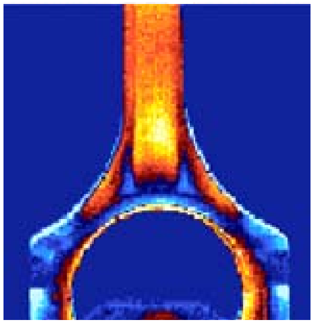
Non-Destructive Evaluation / Testing - NDE / NDT

Overview



Thermoelastic Stress Analysis (TSA)

The process of nondestructive testing determines the existence of flaws , discontinuities, leaks, contamination, thermal anomalies, or imperfections in materials , components or assemblies without impairing the integrity or function of the inspected component. NDE is also utilized for real - time monitoring during Manufacturing , measurement of physical properties such as Hardness and internal stress , inspection of assemblies for Tolerances , alignment , and periodic in - service monitoring of flaw/damage growth in order to determine the maintenance requirements and to assure the reliability and continued safe operation of the part.

Nondestructive evaluation (NDE) is becoming increasingly important to the design-through-manufacture process. The cost of parts and components is ever-increasing due to the corresponding costs of material and labor. Consequently, emphasis is being placed on use of NDE early in the design and fabrication process. Often components are too costly to permit the luxury of destructively testing a number of them to demonstrate their design goals. Environmental and liability concerns are also resulting in increased use of NDE.

NDT is a Quality Assurance management tool which can give impressive results when used correctly. It requires an understanding of the capabilities and limitations of the various methods available and knowledge of the relevant standards and specifications for performing the tests. Materials, products and equipment which fail to achieve their design requirements or projected life due to undetected defects may require expensive repair or early replacement Such defects may also be the cause of unsafe conditions or catastrophic failure, as well as loss of revenue due to unplanned plant shutdown.

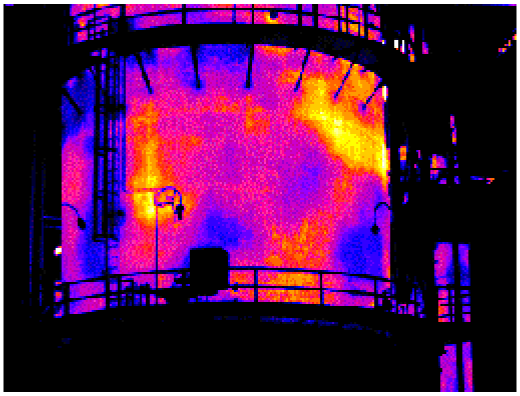
NDT technology is constantly being improved and new methods developed, particularly in an effort to keep pace with the development of new materials (i.e. composites) and applications. Advances in the use of lasers and imaging technology (including video, holography and thermography) have made non contact NDT more viable in many situations. Optical fibers and new piezo-electric materials are allowing the creation of intelligent materials and structures which can not only monitor themselves but may even respond to their environment. Computer advances have allowed signal processing techniques and expert systems to be used which enhances the quality of the information obtained using traditional and new NDT methods.

Basic NDT Methods :

1. **Visual Testing (VT) - Ultraviolet, Infrared, and Visible Light.**
2. **Penetrant Testing (PT)**
3. **Electromagnetic Testing (ET)**
4. **Magnetic Particle Testing (MT)**
5. **Acoustic Emissions (AE)**
6. **Utrasonic Testing (UT)**
7. **Radiography (RT) - X-Rays, Gamma Rays, Beta Particles, Protons, Neutrons**

Visual / Optical Testing - VT

Visual inspection is one NDT method used extensively to evaluate the condition or the quality of a weld or component.
It is easily carried out, inexpensive and usually doesn't require special equipment. It requires good vision , good lighting and the knowledge of what to look for.
Visual inspection can be enhanced by various methods ranging from low power magnifying glasses through to boroscopes.



Infrared Thermography

Methods :

1. Infrared Thermography

Thermography is the use of an infrared imaging and measurement camera to "see" and "measure " thermal energy emitted from an object.

