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The Intelligent Storage Recording System Based On Cluster Bombs Testing and The Data Analysis

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Abstract: According to the bullet of cluster bombs in the separated Rotate- speed, dispensing overload, parachute-opening overload, landing overload and other parameters testing background, this paper designs a intelligent storage recording system which selects a the thin film geomagnetic sensor and photoelectric accelerometer as the sensitive unit, the intelligent storage recording system is mainly composed of the FPGA controller, FLASH memory, 12 bit high speed analog to digital converter. After live-fire test and numerical analysis, intelligent storage recording system can accurately obtain the whole process of flight parameter data from scatters to fall to the ground.

Keywords: Cluster bombs, the thin film geomagnetic sensor, intelligent storage recording system, numerical analysis.

1. INTRODUCTION

The development of the future war is gradually towards the direction of the localization and miniaturization, the highly cost - effective, flexibility and the high universality of the cluster bombs attract the attention from various countries in the world [1]. The cluster bombs of the armed helicopter is lately miniaturized air-to-ground cluster bombs model, a bomb can be equipped with 10 to 20 bullets, when compared to the traditional air -to -ground cluster bombs of the armed helicopter, it can from stronger suppressive fire and depth assault firepower, in order to interplay the enemy's armored vehicles, tanks effectives and other important military targets more efficiently. The process from detonating the cluster bombs of the armed helicopter to hit the target is very complicated, which includes dispersion ballistic open, dispensing, parachute-opening, flying and other stages. In the development stage, the designers are urgently in need of the accurate parameter information of the different flying stages of the bullets, including bullet of cluster bombs in the separated Rotate- speed, dispensing overload, parachute-opening overload, landing overload and other parameters of the bullet, in order to test whether the operation of the throwing the cluster bombs is normal or meet the reasonable distribution density and the spread range or not and so on.

This paper designs a dynamic storage measurement technology of the flying parameters of the cluster bombs, the system uses the piezoelectric accelerometer and the thin film geomagnetic sensor as the sensory unit to test the whole ballistic accelerated speed and Rotate- speed parameters of the bullet of the cluster bombs.

2. THE THIN FILM GEOMAGNETIC SENSOR

The advanced thin film technology is used to make the thin film geomagnetic sensor, thus the flexible thin multistory film coils. The principle of the design is based on the Faraday's law of electromagnetic induction, the operation principle is n turns coil closed circuit incises the magnetic force line of the earth magnetic field, it will bring about the induction electromotive, the thin film geomagnetic sensor can be fixed on the surface of the testing device flexibly, when the thin film geomagnetic sensor flies by the rotary movements with the bullets and other carriers, because of the effect of cutting the magnetic lines, the sensor produces the induction electromotive force, the induction electromotive force includes the angle signal between the direction of magnetic field vector and bullets, the change of the induction electromotive force can reflect the condition of the bullet rotary, in fact, the periodicity of the induction electromotive force represent the rotational speed of the bullet [2].

The advantages of the thin film geomagnetic sensor:

1. The structure of the thin film geomagnetic sensor is simple and its size is small. Besides, it can also resist the high over-load and beating, the signal detection circuit has high sensitivity, working stability, reliability and high performance cost ratio [3];
2. The thin film geomagnetic sensor do not accumulate errors as the flying time goes, it also has nothing to do with the movement state of the aircraft, however, it is related to the intensity of the geomagnetic field [4]. The induction electromotive force produced by the coil installed in the aircraft motioning around earth's magnetic field relatively:

$$E = \frac{d\varphi}{dt} = N \cdot A \cdot \mu \cdot H \cdot \frac{d}{dt}\cos\theta = N \cdot A \cdot \mu \cdot H \cdot \sin\theta \cdot \frac{d\theta}{dt} \quad (1)$$

In the formula (1), $\frac{d\theta}{dt}$ is the angular speed of the coil rotate ϖ .Therefore the formula above can change into

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$$E = N \cdot A \cdot \mu \cdot H \cdot \sin \varpi t \cdot \varpi \quad (2)$$

φ --- the magnetic flux ;

A --- the area of the coil ;

H --- the magnetic field ;

N --- the number of turns ;

t --- time ;

μ --- the magnetic permeability of the coil core ;

θ --- the angle between the normal of coil and magnetic field line ;

ϖt --- the angle variation between geomagnetic field direction and the total normal direction of the coil ;

ϖ --- the palstance of the varying angle between geomagnetic field direction and the total normal direction.

