Available online at www.sciencedirect.com

ScienceDirect

Materials Today: Proceedings 5 (2018) 3690–3698

materialstoday: PROCEEDINGS

www.materialstoday.com/proceedings

ICMPC 2017

Advances and Researches on Non Destructive Testing: A Review

Sandeep Kumar Dwivedi[a], Manish Vishwakarma[b], Prof.Akhilesh Soni[c]

[a]*Ph.d scholar,Mechanical Engineering, Manit, Bhopal 462003, India*
[b]*Assistant professor, Mechanical Engineering, Manit Bhopal 462003, India*
[c]*Assistant professor, Mechanical Engineering, Manit Bhopal 462003, India*

Abstract

This paper provides the recent advances and researches about non-destructive testing (NDT) methods for defect characterization in engineering materials and composites. The paper covers the review on the capabilities of NDT applications such as Visual Testing (VT), Ultrasonic Testing (UT), Thermography, Radiographic Testing (RT), Electromagnetic Testing (ET), Acoustic Emission (AE) and shearography testing with respect to advantages and disadvantages of these methods. Further methods are classified on basis of their intrinsic characteristics and their applications. Mostly, an NDT evaluator uses only one non-destructive test method to perform the evaluation. If the scope of work is straight forward, using a single test method is acceptable. However, there are times when a single test method does not provide enough information about the material integrity and thereby combination of different methods is essential. Non destructive testing is widely applied in power plants, aerospace, nuclear industry, military and defence, storage tank inspection, pipe and tube inspection and composite defects characterization. This paper mainly focuses on the scope of NDT application for composite materials.

Keywords: Non destructive testing;Ultrasonic technique;Composite material.

1. Introduction

Nondestructive testing are methods to evaluate material integrity for surface or internal flaws or metallurgical condition without interfering in any way with the destruction of the material or its suitability for service. [1] There are varieties of methods to evaluate materials and components as per their state of application.

* Corresponding author. Tel.: +919424332668.
*E-mail address:*sandeep0183@gmail.com

The field of Non-Destructive Evaluation (NDE) or Non-Destructive Testing (NDT) involves the identification and characterization of damages or defect on the surface and interior of materials without cutting apart or otherwise altering the material. In other words, NDT refers to the assessment or evaluation and inspection process of materials or components for characterization or finding defects and flaws in comparison with some standards without altering the original attributes or harming the object being tested. NDT techniques make available or provide a cost effective means of testing of a sample for individual investigation and examination or may be applied on the whole material for checking in a production quality control system. [2]In many cases, the approach to finding a defect requires more than use of a single NDT test method. It may require a combination of methods and also exploratory, invasive openings. A better understanding of the background, advantages and limitation of each NDT method is essential in ensuring the success of the evaluation. Understanding one NDT method alone may not be enough to ensure the success in solving the problem at hand. [3]A wide variety of non destructive testing methods plays most important roles in testing of composite materials. The applications of composite NDT may include in many places such as in manufacturing, pipe and tube manufacturing, storage tanks, aerospace, military and defence, nuclear industry, and composite defects characterization. Damage in composite materials can arise during material processing, fabrication of the component or in-service activities among which cracks, porosity and delamination are the most common defects. [4] Numerous techniques are used in the composite NDT field, including radiographic testing, visual testing (VT) or visual inspection (VI), ultrasonic testing, thermographic testing, infrared thermography testing, acoustic emission testing (AE), acoustic-ultrasonic, electromagnetic testing, shearography testing, optical testing, liquid penetrant testing and magnetic particle testing. This paper reviews various NDT methods for defect identification and characterization in material and composite and find out most efficient method.

2. Non-Destructive Testing Methods

There is wide variety of nondestructive techniques or methods. These methods can be performed on metals, plastics, ceramics, composites, cermets, and coatings in order to identify cracks, internal voids, surface cavities, delamination, incomplete defective welds and any type of flaw which would lead to premature failure. Commonly used NDT test methods can be seen in table 1.

