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A REVIEW OF CHARACTERIZATION TECHNIQUES OF COMPOSITE MATERIALS

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Abstract:

A review of characterization methods of composite materials. The review considers the evaluation of composite by different methods. This article review about Non dustractive testing methods and capabilities of most common methods in composite NDT applications such as Ultrasonic testing, Infrared testing, Radiography, Rcoustic testing principals, Ultrasonic phased array detection technique and Shearography with respect to merit and demerit of these methods. Composite materials are increasing in product efficiency, cost-effectiveness and the development of superior specific properties. There is increasing importance in their applications to load-carrying structures. Thus, tough and reliable non-destructive testing of composites is important here to reduce safety concerns and maintenance costs. There have been various non-destructive testing methods built upon different principles for quality assurance during the whole lifecycle of a composite product.

Keywords

Non dustractive testing, composite materials, capabilities, product efficiency, properties.

1. INTRODUCTION:

Composite materials prove themselves to be very efficient as compared to other conventional materials. They are budget friendly and offer superior properties. Thus, demands increase a lot for these materials. Therefore, to reduce the risk of failure, NDT is very much essential for this kind of materials. In this article we covered the basics of various NDT techniques including introduction, principle, scope in which they can be used, history, applications, equipment, etc. We also covered various advantages as well as drawbacks associated with these tests.In order to achieve such robust properties efficiently, the manufacturing process associated with these materials is very sensitive and difficult task so that they can be strong enough to be sued in aerospace, turbine, etc. manufacturing areas. Today, carbon fiber composites are variedly used in many applications dur to their complementary properties varying from material to material.

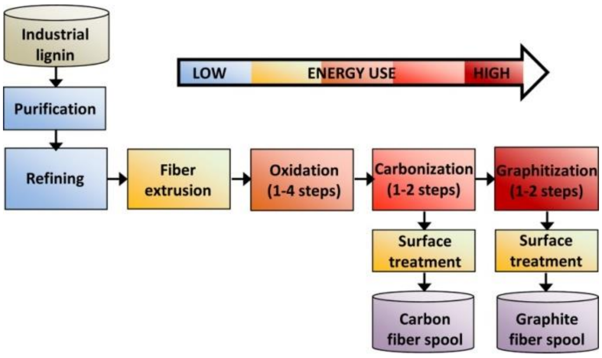
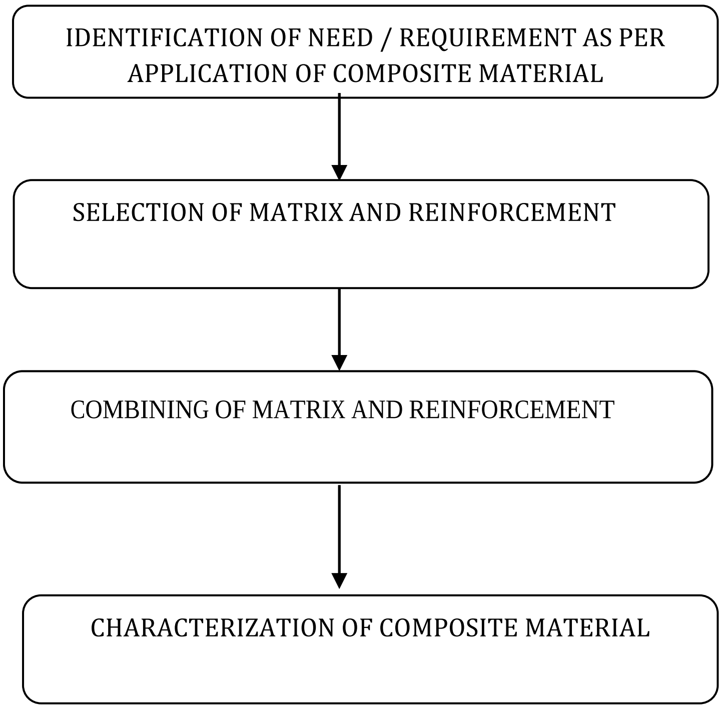


