

MATERIALS SCIENCE

NON DESTRUCTIVE TESTING – NDT

Nondestructive Testing

The field of Nondestructive Testing (NDT) is a very broad, interdisciplinary field that plays a critical role in assuring that structural components and systems perform their function in a reliable and cost effective fashion. NDT technicians and engineers define and implement tests that locate and characterize material conditions and flaws that might otherwise cause planes to crash, reactors to fail, trains to derail, pipelines to burst, and a variety of less visible, but equally troubling events. These tests are performed in a manner that does not affect the future usefulness of the object or material. In other words, NDT allows parts and materials to be inspected and measured without damaging them.

Non Destructive Testing Methods

The number of NDT methods that can be used to inspect components and make measurements is large and continues to grow. Researchers continue to find new ways of applying physics and other scientific disciplines to develop better NDT methods. However, there are six NDT methods that are used most often. These methods are visual inspection, penetrant testing, magnetic particle testing, electromagnetic or eddy current testing, radiography, and ultrasonic testing. These methods and a few others are briefly described below.

Visual and Optical Testing (VT)

Visual inspection involves using an inspector's eyes to look for defects. The inspector may also use special tools such as magnifying glasses, mirrors, or borescopes to gain access and more closely inspect the subject area. Visual examiners follow procedures that range from simple to very complex.

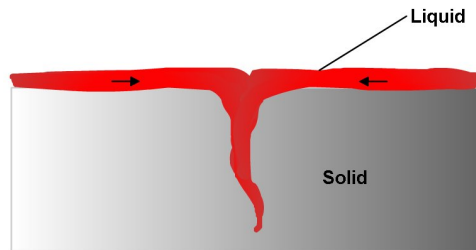
Penetrant Testing (PT)

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 colour 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.

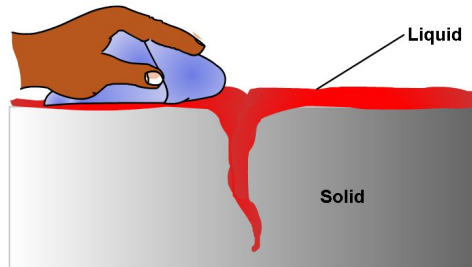
Basic Processing Steps of a Liquid Penetrant Inspection

1. **Surface Preparation:** One of the most critical steps of a liquid penetrant inspection is the surface preparation. The surface must be free of oil, grease, water, or other contaminants that may prevent penetrant from entering flaws. The sample may also require etching if mechanical operations such as machining, sanding, or grit blasting have been performed. These and other mechanical operations can smear metal over the flaw opening and prevent the penetrant from entering.

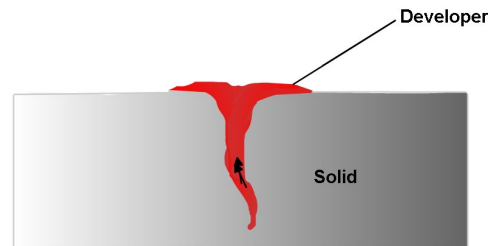
- Penetrant Application:** Once the surface has been thoroughly cleaned and dried, the penetrant material is applied by spraying, brushing, or immersing the part in a penetrant bath.



- Penetrant Dwell:** The penetrant is left on the surface for a sufficient time to allow as much penetrant as possible to be drawn from or to seep into a defect. Penetrant dwell time is the total time that the penetrant is in contact with the part surface. Dwell times are usually recommended by the penetrant producers or required by the specification being followed. The times vary depending on the application, penetrant materials used, the material, the form of the material being inspected, and the type of defect being inspected for. Minimum dwell times typically range from 5 to 60 minutes. Generally, there is no harm in using a longer penetrant dwell time as long as the penetrant is not allowed to dry. The ideal dwell time is often determined by experimentation and may be very specific to a particular application.
- Excess Penetrant Removal:** This is the most delicate part of the inspection procedure because the excess penetrant must be removed from the surface of the sample while removing as little penetrant as possible from defects. Depending on the penetrant system used, this step may involve cleaning with a solvent, direct rinsing with water, or first treating the part with an emulsifier and then rinsing with water.



5. **Developer Application:** A thin layer of developer is then applied to the sample to draw penetrant trapped in flaws back to the surface where it will be visible. Developers come in a variety of forms that may be applied by dusting (dry powdered), dipping, or spraying (wet developers).



6. **Indication Development:** The developer is allowed to stand on the part surface for a period of time sufficient to permit the extraction of the trapped penetrant out of any surface flaws. This development time is usually a minimum of 10 minutes. Significantly longer times may be necessary for tight cracks.
7. **Inspection:** Inspection is then performed under appropriate lighting to detect indications from any flaws which may be present.
8. **Clean Surface:** The final step in the process is to thoroughly clean the part surface to remove the developer from the parts that were found to be acceptable.