Table 1. Commonly used NDT techniques [33]

Technique	Capabilities	Limitation
Visual Inspection	Macroscopic surface flaws	Small flaws are difficult to detect, no subsurface flaws.
Microscopy	Small surface flaws	Not applicable to larger structures; no subsurface flaws
Radiography	Subsurface flaws	Smallest defect detectable is 2% of the thickness; radiation protection. No subsurface flaws not for porous materials
Dye penetrate	Surface flaws	No subsurface flaws not for porous materials
Ultrasonic	Subsurface flaws	Material must be good conductor of sound.
Magnetic Particle	Surface / near surface and layer flaws	Limited subsurface capability, only for ferromagnetic materials.
Eddy Current for metals	Surface and near surface flaws	Difficult to interpret in some applications; only for metals
Acoustic emission	Can analyze entire structure	Difficult to interpret, expensive equipments

Visual Inspection- Visual inspection is particularly effective for detecting macroscopic flaws, such as poor welds. Many welding defects are macroscopic such as crater cracking, undercutting, slag inclusion, incomplete penetration welds, and the like. Likewise, VI is also suitably used for detecting flaws in composite structures and piping of all types. Bad welds or joints, missing fasteners or components, poor fits, wrong dimensions, improper surface finish, large cracks, cavities, dents, inadequate size, wrong parts, lack of code approval stamps and similar proofs of testing. [1]

Radiography- Radiography technique has a benefit or advantages over some of the other NDT methods in that the radiography provides a permanent reference for the internal soundness of the object that is radiographed. The x-ray emitted from a source has an ability to penetrate metals as a function of the accelerating voltage in the x-ray emitting tube. If any defect or irregularities such as void present in the object are radiographed, more x-rays will pass in that area and the film under the part in turn will have more exposure or spot light than in the non-void areas. The sensitivity of x-rays is nominally 2% of the materials thickness. Thus for a piece of steel having a thickness of 25mm, the smallest void that could be detected from this x ray would be 0.5mm in dimension. For this reason, parts are often radiographed in different planes. A thin crack does not show up unless the x-rays ran parallel to the plane the crack. We also find out that Gamma radiography is identical or similar to x-ray radiography in function. However this method is less popular because it has a disadvantage of hazards during the handling radioactive materials. This technique is appropriate for the detection of internal flaws or defects in ferrous and non-ferrous metals and other materials. X-rays, generated electrically, and Gamma rays emitted from radio-active isotopes, are penetrating radiation which is differentially absorbed by the material through which it passes; the greater the thickness, the greater the absorption. [1]

Dye Penetrate Testing- This technique is based on the ability of a liquid to be drawn into a "clean" surface breaking flaw by capillary action. Materials that are commonly inspected using DPT or LPI include metals (aluminium, steel, titanium, copper, etc.), glass, many ceramic materials, rubber, plastics. The penetrant which is used in dye penetrate testing may be applied to all non-ferrous materials and ferrous materials; we also known that for ferrous components magnetic-particle inspection is often used instead for its subsurface detection capability. DPT is used to detect defects in casting, forging and welding surface defects such as hairline cracks, surface porosity, leaks in new products, and fatigue cracks on in-service or in operating components. LPI is based upon capillary action, where as low surface tension fluid penetrates into clean and dry surface-breaking discontinuities. Penetrant may be applied to the test component or specimen by dipping, spraying, or brushing. After adequate penetration time has been allowed, the excess penetrant is removed and a developer is applied. The main advantage of using a developer in DPT is that it helps to draw penetrant out of the flaw so that an unseen or invisible indication becomes visible to the inspector. Inspection is performed under ultraviolet or white light, depending on the type of dye used fluorescent or non fluorescent (visible). [1]

Ultrasonic Testing- The ultrasonic technique is used for the detection of internal defects in sound conducting materials. The principle of operation of ultrasonic testing is in some respects similar to echo sounding. A short pulse of ultrasound is generated by means of an electric charge applied to a piezoelectric crystal, which vibrates for a very short period at a frequency related to the thickness of the crystal. In flaw detection this frequency is usually in the range of 1 MHz to 6 MHz Vibrations or sound waves at this frequency have the ability to travel a significant distance in homogeneous elastic material, such as many metals with very little attenuation. For example the velocity in steel is 5900 meters per second, and in water 1400 meters per second. Ultrasonic testing employs an extremely diverse set of methods based upon the generation and detection of mechanical vibrations or waves within test objects. Cathode ray tube is the standard method of presenting information in ultrasonic testing, in which horizontal movement of the spot from left to right represents time elapsed. The rate at which the spot moves is such that it gives the appearance of a horizontal line on the screen. [1]