Figure:1 -Steps involved in carbon fiber manufacture

A ample range of NDT methods plays major roles in testing of composite materials (Scott & Scala, 1982). The applications of composite NDT may include manufacturing (Venkataraman, 2001), pipe and tube manufacturing (Hufenbach et al. 2011; Schneider, 1984), storage tanks (Castaings & Hosten, 2008), aerospace (Liew et al. 2011; Yekani Fard et al. 2014) military and defense (Bennett et al. 2013), nuclear industry (Vavilov et al. 2015), and composite defects characterization (Fotsing et al. 2014). Numerous techniques are used in the composite NDT field, including ultrasonic testing (Peng et al. 2012), thermographic testing (Kroeger, 2014), infrared thermography testing (Vavilov et al. 2015), radiographic testing (Tan et al. 2011), visual testing (VT) or visual inspection (VI) (Bossi & Giurgiutiu, 2015), acoustic emission testing (AE) (Sarasini & Santulli, 2014), acousto-ultrasonic (Su et al., 2014), shearography testing (Hung et al. 2013), optical testing (Liu et al. 2014), electromagnetic testing (Yang et al. 2013), liquid penetrant testing (Kalinichenko et al. 2013), and magnetic particle testing (Lu et al. 2013). Due such a wide range of applications, they can have some deformations and shortcomings in lattice, which may affect stability and limit the applications of these fibers in long term.



2. Non-Destructive testing method

This article depicts various such instabilities in the lattice of carbon fibers on long terms and some non-destructive tests. These not destructive tests can prove to be an important tool because they can test material without damaging. Though some minute damages occur, but this saves a lot of time and material required in manufacturing those specimens. There are many prerequisites for non-destructive tests which includes the conforming of materials. This identifies the form of problem and then comparing it with original pure fiber, we get to know the problem. Some commonly used types of non-destructive tests are: CT, X-ray, Ultrasound, IR-thermography, phased array detection, etc. Coming to NDT, we have various subcategories of NDT that are classified as: contact and non-contact testing.

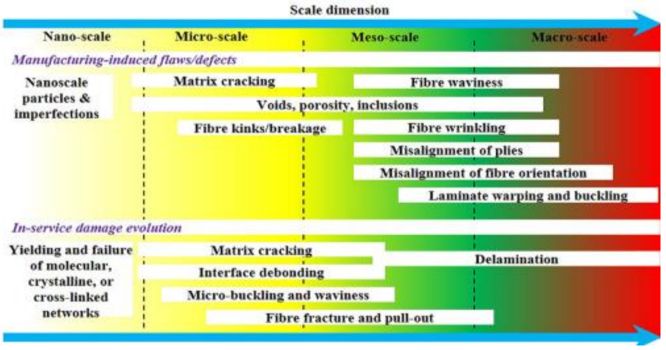
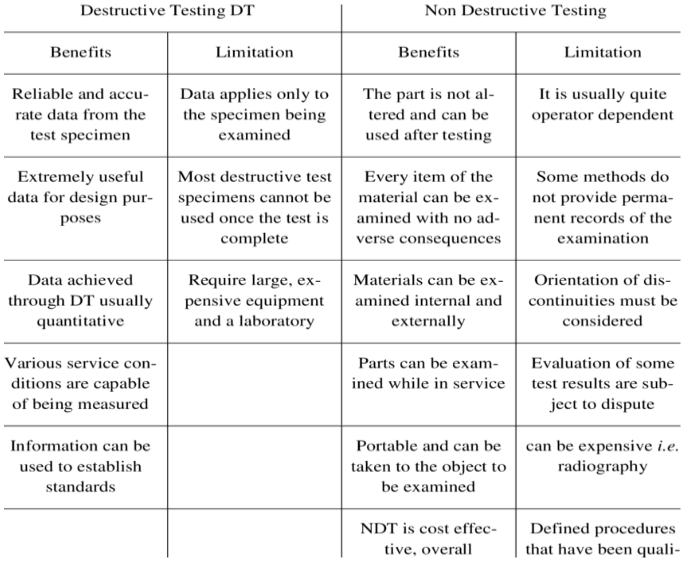


Figure:2-Picture showing various manufacturing defects and in-service damages on various scales

