Design of automatic measurement system for direct fire shell impact point

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Abstract. Aiming at the problems of traditional manual detection of gun firing, such as hidden danger, poor accuracy and low efficiency, this paper proposes an automatic measurement system for the impact point of direct fire shell. Based on the acoustic positioning principle, collimation noise shielding technology based on slit, distributed sensing and coordinate conversion method, the impact is realized by integrating the time difference of shock wave arrival and the geometric relationship between sensors the accurate detection of points can improve the rapid detection ability of artillery performance test and firing training.

Keywords: impact point, ultrasonic positioning, distributed, noise shielding.

1. Introduction
Target hit rate is the most important index to measure the performance of weapon equipment and military training level. The improvement of target hit rate depends on the feedback of impact point information by trainers in military training. Therefore, accurate measurement of impact point plays an important role in weapon test and military training. Relying on manual method to detect the impact point of all kinds of large caliber direct pointing gun, this method has the problems of hidden danger, low precision and poor real-time performance, which cannot meet the requirements of modern training of our army. In view of the current situation and development of weapon test and military training of our army, we need a set of more scientific and effective technology to improve the shooting level of all kinds of large caliber direct pointing gun the impact point was measured.

The automatic measurement system of direct fire shell's impact point is based on acoustic positioning principle, distributed sensor array, and the geometric relationship between sensors and shock wave arrival time difference. The method has strong real-time performance, high precision and good safety performance. It has a good application prospect to improve the scientific level of weapon performance test and shooting training.

2. System composition and working principle
The composition of the system involved in the "automatic measurement system of direct fire shell impact point" is shown in Figure 1: three horizontal array acoustic sensor arrays, one ambient temperature compensation sensor, signal acquisition processor, wireless module and display and control terminal. Three horizontal array acoustic sensors and one ambient temperature compensation sensor are installed under the target. The output ends of acoustic sensor and temperature sensor are connected with signal
acquisition processor through signal cable. The output of acoustic sensor and temperature sensor is sent to signal acquisition processor. Signal acquisition processor is connected with rear display and control terminal via wireless mode to collect and process signal the two-time difference data and temperature compensation data collected in real time are sent to the rear display and control terminal. The display and control terminal calculates the results and displays the shooting results.

![Block diagram of automatic measurement system for direct fire shell impact point.](image)

3. Technical principle

3.1. Measurement technology of impact point

The impact point measurement technology is to measure the shock wave generated by the projectile flying in the air to automatically report the target. Its key point is to place three ultrasonic sensors horizontally below the shell flight, as shown in Fig. 2. The projectile shock wave makes each sensor produce induction signal in the flight process, and the intensity and time of the induction signal of the projectile shock wave on each sensor and the time of the sensor receiving the induction signal are different with the different position of the projectile shock wave. The measurement part of the impact point coordinate is to use the acoustic sensor to collect the projectile shock signal, and then through the processing circuit and operation the calculation circuit measures the time width of the projectile shock wave passing through each sensor and the time interval between sensors, and calculates the coordinates of the impact point.

S1, S2 and S3 are three ultrasonic sensors with the spacing of L. the connecting line of the central points of S1, S2 and S3 sensors is the x-axis, and the positive direction of y-axis is shown in Fig. 3. Perpendicular to X axis and passing through S2 center is Y axis. Suppose that the coordinates of the
bullet passing through point Pare \((x, y)\), the time when the generated sound wave reaches \(S_1\) is \(T_1\), the time to \(S_2\) is \(T_2\), and the time to reach \(S_3\) is \(T_3\), then the time difference between \(S_1\) and \(S_2\) is \(\Delta T_1 = T_2 - T_1\), the time difference between \(S_2\) and \(S_3\) is \(\Delta T_2 = T_3 - T_2\). The distance between point P and point \(S_1\) is \(l_1 = T_1 \times V\), that of \(PS_2\) is \(l_2 = T_2 \times V\), and that of \(PS_3\) is \(l_3 = T_3 \times V\).