Magnetic Particle Inspection- This method uses magnetic fields and small magnetic particles, such as iron filings to detect flaws in components. The only requirement from an inspect ability standpoint is that the component being inspected must be made of a ferromagnetic material such iron, nickel, cobalt, or some of their alloys, since these materials are materials that can be magnetized to a level that will allow the inspection to be effective. In its simplest application, an electromagnet yoke is placed on the surface of the part to be examined, a kerosene-iron filling suspension is poured on the surface and the electromagnet is energized. If there is a discontinuity such as a crack or a flaw on the surface of the part, magnetic flux will be broken from that place and a new south and north pole will form at each edge of the discontinuity. Then just like if iron particles are scattered on a cracked magnet, the particles will be attracted to and cluster at the pole ends of the magnet, the iron particles will also be attracted at the edges of the crack behaving poles of the magnet. This cluster of particles is much easier to see than the actual crack and this is the basis for magnetic particle inspection. This method is suitable for the detection of surface and near surface discontinuities in magnetic material, mainly ferrite steel and iron. [1]

Eddy Current Testing- Eddy currents are created through a process called electromagnetic induction. When alternating current is applied to the conductor, for example as in copper wire, a magnetic field develops in and around the conductor. During the process this magnetic field expands as the alternating current rises to maximum and collapses as the current is reduced to zero. If a new or secondary electrical conductor is brought into the close proximity to this changing magnetic field, current will be induced in this second conductor. These currents are influenced by the nature of the material such as voids, cracks, changes in grain size, as well as physical distance between coil and material. These currents form impedance on a second coil which is used to as a sensor. In practice the surface of the part is to be inspected or examined by placing a probe above the surface, and electronic equipment monitors the eddy current in the work piece through the same probe. Eddy currents testing can be used to find out n number of things such as in crack detection, material thickness measurements, coating thickness measurements, heat damage detection, case depth determination, conductivity measurements for material identification, heat treatment monitoring. [33]

Acoustic Emission Testing- Acoustic emission (AE) is the sound waves created when a material undergoes stress (internal change), as a result of some external force. AE is a phenomenon occurring in for instance mechanical loading generating sources of elastic waves. This occurrence is the result of a small surface displacement of a material produced due to stress waves generated when the energy in a material or on its surface is released quickly. The wave which is generated by the source is of practical interest in methods used to stimulate and capture AE in a controlled fashion, for study and/or use in inspection, examination, quality control, system feedback, process monitoring and others. [1] The very important thing is that the acoustic emissions are detected with sensors consisting of piezoelectric ceramic elements. This method is particularly effective for continuous surveillance of load-bearing structures. [33]

3. Non Destructive Testing Of Composite Material

Nowadays Composite material are receiving much attention not only because they are on the cutting edge of active material research field but also because there is a great deal of promise for their potential and likely applications in a variety of industries ranging from aerospace to construction due to their various outstanding properties. The non-destructive testing and inspection or examination of composite structures, both for manufacturing quality assurance and for in-service damage recognition, has prompted the development and adaptation of a number of methods and techniques over the years. Detection of flaws in composite materials requires a skilled work since the materials are often non-homogeneous and anistropic. [34] There are wide variety of non-destructive testing techniques are available for composite material defect evaluation. Ultrasonic technique, acoustic emission technique, infrared thermography etc techniques are successfully applied in composite material. The result proven by ultrasonic technique is more accurate and reliable. This process is also non hazardous. The skill is required during the operation. Shearography technique is also used to scan the aerospace structures. This is also applied and useful in GRP pressure vessels where shearography is used to detect inclusion.

