Research on Precise Control Technology of Explosion Point Based on Ballistics

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Abstract. According to the characteristics of small caliber grenade, this paper establishes its internal and external ballistic model, and studies the characteristics and basic rules of internal and external ballistic of grenade. The key factors affecting the accuracy of the distance model are analyzed, and the techniques and methods for determining the parameters of the distance model are studied. The measuring system and wireless setting system for the precise control of small caliber grenade blast point are designed. The theoretical method of controlling the blast point of projectile by DSP chip and improving the accuracy of distance determination is described. Finally, a wireless setting system is constructed based on related theories and sensors.

1. Introduction

Wireless setting refers to the technology that sets various data affecting ballistic factors into the fuze through wireless transmission in order to make the projectile hit the target. In modern warfare, the requirements for fuze functions are becoming more and more complicated. Traditional mechanical fuzes can no longer meet the requirements in terms of precise timing explosion, precise fixed-range explosion, and safety and stability. Electronic fuzes are less affected by mechanics, have high reliability, and achieve a miniaturized design while ensuring functions, so they are widely used. In order to give full play to the advantages of electronic fuzes and adapt to the high-precision and rapid response requirements of modern warfare, wireless setting technology came into being.

Trajectory is the trajectory of the motion of the projectile or other launching body. Ballistics is a discipline that studies the motion of various projectiles or other projectiles from the beginning to the end of the launch and the associated phenomena. The ignition and combustion of the projectile charge, the effect of high temperature and high pressure gas on the projectile, the air movement of the projectile or other projectile, the effect on the target, and various accompanying phenomena are the contents of ballistics research [1].

Projectile setting means that the target data such as projectile’s initial velocity, target distance, firing angle, temperature, humidity, air pressure, and other information affecting ballistic factors are sent to the electronic fuze within a period of time after the projectile is launched [2]. The wireless setting is essentially to accurately control the predetermined conditions such as the time, mode and technical parameters of the fuze, such as the need to delay the explosion, count the explosion, etc., in order to achieve greater lethality on the target.
2. Methods and Materials

2.1. Ballistics model establishment and simulation

The overall plan was designed by analyzing the characteristics of the internal space structure, storage life, and internal and external ballistic bearing capacity of the 35mm grenade fuze. By selecting reasonable sensors, components, power supplies and packaging methods, it has high impact resistance and overload resistance, which can meet the miniaturization requirements of 35mm grenade weapon fuze.

In order to enable the data measured by the acceleration sensor to be directly used for displacement calculation, it is necessary to conduct a bottom-up test on the ballistic performance. The establishment of the ballistic equation needs to eliminate the influence of the angle of attack on the data collected by the acceleration sensor, and obtain the full ballistic flight data of the projectile at different firing angles. The whole ballistic flight data is used to further modify the projectile mass point ballistic model so that it can more accurately describe the actual flight trajectory characteristics of the projectile.

The speed direction of the projectile in flight does not completely coincide with the direction of the projectile axis, that is, there is an angle between the two, which is called the projectile flight angle of attack [4]. The projectile acceleration obtained by the MEMS accelerometer is the axial acceleration data of the projectile, and it is difficult to obtain a more accurate value for the actual tangential acceleration of the projectile. Through Simulink simulation, the variation of the angle of attack at different firing angles can be obtained.

Through simulation, it can be known that the angle between the projectile axis and the velocity direction is very small at different firing angles, so the acceleration obtained in the axial direction can be directly used for quadratic integration to obtain the projectile displacement[5,6]. According to the six-degree-of-freedom rigid external ballistic model, the actual horizontal distance of the projectile can be calculated by using the relationship between the arc length of the trajectory and the inclination angle \( \theta \) of the projectile measured by the acceleration sensor.

In addition to the quadratic integration of the acceleration, the ballistic arc length model also needs to be modified according to the wind speed, air pressure, temperature and humidity and other data into the ballistic center-of-mass motion equation set in the time coordinate system. The modified trajectory design is mainly to improve the consistency of the change law of the trajectory characteristics of different projectiles under the same shooting conditions and meteorological conditions, and to improve the accuracy of the ballistic model's description of the projectile's flight status. Correcting the trajectory can provide an important guarantee for improving the accuracy of the distance.

