The Basics of Non-Destructive Material Testing – Part 1

Hailey Kupiec posted on June 15, 2016

Ultrasonic testing of a pipeline weld

Non-destructive testing methods test mechanical and other properties without permanently altering the subject, which saves time and money in product evaluation.

There are many companies that sell non-destructive machines to test material properties but they rarely explain how their methods work. Eng-Tips Forums member "afronova" posted the question, "Are there any good sites that inform about destructive and non-destructive material testing techniques?"

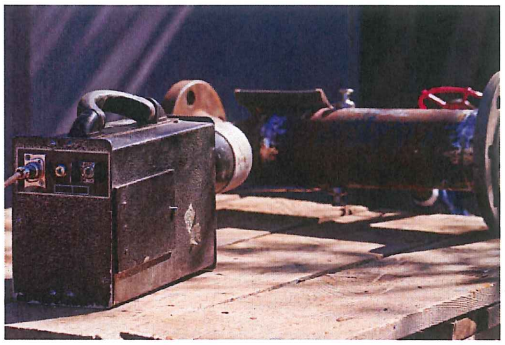
Well, afronova, there is now.

And so begins a three-part series on nine methods of non-destructive material testing. In part one, we discuss radiographic testing, ultrasonic testing and magnetic particle inspection.

1. RT - Radiographic Testing

Radiographic testing is often used to inspect assembled components and to find flaws in complex structures. It uses short wavelength electromagnetic radiation in the form of high-energy photons to penetrate materials and inspect for hidden flaws. Neutron radiographic testing uses neutrons in the place of photons.

Neutron radiation can pass easily through lead or steel but is stopped by plastics, water and oils. When radiation directed through the material hits a defect, it scatters. Variations in the radiation exiting the opposite side of the material thus allow quality professionals to identify the location of defects as well as determine the thickness and composition of the material.



Radiographic testing of a welded joint

Pros	Cons
Requires very little surface preparation	Safety precautions required for working with radiation
Can detect both surface and interior defects	Requires access to both sides of a specimen
Sensitive to thickness and corrosion flaws and material density changes	Impossible to determine depth of flaws without multiple angle exposures
Measures dimensions and angles	

2. UT - Ultrasonic Testing

Ultrasonic testing is used to detect defects in materials of any shape or type so long as they have smooth surfaces. Ultrasonic testing uses a transducer connected to a diagnostic machine to send vibrations/sound waves through a material. The apparatus is passed over the object being inspected. This often requires the use of a couplant (like oil or water) to connect the transducer and the object, which decreases inaccuracies and false readings in the results.

There are two methods of receiving the signal. First is 'reflection', where the transducer can both send and receive the signal. The other is 'attenuation', where the transmitter sends ultrasound through one

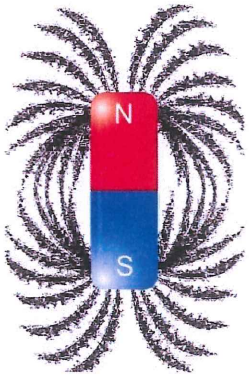
surface and a separate receiver detects the amount that reaches the other side through the medium. Any decrease in the sound detected is caused by defects.

Pros	Cons
Only single side access is required	Requires a trained technician
High penetrating power and very sensitive	Not good for a rough surface or for irregular objects
Non-hazardous to the operator	Surface must be prepared
Portable	Object must be water resistant
Immediate results	

3. MPI - Magnetic Particle Inspection

Magnetic particle inspection is commonly used outdoors and at remote locations for detecting surface and subsurface defects. It is based on the concept of magnetic flux leakage. Magnetic flux leakage occurs when an additional north and south pole are created by a crack in a magnet. At the crack, the magnetic field bulges to form a 'leakage'.

In magnetic particle inspection, a part is magnetized either directly or indirectly. Direct magnetization occurs when an electric current is passed through the test object and a magnetic field forms in the material. Indirect magnetization does not involve a current applied to the material but occurs when a magnetic field is applied from an outside source.Since iron particles concentrate along magnetic field lines, when they are applied to the magnetized part they will cluster around a leakage.



