Design of Fiber Optic Gyro Inertial Measurement System with High Vibration Resistance

Dong-sheng YANG

Aviation Maintenance NCO Academy of Air Force Engineering University, Xinyang, Henan Province, China, 464000

Keywords: FOG, Inertial measurement system, Quartz accelerometer.

Abstract. Because the inertial measurement system based on traditional inertial device cannot meet the requirements of the new tactical weapons, this paper demonstrates an inertial measurement system using full digital fiber optic gyro, impact resistant quartz accelerometer and ontology thin-walled reinforced metal alloy structure. It can be able to withstand severe shock, vibration and other mechanical environmental conditions and maintain a good accuracy, a long-term stability, improve the comprehensive performance of the inertial measurement system.

Introduction

Inertial measurement system is the realization of a missile, rocket and other vehicle guidance and stability control of key sensitive measuring equipment and benchmark information source, can be set benchmark coordinate system for the aircraft during flight, sensitive to the movement of the angular velocity and acceleration, accurate measuring posture, such as position, velocity, and high speed output data through the interface, at the same time as the inertial guidance and attitude control system to provide the measurement information, in order to realize stable flight, hit the target. New tactical weapons not only requires rapid response, mobile penetration and precision strike capability, also require miniaturization, multi-function, maintain high reliability in harsh environmental conditions, to adapt to the strong vibration, big impact and overload, and maintain long-term, stable performance and high life, able to keep stable performance under long-term storage conditions, the inertial measurement system of high demands are put forward.

Inertial measurement system based on traditional inertial components often with imu, structure and accelerating rate gyroscope power system separation methods such as it is difficult to realize miniaturization, because there are a high speed rotor, mechanical inertial instrument itself ant-vibration performance is poor, external connection depends on the shock absorber can adapt to play on the bad mechanical environment request, this needs in service during test, calibration and maintenance for many times, long-term stability can't guarantee anything, but later period maintenance cost is high, the above analysis shows that the inertial measurement system based on traditional inertial device cannot meet the requirements of the new tactical weapons.

Fiber optic gyro is a new type of solid-state inertial instrument based on the Sagnac effect, has small volume, light weight, high reliability, resistance to vibration and impact, as well as good mechanical environment characteristics, and optical fiber gyro inertial measurement system for its excellent performance as the key support of the new guidance and control system is being developed at home and abroad of new and high technology.

The size of the fiber optic gyroscope developed in the initial stage is large, and the inner optical path of the fiber optic gyroscope and the fiber optic ring are not cured and packaged. Although some of them are cured, the traditional curing methods and materials cannot match the new material of fiber optic, so the anti-vibration and other performance indexes of the fiber optic gyroscope are not high.

Existing accelerometers have poor impact resistance. When the accelerometer is subjected to a large impact along the direction of the output axis, the quartz flexible pendulum plate will be greatly deformed. Once the stress on the flexible beam is greater than the strength of the material, the flexible beam will fail.

Ontology structure provide only part of the installation of the instrument design, circuit part and ontology part respectively installed on a base, big volume, weight, and the system of shock absorbers must be used foreign connection, only low to meet the demand of the mechanical environment condition, can't meet play (arrow) in the launch, flight and reentry phase in the process of strong vibration, big impact and overload.

Inertial Measurement System Design of Fiber Optic Gyro

The inertial measurement system of fiber-optic gyroscope with high anti-vibration performance mainly includes three fiber-optic gyroscopes, three quartz accelerometers, and the structure of the body, etc. Three fiber-optic gyroscopes with orthogonal placement are used to complete the angular velocity measurement of three axes in the coordinate system of the measured body, and three fiber-optic gyroscopes adopt all-solid digital closed-loop fiber-optic gyroscopes.

Three quartz accelerometers are placed orthogonal to complete the acceleration measurement of three axes in the coordinate system of the measured body. The three quartz accelerometers adopt shock resistant quartz accelerometers.

All Digital Closed-Loop Fiber Optic Gyroscope

All-solid digital closed-loop FOG is composed of optical path part and circuit part, as shown in figure 1.