The induction electromotive force includes the angular speed information of the bullet motion, especially when the ϖ is constant value, the output induction electromotive force of the coil is sine wave, the angular frequency of the sine wave is the angular speed of the bullet at certain direction [5]. The periodicity of the sine wave is the time which the bullet spins once, thus the rotation rate of the bullet. By extracting the value through zero, wave peak, the trough value and other characteristics, and calculate the time gap between them, the rotation rate can be got. In order to eliminate the errors, we can select many sine waves on average, the average can be regarded as the rotation rate at the middle time of the whole period [6].

3. THE FORM AND PRINCIPLES OF THE DYNAMIC STORAGE MEASUREMENT SYSTEM

Before loading, the measurement system should have strict counterweight to make sure the consistent of the quality between bombs and center-of-mass, and also make sure the posture of the thrown bullet will not be affected. The measurement system have the characteristics of the small volume, better ability against the dash and losing electricity without losing data, meanwhile the system can charge, low consumption, easy to operate and use, and other advantages. It is suitable for the high impact measurement in harsh environment [7].

3.1. The form and the function of the measurement system

The whole measurement system is consist of four parts:

a. the part of the sensor: according to the range and precision of the technical indicators, unidirectional overload senor select the domestic piezoelectric sensor CA-YD-140, the measurement range of the accelerated speed is ±5000g, resist overload is 50,000g ; the non-linear is ≤1%FR. The geomagnetic magnetic sensor select the thin film geomagnetic sensor made by ourselves, it uses the weak magnetic field of the earth to measure the rotating angular velocity. When the magnetic sensor installed in the measurement bullets go with the bullets, cutting the magnetic lines, the produced induction electromotive force includes the angle signal between the bullet and magnetic field vector direction, therefore the rotating speed can be got.

b. The part of storage measurement: Its function is mainly to amplify, wave filtering, the output electric signal of the sensor, ADC, as well as the storage of digital value orderly, its function of the output electric signal of the sensor A/D converter selects the 12bit high speed, low power consumption, successive approximation A/D, the highest conversion rate is 1.5MSPS, resolution 12bit. The memory selects the low power consumption FLASH RAM which produced by the ATMEL company, the volume is 2M, the word length is 16bit. The sampling frequency of the measurement system is: 25kHz/channel, the record capacity is: 2M Word FPGA is the core control chip of the measurement system. It is not only in charge of conversion of the system analog , the read and write timing of memory, but also can receive the instruction from the signal to complete the trigger level, negative delay length, sample length, sampling frequency of the programming setting of the measurement system.

c. The part of the interface and the reading: its function is to read the recorded data of the measurement system into the computer, in order to deal with the measurement data. The system selects the FT245RL chip produced by the FTDI company as the interface chip of the USB, which meet the requirements of USB1.1, thus powerful function, quick transmission speed , small volume, easy to interface with the microprocessor and other characteristics, which can perfectly fit in the interface design embedding it in the storage measurement system. The main function of the FT245RL is to achieve the bidirectional conversion of USB serial data format and parallel data format under the internal hardware logic control, the PC machine can transmit data from the USB communication interface to FT245RL, and the FT245RL communicate with the microcontroller through the parallel mode.

d. The part of the data treatment: its function is to convert the recorded numbers to measured physical quantity, the software system consists of the reading data, scaling value read, waveform printing, flash erases and other functions.

3.2. The Procedure of the System Work

The accelerated speed and geomagnetic signal are amplified and filter processing through the signal adjust circuit, then enters the A/D converter and converted to the digital signal, after that it is stored in FLSAH memory, the computer communicates with the system by the interface circuit, the data stored in the FLSAH memory can be read, thus completing a sampling test. The electricity of the whole system is in charge of the power supply to the whole system,

meanwhile completes the mode setting of system on-power, down-power and power-saving; The time program controller of FPGA provides A/D converter, FLASH memory and Address generator, interface circuit and so on with needing all timing and control signals Fig. (**1**) [8].