Iron particles concentrated along magnetic field lines

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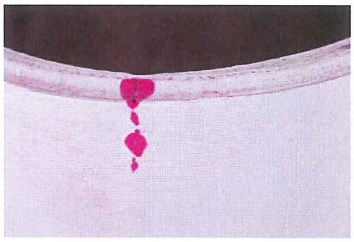
Pros	Cons
Relatively inexpensive	Only for ferromagnetic materials
Extensive pre-cleaning is not necessary	Cannot be used if there is a thick coat of paint
Quick and uncomplicated	

The above three methods have different uses and require different amounts of training to complete but all will leave your part just as you found it.

In part two we discuss dye penetrant inspection, eddy current testing and thermographic inspection. In part three we discuss leak testing, guided wave testing and visual testing.

The Basics of Non-Destructive Material Testing – Part 2

4. DPI - Dye Penetrant Inspection



Detection of a crack by dye penetrant inspection

Dye penetrant inspection is often used to detect casting, forging and welding surface defects. This includes hairline fractures, leaks and fatigue cracks. This method is based on the concept of capillary action, which is caused by intermolecular forces. In this case the capillary action occurs when the combination of the surface tension of the liquid penetrant and the adhesive forces of the walls of the crack work together to cause the liquid to climb and color the developer.

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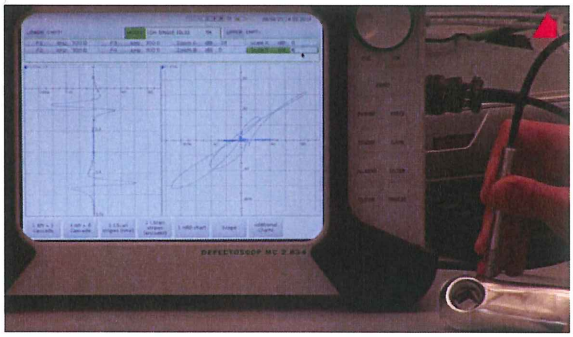
The basic steps of dye penetrant inspection are as follows:

1. Clean the part to be inspected thoroughly, removing anything that would prevent the penetrant from entering a defect. Ensure the surface is dry and free of contaminations that could lead to false results.
2. Apply the penetrant and leave it for the time it takes to sink into any defects (the dwell time).
3. Thoroughly remove any excess penetrant.
4. Apply the developer, this draws the penetrant out of any defects, coloring the area.
5. Visually inspect the part for remaining penetrant, which reveals the defects.

Pros	Cons
Low cost	Only detects surface defects
Fast	Can cause skin irritation
Limited training required	Can produce false results on rough surfaces
	Only for use on non-porous surfaces

5. ECT – Eddy Current Testing

Eddy current testing is used to detect surface and subsurface defects in parts composed of conductive material. It is based on the concept of electromagnetic induction. A current running through a wire coil creates a magnetic field. If an alternating voltage is applied to the coil, a counter voltage from self-induction by the alternating magnetic field causes a decrease in current consumption.



A crack is detected in the part. Screenshot courtesy of _

Hochschule Karlsruhe - University of Applied Sciences

When the coil is run over a conductive material, the current increases because the alternating magnetic field induces a current in the material, called the eddy current. The eddy current creates its own magnetic field which counteracts that of the coil. This decreases the self-induction in the coil and increases the current consumption.

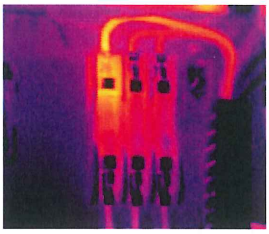
If a defect is present in the material and is in the path of the eddy current, the current flows around the defect, lengthening its path and increasing the resistance in the eddy current circuit. The resistance increase causes a corresponding decrease in the strength of the magnetic field. Thus, the self-induction of the coil increases and its current consumption decreases.

A decrease in the coil current is therefore indicative of a defect in the material. Monitoring the change in current shows the location of defects.

Pros	Cons
Partial computerized record	Slow
Effective on coating/paint	Conductive material only
Very sensitive	Near surface flaws only

6. IR - Thermographic Inspection

Thermographic inspection is used to find cracks, voids, cavities and other defects in shafts, pipes and other metal or plastic parts. Every object gives off radiation. The more energy an object has, the more radiation it emits. Thermographic inspection uses infrared video or still cameras to see radiation in the infrared spectrum and create an image of thermal patterns on an object's surface.