Composite have better specific stiffness and their anisotropic character can be customized to the structural load requirements. The use of composites is acceleration and now spans transportation industry applications including next generation aircraft such as new Boeing 787.Composites are widely used in marine applications and have been revolutionary in sporting applications such as skiing, tennis rackets or golf clubs. [35]

Composite mechanical damage is typically in the form of delaminations or disbonds (laminate-to laminate or laminate-to-core), broken fibers due to impact, fatigue damage that affects the zone of composite material via micro cracking, fiber delaminations, fiber breaks and overall loss of mechanical modulus, or can be caused by thermal damage from prolonged exposure to heat above resin cure temperatures as well as combination of effects due to extreme operational conditions. Table 2 shows a list of possible defects and damage found in composite materials.

Table No. 2 Defects in composite [35]

Defects in Composites	
Delaminations	Missing Adhesive
Disbonds	Misoriented Fibers/ Ply
Porosity	Wavy Fibers
Contamination	Mislocated Ply/ Details
Improper Cure	Impact Damage
Resin Rich/Poor	Thermal Damage
Damaged Fiber	Thickness Variation
Voids	Dimensional Problem
Cracks	Interface Integrity

Combination of the non destructive testing methods and a need for continuous monitoring of the composite material structural condition supports a rapid development and advances in health monitoring applications and eventual prognostics of the structural degradation. [35] These all factors have significant effect on testing of composites through non-destructive methods.

4. Literature Survey

Sanjay Kumar et al [1] stated that Non-destructive testing techniques typically use a probing energy form to determine material properties or to indicate the presence of material discontinuities (surface, internal or concealed). It was also found that most of the non destructive testing techniques are primarily being used in many places such as in the aerospace industry, manufacturing industries and have likely to be used for evaluating civil work and infrastructures. From this paper, it is concluded that there is a need of more research work which is carried out so that these techniques are applicable for field use for civil infrastructure. This paper reviews the dissimilar or different works in the area of NDT and trying to find out most recent developments and trends available in industries and other fields in order to minimize damages, minimize the total equipment cost and maximize the safety of equipment, machine, structures and materials.

S.Gholizadeh [2] reviewed the non-destructive testing (NDT) methods for the evaluation of composites. Composite tools are mostly used in critical-safety applications in aircraft primary construction. So to know the incipient faults in composite material, the non destructive testing techniques are very much essential. Gholizadeh uses different NDT methods such as visual inspection, ultrasonic technique, Thermography testing and more to evaluating faults in composite material. The best NDT technique chosen is depending upon the safety of operation and cost incurred during the operation. In addition, non-destructive tests use physical principles to identify and evaluate faults or destructive defects.

Malcolm K. Lim et al [3] describes the use of different non destructive techniques. Some time from one NDT method we could not get the required result so that we use the combination of the NDT techniques to get more detail information and result. In this paper two NDT ultrasonic testing and impulse Response method has been used to evaluate the condition of concrete and defect on concrete structure. By using these techniques together we find out more accurate condition of concrete. The Ultrasonic Pulse Velocity method relies on the time of flight of sonic energy in concrete, to determine the wave propagation velocity. The reduction in velocity is normally an indication that a potential anomaly is present at that test point. On the other hand, IR testing measures the global response of a structure and tends to be influenced by conditions between adjacent test points, and edge or boundary effects.

MR Jolly et al [4] describes the highly reliable and cost effective non destructive testing technique for the thick walled carbon fibre component that can detect delamination, cracks and other defects and can be applied in series production at an acceptable cost point. There are a number of NDT techniques which might be suitable for thick-walled carbon composite components. From this paper we found that delamination is the main type of defect that exists within the component which lead to in-homogeneity within the composite component. Delamination size longer than 1 mm has to be detected. In Radiography the object is penetrated with short wavelength electromagnetic radiation. The total amount of radiation that passes through the object is captured by a detector. The absorption is a function of density and thickness of the material. Another method called Computed Temography is used for thick walled carbon fibre component. This scanning technique is used to generate an exact three-dimensional cross sectional image of the entire part. Typical defects that can be detected using this Computed Temography technique are delamination, undulations, porosities, fibre cracks or impact damages. Thermography testing makes use of infrared (IR) imaging to detect defects within the component. Although Computed Temography equipment is significantly more expensive than Ultrasonic Technique and thermography equipment, it is a proven or established system with high reliability and a much better traceability.

