# Application of Electronic Technology in Non-Destructive Testing of Aerospace Materials

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**Abstract.** Describes the application of electronic technology in nondestructive testing of aerospace materials, including the application of radiographic testing, eddy current testing, ultrasonic phased array testing, laser ultrasonic testing, and other testing, and analyzes the advantages of its use in improving the accuracy, speed, and reliability of testing.

**Keywords:** Electronics, aerospace materials, nondestructive testing, laser ultrasonic testing.

## 1. Introduction

Nondestructive testing of aerospace materials is a very important technology in the field of aviation, which plays a vital role in guaranteeing the flight safety and reliability of airplanes. Traditional NDT methods, such as ultrasonic and magnetic particle flaw detection, have been widely used, but still have some limitations, such as problems in detection accuracy, speed and complexity. Therefore, seeking a more advanced, accurate, reliable and efficient NDT method is a problem that needs to be solved in the field of NDT of aerospace materials. In this paper, through an in-depth study of the application of electronic technology in the nondestructive testing of aerospace materials, a more accurate, reliable and efficient nondestructive testing method can be provided for the aerospace field to improve the safety and reliability of airplanes. There are various types of aerospace materials, including metals, composites, etc. Each material has its own unique physical and chemical properties, so it is necessary to develop and optimize the corresponding nondestructive testing techniques for different materials. The defect forms and manifestations of different materials are also different, for example, metal materials may have cracks, corrosion and other defects, while composite materials may have problems such as interlayer peeling and fiber breakage. Therefore, electronic technology needs to be continuously developed and improved to adapt to the inspection requirements of different materials and provide accurate and reliable inspection results. This requires an in-depth understanding of material properties and continuous innovation in technology to ensure a high degree of adaptability and reliability in the application of NDT techniques to aerospace materials.

## 2. Overview of Non-Destructive Testing Technology

### 2.1. Concept and Purpose of Non-Destructive Testing Technology

Non-destructive testing technology refers to the process of product testing, without damaging the internal structure and performance of the object to be tested, through specific physical or chemical means, modern instruments and other means of testing its quality, and timely detection of defects and problems in the product. The main purpose of carrying out non-destructive testing technology is to ensure the quality of products, timely check whether the performance of the product is intact within the specified period, whether it can fully meet the actual needs of users, and to detect the reliability and safety of the use of the product and so on. If quality problems are found during the inspection, the quality and value of the product should be guaranteed by improving the production process or management methods according to the root cause of the defects. If the lack of non-destructive testing of this link will cause great economic losses to the production enterprises, once into the market, will cause serious social problems [1].

### 2.2. Scope of Application of Non-Destructive Testing Technology under Electronic Technology

Non-destructive testing technology has a relatively wide range of applications at present, mainly in the following aspects: (1) applicable to the combination of the internal structure of the product as well as the composition of the detection and inspection. (2) It is suitable for the inspection of product materials, defective seams in welding and castings and forgings, etc., which provides the basis and reference for its quality assessment and service life assessment. (3) It is possible to test the measurement of materials and mechanical equipment, but it is based on the quantitative method, and assesses the service life by testing the deformation or corrosion of materials and equipment. (4) NDT technology is also more suitable for the detection of the correctness of material varieties, verifying whether they are handled in accordance with the corresponding processes [2]. (5) It is capable of determining the thickness of the surface treatment layer of the product. (6) Applicable to strain testing.2 electronic technology nondestructive testing technology under the prominent features of the current electronic technology nondestructive testing technology with non-destructive, dynamic, rigorous and test results of the outstanding characteristics of the divergence. First of all, the non-destructive nondestructive testing technology refers to the non-destructive testing object cannot destroy the premise of unqualified products will be eliminated, can effectively avoid the damage to qualified products. In the actual use of the process, the relevant personnel can be based on the type of testing products and demand, reasonable choice of comprehensive testing or sampling testing, with high reliability and flexibility; and dynamic characteristics refers to the electronic technology under the nondestructive testing technology can be in use to detect the product, and can be able to examine the cumulative impact of the product operation period and measure, in order to determine the failure of the object to be detected Mechanism; electronic technology nondestructive testing technology rigor is reflected in the detection process requires relatively professional personnel and equipment management and operation, and has standardized operating procedures to ensure the accuracy and reliability of the test results; test results divergence refers to the same object to be detected using different detection methods, there may be differences in the test results, so it is necessary to synthesize all the results for uniform analysis [3]. So, it is necessary to synthesize all the test results for unified analysis [3].

## 3. Types and Applications of Non-Destructive Testing Technology under Electronic Technology

### 3.1. Radiographic Inspection

Radiographic inspection utilizes a radioactive source to emit X-rays incident along a straight line into the test piece, and the intensity of the penetrating rays is detected on the backside of the specimen to obtain useful defect information. Radiation frequency is very high, the wavelength is very short, about 10-9 ~ 10-13 meters, so the penetrating power is strong [4]. Radiation penetration of the measured part, both the use of film sensitivity can be obtained by the intensity of the transmitted rays, but also by the image detector received and stored as a digital image signal through computer processing. Currently the ray detection method is to check the composite material in the pores, inclusions and impact damage and other volumetric defects in an excellent method, the carbon fiber row uneven also has a certain detection ability. Ray detection can only be used in both directions, and the equipment is huge and radioactive contamination, and because the carbon fiber composite material is a weak absorber of X-rays, it is still very difficult to obtain a high contrast image.