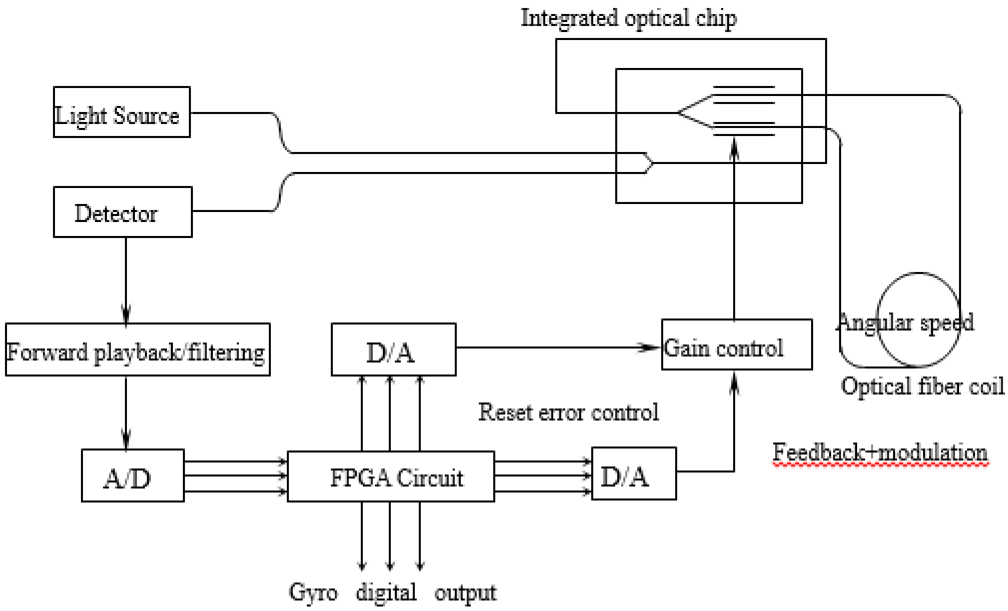

Figure 1. All-digital closed-loop FOG design

Part of the light path is broadband light source, optical fiber coupler, photoelectric detector, multi-function integrated optical chips, and fiber optic ring, from broadband light source the light, the fiber coupler and multifunction integrated optical chip is divided into two beams, respectively according to clockwise and reverse time direction along the fiber optic ring transmission, and the multifunction integrated optical chip Y branch of the light spot on the phase difference, intervene with multifunction integrated optical chip for 3 phase modulator the phase modulation after fiber coupler when returning to the photoelectric detector.

Part by preamplifier and filter circuit, A/D conversion, the FPGA logic circuit, digital signal of the FPGA logic circuit to produce analog-to-digital conversion of D/A converter and the reset digital compensation signals generated by the FPGA logic circuit of D/A conversion of D/A converter and gain control circuit, amplifier filtering circuit of the photoelectric detector output signal with preamplifier and gating filtering, and through the A/D converter to convert the modulus, into the FPGA logic circuit for processing to the digital quantity, and storage of gyro output signal. At the same time, the superposition sum of the generated square wave modulation signal and digital phase step wave feedback signal is converted by D/A and input into the gain controller. After the gain amplitude is adjusted by the gain control, the sum of square wave modulation signal and digital phase step wave feedback signal is added to the arm of the multifunctional integrated optical chip.

Impact Quartz Accelerometer

The impact resistant quartz accelerometer is composed of upper torque, lower torquer and quartz glass pendulum with coils. Quartz glass set piece including the bearing ring, the flexible beam, place, six on both sides of the bearing and limit convex sets, convex outer bearing ring is located at the place and, for round rings, bearing ring on both sides of a total of six supporting convex sets, and with two limit convex sets, in the middle of the quartz pendulum piece for a half-circle, set by two square thin flexible beam are connected to the bearing ring, the place has a certain gap between bearing ring, two limit in supporting ring and put the clearance between the convex.

The maximum stress of the accelerometer flexible beam is calculated under the action of 250g output axis acceleration. Due to the protection of the limit structure, the maximum stress of the flexible beam is limited to 3.898×10^{7}Pa, which is less than the tensile strength 5×10^{7}Pa Pa of quartz glass, and the flexible beam will not be damaged. The test results show that the impact resistant quartz flexible accelerometer can withstand the half sine drop impact of 250g, which provides a basic guarantee for the vibration resistance of the inertial measurement system.

Ontology Structure

The body structure is used to install the above components. It adopts thin-walled reinforced aluminum alloy or magnesium alloy metal alloy or aluminum matrix composite material, etc., to ensure the three-axis orthogonality of the sensitive axis of FOG and accelerometer, provide electromagnetic shielding and vibration reduction function, and ensure the required stiffness.

The connection datum and connection hole with the measured body are provided, and the external connection of the whole inertial measurement system can meet the requirements of harsh mechanical environment without shock absorber.

Through the above measures, the anti-vibration impact ability of FOG is greatly improved, reaching the order of magnitude of 100g in impact test, 55g in overload test, 10hz ~ 200hz /8g sinusoidal scanning vibration, maintaining the accuracy under vibration conditions, no resonance in 2000Hz and other excellent anti-vibration performance. Figure 2 shows the output curve of fiber optic gyroscope inertial measurement system in sinusoidal scan vibration test. Figure 3 shows the typical output curve of the accelerometer before, during and after the random vibration test.

