Introduction to NDT for Metals

An Online Continuing Education Course for Engineers

Course Number: MA-1004

Credit: 1 Hour / 1 PDH / 1 CPD

Introduction to NDT for Metals

Animesh Talapatra

INTRODUCTION

Non-Destructive Testing (NDT) is defined by the American Society for Non-destructive Testing (ASNT) as:

"The determination of the physical condition of an object without affecting that object's ability to fulfill its intended function. 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)."

For the purpose of this course, the terms non-destructive testing, Non-Destructive Inspection (NDI), and Non-Destructive Evaluation (NDE) will be considered to be equivalent.

NDT can be broken into several categories where it plays an important role:

- Material property measurements
- Inspection of Raw Products
- Inspection Secondary Processing
- In-Services Damage Inspection (Corrosion, Fracture, Fatigue and Creep etc.)
- Quality controls as various stages of manufacturing are completed.

Characteristics of NDT are given below:

- Applied directly to the product
- Tested parts are not damaged
- Various tests can be performed on the same product
- Specimen preparation not required
- Can be performed on parts that are in service
- Low time consumption
- Low labour cost

Major types of NDT are:

(a) Detection of surface flaws

(Visual, Magnetic Particle Inspection, Dye Penetrant Inspection and Eddy current Testing).

(b) Detection of internal flaws (Radiography, Ultrasonic Testing, Thermography).

The application of non-destructive testing methods can be summarized in the following three groups:

1) **Defectology of materials:** Allows for the detection of discontinuities, assessment of corrosion and deterioration caused by environmental agents; determination of tensions; detection of leaks.

2) **Characterization of materials**: Assessment of the chemical, structural, mechanical and technological features of materials; physical properties (elastic, electrical and electromagnetic); heat transference and isotherm pathways.

3) **Metrology of materials**: Control of thicknesses; measurements of thicknesses on a single side, measurements of coating thicknesses; filling levels.

Notable events in early NDT

1854 Hartford, Connecticut: a boiler at the Fales and Gray Car works explodes, killing 21 people and seriously injuring 50. Within a decade, the State of Connecticut passes a law requiring annual inspection (in this case visual) of boilers.

1880 - 1920 The "Oil and Whiting" method of crack detection is used in the railroad industry to find cracks in heavy steel parts. (A part is soaked in thinned oil, and then painted with a white coating that dries to a powder. Oil seeping out from cracks turns the white powder brown, allowing the cracks to be detected.) This was the precursor to modern liquid penetrant tests.

1895 Wilhelm Conrad Röntgen discovers what are now known as X-rays. In his first paper he discusses the possibility of flaw detection.

1920 H. H. Lester begins development of industrial radiography for metals.

1924 — Lester uses radiography to examine castings to be installed in a Boston Edison Company steam pressure power plant.

1926 The first electromagnetic eddy current instrument is available to measure material thicknesses.

1927 - 1928 Magnetic induction system to detect flaws in railroad track developed by Dr. Elmer Sperry and H.C. Drake.1929 Magnetic particle methods and equipment pioneered (A.V. DeForest and F.B. Doane.)

1930s Robert F. Mehl demonstrates radiographic imaging using gamma radiation from Radium, which can examine thicker components than the low-energy X-ray machines available at the time.

1935 - 1940 Liquid penetrant tests developed (Betz, Doane, and DeForest)

1935 - 1940s Eddy current instruments developed (H.C. Knerr, C. Farrow, Theo Zuschlag, and Fr. F. Foerster).

1940 - 1944 Ultrasonic test method developed in USA by Dr. Floyd Firestone.

1950 The Schmidt Hammer (also known as “Swiss Hammer”) is invented. The instrument uses the world’s first patented non-destructive testing method for concrete.

1950 J. Kaiser introduces acoustic emission as an NDT method

NON DESTRUCTIVE TECHNIQUES

Visual/Optical NDT: Using visual inspection methods for enclosed systems can be challenging and possibly ineffective. Methods of visual/optical NDT methods include:

1. Infrared Thermography,
2. Passive Thermography,
3. Laser Stereography,
4. Optical Holography

To enable a technician or engineer to inspect these difficult-to-see areas, a device known as a borescope is often used. There are a variety of enhanced visual/optical NDT methods available. In terms of corrosion these NDT methods are generally used to detect and measure deformations on surfaces. These deformations may be caused by pitting on the exposed surface, or by subsurface corrosion damage in built-up structure.

Magnetic particle Testing (MT): When **a** ferromagnetic (steel or iron) component is magnetized-by another magnet or by a coil carrying electrical current and fine iron particles are spread onto the component's surface, the particles will cling to and outline any discontinuity, since the discontinuity breaks the magnetic field. Surface corrosion cracks can be readily, and at very little expense, outlined in this way. Unless the cracks are very small, they can be detected even in the presence of corrosion products and paint. A disadvantage of MT is that it can only be used on ferrous materials and alloys, such as iron, nickel and carbon steel.