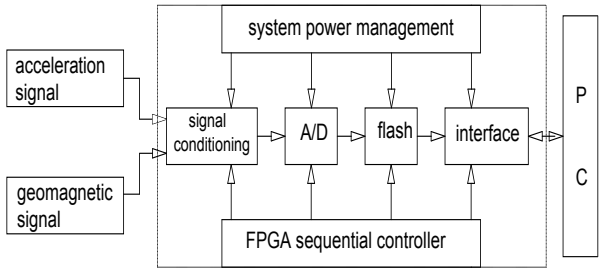

Fig. (1). The principle framework of the test system.

3.3. The Working Principle of the System Data Storage

The working principle of the data storage: system collected elements select the analog-digital converters called AD7492, the memory adopts the method of combination of the flash and static memory, before the trigger time comes, the digital signal which A/D finishes the converting, it remains circular cycling in the static memory, its aim is to complete the function of negative delay records the signals before trigger point. The data after triggering write in the flash memory: At first, the type of the writing write the data of some addresses in the static memory into the flash memory, then write the new data into the new dress. The structure of the data storage is as the Fig. (**2**).

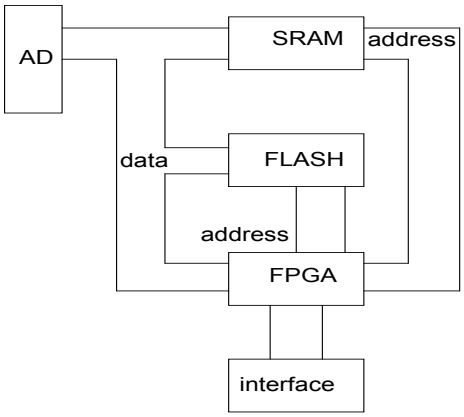

Fig. (2). The data storage structure of the test system.

4. ACTUAL MEASUREMENT CURVE

The cluster bomb in the experiments carry 15 bullets for one time, among them we select three different angles to install the dynamic testing system of cluster bombs flight parameters, the experiments are conducted for many times, all the measurement systems get complete data. Figs. (**3-5**) are all the curves got from a set of the measurement system, thus the curve of bullet dispensing accelerated speed, the curve of the bullet parachute-opening accelerated speed, the curve of the bullet landing accelerated speed and the curve of the bullet rotation speed.

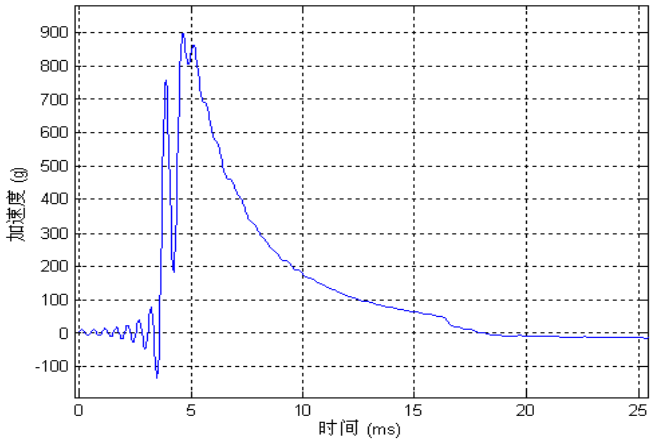

Fig. (3). The curve of bullet dispensing accelerated speed.

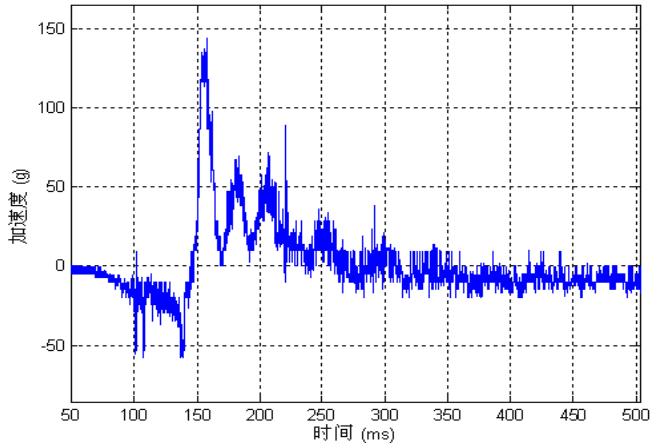

Fig. (4). The curve of the bullet parachute-opening accelerated speed.