Then
\[
\Delta S_1 = l_1 - l_2 \\
\Delta S_2 = l_2 - l_3
\]

With \(S_1\), and \(S_2\) as the focus, point P should meet the requirements:
\[
\frac{x^2}{a_1^2} - \frac{y^2}{b_1^2} = 1
\]

With \(S_2\), and \(S_3\) as the focus, point P should meet the requirements:
\[
\frac{x^2}{a_2^2} - \frac{y^2}{b_2^2} = 1
\]

Then the coordinate value of \((x, y)\) can be obtained.

**Figure 2.** Schematic diagram of ultrasonic sensor array

**Figure 3.** Block diagram of system application scenario.
3.2. Noise shielding principle based on slit

In the process of artillery impact point ultrasonic positioning detection, the commonly used target cavity of light weapons cannot meet the requirements. At the same time, in order to protect the ultrasonic positioning equipment, the target and the equipment must be separated, and the firing process of gun direct aiming cannot be affected. According to the principle of projectile shock location technology, it can be known that the effective signal is received by the ultrasonic sensor on the plane perpendicular to the distributed sensor plane. The effective signal can be extracted by using the noise shielding method based on the slit. The noise shielding device based on the slit is shown in Fig. 4. The outer frame and base are made of aluminum plate, and the shock sensor is embedded in the inner center. The base is provided with mounting holes for easy installation on the movable support frame; the installation position of shock sensor is set inside the base; the rubber sound insulation cover of shock sensor is set at the contact part between shock wave device and base, which can effectively isolate vibration; the protection plate on the outside can effectively protect the noise shielding device based on slit. There is a 6 mm sound-absorbing foam board on its inner side, which can realize the damping and vibration elimination of shock wave transmitted through the aluminum plate, and at the same time complete the sound absorption of the wavelet formed by reflection in the slit. On the left and right sides of the noise shielding device based on the slit, there are 120° sound-absorbing triangular foam plates, which can limit the signal receiving range of the shock sensor and match the inherent signal receiving range of the shock sensor.

Figure 4. Effect picture of noise shielding device based on slit.

When the projectile passes through the target, the warhead wave propagates around through the air medium under the action of its pulse pressure until it meets the slit shielding device. A part of the shock wave reaches the shielding device shell, which is damped and damped by the sound-absorbing foam board inside the shielding device, and a part of the shock wave reaches the sensor through the slit shield device. If there is no shielding device for the former signal, it will form a false signal, which will lead to misjudgment of the impact point. The latter is an effective signal. Because the slit has a certain height, the wavelet generated in the acoustic propagation process does not directly transmit to the sensor through the air, and repeatedly reflect back and forth on the sound-absorbing foam board of the shielding device, and finally most of the signal strength reaching the sensor is absorbed Sound foam board absorption, effectively ensure the effective signal extraction, meet the shock wave positioning design requirements.

4. System software design

Visual studio C++ 2010 development platform is used to develop the software of automatic measurement system of direct fire shell impact point. Libuidk is used to develop the interface. The requirement of data storage is not high, and the database is SQLite. The system flow chart is shown in Figure 5:
Figure 5. Flow chart of automatic measurement system of direct fire shell impact point.

According to the relevant block diagram of the program design, the program is specifically implemented, and the impact point detection and evaluation software is designed. For the convenience of operation, the main interface of the software system is a single interface, as shown in Figure 6:
After the parameters are set, click the "start shooting" button in the main interface, the software system can obtain the data sent by the signal processing unit of the detection equipment, and calculate the specific position of the impact point through the impact point detection algorithm. According to the calculated coordinate values, the impact point detection and evaluation software can draw the coordinate points on the main interface.

5. Conclusion
In this paper, aiming at the problems of traditional manual detection of gun firing, such as hidden danger, poor accuracy and low efficiency, according to the variation law of shock wave propagation velocity in supersonic flight of projectile, a scheme of horizontal array acoustic sensor array is established, which integrates the time difference of shock wave arrival and the geometric relationship between sensors to realize accurate detection of impact point. So as to provide accurate feedback information for weapon test and military training, which is conducive to the improvement of our military training and even the actual combat target hit rate, to the improvement of military combat effectiveness, and to the construction of national defense modernization.

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