AIJRPLS VOLUME 9, ISSUE 4 (2024, Oct/Nov/Dec) (ISSN-2456-3889)ONLINE
Anveshana's International Journal of Research in Pharmacy and Life Sciences

A REVIEW ON ULTRASONIC SOUND TESTING: A KEY TO NON-DESTRUCTIVE EVALUATION

Abhishek Annasaheb Pande, Sanchit Pradip Deshpande, Ashish Shalik Falatankar, Prashant Shivaji Narode
Gajanan Maharaj College Of Pharmacy, Chh. Sambhajinagar.

Pande6522@gmail.com

DR. KAVITA KULKARNI (phd. Mpharm), Department Of Quality Assurance, Gajanan Maharaj College Of Pharmacy, Chh. Sambhajinagar.

Abstract:

The manufacturing of prototype components using ENEA's patented technologies, PBC (Pre-Brazed Casting) and HRP (Hot Radial Pressing), has been successfully completed as part of contracts with EFDA. The thermal fatigue tests conducted at the FE200 facility (200 kW electron beam facility in CEA/AREVA, France) showed outstanding results, exceeding the ITER requirements. These tests involved subjecting the components to high heat loads, with 3,000 cycles at 10 MW/m² for 10 seconds on both CFC (carbon fiber composite) and tungsten parts, followed by 2,000 cycles at 20/15 MW/m² for 10 seconds on the CFC/w tungsten parts. The results indicate that the technologies developed are strong candidates for producing monoblock divertor components for fusion reactors.

To achieve these successful results, a reliable non-destructive testing (NDT) procedure was established. The chosen method, ultrasonic water gap technique, was selected for its reliability and applicability throughout the entire manufacturing process. This technique can effectively detect defects and assess their size and location, thanks to the design and assembly of specialized ultrasonic equipment. ENEA developed specific software that provides all necessary information regarding the testing results.

Ultrasonic testing (UT) is a non-destructive testing method that uses high-frequency sound waves, typically between 0.5 and 15 MHz, to inspect materials and components for defects. This technique is widely used in mechanical engineering due to its versatility and effectiveness in various applications.

Despite its advantages, improving the efficiency of ultrasonic testing techniques remains a challenge for researchers and practitioners. They are continuously seeking better ways to identify and locate defects in a wide range of mechanical components, from metals to polymers and ceramics.

The fundamental applications of ultrasonic testing cover a broad spectrum, including metals, non-metals, ceramics, polymers, and concrete. The future of ultrasonic testing in mechanical engineering looks promising, with ongoing developments aimed at enhancing its capabilities. These advancements may include improved detection techniques, better equipment, and innovative software solutions, making ultrasonic testing an even more valuable tool for ensuring the safety and integrity of engineering components.

Keywords: *ultrasonic test, Non-Destructive Teting, Carbon Fiber Reinforced plastic*

Introduction:

In modern transportation, especially in the aircraft and aerospace industries, ensuring high operational safety is crucial for protecting lives and minimizing financial losses. Aircraft components made from composite materials, like wings, stabilizers, and fuselages, face various challenges during operation that can lead to damage. Common issues include impacts, static overloads, fatigue, and overheating.

Several types of in-service damage can occur, including delamination, bond failures, cracking, moisture ingress, and failures at the interface between the matrix and fibers.

To assess structural integrity, a damage tolerance methodology is employed. This approach allows composite components to remain operational even when they have existing damage, provided that this damage does not compromise the overall structural integrity. Consequently, these structures are included in maintenance programs designed to identify damage before it weakens the structure beyond acceptable limits. Inspection intervals are calculated to ensure that no crack can grow to a critical size before the next scheduled inspection.

The damage tolerance approach emphasizes the importance of identifying the extent of damage and monitoring its progression through regular inspections using non-destructive testing (NDT) methods. This is particularly vital due to the complex nature of damage propagation in composite materials. Typically, micro-cracks form in the composite matrix due to cyclic loading. As the loading continues, these micro-cracks can develop into larger cracks, which may then spread through the composite layers and eventually lead to delamination due to stress concentrations. Once delamination occurs, the damage can escalate rapidly, potentially leading to failure.

Given this progressive damage behavior, periodic inspections of composite elements are essential for monitoring the progression of damage and ensuring safety.