Thermal, or infrared energy, is light that is not visible because its wavelength is too long to be detected by the human eye; it's the part of the electromagnetic spectrum that we perceive as heat. Unlike visible light, in the infrared world, everything with a temperature above absolute zero emits heat. Even very cold objects, like ice cubes, emit infrared. The higher the object's temperature, the greater the IR radiation emitted. Infrared allows us to see what our eyes cannot.

Infrared thermography cameras produce images of invisible infrared or "heat" radiation and provide precise non-contact temperature measurement capabilities. Nearly everything gets hot before it fails, making infrared cameras extremely cost-effective, valuable diagnostic tools in many diverse applications. And as industry strives to improve manufacturing efficiencies, manage energy, improve product quality, and enhance worker safety, new applications for infrared cameras continually emerge.

2. Passive Thermography

The objective of conventional thermography is the measurement of surface temperatures. Using passive thermography, one can get contactless information about the surface.

3. Transient Thermography

Transient thermography is applicable for the detection of deep-seated defects in materials with low temperature conductivity. The sample is heated up over a long period of time in a furnace (non-destructive temperature, e.g. 50°C). After that it is brought into a normal climate and at the same time the surface temperature is gathered with an infrared camera. Because the sample is losing heat to the environment due to convection and radiation, the surface is cooling down. Heat is flowing from the inside to the surface of the sample. A defect, typically a delamination or a cavity, is a thermal barrier for the heat flow. This leads to an inhomogeneous temperature distribution on the surface, which is detected from the infrared camera. Only one way, from the defect to the surface of the sample, is relevant for the measurement: The heat has to cover only half the distance compared to other thermal methods. This explains, why it is possible to detect deep-seated defects in short time with this method.

4. Laser Shearography

Shearography is a variation of holography specifically designed for NDT applications. Shearography provides full-field, non-contact nondestructive testing for rapid wide-field inspection of composites, bonded structures and other advanced materials. Shearography is an optical video strain gauge and an appropriately applied stress is used to locate strain concentrations caused by internal defects.

5. Optical Holography

Optical holography is an imaging method, which records the amplitude and phase of light reflected from an object as an interferometric pattern on film. It thus allows reconstruction of the full 3-D image of the object. In HNDT, the test sample is interferometrically compared in two different stressed states. Stressing can be mechanical, thermal, vibration etc. The resulting interference pattern contours the deformation undergone by the specimen in between the two recordings. Surface as well as sub-surface defects show distortions in the otherwise uniform pattern. In addition, the characteristics of the component, such as vibration modes, mechanical properties, residual stress etc. can be identified through holographic inspection. Applications in fluid mechanics and gas dynamics also abound.

Penetrant Testing - (PT)

Liquid Penetrant Inspection

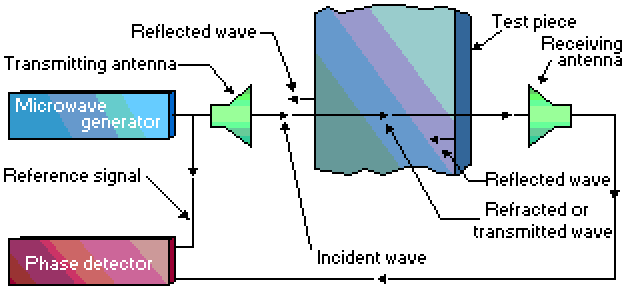
Apart from visual inspection this is probably the oldest and most widely

used of all the NDT methods. It can be used on any non-porous material. Its use is confined to the detection of surface breaking defects.

Liquid penetration inspection is used to reveal surface breaking flaws by bleedout of a colored or fluorescent dye from the flaw. Test objects are coated with visible or fluorescent dye solution. Excess dye is then removed from the surface, and a developer is applied. The developer acts as blotter, drawing trapped penetrant out of imperfections open to the surface. With visible dyes, vivid color contrasts between the penetrant and developer make "bleedout" easy to see. With fluorescent dyes, ultraviolet light is used to make the bleedout fluoresce brightly, thus allowing imperfections to be readily seen.