Before and after inspection pictures of cracks emanating from a hole

Dye Penetrant Testing (DPT): When a dye with low surface tension is applied to a component, it will penetrate into surface cracks and discontinuities. If the surface dye is then washed off and the part is subsequently treated to draw the dye out of the discontinuities, the configurations of the discontinuities will be outlined, Surface corrosion cracks can readily evaluated by using dye penetrant techniques However, corrosion products tend to absorb the dye, thereby masking the cracked areas. It is therefore necessary to clean surfaces thoroughly for dye penetrant inspections. Inspection can be performed using visible (or red dye) or fluorescent penetrant materials.

Ultrasonic Testing (UT): The ultrasonic method normally utilized in non destructive testing evaluations of corrosion damage is the pulse-echo technique. Here, the distance between the surface (to which the ultrasonic - transducer is applied) and sub surface interface is determined by the time (in microseconds) required for the pulse to be reflected. The technique is very sensitive and accordingly very small interfaces can be detected by this method.

In corrosion evaluation, ultrasonic has the important advantage that access to only one side of the component is required. Also, the cost of the testing procedure is relatively low, although capable, experienced ultrasonic technicians are required if reliable results are to be expected. The major disadvantage of ultrasonic testing for corrosion damage is that the evidence is normally assessed in field by the ultrasonic technician, and the engineer must therefore rely heavily on the technician's judgment or must accompany him on the job in order to gain experience in applying and interpreting ultra-sonic signal displays.

Most ultrasonic techniques employ frequencies in the range of 1 to 10 MHz. The velocity of ultrasonic waves traveling through a material is a simple function of the material's modulus and density, and thus ultrasonic methods are uniquely suited to materials characterization studies. In addition, ultrasonic waves are strongly reflected at boundaries where material properties change and thus are often used for thickness measurements and crack detection. Recent advances in ultrasonic techniques have largely been in the field of phased array ultrasonic, now available in portable instruments. The timed or phased firing of arrays of ultrasonic elements in a single transducer allows for precise tailoring of the resulting ultrasonic waves introduced into the test object.

Full record of examination is done in A-Scan, B-Scan, C-Scan, P-Scan, S-scan, Zip or TOFD Scan. Due to its sensitivity and sizing accuracy, TOFD (Time of Flight Diffraction) is also an excellent tool for in-service material and flaw monitoring. There are various other types of advance ultrasonic instruments such as SAFT (Synthetic Aperture Focusing Technique), ALOK and Phased array. Ultrasonic phased arrays are a novel technique for generating, receiving & imaging ultra-sound. Instead of a single transducer & beam, phased arrays use multiple ultrasonic elements & electronic time delays to create beams by constructive & destructive interference. SAFT as an imaging method offers the benefit of high-resolution defect detection accompanied by simple interpretation of the signals. However, due to the large amount of raw data, SAFT has only limited suitability as a search method. In the event of large components and unknown defect orientation, TOFD is the best choice.

Eddy current Testing (UCT): In eddy current testing, the probe (a coil with alternating current normally in the KHz frequency) is applied to the component and the effect of the presence of the component in its resistance to the field created by the coil is indicated. The eddy current effects are sensitive to compositional and metallurgical changes as well as to thickness and discontinuities, and the results may, therefore, be difficult to evaluate unless a number of the variables are standardized. In corrosion studies, eddy current tests are devised in order to evaluate specific problems: corrosion in condenser tubes of known composition, corrosion under aircraft skin of a known composition and heat treatment, crack in the surface of a neoprene-coated maraging steel component. Once the instrument has been suitably standardized, this inexpensive testing can in some instances be performed by relatively inexperienced personnel; however, more frequently, the interpretation of the results is open to considerable question.

Radiographic Testing (RT): Radiography is also used in the fight against corrosion and especially for corrosion under insulation. Today digital radiography and specifically computerized radiography (CR), is being increasin ... liography works on the shadow picture principle. The ... y electric apparatus, or gamma rays, as em ... he object being inspected, and the shadow in ... lingly, differences in metal thickness result in d ... sion studies, these density differences indicate

In corrosion evaluati ... giving the corrosion engineer a general im ... ent of the areas of wastage. It may be ... oth the corrosion mechanism and also ... anent record; the engineer can, therefo ... t rely completely on the interpretation of h ... ent calibration requirements and one ... of error in evaluating results. Radiography ha ... out the configuration of hidden components ... n-metallies which may be associated with the ... int). The major limitation of radiograph ... quired. Also, the costs of inspection may ... ddition, X-rays and gamma rays are inherent ... e used at inconvenient hours to avoid working personnel.

Thermographic testing (TT): Infrared and thermal testing methods are characterized by the use of thermal measurements of a test object as it undergoes a response to a stimulus. Thermal imaging cameras are the most common sensing method. Passive imaging of machinery or electronics may be used to detect hot spots indicative of problems. Imaging of test objects after the application of energy can be used to monitor the flow of heat in the object, which is a function of material properties as well as boundaries. Flash thermography techniques have been very successful in imaging disbonds and delaminations in composite parts, for example. The high cost of quality thermal cameras was previously a drawback of the IR method, but recently these have become significantly less expensive. Another significant recent advancement is the use of mechanical energy to stimulate localized heating at sub-surface discontinuities, such as cracks in metals, opening up a new field of application for the IR method.