Ultrasonic inspections use an acoustic coupling medium to transmit sound waves into materials. For inspecting composites, water is often ideal because its acoustic impedance is similar to that of the materials, allowing for effective sound penetration. However, maintaining consistent water coupling on large components can be challenging due to issues like air bubbles and limescale buildup. Additionally, water can cause corrosion in the scanning equipment, and techniques like squirter systems require stable water pressure and precise adjustments, especially with through-transmission methods.

Many inspections cannot be conducted with liquid couplings, like water, because they introduce complications, such as the risk of incoming water. This is where air-coupled techniques (ACT) come in; they eliminate the need for a coupling liquid, simplifying the process. However, this comes at a cost: there's an acoustic mismatch between the solid materials (like transducers and the test component) and the air, which can reduce the effectiveness of the inspection.

To mitigate this mismatch for transducers, a matching layer can be used, which can decrease amplitude loss from about 80-90 dB to around 40 dB. Unfortunately, the mismatch caused by the test component itself (which can result in 70-80 dB loss) cannot be reduced, necessitating the use of specialized equipment.

Air-coupled ultrasonic systems have primarily been used in laboratory settings so far, mainly because the echo technique isn't applicable with these systems. The first studies on air-coupled ultrasonics appeared in the 1970s. For over 14 years, Dr. Hillger Ultrasonic Techniques has been developing systems for this type of coupling, aiming for both laboratory and industrial applications. Since sound frequency in air experiences exponential attenuation as frequency increases, air-coupled ultrasonics typically operate below 1 MHz.

Principles of ultrasonic testing:

Ultrasonic testing (UT) relies on the propagation of elastic waves in solid materials, which reflect off interfaces and internal flaws like separations and inclusions. This method involves sending ultrasonic waves into a test material and then observing either the reflected waves (in the Pulse-Echo technique) or the transmitted waves (in the Through-Transmission technique). In practice, Pulse-Echo systems are more commonly used because they only require access from one side of the material being tested.

The most common UT methods use longitudinal and transverse (shear) waves, but other types of wave propagation, like Rayleigh and Lamb waves, are also employed. Most ultrasonic transducers operate on the piezoelectric principle, meaning they generate ultrasonic pulses when a short electrical discharge is applied and produce an electrical signal when they receive the returning ultrasonic waves. This conversion happens through a polarized ceramic or crystal plate with electrodes on opposite sides.

Transducers can be designed for two types of testing: contact testing and immersion testing. Contact transducers often need a coupling agent—like water, oil, or a special paste—between the probe and the material's surface to help transmit the ultrasonic energy, as air tends to absorb much of it. In immersion testing, the ultrasonic waves travel through a liquid, such as water, to reach the material.

Flaw detection in ultrasonic testing is possible due to differences in acoustic impedance between various materials, which indicates how well they allow ultrasonic waves to pass through. When there's a mismatch in acoustic impedance, the waves reflect at the interface between two materials or at other discontinuities.

Additionally, there's an air-coupled ultrasonic technique that removes the need for a liquid couplant, making it suitable for structures like honeycomb sandwich materials with perforated face sheets. However, the main challenge with air-coupled UT is the significant loss of ultrasonic energy at the air-solid interface, so specialized types of transducers are necessary to make this method effective. The general principles of ultrasonic testing are detailed in the standard.

2. Ultrasonic Imaging System

2.1 Overview:

The imaging system for ultrasonic testing includes several key components: transducers, a powerful pulse transmitter, an ultra-low preamplifier, a receiver amplifier, a digital-to-analog converter, and a computer for setup and evaluation. Additionally, it requires a mechanical scanning system tailored to the design of the component being tested, as well as software for system control, data acquisition, and image processing.

A block diagram of the complete system, known as USPC 4000 AirTech, illustrates how these components work together.