Table:1- Comparison between Destructive testing and Non Destructive testing



Destructive Testing DT		Non Destructive Testing	
Benefits	Limitation	Benefits	Limitation
Reliable and accurate data from the test specimen	Data applies only to the specimen being examined	The part is not altered and can be used after testing	It is usually quite operator dependent
Extremely useful data for design purposes	Most destructive test specimens cannot be used once the test is complete	Every item of the material can be examined with no adverse consequences	Some methods do not provide permanent records of the examination
Data achieved through DT usually quantitative	Require large, expensive equipment and a laboratory	Materials can be examined internal and externally	Orientation of discontinuities must be considered
Various service conditions are capable of being measured		Parts can be examined while in service	Evaluation of some test results are subject to dispute
Information can be used to establish standards		Portable and can be taken to the object to be examined	can be expensive *i.e.* radiography
		NDT is cost effective, overall	Defined procedures that have been quali-

Table:2- Contact vs. Non-contact NDT testing methods

Contact vs. non-contact NDT methods:	
Traditional Ultrasonic testing	Through transmission ultrasonic testing
Eddy current testing	Radiography Testing
Magnetic Testing	Thermography
Electromagnetic Testing	IR testing
Penetrant Testing	Holography
Liquid Penetrant testing	Shearography & Visual Inspection

2.1 Types of Non- Destructive Testing Method

One major aspect of these methods is that not all the methods are suitable for every kind of application. So, careful choice of testing method is necessary. Like, in aerospace sector, in aircraft health monitoring and damage identification, we can use Ultrasonic, thermographic, Usamentiaga vibrations, IR thermography and Shearography testing methods. For health monitoring of structures, we can use ultrasonic testing, for health monitoring of composite wind-box and damage in GFRP, we can use ultrasonic testing and thermographic testing, respectively. For auto detection of impact damage in carbon fibers, we can use thermographic testing and Usamentiaga radiography. Likewise, there are many more fields with different testing techniques. Ultrasonic testing is one of the commonly use testing method.

2.2 Ultrasonic Testing

Out of these testing, visual testing is one of the basic and quick technique that can save lot of time and money. Though it doesn't need scientific equipment, it has its own disadvantages in accuracy and other parameters. In this, the analyst can simply observe the surface of material by looking for cracks or failures. LPT (Liquid Penetrant Testing) is one of the major techniques in this field. This is mainly applied for non-porous materials. So that, cracks or failures can easily absorb the liquid and we can find damages. One major success in this field is the use of transmitters, receivers, transducers and other display devices in so called ultrasonic testing. The information is defined by a unique crack location, flaw size and orientation. Ultrasonic testing can either be based on pulse echo or based on transmission of radiations, using a high frequency sound wave having frequency range of 1-50MHz to detect internal features. Ultrasonic testing has high accuracy due to the fact that it uses different probes for different materials. Thus, frequent replacement is required, which in turn reduces efficiency. So, another technique called SWF is developed.

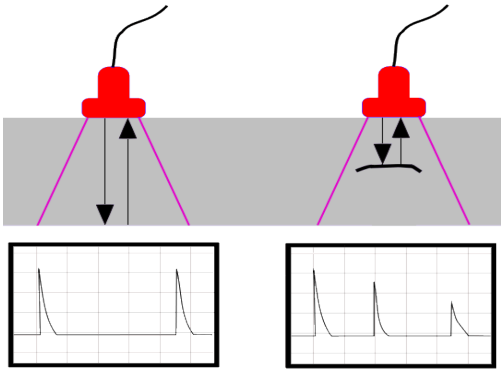


Figure 3: -Principle of ultrasonic testing

2.3 Principle of Infrared Testing

Another major type of testing technique is thermography, which uses the principle of thermal imaging. This is based on the phenomena that when there is a crack in the body of the fiber, the heat fluctuation occurs there due to sudden change in conductivity. One thing to note is that cracks on deeper side of the fiber cause less effect on heat as compared to the cracks on outer side. Hence, this technique is used for thinner fibers. Using this technique offers some advantages one of which is that we can inspect a relatively larger area of the fiber. But this technique requires large investment on instrumentation and highly skilled person. Further, if the crack goes deeper, the clarity decreases.