### 3.2. Eddy Current Inspection

Eddy current detection usually contains an excitation coil and a receiving coil (sometimes only a coil is used, when the coil is used for both excitation and receiving), when the excitation coil is applied to a certain amplitude and frequency of the alternating current, the coil will generate a magnetic field around the coil, when the coil is close to the conductor, the conductor will be due to the electromagnetic induction of eddy currents generated within the eddy current induced by the eddy currents will generate a magnetic field and thus change the original distribution of magnetic field. This change in magnetic field is reflected in the coil impedance changes, when there is damage in the conductor, the damage will cause changes in the distribution of eddy currents in the conductor, thereby changing the magnetic field, this change can be detected by the detection coil, which is the basic principle of eddy current detection [5]. Eddy current detection is very effective for the detection of conductors, but the eddy current detection method can also be used for the detection of composite materials [6]. The use of eddy current detection technology can be achieved in carbon fiber composites, such as fiber breakage, fiber direction and other detection. The use of eddy current detection technology can also detect structural damage caused by small energy impact (500mJ), and its detection effect is better than some other detection methods such as ultrasound, infrared thermography.

### 3.3. Ultrasonic Phased Array Inspection

The basic concept of ultrasonic phased array is inspired from radar phased array technology [7]. In phased array radar, a large number of unit antennas are arranged in a certain shape and position, and by controlling the time delay and amplitude of the electromagnetic wave beam emitted by each antenna unit (the frequency is kept the same), a focused and scanned electromagnetic wave beam can be composed within a certain range. Ultrasonic phased array inspection technology is a non-destructive testing method that realizes structural scanning by controlling each array element in the transducer array through the electronic system, transmitting and receiving ultrasonic waves according to a certain delay time rule, and thus dynamically controlling the focusing of the ultrasonic transducer assembly in the workpiece [8]. The most significant feature of ultrasonic phased array technology is that the time delay of each wafer in the phased array transducer is assigned by the system controller. Each wafer is excited to produce an ultrasonic beam. Ultrasonic beam parameters such as angle of incidence, focal length and focus size can be adjusted by the controller as well as the computer. The beam angle, focal position and focus size are continuously and dynamically adjustable within a certain range [9]. The most distinctive feature of ultrasonic phased arrays is that the acoustic beam can be controlled simply, conveniently and effectively to accomplish local as well as overall inspection of structural components.

### 3.4. Laser Ultrasonic Inspection

Laser ultrasonic testing technology is the use of laser pulse excitation and sensor devices to detect ultrasonic signals to achieve non-destructive testing of a method, and gradually become an important means of non-destructive testing of materials and development direction [10].

Laser ultrasonic detection technology can be divided into two categories: transducer detection technology and optical detection technology, of which the transducer detection technology is used to obtain high sensitivity must be in contact with the specimen or very close to the specimen surface. Transducer due to its mature technology, in-depth research, in the acquisition of ultrasonic signals often have a high signal-to-noise ratio. Optical detection is a new type of non-destructive testing technology, this detection method is characterized by non-contact, high sensitivity. Optical detection methods are greatly affected by the material surface properties, so the signal-to-noise ratio is slightly lower than the signal collected by the sensor. Commonly used ultrasonic optical non-contact detection techniques include optical interference extinction aberration method and velocity type interference method. Optical method detection technology can be divided into non-interference detection technology and interference detection technology. Non-interferometric detection techniques include surface grid diffraction techniques, knife-edge detection techniques, and so on. According to the type of crystal used, the interference detection technology can be divided into linear interference detection technology and nonlinear interference detection technology. Linear interferometric detection techniques include outlier, self-differential and other interferometric techniques.

Compared with conventional ultrasonic detection methods, laser ultrasonic detection methods have the following characteristics [10]:

(1) No coupling agent, eliminating the traditional ultrasonic detection due to the coupling medium to change the impact on the signal, as well as the use of coupling agent on the structure, the environment and the pollution and damage;

(2) The excellent quality of the laser beam makes the measured ultrasonic field subject to very small interference factors and has a strong anti-interference capability;

(3) The excitation and reception of ultrasonic waves are carried out by laser, which is easy to accomplish remote sensing manipulation of excitation and reception at long distances and realize real-time detection of structural parts;

(4) The laser beam can be guided into a specific working area using optical fiber, thus enabling it to be conveniently applied to high temperature, high pressure, high humidity, toxic, acid and alkali detection environment and even the presence of nuclear radiation, strong corrosive and violent chemical reactions and other harsh environments;

(5) It is not dependent on piezoelectric crystals and can be directly excited in non-piezoelectric crystals;

(6) The use of mode-locked lasers makes it easy to obtain ultrasonic pulses close to the laser pulse width, making it a reality to obtain a wide range of applications for defect detection techniques based on ultrasonic diffraction methods;

(7) The probe laser beam can be converted into very small light spots, enabling spatial resolution at the micrometer level even with commonly used laser systems.