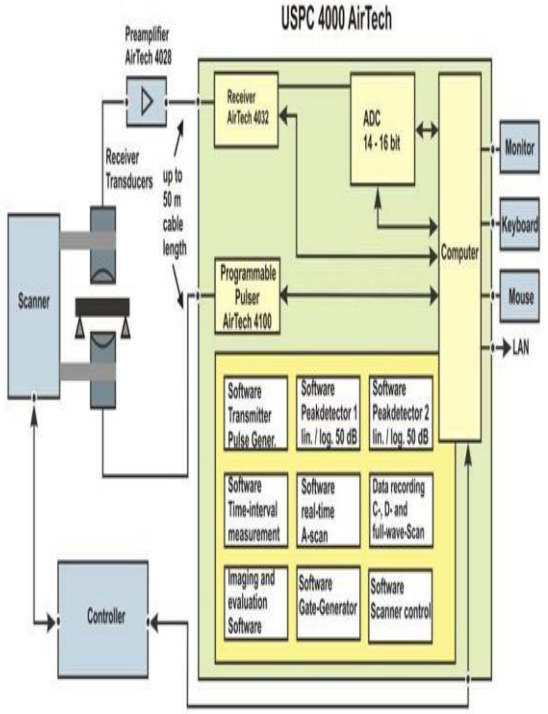

Figure 1. Block diagram of the air-coupled ultrasonic system USPC 4000 AirTech

2.2 Transducers:

Standard transducers cannot be used for air-coupled ultrasonic techniques due to the significant acoustic mismatch between the transducer and the surrounding air. For example, immersion transducers can experience amplitude losses of up to -90 dB, which makes them ineffective for this application.

As part of the MNPQ project in collaboration with BAM in Berlin, which is funded by the German government (BMWi), researchers are investigating special ferroelectric foil transducers. These transducers have small pores embedded in the foil, giving them a very low acoustic impedance, which means matching layers are not needed.

However, these transducers come with high electrical impedance (around 10 picofarads), requiring a high transmitter voltage of over 2 kV and a specially designed preamplifier in the receiver. Because of the risk of high voltage flashovers, these transducers are not yet suitable for industrial use and are still in development. Figure 2.1 illustrates how the pulse builds up and decays in this system.

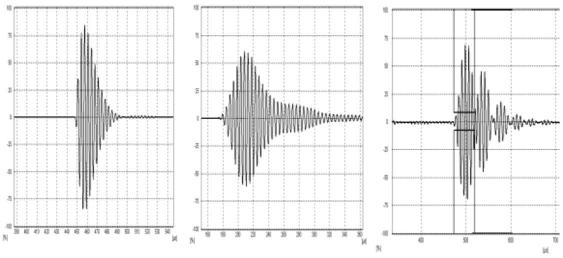

Figure 2. Pulses responses of different transducers

Piezoelectric transducers are commonly used in ultrasonic testing due to their high efficiency in converting electrical energy into acoustic energy. However, because piezoelectric materials have high acoustic impedance, they require a quarter-wavelength (λ/4\lambda/4λ/4) matching layer. This layer acts as a narrowband frequency filter, allowing for the generation of long ultrasonic pulses.

To achieve high amplitude signals, these transducers typically do not include a damping unit. By using multiple matching layers, the bandwidth can be expanded, and the pulse width can be shortened. A typical pulse produced by these transducers may consist of three wave packets, with post-pulse oscillations resulting from different wave modes. However, manufacturing these transducers is complex, and ensuring consistent quality can be challenging.

Figure 3. AirTech transducers with frequencies from 50 to 300 kHz

2.3 Ultrasonic System:

The USPC 4000 AirTech system, illustrated in Figure 1, comprises several key components: a scanner with a controller, two transducers (one for transmitting and one for receiving), an ultra-low noise preamplifier, a pulser unit, and an industrial PC running Windows. The main amplifier and the programmable pulser unit are integrated into PC boards.

The programmable pulser, known as AirTech 4100, can deliver a peak power of up to 1.2 kW. It produces quartz-controlled tone-burst pulses, which can range from 1 to 15 bursts in frequencies between 10 kHz and 1 MHz. Additionally, it can generate freely programmable pulses using a digital arbitrary generator, allowing for the use of chirp and coded signals to enhance the signal-to-noise ratio for research and development purposes. The pulser includes internal overload protection to prevent damage to the transducer and can be housed in a separate case for standalone operation.

The receiver part of the USPC 4000 AirTech includes the AirTech 4028-1-BB ultra-low noise preamplifier, specifically matched to the receiving transducer, and it offers remote-controlled amplification. It connects to the main amplifier, AirTech 4032, which features digital gain control and both high and low-pass frequency filters, along with a 14 to 16-bit analog-to-digital converter (ADC). The separate preamplifier connects to the receiver transducer via a short cable, minimizing electromagnetic noise and signal loss that can occur with longer cables. It can accommodate cable lengths of up to 50 meters between the preamplifier and the USPC 4000 AirTech system without issues, thanks to its 50-ohm technology. The gain of the preamplifier is controlled via software, allowing adjustments between 6 and 46 dB. The system can also be expanded to support up to eight channels for parallel data recording, which is helpful for speeding up the scanning process.

