

Metallurgical and Materials Engineering Department

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Semester: 7th

Subject: Non-Destructive Testing

Lecture Notes

1. Importance of Non-Destructive testing in the quality control of materials

Up to this point we have learnt various testing methods that somehow destruct the test specimens. These were, tensile testing, hardness testing, etc. In certain applications, the evaluation of engineering materials or structures without impairing their properties is very important, such as the quality control of the products, failure analysis or prevention of the engineered systems in service. This kind of evaluations can be carried out with Nondestructive test (NDT) methods. It is possible to inspect and/or measure the materials or structures without destroying their surface texture, product integrity and future usefulness. The field of NDT is a very broad, interdisciplinary field that plays a critical role in inspecting that structural component and systems perform their function in a reliable fashion. Certain standards has been also implemented to assure the reliability of the NDT tests and prevent certain errors due to either the fault in the equipment used, the miss-application of the methods or the skill and the knowledge of the inspectors. Successful NDT tests allow locating and characterizing material conditions and flaws that might otherwise cause planes to crash, reactors to fail, trains to derail, pipelines to burst, and variety of less visible, but equally troubling events. However, these techniques generally require considerable operator skill and interpreting test results accurately may be difficult because the results can be subjective. These methods can be performed on metals, plastics, ceramics, composites, cermet's, and coatings in order to detect cracks, internal voids, surface cavities, delamination, incomplete c defective welds and any type of flaw that could lead to premature failure. Commonly used NDT test methods can be seen in table 1. These are universal NDT methods; however, very special tests have been developed for specific applications.

Table 1 Commonly used NDT techniques

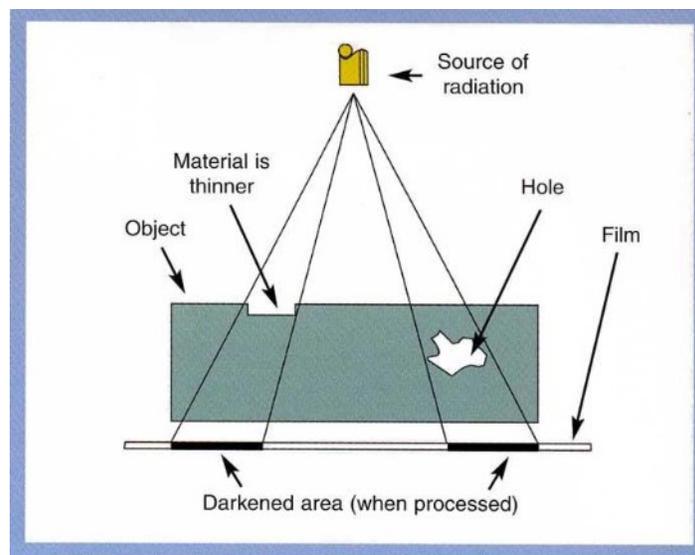
Technique	Capabilities	Limitations
Visual Inspection	Macroscopic surface flaws	Small flaws are difficult to detect, no subsurface flaws.
Microscopy	Small surface flaws	Not applicable to larger structures; no subsurface flaws.
Radiography	Subsurface flaws	Smallest defect detectable is 2% of the thickness; 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	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.

2. Visual inspection:

VI is particularly effective detecting macroscopic flaws, such as poor welds. Many welding flaws are macroscopic: crater cracking, undercutting, slag inclusion, incomplete penetration welds, and the like. Likewise, VI is also suitable for detecting flaws in composite structures and piping of all types. Essentially, visual inspection should be performed the way that one would inspect a new car prior to delivery, etc. Bad welds or joints, missing fasteners or components, poor fits, wrong dimensions, improper surface finish, delamination's in coatings, large cracks, cavities, dents, inadequate size, wrong parts, lack of code approval stamps and similar proofs of testing.

3. Radiography:

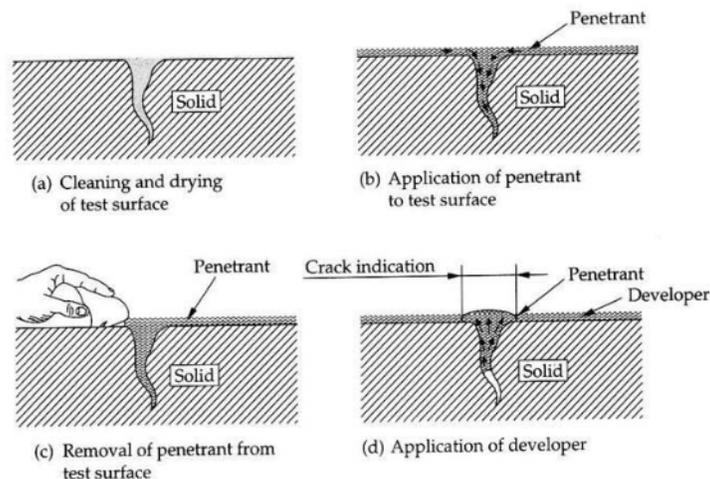
Radiography has an advantage over some of the other processes in that the radiography provides a permanent reference for the internal soundness of the object that is radiographed. The x-ray emitted from a source has an ability to penetrate metals as a function of the accelerating voltage in the x-ray emitting tube. If a void present in the object being radiographed, more x-rays will pass in that area and the film under the part in turn will have more exposure than in the non-void areas. The sensitivity of x-rays is nominally 2% of the materials thickness. Thus for a piece of steel with a 25mm thickness, the smallest void that could be detected 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 of the crack. Gamma radiography is identical to x-ray radiography in function. The difference is the source of the penetrating electromagnetic radiation which is a radioactive material such as ^{60}Co . However this method is less popular because of the hazards of handling radioactive materials.



