Written by Michael Twomey, Conam Inspection, Inc. Sunday, 01 March 1998 13:04

# A review of two fundamental nondestructive testing methods for identifying manufactured defects and service defects in plant equipment components.

Preventive maintenance can save considerable cost in terms of downtime, injury, lost opportunity, and lost revenue. Two very basic nondestructive testing methods, magnetic particle testing (MT) and liquid penetrant testing (PT), can be useful in identifying manufactured defects in components before they go into service where they could fail and identifying service related defects that arise from damage in use.

The principal maintenance applications for these nondestructive testing (NDT) methods are final inspection, receiving inspection, in-process inspection, maintenance and overhaul in the transportation industries, and plant and machinery maintenance.

Semi-finished purchased parts and raw materials also can be inspected to detect any initially defective material during a receiving inspection, which can be an important application during plant expansions and overhauls.

Because of severe and sudden stress applications, punch-press crankshafts, casings, frames, and flywheels may crack. Crane hooks also may develop fatigue cracks. The MT and PT tests are frequently used in planned overhaul schedules to inspect such critical components for cracks. The work schedule at many planned outages includes an MT or PT inspection of the shaft, blades, and cases of steam turbines and pumps and a weld inspection in deaireators for environmental cracking.

## Magnetic particle inspection

Magnetic particle inspection is a method of locating surface and near subsurface discontinuities in ferromagnetic materials. It operates on the premise that when the material under test is magnetized, discontinuities transverse to the direction of the magnetic field will cause a leakage field to be formed at and above the surface of the part. The leakage field is rendered visible by the application of finely divided ferromagnetic particles over the surface, with some of the particles being clustered and held by the leakage field. These magnetically aligned ferromagnetic particles form the rough outline of the discontinuity and generally indicate its location, size, and shape.

The ferromagnetic particles can be applied as dry particles or as wet particles in a liquid carrier

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such as oil or water. Dry particles are usually brightly colored for high visibility. The wet particles can be coated with a fluorescent to render them more visible under an ultraviolet light.

The MT technique is also suitable for weld inspection in ferromagnetic materials. Magnetic particle inspection cannot be used for the inspection of nonferromagnetic materials. This includes materials such as copper and copper alloys, aluminum alloys, magnesium alloys, lead, titanium, and austenitic stainless steels.

Both direct current (dc) and alternating current (ac) can magnetize a part for an MT inspection, although their fields differ in many respects. The key difference is that the fields produced by dc generally penetrate the cross-section of the part, while the fields produced by ac are confined to the metal at or near the surface of the part (known as skin effect). Therefore, ac should not be used when searching for subsurface discontinuities.

Magnetic particle inspection systems range from a simple handheld yoke to large bench systems, depending on the application. The handheld yoke will be outlined here because it is portable and appropriate for maintenance testing in the field. There are two yoke types: permanent magnet and electro magnet. Permanent magnets have the advantage of not requiring a power source; however, they cannot magnetize as large an area as an electromagnetic yoke. If the permanent magnet is very strong, it can be difficult to lift off the test part. Electromagnetic yokes consist of a coil wound around a U-shaped core of soft iron. The legs usually articulate to fit the configuration of the test piece. The electromagnetic yokes can be either ac, or dc, or both.

When performing the inspection only the discontinuities transverse to the field are likely to become visible. It is therefore important to magnetize the part in both directions, with the best result when the yoke is oriented at 90 deg to the flaw. The usefulness of magnetic particle testing in the search for discontinuities depends on the type of discontinuity the method is capable of detecting and on the size, shape, and orientation of the discontinuity. A penetrameter such as pie gauge should always be used to verify the sensitivity of the test.

The MT method can locate surface cracks and discontinuities caused by or associated with fatigue, laps, seams, quenching, and grinding in castings, forgings, and welds. While the application technique appears simple in the case of magnetic particle testing, skill and experience are needed for the interpretation of indications.