Based on the above characteristics, laser ultrasonic inspection technology has been applied in structural damage detection and localization [11-13], and has made great progress in the research of material parameter measurement [14, 15]. With the development of industrial technology, laser ultrasonic detection technology will be more mature, so that it can be truly applied in the field of nondestructive testing. Therefore, laser ultrasonic detection technology has a broad application prospect, and it is of great significance to conduct research on laser ultrasonic detection technology so that it can be applied in aerospace and other fields to improve the safety and stability of structures.

Research in laser sonication began in 1962. By the late sixties and early seventies, the technological research was divided into two main categories: one was the use of ultra-high-power pulsed lasers to generate large-amplitude short acoustic pulses (LSD waves) in gases, liquids, and solids [16], with the research focusing on laser damage and laser weaponry; the other was devoted to reducing the energy and adding a cover film on the test object in order to avoid surface damage and to obtain medium-amplitude short stress pulses (LGAP waves ), thus enabling non-destructive testing of material properties.

In recent years, there have been important breakthroughs in the study of laser ultrasonic mechanisms and techniques, and great progress has been made in the theory and application of excitation, reception, and propagation of laser ultrasonic signals. The propagation characteristics of laser-excited ultrasonic waves from a flat plate have been analytically investigated by Hideo Nishino and Toshiro Tanaka [17]. N. Hu on metal flat plates and composite plates A novel damage localization imaging method was used to localize and image circular holes and elliptical through holes [18]. Jung-RyulLee has completed a study on the monitoring of damages such as cracks on small test pieces of complex non-flat plate structures such as drills and pipe fittings by using laser-excited elastic stress waves [19].Chia C C et al. have developed a high temperature sensor for a maximum temperature of 145 degrees Celsius on the surface of a structure and achieved good detection results [20]. AnYun-Kyu et al. used a laser Doppler vibrometer to collect the signals reflected from the surface of a structure to build a completely non-contact inspection system for laser ultrasonic field visualization [21].Ruzzene M et al. conducted a theoretical study on the visualization of three-dimensional wave field data collected by laser ultrasonic inspection system Ruzzene M et al. conducted a theoretical study and experimental analysis of the three-dimensional wavefield data collected by the laser ultrasonic inspection system [22]. Michaels TE et al. conducted a more in-depth study on the data analysis method based on the frequency-wave number domain, which not only separates the reflected wave but also the guided wave modes from the laser ultrasonic-generated wavefield to provide a theoretical basis for the identification and localization of defects and damages as well as the imaging of defects and damages by laser ultrasonic technology [23].

### 3.5. Other Inspection

The application of Scanning Electron Microscope (SEM) in non-destructive testing of aerospace materials is of great significance. by scanning the surface of the sample and interacting with the electron beam, SEM is able to provide high-resolution images and detailed morphological information, which is very helpful for observing and analyzing defects, cracks and corrosion in aerospace materials. The high resolution and magnification of SEM makes it possible to detect minute defects and subtle structural changes. By observing the microscopic morphology of the surface of aerospace materials through SEM, the quality and properties of the materials can be accurately analyzed. For example, SEM can reveal microscopic cracks, pores, and grain-boundary defects in metallic materials, helping to determine the strength and reliability of the material. In addition, SEM can determine the composition and chemical makeup of materials through Energy Dispersive X-ray Spectroscopy (EDS), a technique that helps assess the chemical properties and compositional distribution of aerospace materials by measuring the X-ray energy spectrum emitted by the material to determine the type and content of elements. The application of EDS in non-destructive testing of aerospace materials can also be combined with other techniques such as electron beam weld probing and electroacoustic emission testing to improve the accuracy and reliability of the testing.

E-beam welding flaw detection technology utilizes a high-speed electron beam to detect and evaluate welded joints, which can accurately detect defects such as cracks, porosities, and imperfections in welded joints and provide information on the location and size of the defects. Compared with traditional welding flaw detection methods, electron beam welding flaw detection has several significant advantages. (1) E-beam has a smaller beam spot and higher energy density, making it possible to achieve high sensitivity and high resolution in the detection process. This means that E-beam weld flaw detection can detect small defects and provide more detailed and accurate information about the defects, which is essential for assessing the quality of welded joints. (2) E-beam welding flaw detection has the advantage of fast detection. The high-speed scanning and short response time of the electron beam allows for comprehensive scanning and probing of welded joints in a short period of time. This is very important for the production and maintenance of aerospace materials, which can improve work efficiency and reduce production and maintenance cycles. (3) E-beam weld flaw detection can also be combined with other techniques, such as scanning electron microscopy (SEM) and X-ray inspection, to achieve a more comprehensive and accurate non-destructive testing.

## 4. Concluding remarks

Electronic technology has a broad application prospect in the nondestructive testing of aviation materials, which can provide strong support for the development of the aviation industry. In the face of challenges, we need to strengthen technical research and development, increase personnel training, and continuously promote the innovation and application of nondestructive testing technology in order to improve the quality and safety of aerospace materials.

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