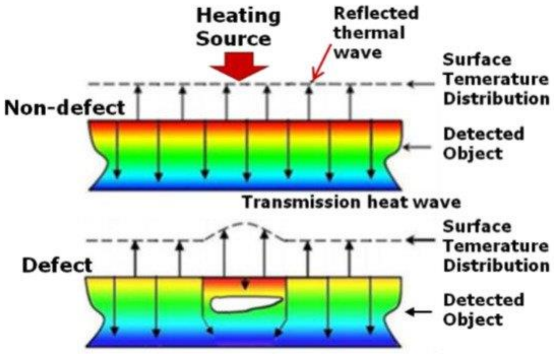


Figure 4: -Principle of Infrared Testing

3. Radiography

Next most commonly used testing technique is radiography. Delamination (generation of air voids) is the most common type of problem solved by this method. However, we can notice it in the output only when it is not perpendicular to path of X-rays. For thinner parts, we use 1-5V source as light radiography while in thick parts we use γ-rays. It can also detect inclusions, non-uniform fiber distribution and fiber mislocation.

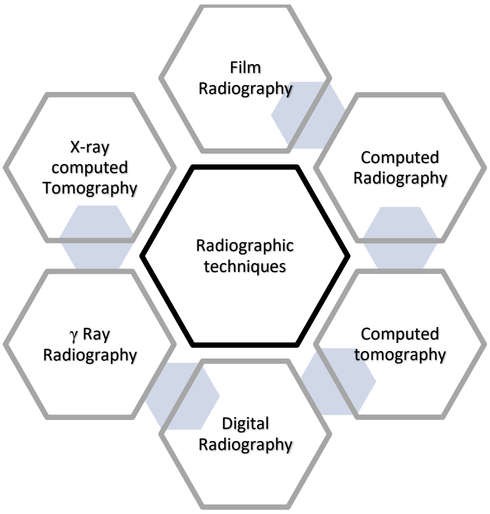


Figure 5:-Radiographic techniques

Some of the most common types of radiography technique:

1) Compton Scatter Imaging technique
2) Neutron Photographic Method
3) Computed Tomography

Though radiography is more accurate as compared to X-ray testing, it requires a very costly neutron beam and also used only for high testing requirements.

Principles of electromagnetism and electricity are applied in electromagnetic testing. This mainly reveals defects like, fracture, fault, corrosion or any other condition of materials. Electric and magnetic fields are created in the test object for this. Some most commonly used techniques of this kind are:

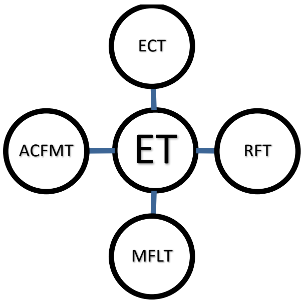


Figure 6: -Techniques of electromagnetism

2.4 Acoustic testing principle

One of the most effective technique for analysis of failure is acoustic emission analysis. This method was developed in early 1950s by Kaiser. The defects tested by this method are matrix micro cracking, fibbers-matrix debonding, localized delimitation or fibre pullout and breakage. The mechanical stress waves generated by these cracks or defects are in concentric form and are sensed by piezoelectric sensors. The main difference between this and other types of analysis is that it uses energy generated by object in the form of vibrations while other techniques impart energy to the object. The major advantages include its global scope of sensors, fast, accurate and no need for disassembling. However, it makes difficult to correlate between type of damage and the intensity and type of vibrations coming out. Since, this can only determine the type of failure, we can use a combination of acoustic and ultrasonic testing called acousto-ultrasonic testing. This makes the test more sensitive and efficient.

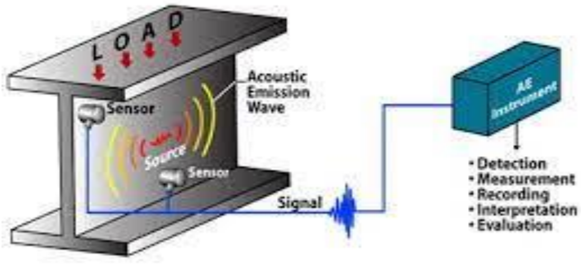


Figure 7: -Acoustic testing principle

2.5 Principle of ultrasonic phased array detection technique

Use of lasers in this field can prove itself to be more efficient and is used in Shearography testing. It offers the advantage that we require less skilled users to operate the process. Also, it produces less noise as compared to other tests. During testing, stress concentrations vary around defects, which deduct the concentration and criticality of failure. This is a major advantage in this test.