YANG Zhan-feng et al [5] describes the nonlinear ultrasonic testing technique for micro-damage of TATB based Polymer Bonded Explosive (PBX). Ultrasonic non-destructive testing technique is used to evaluate the defects inside explosive parts. For PBX parts examination, the linear wave theory based ultrasonic testing method such as the ultrasonic Pulsed Echo method or transmission method is mainly used. From the research we find out that the materials damage and property degradation are always come with with some kind of non-linear mechanical behaviours, result in the non-linear ultrasonic transmission, such as the forming of the high-order harmonic wave. The non-linear ultrasonic techniques used in the research of micro-damage and performance of PBX parts can be meaningful, which will present a new method for the evaluation of the micro-damage and its expansion regularity as well as the reliability of explosives storage. During this examination we found out that the Ultrasonic linear parameters such as gain or velocity were not changed obviously during the whole fatigue cycle loading process. Concluding to this work author suggested that the ultrasonic linear parameters are not sensitive to accumulation and development of micro-damage, unlike ultrasonic nonlinear coefficient, which was very sensitive to that.

M. Rojek et al [6] explained the Fatigue and ultrasonic testing of epoxy-glass composites. Epoxy-glass composites are useful and apply more and more frequently as high performance engineering materials. Also they find applications in such demanding and challenging fields as civil engineering, car industry, electronic industry, aerospace technology and many others. During composites development and exploitation many degrading processes take place. Main degrading influences are thermal ageing, radiation and chemical attack, creep and fatigue. It shows the relationship between the degree of strength degradation caused by fatigue and the changes of ultrasonic wave characteristics such as wave velocity and damping coefficient. A good correlation between velocity of ultrasonic wave propagation and the degree of strength degradation of epoxy-glass composites caused by fatigue was found. Ultrasounds can be applied as useful tool to assessment of fatigue degradation of polymer composites. This explains the mechanical properties such as flexural strength and flexural modulus decrease as a result of cyclic loadings. We also find out that the Strong dependence between velocity of ultrasound wave propagation and number of loading cycles. Velocity of sound propagation is decreasing as load increasing.

Eiichi Sato et al [7] explained the ultrasonic testing method for detection of planar flaws in graphite material. An ultrasonic inspection method was used for graphite ingot to detect internal planar flaws that are oriented in various directions. This method is very essential to perform quality assurance of throat inserts of solid rocket motors. From the study we know that an ultrasonic beam in graphite shows uneven propagation behaviour both within and among individual ingots. So that the two-dimensional scanning procedure is necessary and required to detect internal planar flaws that orient in various directions. The unevenness and irregularities among ingots can be compensated by measuring the wave velocity and attenuation coefficient in the test block itself before inspection. A test block together with artificial internal flaws was fabricated and inspected using the developed method. For examination, it was sliced into several thin disks. Then the sliced disks were inspected using the conventional ultrasonic testing method using a normal beam technique. The intrinsic and natural graphite property of water absorption caused uneven ultrasonic propagation characteristics in immersion testing, but epoxy coating over all surfaces solved the problem. This gives very well-conformed locations of the existent flaws.

5. Summary Of Literature Survey

The summary of researches done by experts in the area of NDT have been presented in Table 3.