Penetrant inspection can be used on any material and is most often used on materials clad in stainless steel, and stainless welded items which cannot be inspected by other methods.

Electromagnetic Testing - (ET)



Eddy current, penetrating radar and other electromagnetic techniques are used to detect or measure flaws, bond or weld integrity, thickness, electrical conductivity, detect the presence of rebar or metals. Eddy current is the most widely applied electromagnetic NDT technique. The eddy current method is also useful in sorting alloys and verifying heat treatment. Eddy current testing uses an electromagnet to induce an eddy current in a conductive sample. The response of the material to the induced current is sensed. Since the probe does not have to contact the work surface, eddy current testing is useful on rough surfaces or surfaces with wet films or coatings.

Methods :

1. Eddy Current Testing

In standard eddy current testing, a circular coil carrying an AC current is placed in close proximity to an electrically conductive specimen. The alternating current in the coil generates a changing magnetic field, which interacts with the test object and induces eddy currents. Variations in the phase and magnitude of these eddy currents can be monitored using a second 'search' coil, or by measuring changes to the current flowing in the primary 'excitation' coil. Variations in the electrical conductivity or magnetic permeability of the test object, or the presence of any flaws, will cause a change in eddy current flow and a corresponding change in the phase and amplitude of the measured current. This is the basis of standard (flat coil) eddy current inspection, the most widely used eddy current technique.

2. Barkhausen Noise Analysis (BNA)

Barkhausen Noise Analysis (BNA) method, also referred to as the Magnetoelastic or the Micromagnetic method is based on a concept of inductive measurement of a noise-like signal, generated when magnetic field is applied to a ferromagnetic sample. After a German scientist Professor Heinrich Barkhausen who explained the nature of this phenomenon already in 1919, this signal is called Barkhausen noise.

3. Ground Penetrating Radar (GPR)

Ground penetrating radar is a nondestructive geophysical method that produces a continuous cross-sectional profile or record of subsurface features, without drilling, probing, or digging. Ground penetrating radar (GPR) profiles are used for evaluating the location and depth of buried objects and to investigate the presence and continuity of natural subsurface conditions and features.

Ground penetrating radar operates by transmitting pulses of ultra high frequency radio waves (microwave electromagnetic energy) down into the ground through a transducer or antenna. The transmitted energy is reflected from various buried objects or distinct contacts between different earth materials. The antenna then receives the reflected waves and stores them in the digital control unit.

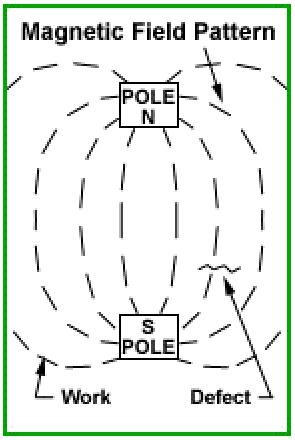
4. Magnetic Resonance Imaging (MRI)

Magnetic resonance imaging (MRI) is an imaging technique used primarily in medical settings to produce high quality images of the inside of the human body. MRI is based on the principles of nuclear magnetic resonance (NMR), a spectroscopic technique used by scientists to obtain microscopic chemical and physical information about molecules.

5. Microwave Inspection

Microwave (or short-pulse radar) inspection techniques involve the transmission and reflection of relatively low frequency (often around 1 GHz) electromagnetic (EM) waves in various materials. The term ground penetrating radar (GPR) is often used to describe microwave inspection systems for locating utility lines below ground and mild steel rebar in concrete decks/pavements. Microwave inspection exploits the principle that dielectric properties of various materials affect the transmission and reflection of EM waves in those materials.