Based on Huygens' principles and Helmholtz's integral sound pressure theorem, another method was developed called Ultrasonic phased array detection method. This method uses multiple beams for scanning and imaging purposes. The apparatus uses some phased array controllers, chips of probe and some electrical and detection systems to detect sound waves coming from the object, after emitting form chips. Basically, time lag between various waves determines the crack or failure. Ultrasonic phased array controlling mechanism distributes the sound pressure accordingly so as to speed up the task and increase the accuracy.

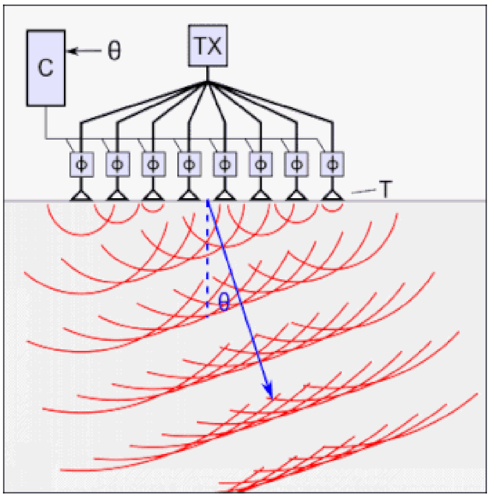


Figure 8: -Principle of ultrasonic phased array detection technique

2.6 Shearography

Shearography testing (ST) is one of the important types of NDT technique that comes under non-contact type. It was developed by Leendertz and Butters in around 1970s. It can be used as a powerful way to detect, flaws and defects, leakage, delimitation, displacement, strain, curvature and residual stress. Along with these, it can also do mechanical analysis, surface profiling test, etc. In this, a laser beam is made to fall on the surface of material to be tested. The reflected part of this beam is then imagined in a shearing device, dividing into two coherent images, one of which is monitored for damages in material. Pattern is recorded in a CCD(Charge Coupled Device) camera and displayed and analysis for further ting digitally. This technique can be used in analysis of structures like pipes, sandwich, wind turbine blades, aerospace structures as well as racing types.

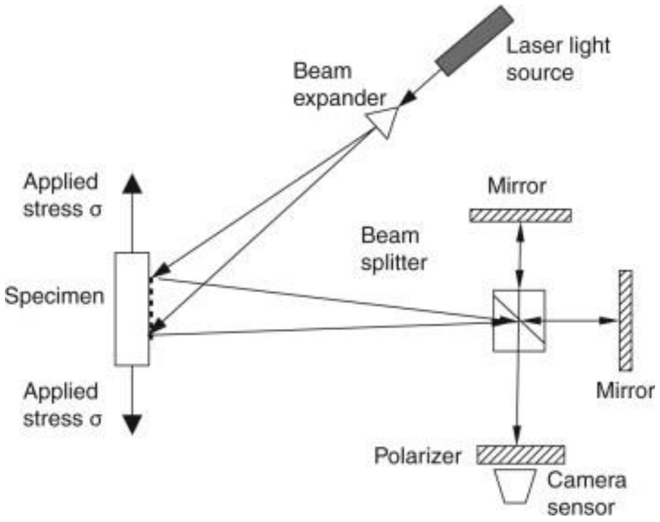


Figure 9: -Principle of Shearography

3 CONCLUSION

NDT techniques are impressive methods for testing and evaluation, as it is required during different phases within the lifetime of a composite product, it is significant that each method has its strength but some techniques show capabilities for a full diagnosis of possible defects and damage evaluation in a composite system. In this technique we use different-different tests on composite materials, in this review, we present the benefits and limitations of NDT methods. The selection of suitable methods can be challenging but essential to providing the right information for balanced composite materials and structures.

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