The optimization design of interior ballistics is mainly to reduce projectile diameter tolerance, belt size tolerance, and charge weight tolerance. The optimized design of internal ballistics can further improve the consistency of the projectile’s initial velocity with a fixed-range fuze under the condition that the maximum pressure in the chamber is not greater than the minimum initial velocity of the projectile. The external trajectory is mainly based on the mass point ballistic equation to correct and solve the trajectory.

\[
\begin{align*}
\frac{dx}{dt} &= v_x, \\
\frac{dy}{dt} &= v_y, \\
\frac{dz}{dt} &= v_z, \\
\frac{dp_x}{dt} &= -p_x, \\
\frac{dm}{dt} &= F_x / \rho_0.
\end{align*}
\]
In the above formula:

\[ h(y) = \rho / \rho_\infty \]

\[ \rho = \frac{\rho}{R_\tau} \]

\[ v = \sqrt{v_x^2 + v_y^2 + v_z^2} \]

\[ c_v = \sqrt{kR_\tau} \]

\[ \Omega = 7.292 \times 10^{-5} \text{ rad} / s \]

According to the above algorithm in the projectile fuze with DSP as the core and combined with the corresponding sensor the final design of missile muzzle velocity measurement system. The system can accurately measure muzzle muzzle velocity, thus effectively improving the accuracy of distance determination.

2.2. System sensor selection

In the fuze system, the information acquisition device needs to measure the physical quantities that affect the ballistic factors, such as wind speed, air pressure, temperature and humidity, etc. It also needs to transmit information such as the firing angle and target distance [7]. The wind speed measurement uses a wind sensor shown in Figure1, which is composed of a small DC brush motor and a three-cup rotating wind speed cup.

![Figure1. Wind speed sensor.](image)

The air pressure sensor (which is shown in Figure2) is an instrument used to measure the absolute pressure of gas. Inside it is a piezoresistive atmospheric pressure sensing element, that is, a thin film that is sensitive to air pressure and a thimble. It is connected to a flexible resistor in the circuit. When the pressure of the gas to be measured decreases or increases, the membrane deforms to drive the thimble, and at the same time the resistance of the resistor will change.

![Figure2. Air pressure sensor.](image)

Acceleration sensors are used to measure the velocity of the projectile. Modern acceleration sensors all use micromechanical structure, as shown in Figure3. The interior of the acceleration sensor is crossed by two comb-like electrodes. When the acceleration changes, the velocity acceleration can be detected by charging and discharging between the charges [8,9].
2.3. Wireless setting plan design

After data collection, the information needs to be processed and sent. A single message is first transmitted using electromagnetic induction and then the target distance is sent to the fuze[10]. The distance information is calibrated corresponding to the signal frequency, and targets at different distances are converted into sinusoidal signals of different frequencies.

First, the frequency of the AC signal is controlled by the controller, and the frequency component of the signal represents the explosion distance. The AC signal is amplified by the voltage amplifier and then passed through the power amplifier. The role of the power amplifier is to enhance the magnetic field strength of the coil. The magnetic field distribution of the energized coil is shown in Figure 4.

The disadvantage of the above scheme is that only one type of information can be set, but the trajectory of the projectile often requires multiple influencing factors such as the angle of fire, temperature, humidity, and air pressure. The sine signal has only three characteristic quantities: amplitude, phase and frequency. Once these three characteristic quantities are determined, the sine signal is also determined. It is difficult to calibrate the phase and amplitude, so only the frequency is used for data setting. In addition to the frequency, phase, and amplitude of the square wave signal, compared with the sine signal, the square has the characteristic of duty cycle, so the use of the square wave signal for data setting will transmit more information. The schematic diagram of signal reception and signal transmission is shown in Figure 5.

In order to enhance the stability and reliability of signal transmission, it is necessary to conduct wireless transmission after the modulation of the opposite wave signal. In this system, the transmission distance is not very far, and the modulated high-frequency signal is less affected by the climate, and the signal penetration after the modulation is strong, the transmission is more stable and reliable. However,
due to the many frequency components of square wave signal, there will be great changes after passing through the circuit, and both the transmitting coil and the receiving coil may generate differential operation for the opposite wave signal. The low pass filter of demodulation circuit will make the square wave signal lose the high frequency component, but because the square wave signal frequency component is regular. Therefore, although the signal waveform changes, the frequency and duty cycle information of the original signal can still be retained. Since the amplitude information of the square wave signal is not used in the information setting, the received and processed signal can be restored through the comparator to retain the frequency and duty cycle information of the original square wave signal.

Finally, the restored signal is input into the controller, and the controller can calculate the frequency and duty cycle of the signal. According to the calculated frequency and duty cycle, the corresponding shooting Angle and target distance are calculated.

3. Conclusion
In this paper, the theoretical method of real-time measurement using MEMS acceleration sensor and various sensors that affect ballistic factors is studied, aiming at the insufficiency of the precision of air blast determined by the traditional method of timing and counting revolution. Firstly, a three-dimensional coordinate dynamic model of the projectile is established to solve the tangent acceleration, and then the measured parameters are transmitted to the electronic fuze through the linear setting. Relying on the high performance operation ability of DSP, according to the ballistics theory, the design algorithm is used to solve the sensor parameters, control the blast point of the projectile, and improve the accuracy of distance determination.

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