Schematic Design of FOG Magnetic Sensitivity Test System

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Abstract: Magnetic sensitivity is one of the research contents of environmental adaptability of fiber optic gyroscope (FOG). Based on the mechanism of the magnetic sensitivity of FOG, this paper sets forth the technical scheme of FOG magnetic sensitivity test system in detail, including completing the demands of measuring parameters such as the error coefficient of magnetic field, hardware scheme and software design. It is of great significance to act as a platform for the research on the magnetic sensitivity of FOG.

1. Introduction
Since fiber optic gyroscope (FOG) came out in 1976, it has become a research hotspot in the field of domestic inertial instrument in recent years. It features all solid-state structure without moving parts, large dynamic range, fast response speed, low power consumption, resistance to shock vibration, short start-up, long service life and others, which can be widely used in military and civilian fields[1]. The operating principles of FOG are based on the Sagnac effect of optical path. Its sensing element is a fiber optic ring. The fiber optic ring is not only sensitive to the nonreciprocal phase shift generated by Sagnac effect but also sensitive to a variety of physical quantities. Therefore, the external environment is easy to produce a variety of nonreciprocal errors in gyroscope. This error is superimposed on the Sagnac effect of the FOG, which will lead to the variation of the output bias of the FOG[2-4].

In the practical application of FOG, magnetic field is an inevitable interference source. Hence, the study of FOG magnetic sensitivity is of great significance to its environmental adaptability in practical application. In order to further study the magnetic sensitivity of FOG, this paper proposes the development of FOG magnetic sensitivity testing platform.

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2. FOG magnetic sensitivity testing method

The magnetic sensitivity of FOG is mainly manifested as the change of the zero deviation of FOG with the magnetic field intensity, and its size can be expressed by the ratio of zero deviation change to magnetic field intensity - the magnetic field error coefficient (Km). To reduce the influence of non-magnetic field factors on the evaluation results, the following methods are used to detect and evaluate the magnetic sensitivity of FOG.

(1) Place the FOG in the center of a three-dimensional Helmholtz coil (with good magnetic field uniformity) to make the sensitive axis of FOG consistent with one magnetic field direction; and then make corresponding marks on the gyroscope according to the other two magnetic field directions;

(2) Measure the zero deviation of FOG under 0Gs (or constant value) magnetic field conditions and stable temperature environment;

(3) Use magnetic field generator to generate a static magnetic field in X-axis direction; then set the magnetic field intensity as Bx(m) in turn and get a group of zero-deviation data Box(m) of FOG under different magnetic field intensities.

(4) According to the method mentioned in (3), measure the magnetic field of y and z axis and the FOG zero-deviation data Boy (m) and Boz (m) respectively.

Data processing methods are as follows:

(1) Data fitting method is adopted to linearly fit the zero-deviation data of FOG under the magnetic field conditions in directions of x, y and z axis respectively, and to determine the sensitivity coefficients Kx, Ky and Kz of the zero-deviation of gyroscope in the direction of x, y and z axis.

Determine Kx, Ky and Kz with least square method.

\[
K_x = \frac{\sum_{i=1}^{m} B_x(i) \times B_{0x}(i) - \frac{1}{m} \sum_{i=1}^{m} B_x(i) \times \sum_{j=1}^{m} B_{0x}(i)}{\left(\sum_{i=1}^{m} B_x(i)^2 - \frac{1}{m} \left(\sum_{j=1}^{m} B_x(i)\right)^2\right)^{\frac{1}{2}}}
\]

\[
K_y = \frac{\sum_{i=1}^{m} B_y(i) \times B_{0y}(i) - \frac{1}{m} \sum_{i=1}^{m} B_y(i) \times \sum_{j=1}^{m} B_{0y}(i)}{\left(\sum_{i=1}^{m} B_y(i)^2 - \frac{1}{m} \left(\sum_{j=1}^{m} B_y(i)\right)^2\right)^{\frac{1}{2}}}
\]

\[
K_z = \frac{\sum_{i=1}^{m} B_z(i) \times B_{0z}(i) - \frac{1}{m} \sum_{i=1}^{m} B_z(i) \times \sum_{j=1}^{m} B_{0z}(i)}{\left(\sum_{i=1}^{m} B_z(i)^2 - \frac{1}{m} \left(\sum_{j=1}^{m} B_z(i)\right)^2\right)^{\frac{1}{2}}}
\]