Radiography

4. Liquid (Dye) penetrant method:

Liquid penetrant inspection (LPI) is one of the most widely used nondestructive evaluation (NDE) methods. Its popularity can be attributed to two main factors, which are its relative ease of use and its flexibility. The technique is based on the ability of a liquid to be drawn into a "clean" surface breaking flaw by capillary action. . This method is an inexpensive and convenient technique for surface defect inspection. The limitations of the liquid penetrant technique include the inability to inspect subsurface flaws and a loss of resolution on porous materials. Liquid penetrant testing is largely used on nonmagnetic materials for which magnetic particle inspection is not possible. Materials that are commonly inspected using LPI include the following; metals (aluminum, copper, steel, titanium, etc.), glass, many ceramic materials, rubber, plastics. Liquid penetrant inspection is used to inspect of flaws that break the surface of the sample. Some of these flaws are listed below; fatigue cracks, quench cracks grinding cracks, overload and impact fractures, porosity, laps seams, pin holes in welds, lack of fusion or braising along the edge of the bond line.

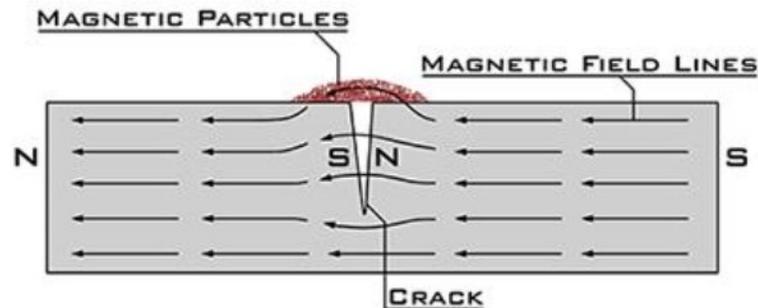


Liquid (Dye) penetrant

5. Magnetic particles:

Magnetic particle inspection is one of the simple, fast and traditional nondestructive testing methods widely used because of its convenience and low cost. 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. On the other hand, an enormous volume of structural steels used in engineering is magnetic. 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

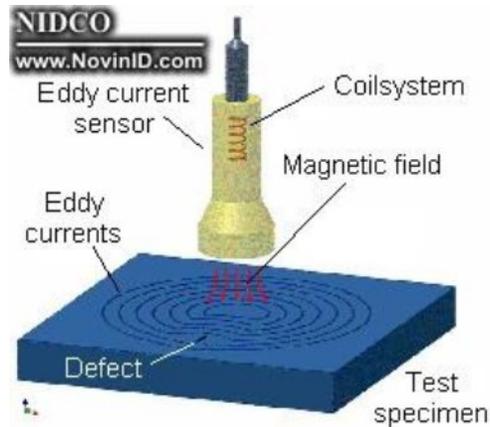
electromagnet is energized. If there is a discontinuity such as a crack or a flaw on the surface of the part, magnetic flux will be broken and a new south and north pole will form at each edge of the discontinuity. Then just like if iron particles are scattered on a cracked magnet, the particles will 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. For the best sensitivity, the lines of magnetic force should be perpendicular to the defect.



Magnetic Particles

6. Eddy current testing:

Eddy currents are created through a process called electromagnetic induction. When alternating current is applied to the conductor, such as copper wire, a magnetic field develops in and around the conductor. This magnetic field expands as the alternating current rises to maximum and collapses as the current is reduced to zero. If another 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 an impedance on a second coil which is used to as a sensor. In practice a probe is placed on the surface of the part to be inspected, and electronic equipment monitors the eddy current in the work piece through the same probe. The sensing circuit is a part of the sending coil. Eddy currents can be used for crack detection, material thickness measurements, coating thickness measurements, conductivity measurements for material identification, heat damage detection, case depth determination, heat treatment monitoring. Some of the advantages of eddy current inspection include; sensitivity to small cracks and other defects, ability to detect surface and near surface defects, immediate results, portable equipment, suitability for many different applications, minimum part preparation, no necessity to contact the part under inspection, ability to inspect complex shapes and sizes of conductive materials. Some limitation of eddy current inspection; applicability just on conductive materials, necessity for an accessible surface to the probe, skillful and trained personal, possible interference of surface finish and roughness, necessity for reference standards for setup, limited depth of penetration, inability to detect of the flaws lying parallel to the probe coil winding and probe scan direction.