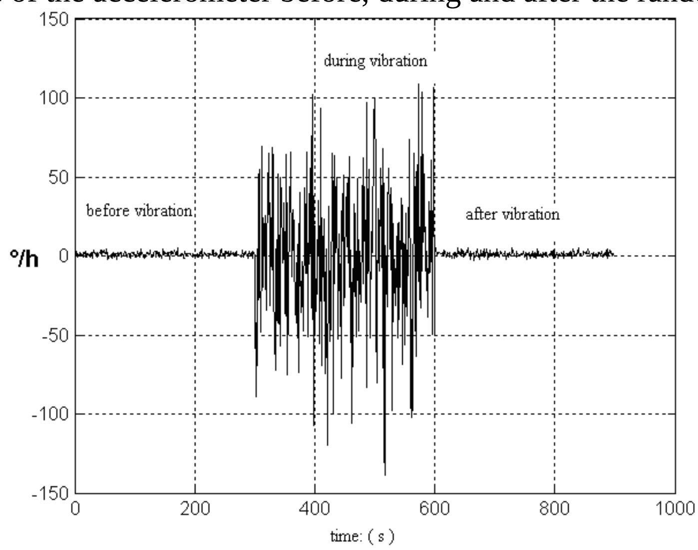

Figure 2. FOG inertial measurement system output curve in random vibration

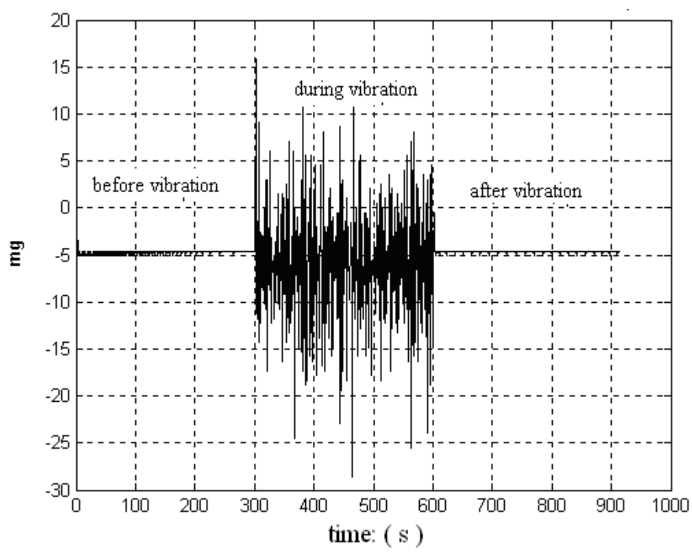

Figure 3. Output curve of the accelerometer in random vibration

Conclusion

Due to adopt all solid state digital closed-loop fiber optic gyroscope, impact resistant quartz flexible accelerometer and ontology thin-walled reinforced metal alloy structure, which make the measuring device external connection under the condition of no vibration, able to withstand severe shock, vibration and other mechanical environmental conditions and maintain a good accuracy, but also make the inertial measurement system maintain the long-term stability of the installation accuracy, improve the comprehensive performance of the inertial measurement system.

References

[1] Udd E, MICHAL RL J, et al. Scale Factor Correction in the phase Nulling Optical Gyro, SPIE,1982:136.

[2] Mark J G et al. Random overmodulation for Fiber Optic Gyros.

[3] Lefevre H C et al. High Dynamic Range Fiber Gyro with All-Digital signal Processing, SPIE, 1990,1367:72-80.

[4] Arditty H J. et al. Fiber-Optic Gyroscope with All-Digital Closed-Loop Processing, Proceedings of OFS6’89, Springer-Verlag,1989:131-136.

[5] Moeller RP et al. Electronics Letters, 1983,19(5):187.

[6] Lefevre H C et al. Lastest Advances in Fiber-Optic Gyroscope Technology at Photonetics, SPIE 1994,2294:156-165.

[7] Spahlinger G, et al. Error Compensation Via Signal Correlation in High precision Closed-Loop Fiber Optic Gyros, SPIE,1996:218-227.

[8] Sanders G A et al. Fiber Optic Gyros for Space, Marine and Aviation Application, SPIE, 1996,2837:61-71.

[9] Digonnet M J F. Theory of Superfluorescent Fiber Lasers. J.Lightwave.Tech.1996, LT-4:1631-1639.

[10] Desurvire E, Erbium-Doped Fiber Amplifiers: Principle and Applications, New York, Willey, 1994.

[11] Wyscocki P F, Digonnet M J F. Board-Spectrum Wavelength Swept Erbium-Doped Fiber Laser at 1.55μm. Opt.Lett, 1990,15:879-881.