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# Liquid penetrant inspection

Liquid penetrant inspection is a nondestructive method of exposing discontinuities that are open to the surfaces of solid and essentially nonporous materials. It is an excellent inspection method for the detection of all types of surface cracks, laps, porosity, shrinkage areas, laminations, and similar discontinuities because the liquid penetrant seeps into these minute surface openings by capillary action.

The test works on both ferrous and nonferrous materials because, unlike the magnetic particle inspection, the liquid penetrant test does not use ferromagnetism. The test is frequently used in the inspection of wrought and cast products, ceramics, plastics, and glass. Some applications use sophisticated computer-controlled automated processing and control systems, but for most maintenance purposes the test kit is very portable, comprising as little as a spray can of cleaner/remover, a can of penetrant, a can of developer, and a handful of rags. The liquid penetrant test is generally considered more sensitive than a magnetic particle inspection.

It is important to remember that liquid penetrant inspection can detect only discontinuities that are open to the surface--the main limitation of this method. Although open to the surface, the tiny cavities revealed by PT are often invisible to the naked eye. The test relies on the ability of the penetrant to flow over the test surface, forming a reasonably uniform coating and seeping into any open cavities.

The ability of a given liquid to flow over a surface and migrate into cavities depends on several factors: surface cleanliness, size and opening of the cavity, geometry of the cavity, wetting ability of the liquid, surface tension of the liquid, and contact angle of the liquid. The cohesive forces between the molecules of a liquid cause surface tension. The height that a liquid rises in a cavity is directly proportional to the surface tension of the liquid and the cosine of the angle of contact.

There are numerous types of penetrant applications, but the penetrant types can be broken into two main categories: type I, fluorescent, and type II, visible, each refined into four basic methods. The correct choice of type and method depends on factors such as the size and surface condition of the component under test, the characteristics of the expected flaws, the time and place of the inspection, and the sensitivity required.

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The four methods are broadly classified as water washable, method A; postemulsifable, lipophilic, method B; solvent removable, method C; and postemulsifable, hydrophilic, method D.

Solvent removable, method C, is the most common method used in field maintenance operations because it is a very portable technique. Only a can of solvent cleaner/remover, a can of penetrant, a can of developer, and rags are required for the visible (type II) inspection. This can be a fast and effective way to evaluate a weld repair for surface cracks or to evaluate machine components for fatigue cracks open to the surface. The technique is mainly used when it is necessary to inspect only a localized workpiece in the field because of its convenience. When properly performed, paying careful attention to dwell times, this is one of the most sensitive penetrant tests available. Many organizations train their welders to perform the test as a validation of their work.

# Performing the liquid penetrant inspection

- Step 1. The surface of the part is cleaned thoroughly with the cleaner/remover.
- Step 2. The liquid penetrant is applied to the surface area under inspection.
- Step 3. A rag soaked in solvent cleaner is used to remove the liquid penetrant from the surface.
  - Step 4. The developer is applied.
- Step 5. The inspection is performed--the discontinuity is revealed as the penetrant bleeds back up to the surface.

It is important to follow the manufacturer's directions when choosing how long the penetrant should be left on the surface (this is known as the dwell time). In many cases, the dwell time is set at about 10 minutes.

There is another caveat that the solvent cleaner should never be sprayed directly on the test surface when removing the penetrant. To avoid flushing the penetrant from a discontinuity the cleaner should be sprayed on a rag, and the test piece wiped clean with the rag. Resist the urge to spray too much when applying the developer; spray lightly from a distance of 6 in. or more.

While magnetic particle inspection is an excellent tool for the detection of surface and near surface defects, and liquid penetrant inspection is even more efficient in the detection of surface flaws, we must look to other nondestructive testing applications such as ultrasonics and

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radiography to find subsurface flaws.

When inspecting hot, in-service components remember that magnetic particles lose their magnetism at high temperatures (approximately 760 C in most ferromagnetic materials), and penetrants do not function well at temperatures above those recommended by the manufacturer. **MT** 

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