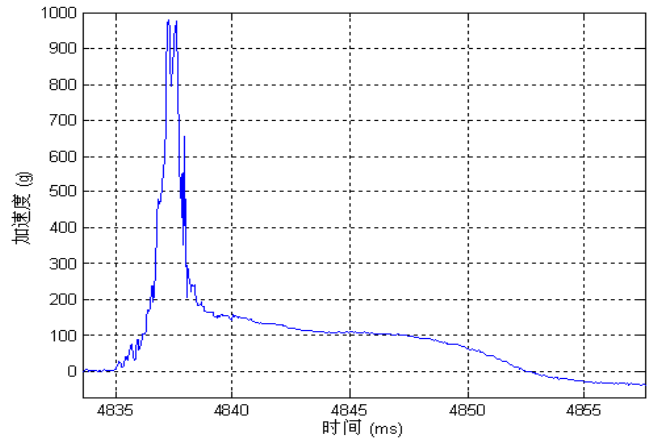

Fig. (5). The curve of the bullet landing accelerated speed.

Through the actual measurement curve the result is the peak value of the dispensing accelerated speed after wave filtering is 900g, the pulse width is 17ms, the peak value of the bullet parachute-opening accelerated speed is130g, the peak value of the bullet landing accelerated speed is 980g, the time from shooting to the dispensing is T1= 15.25s, the time from the end of the dispensing to parachute-opening is T2=94.16ms, and the time from the end of the parachute-opening to landing is T3=4.75s.

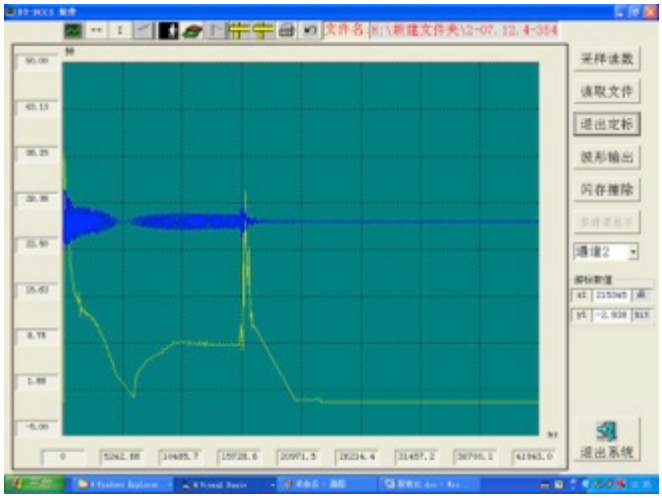

Fig. (6). The curve of the bullet rotation speed.

According to the testing principles, the duration of a sine wave is the same as the time which the bullet turning a circle takes, thus the rotation speed of the bullet. The crossing zero value, peak value and the trough value is the feature points of the sine wave, if they can be picked up, and got the time gap between them by calculation, the rotation speed of the bullet can be got. This method is to get the average angular speed of the characteristics neighboring, which calculates roughly. To get the angular speed during the time from the first crossing zero point t1 to the neighboring peak value T, because the angular speed testing curve of the bullet is cosine curve, the bullets is equivalent to rotate 90 degrees from t1 to T. Therefore, the average angular speed during this period is:

$$\varpi = 1000 \times 90 / (T - t_1) \text{ degree/second}$$

The average angular speed at each successive characteristics period can be got, then the MATLAB the data analysis software can be used to the curve fitting of the worked out data of each average angular speed, in this way the curve fitting can reflect the angular speed changing rules approximately during the whole fight time.

In the Fig. (**6**), curve 1is the output signal of the thin film geomagnetic sensor, curve2 is the curve of the bullet rotation speed after calculation, In the curve 2, we can get to know that the fastest rotation speed of the shooting the bullets flash is 36.72 r/s, the bullet stops the rotation and starts to rollback until it lands after the 6.5 seconds when the bullets shoot.

CONCLUSION

The paper analyses the working principle of the thin film geomagnetic sensor, focus on the design of the dynamic testing system of cluster bombs flight system which is based on the thin film geomagnetic sensor. This system has already put into practice, through analysis the actual measurement data, the expected result can be got. The thin film geomagnetic sensor can reflect the rotation speed of the bullets of the cluster bombs accurately. The thin film coil sensor has been already put into live ammunition measurement; the ideal measurement result has got to give accurate scientific basis for the design type of the cluster bombs.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

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Declared none.

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