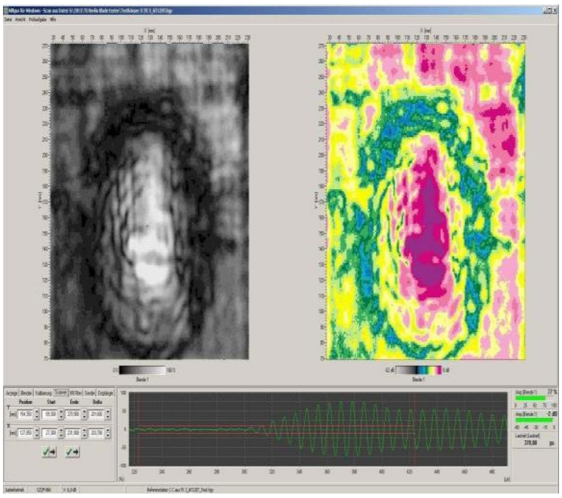

Figure 5. User interface Hillgus for Windows

2.4 Ultrasonic methods:

In any application a separate transmitter transducer and a receiver transducer are necessary. Figure 7 shows the different arrangements of the transducers. The transmission technique with separate transducers on opposite sides of the component is a standard method and useful for standard testing. The transducers are adjusted at right angle to the component. Using angular intromission given by Snell´s Law the longitudinal waves can be converted

In transversal waves in order to increase the resolution. Pitch and catch enables a one sided access of the component. Pitch and catch requires a high precision alignment of the transducers and cannot be achieved for large and complex curved components. Usually the testing is carried out in through-transmission technique with separate receiver and transmitter transducers on opposite sides of the component.

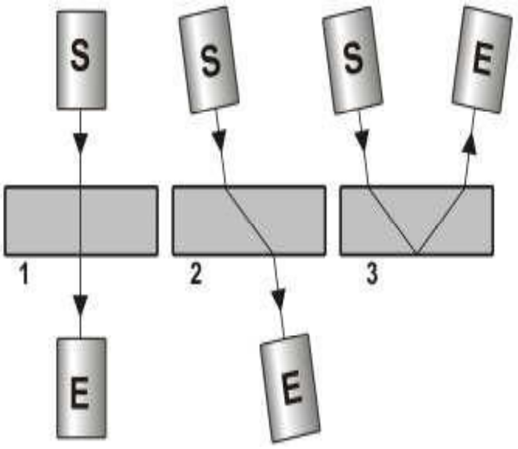

Figure 6. Arrangement of transducers

Literature Review

Before World War II, sonar technology was used to send sound waves through water to detect submerged objects, which later inspired the use of ultrasonic waves for medical diagnostics. Notable developments included Solkov's work (1929-1935) on detecting metal objects and Mulhauser's 1935 patent for using two transducers to identify flaws in solids. By the 1960s, non-destructive testing (NDT) became prevalent in manufacturing, particularly in processes like welding and casting.

Research on ultrasonic testing (UT) has covered a variety of applications, including:

- Railway Inspection: Studies highlighted UT's effectiveness in detecting defects in railway tracks and train wheels using embedded Hall sensor matrices for quick inspections.

- Aircraft Composite Structures: Comparisons of NDT techniques on materials like GFRP and CFRP showed UT provided better defect evaluations than thermography. Structural health monitoring techniques were also discussed for maintaining aircraft integrity.

- Defect Detection in Various Materials: Research demonstrated UT's accuracy in identifying defects in carbon/epoxy composites, honeycomb structures, and Kevlar skins. Laser UT was explored for detecting drilling-induced delamination in aircraft components.

- Advanced Applications: Studies on thermal NDT showed it was faster than traditional UT, while other research investigated the effects of weld nugget size on signal strength. Oblique incident ultrasonic testing was developed for detecting defects in friction stir welds.

- Reliability in Pipe Welds: Research indicated that automated UT was more effective than manual methods for inspecting pipe welds in the oil industry. Additional studies focused on the ultrasonic testing of plastic and concrete pipes.

- Innovative Techniques: Some papers explored combining UT with optical techniques for better visualization of Lamb waves, enhancing inspections of thin-walled components.

