On the Application of Ultrasonic Testing Technology in Ammunition

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Abstract

Ultrasonic testing technology is currently the most widely used, most frequently used, and rapidly developing non-destructive testing technology at home and abroad. It has been throughout the entire process of weapon equipment product design, development, and production, and can be effective without damaging the ammunition structure. Ensuring the inherent quality of ammunition is one of the key technical means for effective detection of the internal quality of weapons and equipment components.

Keywords

Ultrasonic Testing Technology; Ammunition; Equipment components.

1. Overview

1.1 Concept

Ultrasound is a mechanical wave with a frequency higher than 20000Hz. In a conventional ultrasonic testing system, the piezoelectric wafer of an ultrasonic probe is excited with electrical pulses to cause mechanical vibration, and this vibration propagates in the medium in contact with it to form ultrasonic waves. Ultrasonic testing technology is a non-destructive testing technology that uses ultrasonic waves to propagate through a material at a certain speed and direction, and encounters characteristics such as reflection, refraction, and mode conversion at heterogeneous interfaces to determine the location and size of internal defects in the material. Generally divided into pulse reflection method and penetration method. The frequency used for ultrasonic testing is generally 0.25 MHz ~ 15MHz, and the common frequency for ultrasonic testing of metallic materials is 0.5 MHz ~ 10MHz.

1.2 Working Principle

Ultrasonic testing is a non-destructive testing method to detect the internal defects of materials by using the influence of the acoustic performance difference between materials and defects on the ultrasonic propagation. At present, the ultrasonic pulse reflection method is widely used to observe the reflection of the acoustic pulse in the material. In addition, there is the penetration method to observe the amplitude change of the incident sound wave after passing through the material.

a. Pulse reflection method

The pulse reflection method is used to probe the pulse wave from the ultrasonic probe to the inside of the specimen. If the material is homogeneous, the sound wave will travel forward at a constant speed in a certain direction. When an interface with different acoustic impedance is encountered, part of the acoustic energy is reflected. The degree of reflection depends on the difference of acoustic impedance between the two sides of the interface. By detecting and analyzing the amplitude, position and other information of the reflected pulse signal, we can determine the existence of defects and evaluate their size and position. The distance between the reflection point and the incident point can be determined by measuring the propagation time between the incident sound wave and the received sound wave.

When there is no defect in the specimen, only two signals, i.e. the transmitted pulse T and the bottom echo B, are shown in the display. When there is a defect in the specimen, the echo f from the defect will appear between the transmitted pulse and the bottom echo. By observing the height of F to evaluate the size of the defect, and by observing the distance between the echo F and the transmitted pulse, the buried depth of the defect is obtained. That is, the defect in the test piece is quantified and positioned. The pulse reflection method has the advantages of high detection sensitivity, accurate defect location, convenient operation and suitable for various shapes of test pieces. Therefore, as long as the resolution and sensitivity of ultrasonic are enough to get the echo display of the required detection defects, the pulse reflection method is the best choice.

b. Penetration method

In penetration method, two probes are usually used, which are placed on both sides of the test piece. One sends the pulse wave to the test piece, and the other receives the pulse signal after penetrating the test piece. According to the change of energy after the pulse wave penetrates the test piece, the internal defects are judged. When the material is uniform and intact, the penetrating wave amplitude is high and stable. When there is a certain size defect in the material or there is a sharp change in the material, because the defect blocks part of the through sound energy, or the material causes the sound energy attenuation, so that the through wave amplitude obviously decreases or even disappears. The advantage of penetration method is that there is no blind area, and the orientation of defects has little effect on penetration attenuation. At the same time, it only passes once in the test piece, which reduces the material attenuation by half compared with reflection method. Therefore, the penetration method is suitable for thin plates. It is required to detect specimens with larger defect size and materials with larger attenuation.

1.3 Main Advantages

Compared with other nondestructive testing methods, the main advantages of ultrasonic testing methods are as follows: It is suitable for nondestructive testing and evaluation of metal, non-metal, composite materials and other materials; With strong penetrability, it can detect the internal defects of the test piece with large thickness range and scan the whole volume of the test piece; With high sensitivity, it can detect the defects with small size inside the material;

The depth and position of defects can be measured accurately; The equipment is light, harmless to human body and environment, and can be tested on site.