(2) According to vector synthesis law, calculate the error coefficient (Km) of FOG magnetic field and the direction angle \(\theta_x\), \(\theta_y\) and \(\theta_z\) of the magnetically sensitive axis.

\[
K_m = \sqrt{K_x^2 + K_y^2 + K_z^2}
\]
\[
\cos \theta_x = \frac{K_x}{K_m}, \cos \theta_y = \frac{K_y}{K_m}, \cos \theta_z = \frac{K_z}{K_m}
\]

In addition to obtaining parameters such as magnetic field error coefficient (Km), the test system also needs to achieve the following functions:

1. In the standard magnetic field space (200mm×200mm×200mm), the test environment of uniform magnetic field, low frequency alternating magnetic field and controllable magnetic field intensity in any direction in the space are provided to realize the test of FOG magnetic sensitivity under static uniform magnetic field or low frequency alternating magnetic field (Hz);

2. FOG test platform is equipped with vibration isolation and horizontal adjustment functions to avoid the influence of external environment such as vibration on the FOG test precision and to reduce the influence of FOG misalignment angle on gyroscope parameters;

3. Testing environment and process are controllable, and real-time FOG data collection and data processing can be completed. Relevant test technical documents can be generated to achieve the goal of standardization and automation of testing.

3. Test system hardware scheme

Aiming at the functional requirements of test system, FOG magnetic sensitivity test system adopts an overall technical scheme as shown in Figure 1. The hardware of test system consists of three parts: magnetic field environment generator, gyroscope tester and measurement & control system.

![Figure 1 Overall Scheme](image)

The magnetic field environment generator is designed to provide a stable three-dimensional uniform magnetic field environment, consisting of three sets of orthogonal Helmholtz coils, three sets of DC & stabilized current and a coil table. FOG tester provides a standard working environment for FOG testing, including vibration isolator and test specimen bench.
The measurement & control system is the control center of FOG magnetic sensitivity test system, which mainly completes the detection, calibration and control functions of the test environment, completes the collection of FOG output data and provides the working power for the gyroscope. The control system is composed of gyroscope interface unit, gyroscope power supply unit, measurement & control computer and DC & stabilized power supply. The gyroscope interface unit is used to complete the adjustment of gyroscope signals, the collection and arrangement of gyroscope data and transfer the processed data to the measurement & control computer through the communication interface, so as to ensure the accuracy and reliability of the test data. The gyroscope power supply unit is used to provide the gyroscope with power. The measurement & control computer adopts the integrated industrial workstation to realize the functions of test flow control, gyroscope data processing, the detection and control of test environment parameter, etc.

4. Test system software design

The test software mainly realizes the real-time monitoring of test environment (three-dimensional magnetic field intensity and direction), and completes the data collection, data processing, analysis and management of FOG. Test control software adopts Windows XP software platform and takes Labwindows CVI as development platform to utilize the virtual instrument technology and software reuse technology to realize the real-time monitoring of test environment (3-dimensional magnetic field strength and direction), complete FOG data acquisition, data processing and analysis and test data management, and realize the test of FOG magnetic sensibility.

Measurement & control system software consists of ten modules including "master control module", "test process set module", "data acquisition module", "data processing module", "data management module", "report generation and printing module", "data interface module", "coil power control module" and "system setting module". Through the organic integration of modules, different test functions and test environments are constructed to meet different test functions. See test software control structure in Figure 2 and software flow in Figure 3.
For different application demands, the software system sets two kinds of working modes - automatic test mode and manual test mode. Automatic test mode means that the measurement & control computer completes the automatic test function for the whole process of magnetic field environment control, gyroscope data acquisition and data processing according to the pre-set process.
requirements. This method is mainly used to evaluate the magnetic sensitivity of gyroscope. Manual test mode refers to the method of manually changing the features of external magnetic field (strength and direction) is used to complete the collection and data processing of gyroscope data during the test. This mode is mainly used for the analysis experiment of FOG magnetic sensitivity.

5. Conclusions

The FOG magnetic sensitivity test system designed in this paper is feasible for application. It can meet the functional demands of parameter measurement, magnetic field provision, vibration isolation adjustment and test control and has a high cost performance. The realization method of this platform is of reference significance, and the prototype has already been developed.

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