Overall, these studies highlight the versatility and effectiveness of ultrasonic testing across various industries, from transportation to aerospace.

Testing Procedures

There are three main techniques for measuring ultrasonic velocity direct pulse transmission surface velocity measurement and semi-direct pulse transmission.

1. Direct Pulse Transmission: This is considered the most reliable method because it allows for internal examination of the material being tested. In this technique, transducers are placed on opposite faces of the specimen, providing a clear path for the ultrasonic waves.

2. Surface Velocity Measurement: In this method, the exact path length of the ultrasonic waves is uncertain. To improve accuracy, several receiver transducers are placed along a radial line from the transmitter. The average pulse velocity is then calculated by plotting the transit time against the distance between transducers and finding the slope of the best-fit line.

3. Semi-Direct Pulse Transmission: This technique is used when one side of the specimen is inaccessible. The path length is less defined in this case. Generally, the distance between transducers is considered sufficient as long as the angle between them is not too large and the path is not excessively long.

Positioning the transducers properly is crucial. If they are pressed against a discontinuity or near an edge, it can lead to ultrasonic scattering, wave deformation, and reduced signal amplitude. This can result in inaccurately low velocity readings. The minimum distance from edges should be determined experimentally, as it depends on factors like the specimen's microfabric, its dimensions, and the frequency and size of the transducers.

When coupling the transducers to the specimen, it's essential to eliminate air pockets at the interface. The acoustic impedance of the coupling medium should closely match that of the transducers. Using a coupling fluid that is only a small fraction of the wavelength of the ultrasonic wave can help minimize the impact of impedance differences. The effectiveness of the transmission can vary with the thickness of the coupling film, and if the coupling pressure isn't consistent, the intensity of the ultrasonic beam may fluctuate significantly. A smoother test surface is preferable, and while a thicker couplant can help with minor surface roughness, it should be optimized to maintain transmission efficiency.

1. Direct Pulse Transmission

it is a widely used method for measuring ultrasonic velocity in materials. In this technique, two ultrasonic transducers are placed on opposite surfaces of the material being tested. One transducer acts as the transmitter, sending ultrasonic pulses into the material, while the other functions as the receiver, detecting the pulses that travel through the material and return.

This method features a clear path for ultrasonic waves, allowing for effective transmission and reception. By ensuring a direct alignment of the transducers, direct pulse transmission enables the internal examination of the material, making it useful for assessing the integrity of specimens and detecting internal flaws.

The procedure involves carefully positioning the transducers on opposite faces of the material and applying a coupling medium, such as gel or oil, to eliminate air gaps that could significantly affect the transmission of ultrasonic waves. Once the setup is complete, the transmitter sends an ultrasonic pulse into the material, and the receiver detects the returning pulse after it has traveled through the specimen. The time it takes for the pulse to travel from the transmitter to the receiver is recorded, allowing for the calculation of ultrasonic velocity based on the known distance between the transducers and the measured transit time.

The advantages of direct pulse transmission include its accuracy and the ability to identify internal defects, such as cracks or inclusions, which are crucial for assessing material integrity. However, it requires careful surface preparation to ensure smooth and contaminant-free contact between the transducers and the material. Additionally, both sides of the material must be accessible, which can be a limitation in some applications.

Overall, direct pulse transmission is a reliable and effective technique for measuring ultrasonic velocity, playing a vital role in quality assurance across various industries, including manufacturing, aerospace, and civil engineering.

2. Surface Velocity Measurement:

it is an ultrasonic testing technique used to evaluate the velocity of ultrasonic waves traveling along the surface of a material. This method involves placing a transmitter and a receiver on the surface, typically using a contact medium to ensure good acoustic coupling between the transducers and the material.

In this technique, the transmitter emits ultrasonic pulses that travel through the surface of the material, and the receiver detects the time it takes for these pulses to return after reflecting off internal features or flaws. The distance between the transducers and the measured transit time allows for the calculation of the surface velocity of the ultrasonic waves.

One of the key aspects of surface velocity measurement is the positioning of the transducers. Proper alignment is essential to minimize scattering, which can occur if the transducers are near edges or discontinuities. Such positioning can lead to wave deformation and a reduction in signal amplitude, resulting in inaccurately low velocity readings.