2. Development Status at Home and Abroad

2.1 Development Status Abroad

The use of ultrasound for nondestructive testing began in the 1930s. In 1929, sokolv, the former Soviet Union, first used the ultrasonic method to detect defects. In 1935, he published some results of the penetration test, and applied for a patent on the detection of defects in materials. In the 1940s, Firestone in the United States introduced the pulse reflection ultrasonic detector for the first time, and applied for the patent of the instrument [1]. With this technology, the ultrasonic wave can be transmitted and received from one side of the object, and can detect small defects, accurately determine its location and depth, and evaluate its size. Subsequently, a type a pulse reflection ultrasonic detector was developed by the United States and the United Kingdom, and it was gradually used for the detection of forged steel and thick steel plate.

In recent years, with the development of foreign ultrasonic testing technology, it has achieved rapid development in improving the detection accuracy of ultrasonic testing, broadening the application scope, improving the detection speed and other key directions. In the nuclear industry, aviation, aerospace, shipbuilding and other industries with high quality requirements, phased array ultrasonic technology has been introduced for defect detection; for the traditional ultrasonic testing technology is not ideal for austenitic steel welds and composite materials, phased array ultrasonic testing has also been attempted, and formed standards and specifications.

2.2 Domestic Development and Application

With the continuous improvement of industrial production requirements for testing efficiency and reliability, people demand more rapid ultrasonic, more intuitive display of defects, and more accurate description of defects. Therefore, the original A-type display manual operation based detection method can no longer meet the requirements. Since the 1980s, for regular plates, bars and other mass-produced products, automatic detection system has been gradually developed, equipped with automatic alarm, recording and other devices, and B-type display and C-type display have been developed[2]. In the aspect of ultrasonic testing of complex structural parts, phased array testing technology is used in some parts, but compared with foreign countries, it has poor automation and low sensitivity, so most of the testing is still manual testing, which requires high experience of the testing personnel and low testing efficiency. The following introduces the application of ultrasonic testing technology in combination with engineering practice.

a. Engine combustion chamber ultrasonic testing

Most of the combustion chambers in the conventional bomb parts are formed by spinning thick wall tubes. If the pretreatment of spinning blank is improper and the spinning process parameters are not selected properly, such as incomplete spheroidization and excessive thinning rate during spinning, spinning cracks are easy to be caused. This kind of crack generally occurs on the inner surface of the spinning part, distributed along the circumference direction, slightly in the form of fish scales, and seriously in the form of serrated cracks. For this kind of defect, the commonly used detection method is the transverse wave axial detection. The probe frequency is 2.5MHz. The artificial defect of the standard specimen is usually V-shaped groove machined along the circumference direction on the inner and outer walls, and the groove depth is 5% of the wall thickness. Because the probe scans along the axial direction of the workpiece, similar to the plate scanning, there is no case that the inner wall can not be scanned, and the detected workpiece belongs to the thin-walled part, so the probe with larger K value can be selected.

b. Ultrasonic testing of bar

Bars are usually made from ingots by forging, extrusion, or rolling processes. The defects in bar can be divided into surface defects and internal defects. Internal defects are caused by the expansion of defects in ingots and billets in the rolling process, mainly including shrinkage cavity and inclusions in the center, as well as cracks caused by these defects in the deformation process. Surface defects are mainly cracks and folds. Most of the defects in the bar are extended along the longitudinal direction, so the sound beam is mainly incident vertically from the circumferential surface, supplemented by a certain angle of incidence, which is used to detect defects with different orientations. When incident at a certain angle, the sensitivity is adjusted by the test block method. The commonly used methods for vertical incidence are flat bottom hole test block method and bottom wave calculation method. When the bar diameter is more than three times of the probe near-field length, the bottom wave method can be used. The formula is as follows:

$$\triangle \mathrm{dB} = 20\lg\frac{\pi D_P^2}{2\lambda x} \tag{1}$$

3. Key Technologies

In order to carry out an ultrasonic testing, first of all, it is necessary to understand the manufacturing process and use purpose of the tested object, the types of defects that affect the use, the maximum possible orientation and size of defects, the direction of stress and acceptance requirements, so as to determine the defect characteristics and parts to be tested. Then, combined with the shape, size, material and appropriate detection technology of detection object, i.e. determining the wave type, incident direction, ultrasonic characteristic quantity used to display defects, coupling mode, display mode, etc., in order to achieve the purpose of detection as much as possible. After that, choose the appropriate instrument, probe, coupling agent, design the appropriate form of reference block, determine the correct operation steps and methods, and get the reliable test results. Its main technical core has the following three aspects.

3.1 Analysis of Defect Properties

The analysis of defect nature is to analyze what defect the detected defect belongs to. The harm of defects of different nature is different. To analyze the nature of defects is to determine the nature of defects. Type a ultrasonic flaw detector can only provide the height, waveform and position of echo during flaw detection. It is very difficult to determine the nature of defects only according to the height, waveform and position of echo. To determine the nature of the defect, in addition to the height, waveform, position and bottom wave of the defect echo, comprehensive analysis must also be carried out according to the processing technology, material of the workpiece and the characteristics of the actual defect, so as to give a more accurate qualitative analysis of the defect.