Table No. 3 Summary of literature survey

S.No.	Author Name (Year)	Finding
1	Sanjay Kumar & Dalgobind Mahto (2013)	The majority of the NDT techniques are primarily being used in the manufacturing industries, aerospace industry and have the potential to be used for evaluating civil infrastructures.
2	S.Gholizadeh(2016)	Composite tools are mostly used in critical-safety applications such as in aircraft primary construction. That why non-destructive testing of composite materials has become more crucial and demanding.
3	Malcolm K. Lim , Honggang Cao (2011)	The reliability and confidence level of non destructive testing is typically increased by using multiple or combination of various testing methods. It proven a good and accurate results.
4	MR Jolly, A. Prabhakar, B. Sturzu, K. Hollstein, R.Singh, Thomas, P. Foote & A. Shaw (2015)	Due to an advantages of high reliability and a much better traceability Computed temography is widely used for defect determination (delamination) in composite material as compared to ultrasonic testing and thermography.
5	Yang Zhan-Feng, Zhang Wei-Bin, Tian Yong, LI jing-ming, LI li (2012)	A nonlinear ultrasonic testing experiment device developed. Ultrasonic linear parameters such as velocity were not sensitive to accumulation and development of micro-damage, unlike ultrasonic nonlinear coefficient, which was very sensitive to that.
6	M. Rojek, J. Stabik, S. Sokół (2006)	Ultrasounds can be applied as effective and valuable tool to assessment of fatigue degradation of polymer composites. We also find out that mechanical properties such as flexural strength and flexural modulus decrease as a result of cyclic loadings
7	Eiichi Sato, Mitsuharu Shiwa, Yoshio Shinagawa, Takashi Ida, Satoshi Yamazoe and Akiyoushi Sato (2007)	RT is unsuitable to detect planar flaws that orient in various directions in a thick ingot. It was therefore decided to develop a UT method to detect planar flaws that orient in various directions (all directional flaw detection method)
8	Chunguang Xu, Wentao Song, Qinxue Pan, Huanxin Li, Shuai Liu (2015)	Ultrasonic critical refracted longitudinal wave method has the characteristics of high resolution, high penetration, non-destructive and no harmful effect to the human body, and that it is the most promising technology that has used in residual stress testing
9	Tirupan Mandal , James M. Tinjum , Tuncer B. Edil (2016)	Ultrasonic pulse velocity test is used to calculate and finding out the Flexural strength and flexural modulus of the cementitiously stabilized materials.
10	Gabriel Dan Taşcă, Gheorghe Amza (2012)	The ultrasonic non-destructive evaluation technique is used in order to examine or inspect the sub-surface features in titanium alloys type materials. We also find out that for critical and complex part examination the ultrasonic testing gives the best results from the viewpoint of accuracy and the percentage of detectives

Chunguang Xu et al [8] describes the non-destructive testing residual stress using ultrasonic critical refracted longitudinal wave. As we know that residual stress has significant and major impacts on the performance of the mechanical components, especially on its strength, fatigue life and corrosion resistance and dimensional stability. Residual stresses occur in many manufactured structures, components and machinery. A variety of different methods has been developed to measure or determine residual stress for different types of components in order to obtain reliable assessment. Based on theory of acoustic elasticity, the testing principle of ultrasonic LCR wave method is analyzed. From this paper we find out that Ultrasonic LCR wave method has the characteristics of high resolution, high penetration, non-destructive and no harm to the human body, and that it is the most promising technology in the development of residual stress testing. Also by using the ultrasonic detector, we carried out experiment research on residual stress testing of oil pipeline weld joint. The residual stress in oil pipeline welds joint and several other mechanical components are tested. Through experiments and applications, it is confirmed that the accuracy, practicability and universally application fields of the ultrasonic LCR wave method.

Tirupan Mandal et al [9] describes the non-destructive testing of cementitiously stabilized materials (CSMs) using ultrasonic pulse velocity instrumentation. Here flexural strength and flexural modulus tests were conducted on CSMs and their constrained modulus were recorded. The effect and outcome of compaction, curing time, and binder content was evaluated. Results which we got from the ultrasonic pulse velocity tests showed that with decrease in density of the specimens, constrained modulus and P-wave velocity decreases, whereas, with increase in binder content and curing time of the specimens, the constrained modulus and P-wave velocity increases. Thus non-destructive testing is proposed as a suitable and expedient method for determining the flexural properties of CSMs in comparison to destructive methods such as third-point bending beam tests.

Gabriel Dan Tasca et al [10] described research regarding ultrasonic examination of complex parts. Non-destructive evaluation process established and recognized in order to observe cracks and delaminations that occur below the surface in titanium parts and in particular in complex shaped parts. Although X-rays technique might be an obvious choice, but they are not effective in many cases, mostly when the defect has the same density as the surrounding material. Ultrasonic waves can detect and identify variations in the elasticity of the material, as well as in the density. We also know from this paper that the ultrasonic data can be used to give a better understanding of the failure mechanisms in this material. Automated Ultrasonic Testing (AUT) has been applied whenever detailed inspection of critical structures or components is required, e.g. in nuclear power plant, was required. In addition AUT has also been applied to other fields such as the Process or production industry.