A challenge with surface velocity measurement is that the exact path length of the ultrasonic waves can be uncertain, as the waves may not follow a straight line due to material irregularities. To address this, multiple receiver transducers can be arranged along a radial line from the transmitter. By analyzing the transit times at each receiver, the mean pulse velocity can be determined through a best-fit straight line method.

Furthermore, maintaining a suitable coupling medium is critical for accurate measurements. The acoustic impedance of the coupling medium should closely match that of the transducers and the specimen to minimize reflection losses at the interface. Additionally, any air pockets must be eliminated, as they can significantly interfere with the ultrasonic wave transmission.

Overall, surface velocity measurement is a valuable technique for assessing material properties and identifying defects near the surface. It is widely used in various industries, including construction, manufacturing, and aerospace, to ensure the structural integrity and performance of materials.

3. Semi-Direct Pulse Transmission

Semi-Direct Pulse Transmission is a technique used in ultrasonic testing when the opposite face of a material is either inaccessible or absent. This method involves positioning a transmitter and receiver on the same side of the specimen, which means that the path length of the ultrasonic waves is not clearly defined, making it less straightforward than direct pulse transmission.

In semi-direct pulse transmission, the transmitter emits ultrasonic waves that travel through the material and are detected by the receiver after reflecting off internal features or flaws. However, because both transducers are on the same side, the angle between them and the length of the transmission path can introduce uncertainties in the measurement. As a result, careful consideration of these parameters is essential to obtain reliable readings.

Despite the challenges associated with path length uncertainty, the semi-direct pulse transmission technique is valuable in scenarios where access to the opposite side of a specimen is restricted. The technique is typically deemed adequate as long as the angle between the transducers is not too large and the distance between them is reasonable. Proper alignment and positioning of the transducers are crucial to minimize any potential distortion of the ultrasonic waves.

The effectiveness of this method also depends on the quality of the acoustic coupling between the transducers and the material. Just like in other ultrasonic testing techniques, it is vital to ensure that there are no air pockets at the interface and that the acoustic impedance of the coupling medium matches that of the transducers. This reduces reflection losses and improves signal transmission through the material.

While semi-direct pulse transmission may not provide the same level of clarity as direct pulse transmission, it remains a practical solution in various applications, particularly when dealing with large or complex components where access is limited. This method enables inspectors to evaluate internal features and defects without the need for full access to both sides of the specimen, making it a valuable technique in non-destructive testing across multiple industries.

Materials used in ultrasonic sound testsing

Ultrasonic testing (UT) employs a variety of materials and components that play critical roles in the process of generating, transmitting, and receiving ultrasonic waves. Here are the key materials used in ultrasonic testing:

1. Transducer Materials

- Piezoelectric Crystals: Commonly used materials include quartz, lead zirconate titanate (PZT), and lithium niobate. These materials convert electrical energy into mechanical energy (ultrasonic waves) and vice versa.

- Ceramics: Various ceramic materials are used for their piezoelectric properties, providing high sensitivity and efficiency.

2. Coupling Agents

- Liquid Couplants: Water, glycerin, oil, or specialized ultrasonic couplants are used to eliminate air gaps between the transducer and the test surface, ensuring effective transmission of ultrasonic waves.

- Grease or Gel: These are also used as couplants, especially when dealing with rough or uneven surfaces to improve contact and reduce signal loss.

3. Testing Specimens

- Metals: Common metals like steel, aluminum, and titanium are often tested to identify defects such as cracks, voids, or inclusions.

- Composites: Materials like carbon fiber reinforced polymers (CFRP), glass fiber reinforced polymers (GFRP), and other composite structures are evaluated for delaminations or internal flaws.

- Plastics: High-density polyethylene (HDPE), polyvinyl chloride (PVC), and other plastic materials are also tested for defects in their structural integrity.

- Concrete: Ultrasonic testing can be used to assess the quality of concrete and detect flaws within it.

4. Test Equipment Materials

- Steel or Aluminum for Fixtures: Rigid structures are often made from durable metals to hold transducers and test specimens securely during testing.

- Plastic or Composite Materials: Used for housing and protective casings for the transducers and electronic equipment to reduce weight and improve portability.

5. Signal Processing Components

- Electronic Circuits: Composed of various materials, including silicon-based semiconductors, capacitors, and resistors, these are critical for generating, amplifying, and processing the signals received from the ultrasonic waves.

- Analog-to-Digital Converters (ADCs): Often made from semiconductor materials, ADCs convert the received analog ultrasonic signals into digital signals for analysis.