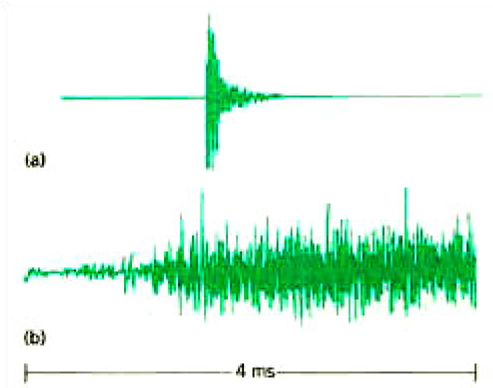
Magnetic Particle Testing - (MT)



Magnetic particle inspection (MPI) is used for the detection of surface and near-surface flaws in ferromagnetic materials. A magnetic field is applied to the specimen, either locally or overall, using a permanent magnet, electromagnet, flexible cables or hand-held prods. If the material is sound, most of the magnetic flux is concentrated below the material's surface. However, if a flaw is present, such that it interacts with the magnetic field, the flux is distorted locally and 'leaks' from the surface of the specimen in the region of the flaw. Fine magnetic particles, applied to the surface of the specimen, are attracted to the area of flux leakage, creating a visible indication of the flaw.

The materials commonly used for this purpose are black iron particles and red or yellow iron oxides. In some cases, the iron particles are coated with a fluorescent material enabling them to be viewed under a UV lamp in darkened conditions.

Acoustic Emission (AE)



Typical acoustic emission waveforms as detected with piezo-electric transducers: (a) burst type; (b) continuous type.

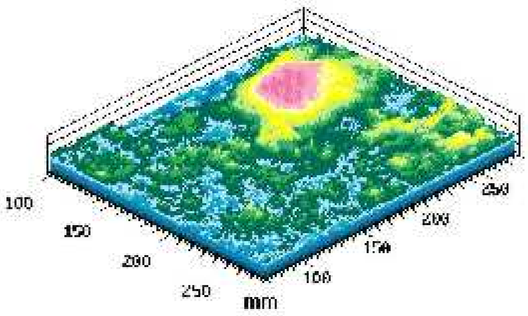
Acoustic emission is the technical term for the noise emitted by materials and structures when they are subjected to stress. Types of stresses can be mechanical, thermal or chemical. This emission is caused by the rapid release of energy within a material due to events such as crack initiation and growth, crack opening and closure, dislocation movement, twinning, and phase transformation in monolithic materials and fiber breakage and fiber-matrix debonding in composites.

The subsequent extension occurring under an applied stress generates transient elastic waves which propagate through the solid to the surface where they can be detected by one or more sensors. The sensor is a transducer that converts the mechanical wave into an electrical signal. In this way information about the existence and location of possible sources is obtained. Acoustic emission may be described as the "sound" emanating from regions of localized deformation within a material.

Until about 1973, acoustic emission technology was primarily employed in the non-destructive testing of such structures as pipelines, heat exchangers, storage tanks, pressure vessels, and coolant circuits of nuclear reactor plants. However, this technique was soon applied to the detection of defects in rotating equipment bearings.

Ultrasonic Testing (UT)

Ultrasonic inspection is a nondestructive method in which beams of high-frequency sound waves are introduced into materials for the detection of subsurface flaws in the material. The sound waves travel through the material with some attendant loss of energy (attenuation) and are reflected at interfaces (cracks or flaws). The reflected beam is displayed and then analyzed to define the presence and location of flaws or discontinuities.

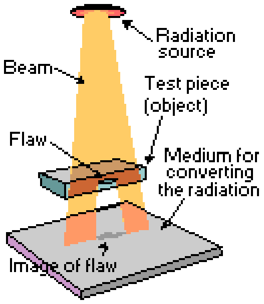


Ultrasonic Testing Image - Concrete

The most commonly used ultrasonic testing technique is pulse echo, wherein sound is introduced into a test object and reflections (echoes) are returned to a receiver from internal imperfections or from the part's geometrical surfaces.

Applications include inspections for voids, cracks, and laminations, inspections of welds and thickness measurements.

Radiography Testing - (RT)



This technique involves the use of penetrating gamma or X-radiation to examine parts and products for imperfections. An X-ray machine or radioactive isotope is used as a source of radiation. Radiation is directed through a part and onto film or other media. The resulting shadowgraph shows the internal soundness of the part. Possible imperfections are indicated as density changes in the film in the same manner as an X-ray shows broken bones.

