction and stable flight. Its flight characteristics are shown in Table 1.

Table 1. UAV motion characteristics table.

	Sport Mode	Positioning Mode	Attitude Mode
Maximum Rising Speed	6 m/s	5 m/s	-
Maximum Falling Speed	4 m/s	3 m/s	-
Maximum Speed	72 km/h	50 km/h	58 km/h



Fig. 1. Small commercial UAV

4.1.2 Magnetic clean facilities

This project is carried out in the large magnetic simulation equipment CM2 of the Zero Magnetic Laboratory, as shown in Figure 2. During the static test, the magnetic moment test can be carried out by using the satellite and component magnetic test methods. During the dynamic test, the UAV is in flight state, which requires a relatively large and high magnetic cleanliness space environment. The environment satisfies the different flight states to test the changes in the magnetic field around the drone.

The coils of the Zero Magnetic Laboratory in CM2 are consist of many square coils of 16 meters' side length. The magnetic field simulation range is from -100000nT to +100000nT. It also has a uniform area of 2.5m in the sphere with no more than 5nT. It can meet the stability of high magnetic cleanliness during short-distance flight.



Fig. 2 CM2 magnetic clean facility of Zero Magnetic Laboratory

4.2. Test Items

The test process firstly generates a zero magnetic field environment in the magnetic field coil, and places the measured object in the central magnetic uniform region, then collects the magnetic field data of the measured object through the pre-arranged magnetometer and uploads the data to the upper position. The computer, through data processing and calculation, obtains the magnetic moment of the measured object. The test is divided into UAV static magnetic test and UAV dynamic flight magnetic test.

5. Results analysis and discussion

5.1. UAV static magnetic test

The environmental field is reduced to zero field condition by the CM2 device, the drone is placed at the center of the non-magnetic turntable, and the non-magnetic turntable is located at the center of the uniform area of the CM2. Three magnetic fluxgate magnetometer probes are arranged at equal intervals on the drone to test the magnetic field around the drone, as shown in Figure 3. When the drone is at rest, each electronic device does not work. The magnetic moment of the unmanned aerial vehicle was tested under the condition of power failure by using the aerospace general component magnetic test method and rotating the non-magnetic turntable.

The drone is connected to the controller, the controller is turned on, the motor is enabled, and the drone is powered. The non-magnetic turntable is rotated to test the magnetic moment of the UAV in the powered state. The magnetic moments of the drone under two conditions are shown in Table 2.

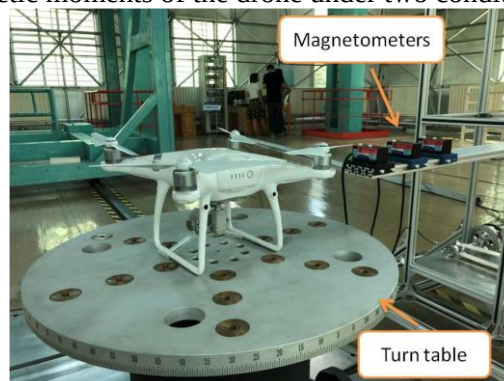


Fig. 3. UAV static magnetic test

Table 2. Two states of magnetic moment measurement results table

Magnetic moment	Power off	Power on
Mx	6 mAm ²	3 mAm ²
My	-4 mAm ²	2mAm ²
Mz	-4 mAm ²	0mAm ²
M	8 mAm ²	4mAm ²

The drone itself uses a variety of new materials, such as engineering plastics, carbon fiber materials, aluminum structural parts, etc. The application of these materials greatly reduces the weight of commercial drones, while supplying certain structural strength. In static test, it performances good at magnetic moment.

5.2. UAV dynamic flight magnetic test

In dynamic flight magnetic test of the drone, firstly, a zero-field environment is established in CM2, the drone is placed on the non-magnetic turntable at the center of the CM2 uniform zone. The test layout is shown in Fig. 4. The drone is started and hover a certain height from the table, the height position of the three magnetometers is adjusted to make the magnetometer parallel to the drone. Test the magnetic field around the drone. Under the dynamic hovering state of the drone, each electronic device works normally, and its dynamic magnetic field data at 1.2 m is obtained by a magnetometer.

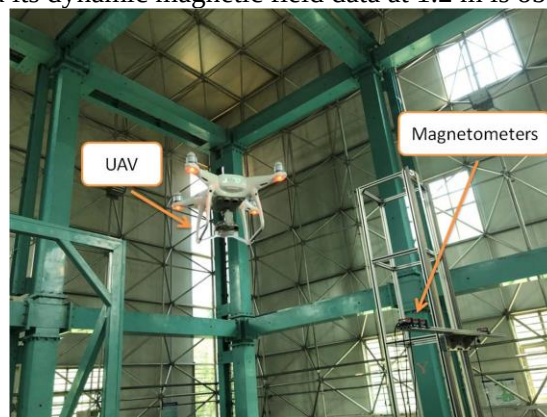


Fig. 4. UAV hover state in Zero Magnetic Laboratory Test



Fig. 5. UAV hover state position (1.2m far from the fluxgate magnetometers)

Table 3. Flight state magnetic field test results table.

Magnetic field measurement result	Magnetic field result at 1.2m from drone
Bx	-7.9nT
By	-26.7nT
Bz	15.1nT
B	31.7nT

6. Conclusions

Based on the development of small commercial drones and aeromagnetic surveys, this paper analyzes various interference factors of airborne geomagnetic measurements. The magnetic characteristics of a certain type of UAV are tested by testing in zero magnetic space. The small drone needs to increase

the distance between the magnetic detector and the aircraft body during the aeromagnetic measurement process to ensure the accuracy of the magnetic measurement. The test selects the magnetic field value at 1.2m in horizontal direction due to comprehensive magnetic moment and magnetic field test results. Considering the unmanned load capacity and overall structural strength, we can obtain aeromagnetic measurement extension length estimation of this type drone, which can be used as a commercial small-scale extension boom basis in future.

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