6.Conclusions

Based on the literature survey and review, it is concluded that their various non destructive techniques are available for defect investigation in composite, material, and construction material (concrete). These non-destructive techniques are used in various places such as in aerospace industry, manufacturing industry and civil infrastructures. These techniques have advantages and limitation depending upon their uses and application. We also conclude that from literature survey those composite tools are mostly used in critical-safety applications for example in aircraft primary constructions, the non-destructive testing of composite materials has become more crucial and demanding. The review of researches carried out in recent past show that no single non-destructive test methods provide us sufficient result about defect characterization in composite material because they have their own limitation . So the combination of two or more techniques is used in order to get better result and increase the effectiveness of investigation. The reliability and confidence level of non-destructive test is typically increased by using multiple test methods. For complex part examination ultrasonic technique is widely used. From above research we conclude that further research work is carried out for getting a more promising result in the field of composite material testing.

References

[1]. S. Kumar, D. G. .Mahto. Recent trends in industrial and other engineering applications of non destructive testing: a review. International Journal of Scientific & Engineering Research. 2013 Sep;4(9).
[2]. S.Gholizadeh. A review of non-destructive testing methods of composite materials. Procedia Structural Integrity. 2016 Dec 31;1:50-7.
[3]. Malcolm K. Lim , Honggang Cao. Combining multiple NDT methods to improve testing effectiveness. Construction and Building Materials, ISSN. 2003:0950-618.
[4]. MR Jolly, A. Prabhakar, B. Sturzu, K. Hollstein, R.Singh, Thomas, P. Foote & A. Shaw. Review of Non-destructive Testing (NDT) Techniques and their Applicability to Thick Walled Composites. Procedia CIRP. 2015 Dec 31;38:129-36.
[5]. Yang Zhan-Feng, Zhang Wei-Bin, Tian Yong, LI jing-ming, LI li. Nonlinear ultrasonic testing technique for micro-damage of TATB based Polymer Bonded Explosive, 2012 , 18th World Conference on Nondestructive Testing, 16-20 April 2012, Durban, South Africa.
[6]. M. Rojek, J. Stabik, S. Sokół. Fatigue and ultrasonic testing of epoxy-glass composites. Journal of Achievements in Materials and Manufacturing Engineering. 2007 Jan;20(1-2):183-6.
[7]. Eiichi Sato, Mitsuharu Shiwa, Yoshio Shinagawa, Takashi Ida, Satoshi Yamazoe and Akiyoushi Sato. Ultrasonic testing method for detection of planar flaws in graphite material. Materials transactions. 2007;48(6):1227-35.
[8]. Chunguang Xu, Wentao Song, Qinxue Pan, Huanxin Li, Shuai Liu. Nondestructive Testing Residual Stress Using Ultrasonic Critical Refracted Longitudinal Wave. Physics Procedia. 2015 Dec 31;70:594-8.
[9]. Tirupan Mandal , James M. Tinjum , Tuncer B. Edil. Non-destructive testing of cementitiously stabilized materials using ultrasonic pulse velocity test. Transportation Geotechnics. 2016 Mar 31;6:97-107.
[10]. Gabriel Dan Taşcă, Gheorghe Amza. Research regarding ultrasonic examination of complex parts.