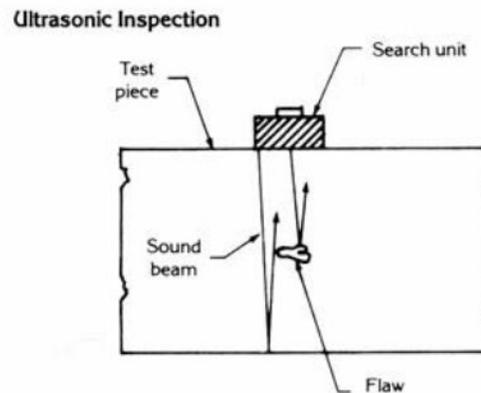


Eddy current testing

7. Ultrasonic Inspection:

Ultrasonic Testing (UT) uses a high frequency sound energy to conduct examinations and make measurements. Ultrasonic inspection can be used for flaw detection I evaluation, dimensional measurements, material characterization, and more. A typical UT inspection system consists of several functional units, such as the pulser/receiver, transducer, and display devices. A pulser/receiver is an electronic device that can produce high voltage electrical pulse. Driven by the pulser, the transducer of various types and shapes generates high frequency ultrasonic energy operating based on the piezoelectricity technology with using quartz, lithium sulfate, or various ceramics. Most inspections are carried out in the frequency range of 1 to 25MHz. Couplants are used to transmit the ultrasonic waves from the transducer to the test piece; typical couplants are water, oil, glycerin and grease. The sound energy is introduced and propagates through the materials in the form of waves and reflected from the opposing surface. An internal defect such as crack or void interrupts the waves' propagation and reflects back a portion of the ultrasonic wave. The amplitude of the energy and the time required for return indicate the presence and location of any flaws in the work-piece. The ultrasonic inspection method has high penetrating power and sensitivity. It can be used from various directions to inspect flaws in large parts, such as rail road wheels pressure vessels and die blocks. This method requires experienced personnel to properly conduct the inspection and to correctly interpret the results. As a very useful and versatile NDT method, ultrasonic inspection method has the following advantages; sensitivity to both surface and subsurface discontinuities, superior depth of penetration for flaw detection or measurement, ability to single-sided access for pulse-echo technique, high accuracy in determining reflector position and estimating size and shape, minimal part preparation, instantaneous results with electronic equipment, detailed imaging with automated systems, possibility for other uses such as thickness measurements. Its limitations; necessity for an accessible surface to transmit ultrasound, extensive skill and training, requirement for a coupling medium to promote transfer of sound energy into test specimen, limits for roughness, shape irregularity, smallness, thickness or not homogeneity, difficulty to inspect of coarse grained

materials due to low sound transmission and high signal noise, necessity for the linear defects to be oriented parallel to the sound beam, necessity for reference standards for both equipment calibration, and characterization of flaws.



Ultrasonic Inspection

8. Acoustic Method:

There are two different kind of acoustic methods: (a) acoustic emission; (b) acoustic impact technique.

8.1 Acoustic emission:

This technique is typically performed by elastically stressing the part or structure, for example, bending a beam, applying torque to a shaft, or pressurizing a vessel and monitoring the acoustic responses emitted from the material. During the structural changes the material such as plastic deformation, crack initiation, and propagation, phase transformation, abrupt reorientation of grain boundaries, bubble formation during boiling in cavitation, friction and wear of sliding interfaces, are the source of acoustic signals. Acoustic emissions are detected with sensors consisting of piezoelectric ceramic elements. This method is particularly effective for continuous surveillance of load-bearing structures.

8.2 Acoustic impact technique:

This technique consists of tapping the surface of an object and listening to and analyzing the signals to detect discontinuities and flaws. The principle is basically the same as when one taps walls, desktops or countertops in various locations with a finger or a hammer and listens to the sound emitted. Vitrified grinding wheels are tested in a similar manner to detect cracks in the wheel that may not be visible to the naked eye. This technique is easy to perform and can be instrumented and automated. However, the results depend on the geometry and mass of the part so a reference standard is necessary for identifying flaws.

Note:

1. Students study the related textbook for the subject.
2. For any doubt or query students can mail me to [*manojmohbe@gmail.com*](mailto:manojmohbe@gmail.com)