Advantages of Penetrant Testing

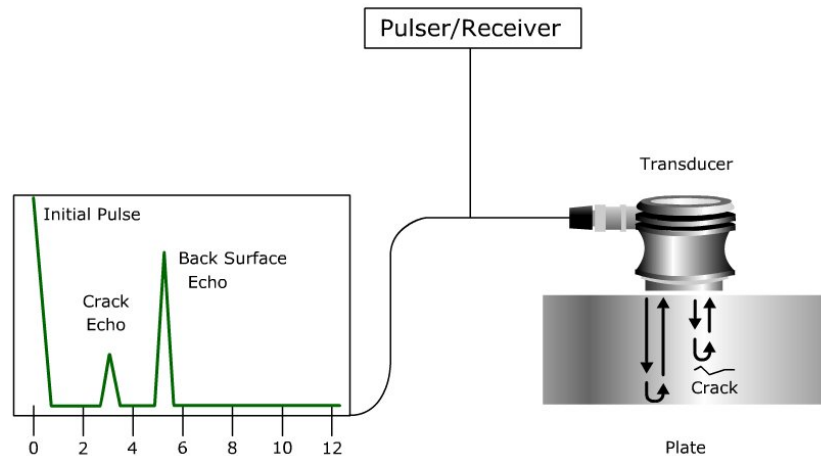
- The method is highly sensitive to small surface discontinuities.
- The method has few material limitations, i.e. metallic and nonmetallic, magnetic and nonmagnetic, and conductive and nonconductive materials may be inspected.
- Large areas and large volumes of parts/materials can be inspected rapidly and at low cost.
- Parts with complex geometric shapes are routinely inspected.
- Indications are produced directly on the surface of the part and constitute a visual representation of the flaw.
- Aerosol spray cans make penetrant materials very portable.
- Penetrant materials and associated equipment are relatively inexpensive.

Disadvantages of Penetrant Testing

- Only surface breaking defects can be detected.
- Only materials with a relatively nonporous surface can be inspected.
- Precleaning is critical since contaminants can mask defects.
- Must have direct access to the surface being inspected.
- Surface finish and roughness can affect inspection sensitivity.
- Post cleaning of tested materials is required.
- Chemical handling and proper disposal is required.

Ultrasonic Testing (UT)

Ultrasonic Testing uses high frequency sound energy to conduct examinations and make measurements. 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. To illustrate the general inspection principle, a typical pulse/echo inspection configuration as illustrated below will be used.



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 pulses.

Driven by the pulser, the transducer generates high frequency ultrasonic energy. The sound energy is introduced and propagates through the materials in the form of waves. When there is a discontinuity (such as a crack) in the wave path, part of the energy will be reflected back from the flaw surface. The reflected wave signal is transformed into an electrical signal by the transducer and is displayed on a screen.

The reflected signal strength is displayed versus the time from signal generation to when an echo was received. Signal travel time can be directly related to the distance that the signal traveled. From the signal, information about the reflector location, size, orientation and other features can sometimes be gained.

Advantages of Ultrasonic Testing

- It is sensitive to both surface and subsurface discontinuities
- The depth of penetration for flaw detection or measurement is superior
- Only single-sided access is needed
- Minimal part preparation is required
- Instantaneous results
- It has other uses, such as thickness measurement, in addition to flaw detection

Disadvantages of Ultrasonic Testing

- Surface must be accessible to transmit ultrasound
- Skill and training is more extensive than with some other methods

- Materials that are rough, irregular in shape, very small, exceptionally thin or not homogeneous are difficult to inspect
- Linear defects oriented parallel to the sound beam may go undetected.
- Reference standards are required for both equipment calibration and the characterization of flaws

Magnetic Particle Inspection (MPI)

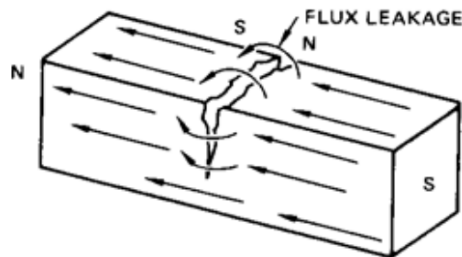
This NDT method is accomplished by inducing a magnetic field in a ferromagnetic material and then dusting the surface with iron particles (either dry or suspended in liquid). Surface and near-surface imperfections distort the magnetic field and concentrate iron particles near imperfections, providing a visual indication of the flaw.

Basic Principles of Magnetic Particle Inspection

In theory, (MPI) is a relatively simple concept. It can be considered as a combination of two nondestructive testing methods: magnetic flux leakage testing and visual testing. Consider the case of a bar magnet. It has a magnetic field in and around the magnet. Any place that a magnetic line of force exits or enters the magnet is called a pole. A pole where a magnetic line of force exits the magnet is called a north pole and a pole where a line of force enters the magnet is called a south pole.