3.2 Identification of Non Defective Waves

In the flaw detection image on the fluorescent screen, in addition to the important signals such as start wave, bottom wave and defect echo, there are often some other echo signals. Non defect echo is the general term of other echo signals except for the first wave, bottom wave and defect echo. Some non defect echoes are easy to be distinguished from defect echoes, while many are difficult to be distinguished, because its appearance affects the confirmation of defect echoes. Therefore, it is necessary to understand the causes and characteristics of the non defect echo, and identify the non defect echo such as late echo, contour echo, variant echo, multiple reflection echo and clutter.

3.3 Automatic Detection and Defect Identification

Due to the low degree of automation of ultrasonic testing equipment, manual testing of A-type display is still the main method, especially for the ultrasonic testing of complex structural parts, it is difficult to identify defects manually. Therefore, it is necessary to expand the application of ultrasonic automatic detection and automatic recording, automatic defect recognition technology, research and develop various display methods and information processing methods, from simple wave display to defect image display, to obtain more abundant information and intuitive results, reduce the impact of human factors, and correctly evaluate the nature of test results and the impact on products.

4. Application of Technology

Ultrasonic testing technology has been successfully used in most ammunition industry testing. The following describes the specific application of ultrasonic testing technology. The components of ultrasonic testing system are ultrasonic detector, probe and reference block. Instrument and probe pair.

The ability of ultrasonic testing system plays a key role, which is the part of generating ultrasonic wave and receiving, processing and displaying the ultrasonic signal transmitted in the material.

Ultrasonic testing instrument is a kind of electronic instrument specially used for ultrasonic testing, which is mainly composed of synchronous circuit, transmitting circuit, scanning circuit, receiving and amplifying circuit and display circuit. Its function is to generate electric pulse and apply it to the probe so that it can emit ultrasonic wave, and at the same time receive the electrical signal from the probe, which will be displayed on the fluorescent screen after amplification.

Probe is a device used to generate and receive ultrasonic, which is one of the most important parts of the ultrasonic detection system. The performance of the probe directly affects the characteristics of the transmitted ultrasonic and the detection ability of the ultrasonic. The key component of the probe is the transducer, the most commonly used is the piezoelectric transducer, also known as the piezoelectric chip. Piezoelectric chip converts electric pulse to ultrasonic pulse, and then converts ultrasonic pulse to electric pulse, realizing the mutual conversion of electric energy and acoustic energy. The most commonly used probes are straight probe and angle probe.

In order to ensure the accuracy, repeatability and comparability of the test results, the test system must be calibrated with samples (test blocks) with known fixed characteristics. The test block for ultrasonic testing is usually divided into two types: standard test block and reference test block. The standard test block is a test block formulated by the competent authority, which is mainly used to test the performance of detection instruments, probes and their combination. The reference block is a test block made according to the flaw detection needs of the specific test object. It is similar to the acoustic characteristics of the tested object material, and contains regular reflectors (flat bottom hole, cross hole, groove, etc.) with clear meaning. It is used to adjust the state of the ultrasonic testing equipment, ensure that the scanning sensitivity is enough to find the required size and orientation of defects, and reflect the detected defects into the test block The signals produced by regular reflectors are compared.

5. Future Development Trend

At present, the ultrasonic testing of complex structural parts is still mainly manual testing, which has low efficiency and reliable testing results.

Sex is greatly influenced by human factors. The future development trend of ultrasonic testing: From general ultrasonic testing to automatic ultrasonic testing and quantitative ultrasonic testing, computer and digital image processing technology are introduced to detect and analyze data, so as to reduce the impact of human factors and improve the reliability of detection.

Develop on-line detection technology and in-service detection technology. The key technologies such as phased array ultrasonic testing technology, laser ultrasonic testing technology, robot ultrasonic testing automatic scanning system are researched to improve the detection sensitivity. Accelerate the development of artificial intelligence technology, adaptive technology, robotics technology, laser technology and computer-aided design / computer-aided manufacturing (CAD / CAM) technology and non-destructive testing technology, so as to realize the ultrasonic scanning imaging detection of complex profile composite components, and correctly evaluate the nature of the detection results and the impact on the products.

Carry out the exploration and research of new principle, method and technology of ultrasonic testing. Such as laser ultrasound, electromagnetic ultrasound, phased array ultrasound, air coupling ultrasound, etc. It can be predicted that there will be more new ultrasonic detection technologies and methods in the future [3].

References

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