6. Calibration Standards

- Calibration Blocks: Often made of known materials (like aluminum or steel) with predefined flaw sizes, these are used to calibrate ultrasonic testing equipment for accuracy.

7. Software Materials

- Computer Hardware: Components like CPUs, memory, and storage used in the processing of ultrasonic data.

- Software Algorithms: Written in various programming languages to process and analyze the ultrasonic signals, providing visual representations and interpretations of the data.

Future Research

Ultrasonic testing (UT) is a non-destructive method that has significantly reduced losses compared to traditional destructive testing methods. It's particularly useful in detecting small defects, such as those less than 0.8 mm in size, making it ideal for applications like rail inspections and evaluating the quality of spot welds (also known as nuggets).

In industries like aerospace, UT plays a crucial role in identifying defects in composite materials such as carbon fiber reinforced polymers (CFRP) and glass fiber reinforced polymers (GFRP), as well as in detecting barely visible impacts or damage (BVIDs). It's increasingly used for maintenance checks on aircraft and is now being integrated into online monitoring systems in manufacturing processes.

Looking ahead, the potential for non-destructive ultrasonic testing is vast. There is a growing need for automated testing systems, especially for challenging applications like rail inspections, complex geometries, assessing severe corrosion, and even in fields like agriculture and medicine. Developing effective and efficient fault detection methodologies using UT will be beneficial for society in various sectors, including engineering, healthcare, geography, and services. With advancements in technology, it's likely that UT will become an essential tool across many industries in the coming decades.

Advanced Ultrasonic Testing Technology

Defects in carbon fiber composites can be identified using both destructive and non-destructive testing (NDT) methods. The destructive method typically involves traditional metallographic techniques, which allow for the observation of the material's internal structure using a metallographic microscope. This approach helps in understanding the shape, size, and distribution of defects within the composite material. However, metallographic methods require grinding and polishing the surface of the carbon fiber composite before inspection, which can be time-consuming and may unintentionally damage the material. This makes it impractical for inspecting large quantities of workpieces in engineering applications.

In contrast, non-destructive testing methods can assess materials without affecting their performance or internal structure. Among these, ultrasonic testing has become one of the most popular techniques due to its safety, high sensitivity, accuracy, ease of implementation, and broad range of applications.

The basic principle of ultrasonic defect detection involves emitting an ultrasonic beam that travels through the material. When this beam encounters a defect, it reflects and attenuates, creating a detectable signal that can be processed. There are three main ways to display defects using ultrasonic testing:

1. **A-scan**: This method shows the depth of the defect and the amplitude of the reflected signal.
2. **B-scan**: This provides a cross-sectional view of the defect's depth and distribution within the material.
3. **C-scan**: This method presents a top-down view of the defect distribution on a plane.

By analyzing the behavior of ultrasonic longitudinal waves in the composite, we can record the characteristics of the echo signals, such as propagation time, signal amplitude, and phase information. This data is typically displayed using A-scan techniques, enabling precise quantitative assessments of the thickness and depth of defects in the composite parts. Additionally, qualitative evaluations of the defects can also be achieved through this method.

Conclusion

It is a highly effective and versatile non-destructive testing (NDT) method that plays a crucial role in various industries, including manufacturing, aerospace, and civil engineering. UST utilizes high-frequency sound waves to detect internal flaws and assess the integrity of materials without causing any damage. Its advantages include high sensitivity, accuracy, and the ability to provide detailed information about defects, such as their size, shape, and location.

The technology is particularly valuable for inspecting complex materials like carbon fiber reinforced polymers (CFRPs) and other composites, where traditional destructive methods may not be practical or efficient. With various display methods—such as A-scan, B-scan, and C-scan—UST enables engineers and technicians to gain comprehensive insights into the structural health of components and ensure their safety and reliability.

As technology continues to advance, the future of ultrasonic sound testing looks promising. Automated systems and enhanced data processing techniques will likely improve the efficiency and effectiveness of UST, allowing for real-time monitoring and evaluation in diverse applications. Overall, UST is an essential tool for maintaining the quality and safety of critical materials and structures across multiple sectors.