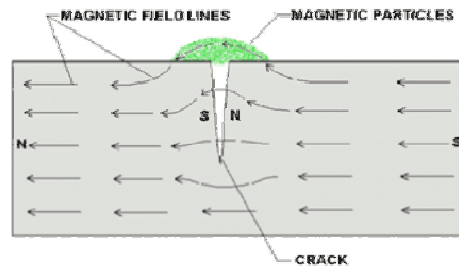


When a bar magnet is broken in the center of its length, two complete bar magnets with magnetic poles on each end of each piece will result. If the magnet is just cracked but not broken completely in two, a north and south pole will form at each edge of the crack. The magnetic field exits the north pole and reenters at the south pole. The magnetic field spreads out when it encounters the small air gap created by the crack because the air cannot support as much magnetic field per unit volume as the magnet can. When the field spreads out, it appears to leak out of the material and, thus is called a flux leakage field.



If iron particles are sprinkled on a cracked magnet, the particles will be attracted to and cluster not only at the poles at the ends of the magnet, but also at the poles at the

edges of the crack. This cluster of particles is much easier to see than the actual crack and this is the basis for magnetic particle inspection.



The first step in a magnetic particle inspection is to magnetize the component that is to be inspected. If any defects on or near the surface are present, the defects will create a leakage field. After the component has been magnetized, iron particles, either in a dry or wet suspended form, are applied to the surface of the magnetized part. The particles will be attracted and cluster at the flux leakage fields, thus forming a visible indication that the inspector can detect.

Advantages of Magnetic Particle Inspection

- It can be done quickly
- It is economical
- The results are visually positive
- Staff can be trained rapidly to use the method
- Instantaneous results
- Minimal part preparation is required
- Only single-sided access is needed

Disadvantages of Magnetic Particle Inspection

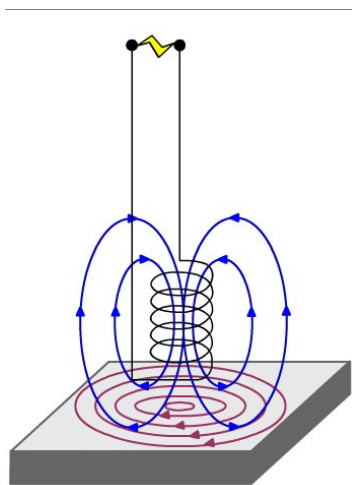
- It can only be used on ferromagnetic materials
- Can only be used to detect surface and or near-surface defects
- While a visible indication is positive, permanent records are not easily made.

Eddy Current Testing

Electrical currents are generated in a conductive material by an induced alternating magnetic field. The electrical currents are called eddy currents because they flow in circles at and just below the surface of the material. Interruptions in the flow of eddy currents, caused by imperfections, dimensional changes, or changes in the material's conductive and permeability properties, can be detected with the proper equipment.

Basic Principles of Eddy Current Inspection

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. Eddy currents are induced electrical currents that flow in a circular path.



Advantages of Eddy Current Inspection

- Sensitive to small cracks and other defects
- Detects surface and near surface defects
- Inspection gives immediate results
- Equipment is very portable
- Method can be used for much more than flaw detection
- Minimum part preparation is required
- Test probe does not need to contact the part
- Inspects complex shapes and sizes of conductive materials

Disadvantages of Eddy Current Inspection

- Only conductive materials can be inspected
- Surface must be accessible to the probe
- Skill and training required is more extensive than other techniques
- Surface finish and roughness may interfere
- Reference standards needed for setup
- Depth of penetration is limited

Radiography (RT)

Radiography involves the use of penetrating gamma or X-radiation to examine parts and products for imperfections. An X-ray generator or radioactive isotope is used as a source of radiation. Radiation is directed through a part and onto film or other imaging media. The resulting shadowgraph shows the dimensional features of the part. Possible imperfections are indicated as density changes on the film in the same manner as medical X-ray shows broken bones. Defective areas such as porosity, cracks, weld undercut usually show up darker on the film except for defects such as excess weld metal, spatter etc.

Advantages of Radiography

- Detects surface and subsurface defects
- Can be used on a wide variety of materials
- Provides permanent record of the inspection.

Disadvantages of Radiography

- Safety precautions are required for the safe use of radiation.
- Access to both sides of the specimen is required.
- Orientation of the sample is critical.
- Bulky and expensive machinery is required.

Leak Testing (LT)

Several techniques are used to detect and locate leaks in pressure containment parts, pressure vessels, and structures. Leaks can be detected by using electronic listening devices, pressure gauge measurements, liquid and gas penetrant techniques, and/or a simple soap-bubble test.