An overheating terminal in an industrial fuse block. By Hotflashhome (Own work) [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0) or GFDL (http://www.gnu.org/copyleft/fdl.html)], via Wikimedia Commons

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There are two approaches to thermographic inspection:

1. Passive: features of interest are naturally at higher or lower temperature than the background
2. Active: energy source is required to produce thermal contrast between the features of interest and the background

Pros	Cons
Can locate deteriorating components prior to failure	Detects only shallow subsurface defects
Fast, safe	Experience is required to correctly interpret results
Nonintrusive, noncontact	High accuracy is difficult to obtain

The Basics of Non-Destructive Material Testing – Part 3

Hailey Kupiec posted on June 29, 2016

7. LT – Leak Testing

Leak testing is used to detect faults in a variety of fluid systems so that corrective action may be taken. Leaks require a pressure difference to generate flow, which runs from higher to lower pressures.

A variety of methods are used to detect flow, including:

- Pressure Decay: The part is filled with air to a set pressure (pressurized). It is then disconnected from the air supply. The air pressure in the part is monitored and the leak rate calculated based on the pressure change over time.
- Mass Airflow: The part is pressurized and remains connected to the air supply. An equilibrium is reached such that the air flowing into the part from the supply is equal to that leaking out. At this point the internal pressure of the part is stable and the leak rate is directly measured as the incoming air flow rate.
- Observation: The part or assembly is pressurized and submerged in a tank of water. Any bubbles that form reveal the location of a leak. If the part is too large or unwieldy to be submerged, the suspected leak area is coated with a soap solution to create bubbles.
- Gas Tracer (Helium): The part or assembly is enclosed in a sealed chamber. The part and/or the chamber is evacuated and one is charged with helium. The gas lost to the other volume is measured with a mass spectrometer.

Pros	Cons
Some methods are inexpensive and require little experience	Very operator-dependent
Safe	Requires close supervision

8. GWT – Guided Wave Testing

Guided wave testing is used to inspect pipelines as well as train tracks, metal plate structures and rods. It can inspect up to 100m from a single location.Though guided wave testing is also known as long-range ultrasonic testing, the two methods are fundamentally different. GWT uses a lower frequency (10-100kHz) of ultrasound. Axially symmetric waves propagate horizontally through the material in both directions from the test site.

By Sprialboy (Own work) [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0) or GFDL (http://www.gnu.org/copyleft/fdl.html)], via Wikimedia Commons

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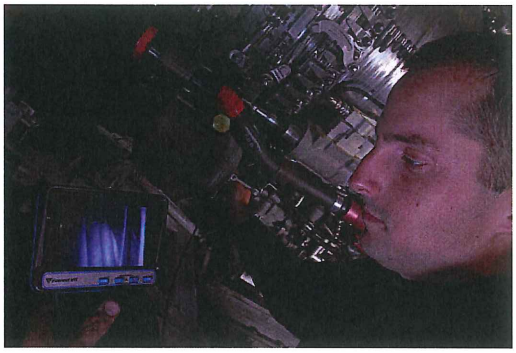
A ring with multiple transducers is attached around the circumference of the object. These transducers are in pulse-echo mode, meaning that they both produce the waves and receive reflected signals. The reflected signals are caused by defects in the material as well as by cross sectional changes such as welds. The arrival time and predicted speed that a wave travels in the medium (often calculated using weld echoes) allows the user to determine the location of defects.

Pros	Cons
Detect both internal and external material loss	Requires an experienced data interpreter
Data is fully recorded	Difficult to detect surface pitting
Fast and long range	Bends and junctions distort the signal
Portable	

9. VT – Visual Testing/Inspection

Visual inspection is the oldest and most basic method of non-destructive testing, but it's also powerful. Visual testing is used for surface flaw identification and inspection of equipment and structures. All other forms of flaw detection must ultimately be confirmed visually. Magnetic particle inspection and dye penetrant inspection are methods used to enhance visual testing.



Visual inspection using a borescope. By U.S. Navy photo by Mass Communication Specialist 3rd Class Gary Prill [Public domain], via Wikimedia Commons

Proper surface preparation, such as etching and cleaning, vastly improves the accuracy of visual testing. Magnifiers, microscopes and other such devices are aides in visual testing. A well trained, experienced inspector can detect most signs of damage, making visual testing highly reliable.

Pros	Cons
Cost-effective	Only detect surface flaws
Safe, non-intrusive	Subject to human error
No equipment required	Training required