Reference

1. *R. A. Smith, Composite defects and their detection, in: R. Rawlings (Ed.), Encyclopaedia of Life Support Systems, Vol. 3 of Materials science and engineering, UNESCO, 2009, pp. 103–143.*
2. *R. Wanhill, Milestone Case Histories in Aircraft Structural Integrity, Vol. 1 of Comprehensive Structural Integrity, Elsevier, 2003, pp. 61–72. doi: 10.1016/b0-08-043749-4/01002-8.*
3. *L. D. Cot, C. Bes, C. Gogu, Structural airframe maintenance strategy comparison: a new approach, in: F.-K. Chang (Ed.), Structural Health 665 Monitoring 2013: A Roadmap to Intelligent Structures: Proceedings of the Ninth International Workshop on Structural Health Monitoring, DEStech Publications, Inc, 2013, pp. 1460–1467*
4. *V. Giurgiutiu, Chapter 5 – damage and failure of aerospace composites, in: V. Giurgiutiu (Ed.), Structural Health Monitoring of Aerospace 670 Composites, Academic Press, Oxford, 2016, pp. 125–175. doi:10.1016/ B978-0-12-409605-9.00005-2*
5. *D. K. Hsu, 15 – non-destructive evaluation (NDE) of aerospace composites: ultrasonic techniques, in: V. M. Karbhari (Ed.), Non-*

Destructive Evaluation (NDE) of Polymer Matrix Composites, Woodhead Publishing Series 675 in Composites Science and Engineering, Woodhead Publishing, 2013, pp. 397–422.

6. *W. Hillger, L. Bühling, D. Ilse: Review of 30 Years Ultrasonic systems and developments for the future, 11th European Conference on Non-destructive Testing, October 6-10, 2014, Prague, Czech Republic, Conf. Proc. on NDT.net*
7. *M. Gaal, J. Döring, J. Bartusch, T. Lange, W. Hillger, G. Brekow and M. Kreutzbruck: Ferroelectric transducers for air-coupled ultrasonic testing of fibre-reinforced, in Review of Progress in Quantitative Nondestructive Evaluation, (QNDE), Denver, CO, USA, 16-20th July 2012*
8. *M. C. Bhardwaj, "Non-Destructive Evaluation: Introduction of Non-Contact Ultrasound", in Encyclopedia of Smart Materials, edited by M. Schwartz, John Wiley & Sons, New York, 2001, pp. 690-714.*
9. *W. Hillger, R. Stößel, S. Lang, J. Schuller, R. Oster, L. Bühling, D. Ilse, J. Bosse, B. Thaler : Automated Air-Coupled Ultrasonic Technique for the Inspection of the EC145 Tail Boom, 4th International Symposium on NDT in Aerospace, November13th to 15th 2012, Augsburg, Germany, DGZfP-Proceedings BB 138 – CD, ISBN 978-3-940283-46- 7*
10. *R. Oster: Non-destructive testing methodologies on helicopter fiber composite components challenges today and in the future, 18th World Conference on Nondestructive Testing, 16-20 April 2012, Durban, South Africa, Conf. Proc. on CD*
11. *Ahmed, K. S., Vijayarangan, S., & Kumar, A. (2007). Low velocity impact damage characterization of woven jute—glass fabric reinforced isothalic polyester hybrid composites. Journal of reinforced plastics and composites, 26(10), 959-976*
12. *Armitage, P. R., & Wright, C. D. (2013). Design, development and testing of multi-functional non-linear ultrasonic instrumentation for the detection of defects and damage in CFRP materials and structures. Composites science and technology, 87, 149-156.*
13. *Carvalho, A. A., Rebello, J. M. A., Souza, M. P. V., Sagrilo, L. V. S., & Soares, S. D. (2008). Reliability of non-destructive test techniques in the inspection of pipelines used in the oil industry. International journal of pressure vessels and piping, 85(11), 745-751.*
14. *ASTM, D 2845, 2000, "Standard Test Method for Laboratory Determination of Pulse Velocities and Ultrasonic Elastic Constants of Rock," ASTM Standards on Disc, Vol. 04.08.*
15. *Bray, D. E. and McBride, D., 1992, Nondestructive Testing Technique, John Wiley, New York.*
16. *W. J. Cantwell and J. Morton, "The impact resistance of composite materials–a review," Composites, vol. 22, no. 5, pp. 347–362, 1991.*
17. *D. Shanyi, "Advanced composite materials and aerospace engineering," Acta Materiae Compositae Sinica, vol. 24, no. 1, pp. 1–12, 2007.*