Radiographic applications fall into two distinct categories evaluation of material properties and evaluation of manufacturing and assembly properties. Material property evaluation includes the determination of composition, density, uniformity, and cell or particle size. Manufacturing and assembly property evaluation is normally concerned with dimensions, flaws (voids, inclusions, and cracks), bond integrity (welds, brazes, etc.), and verification of proper assembly of component pieces.

Methods :

1. Computed Tomography - (CT)

Computed Tomography (CT) is a powerful nondestructive evaluation (NDE) technique for producing 2-D and 3-D cross-sectional images of an object from flat X-ray images. Characteristics of the internal structure of an object such as dimensions, shape, internal defects, and density are readily available from CT images.

2. Photon Induced Positron Annihilation (PIPA) & Distributed Source Positron Annihilation (DSPA)

Photon Induced Positron Annihilation (PIPA) involves penetrating materials with a photon beam. This process creates positrons, which are attracted to nano-sized defects in the material. Eventually, the positrons collide with electrons in the material and are annihilated, releasing energy in the form of gamma rays. The gamma ray energy spectrum creates a distinct and readable signature of the size, quantity and type of defects present in the material.

Distributed Source Positron Annihilation (DSPA) uses a positron source emitter to deposit positrons into the subject material. The process is similar to PIPA after the positrons are deposited and attracted to nano-sized defects in the material.

PIPA and DSPA technologies detect fatigue, embrittlement, and other forms of structural damage in materials at the atomic level, before cracks appear. PIPA and DSPA can also accurately determine the remaining life of various materials and are more precise than any other existing flaw detection technology on the market.

3. Neutron Radiography

Neutron Radiography is an imaging technique which provides images similar to X-ray radiography. The difference between neutron and X-ray interaction mechanisms produce significantly different and often complementary information. While X-ray attenuation is directly dependent on atomic number, neutrons are efficiently attenuated by only a few specific elements. For example, organic materials or water are clearly visible in neutron radiographs because of their high hydrogen content, while many structural materials such as aluminium or steel are nearly transparent. At the present time, Neutron Radiography is one of the main NDT techniques able to satisfy the quality-control requirements of explosive devices used in aerospace and defense programs.

4. X-ray Diffraction (XRD)

X-ray diffraction is a versatile, non-destructive technique that reveals detailed information about the chemical composition and crystallographic structure of natural and manufactured materials.

A crystal lattice is a regular three-dimensional distribution (cubic, rhombic, etc.) of atoms in space. These are arranged so that they form a series of parallel planes separated from one another by a distanced, which varies according to the nature of the material. For any crystal, planes exist in a number of different orientations - each with its own specific d-spacing.

When a monochromatic X-ray beam with wavelength lambda is projected onto a crystalline material at an angle theta, diffraction occurs only when the distance traveled by the rays reflected from successive planes differs by a complete number n of wavelengths.

By varying the angle theta, the Bragg's Law conditions are satisfied by different d-spacings in polycrystalline materials. Plotting the angular positions and intensities of the resultant diffracted peaks of radiation produces a pattern, which is characteristic of the sample. Where a mixture of different phases is present, the resultant diffractogram is formed by addition of the individual patterns.

Based on the principle of X-ray diffraction, a wealth of structural, physical and chemical information about the material investigated can be obtained. A host of application techniques for various material classes is available, each revealing its own specific details of the sample studied.

5. X-ray Fluorescence (XRF)

X-ray fluorescence is a technique of chemical analysis. The technique involves aiming an X-ray beam at the surface of an object; this beam is about 2 mm in diameter. The interaction of X-rays with an object causes secondary (fluorescent) X-rays to be generated. Each element present in the object produces X-rays with different energies. These X-rays can be detected and displayed as a spectrum of intensity against energy: the positions of the peaks identify which elements are present and the peak heights identify how much of each element is present.This is often used by museum curators to study ancient objects because measurements are non-destructive and usually the whole object can be analyzed, rather than a sample removed from one.