[11]. Cawley; Non-destructive testing—current capabilities and future directions; Journal of Materials: Design and Applications; October 1, 2001 vol. 215 (213-223).
[12]. Jacek Jarmulak, Eugene J.H. Kerckhoffs, Peter Paul van't Veen; Case-based reasoning for interpretation of data from non destructive testing; Engineering Applications of Artificial Intelligence; Volume 14, Issue 4, August 2001, Pages 401–417.
[13]. Li Zhijun; Non-Destructive Testing of Advanced Composites; Aerospace Materials & Technology, 2001.
[14]. G. S. Park, P. W. Jang, Y. W. Rho; Optimum Design of a Non Destructive Testing System to Maximize Magnetic Flux Leakage; Journal of Magnetics Vol.6 No.1, 2001, (31-35)
[15]. P. Tschelisnig; Acoustic emission testing (AET) an integral non-destructive testing method; International Journal of Materials and Product Technology 2001 - Vol. 3, No.3/4 pp. 267 – 275
[16]. H. A. Crostack, W. Reimers; Evaluation of component integrity by non-destructive testing; International Journal of Materials and Product Technology 2001 - Vol. 3, No.2 pp. 147 – 162
[17]. Zahran, 0. S., Shihab, S. and AI-Nuaimy, W. (2002). Recent Developments in Ultrasonic Techniques for Rail track Inspection. NDT 2002, Southport, The British Institute of NDT.
[18]. D.Pagodinas - Ultrasonic signal processing methods for detection of defects in composite materials, Ultragarsas Journal, 2002, Vol. 45, No4, p47.
[19]. Prakash R, Non-destructive testing of composites, Composites, **11 (4),** 1980, pp217-224.
[20]. Krumm M, Sauerwein C, Hämmerle V, Oster R, Diesel B, Sindel M, Capabilities and Application of Specialized Computed Tomography Methods for the Determination of Characteristic Material Properties of Fiber Composite Components, Lock-in Thermography, SpringerVerlag, Berlin, pp. 1-8, 2012.
[21]. Kastner J, Schlotthauer E, Burgholzer P, and Stifter D, Comparison of X-ray Computed Tomography and Optical Coherence Tomography for Characterisation of Glass Fibre-Polymer Matrix Composites, 16^{th} World Conference on Nondestructive Testing, September 2004, Montreal, Kanada, 134
[22]. Harara W, Digital Radiography in Industry, 17th World Conference on Non-Destructive Testing, Shanghai, China, 2008.
[23]. Toyoda, T. Iyoku, M. Ishihara, N. Kitagawa and S. Shiozawa: JAERI-M, Vol. 91-102, (Japan Atomic Energy Research Institute, 1991) (in Japanese).
[24]. N. Owoka, T. Iyoku, T. Ishii, N. Kitagawa, S. Shiozawa, M. Kanbe, T. Miki, T. Ogata and H. Kawae: JAERI-M, Vol. 93-003, (Japan Atomic Energy Research Institute, 1993) (in Japanese).
[25]. M. Ishihara, S. Hanawa, T. Iyoku and S. Shiozawa: Tanso 196 (2001) 39–48 (in Japanese).
[26]. J. H. Friedl, T. A. Gray, P. Khandelwal and T. Dunhill: Review of QNDE, Vol. 23A, ed. D. O. Thompson and D. E. Chimenti (2004) pp. 809–816.
[27]. F. J. Margetan, R. B. Thompson, M. Keller and W. Hassan: Review of QNDE, Vol. 23B, ed. D. O. Thompson and D. E. Chimenti (2004) pp. 1091–1098.
[28]. M. Rojek, J. Stabik, G. Wróbel, Ultrasonic methods in diagnostics of epoxy-glass composites, Journal of Materials Processing Technology, 162-163 (2005) 121-126.
[29]. M.Rojek, J. Stabik, Thermall resistance of TSE-6 epoxyglass composite, Proc. V Conf. "High performance polymers and composites", Ustron 2002 178-182 (in Polish).
[30]. M. Rojek, J. Stabik, M. Makselon, Nondestructive investigation of properties of glass-epoxy laminatem (in Polish), Agricular Academy of Bydgoszcz, Chemistry and CHemical Technology 91-95. (in Polish)
[31]. M. Rojek, J. Stabik, G. Wróbel, Ultrasounds in diagnostics of epoxy-glass laminates, Conf. Proc. Nondestructive testing of materials Zakopane (2003) 203-211 (in Polish)
[32]. A. ĝliwiĚski, Ultrasounds and their application, WNT, Warszawa, 1993. (in Polish).
[33]. Web.Itu.Edu.Tr/~Arana/Ndt.Pdf.
[34]. I.V. Kaushal , A.Sai Kiran, A Review Of Non Destructive Testing Methods For Composite Materials , IJMETMR, Jan 24, 2014.
[35]. BB. Djordjevic. Nondestructive test technology for the composites. InThe 10th International Conference of the Slovenian Society for non-destructive testing 2009 Sep (pp. 259-265).